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QUALITY CONTROL STANDARDS FOR COOKED FROZEN GREEN BEANS HELD HEATED FOR VARYING HOLDING TIMES

A Dissertation

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Degree

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DEDICATION

This dissertation is dedicated to my grandparents, Mr. and Mrs. George F. Brenner, and Reverend and Mrs. Isaac L. McKean; to my parents, Mr. and Mrs. Willis F. Brenner; and to my brothers, sisters, and their families for their encouraging support and for their belief that education is a continuum of knowledge and experience past, present, and future.

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ABSTRACT

Objective quality control standards for prepared food, held heated for varying periods of time, were studied. Frozen Grade A whole stringless Peco and Slender White string green beans grown, blast frozen, and packaged in Tennessee were used.

Before cooking, 12 lb of each variety were randomly chosen, removed from the freezer and package, mixed together, then divided into seven 735 g portions. Portions were placed in seven half-size shallow stainless steel steam table inset pans marked with holding times of 0, 10, 20, 30, 40, 50, and 60 minutes.

All pans of green beans were steamed at one time for 30 minutes under 5 pounds of pressure in an upright stack steamer. Six of the pans then were placed on improvised steam tables and held for the specified time. Internal temperature of the beans was held above 140° F. The pan marked for zero holding time was covered and allowed to cool.

Five replications of objective measurements for Peco and Slender White beans were obtained for the seven holding periods with the Kollmorgen Color Eye for dominant wavelength, Munsell color, and Hunter a and b. Instron measurements were used to obtain "force," "shear peak area," and "work." Moisture content and pH of the beans also were determined.

A seven-member trained sensory panel evaluated both varieties of beans for texture, overall acceptability, and color for the first four replications. A consumer panel evaluated each green bean variety for overall acceptability during the fifth replication. Evaluation of

consumer panel scores was by an analysis of contingency tables using chi-square values as test statistics to test no difference in preferernce of the two varieties. Orthogonal comparisons and analyses of variance of mean values for objective measurements and panel scores were performed.

The two varieties of beans were inherently different in color ($P<0.01$). Holding time affected dominant wavelength and Munsell color, significantly ($P<0.01$). Panel scores for color and texture were affected significantly ($P<0.01$) by holding time. Instron measurements of "force" and "work" were affected significantly ($P<0.05$) by holding time. Both panel scores and objective measurements of dominant wavelength indicate a linear change in green bean color from green to yellow with holding time. Panelists discerned a steadily declining rate of firmness of the green beans as indicated by the linear component of the orthogonal comparison. "Force" and "work" components also were linear. Acceptability of the green beans by panelists had a cubic relationship with holding time. The acceptability scores were highest between 30 and 40 minutes' holding time, when the beans were noticeably but not maximally soft and yellow. Consumer panels did not discern a significant difference between varieties with regard to acceptability. Indications from the statistical analysis are that objective quality control standards could be a range of either Munsell colors or dominant wavelengths measured at 30 and 40 minutes of heated holding time as the lower and upper limits. Instron measurements for "force" and "work" at the same holding periods also could be objective measurements.

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CHAPTER I

INTRODUCTION

In recent years the food service industry has expanded rapidly as old and new types of institutions requiring food service proliferate. This expansion forces food systems managers to reconsider how to produce, prepare, and serve food in volume that retains the nutritional and sensory qualities the consumer desires within cost control limits.

Willett (1973) indicates two major trends in society are affecting present and future planning in the food service industry. One trend is toward being impersonal, machine oriented, electronically and computer controlled. The other trend is an awareness of individuality in food preferences and nutritional needs. Food systems managers, being innovative, can follow each trend to the extreme or consider features of both trends.

The impersonal machine-oriented trend has to be considered for several reasons. During the present period of inflation and recession, both food and labor costs have increased sharply. After the World Food Conference in Rome, 1974, plans were made for an international reserve food supply. The world reserve food supply was very low after world-wide drouths and floods in 1972 (Black, 1975). A failure of any one food crop immediately increases the price of that food and the items made from it. To prepare and serve the restricted food supply in a manner that conserves and enhances its nutritional and quality attributes requires well trained food service personnel. At the present time,

trained employees are limited as training has not kept pace with the growth of the food service industry. Mechanical or machine-oriented objective standards could assist unskilled and semi-skilled employees in maintaining the quality of a food. Machines also could assist employees in producing more food efficiently and help to reduce food and labor costs.

Awareness of individuality in food preferences and nutritional needs has to be considered also. As socio-economic conditions improve in the United States, the consumer uses the advantage of leisure time and available educational facilities to pursue individual interests. He is interested in growing, processing, and preparing his own food. He wants to know what nutrients are present in the food and how food processing changes nutritional value. The consumer also is eating away from home more than ever before in history. He is demanding that the food served be prepared to maintain nutritional and quality attributes and to meet his food preferences.

The Pacer Inc. Nationwide Survey (1974) found 54 percent of the general household consumers considered as good to very good the freshness, purity and safety, and taste and flavor of food available to them. Fifty-one percent thought nutritional value was good to very good. This means that nearly half of the consumers felt that the freshness, purity and safety, taste and flavor, and nutritional value of food available to them were poor to fair.

Standards for the attributes of food quality preferred by the consumers must be established before control of food quality can be initiated. Briskey (1973) stated that one of the greatest challenges

facing food scientists is acquiring an understanding of the qualities and conditions that move a substance from the category of being potentially nutritious to the higher level of being a food. Combining nutrients is not enough. A substance must not only be nutritious, but it also must have the qualities of flavor, texture, odor, and appearance that make its consumption enjoyable. Of material aid in attaining this goal will be the development of practical procedures for applying objective and sensory methods for evaluating food for quality control in food service operations.

Objective standards have been used by government agencies (USDA, FDA, USDI) to establish quality controls for fresh, canned, and frozen products purchased for food service systems. Objective standards should be established for food preparation and service of prepared food to insure the maintenance of quality in food that the consumer desires.

One of the factors affecting food during preparation and service is heat. Lund (1973) gives the desirable effects of heat processing as: favorable alteration of the characteristics of the product [browning reaction, textural changes, increased palatability, etc.; destruction of enzymes (peroxidase, ascorbic acid oxidase, thiaminase, etc.); improvement in availability of nutrients (gelatinization of starches and increased digestibility of proteins); and destruction of undesirable food components (avidin in eggwhite, trypsin inhibitor in legumes)]. Undesirable effects of heat occur concurrently with these desirable modifications. There is a loss of nutrients and a change in the physical attributes of the food such as color, texture, and flavor. Food systems

managers must utilize professional knowledge and control to cause heat to produce the desirable effects without producing overly undesirable effects that reduce the sensory and nutritional qualities of the food.

Following preparation in food production units, the food generally is held for a period of time prior to and/or during service (Livingston et al., 1973). In a self-service operation, such as a cafeteria, the holding and service of hot foods may involve the use of a steam table. In conventional restaurants and hotels holding hot food may take place on a bain marie or in a dry food warmer. Temperatures involved in these methods range from 140 to 212° F.

Longrée (1972) gives the danger zone for holding food as 45-140° F. In light of available data, it seems that a minimum holding temperature of 140° F, properly maintained, is required for safety from food poisoning by bacterial growth. In laboratory studies, if foods were placed on the steam table at 170° F or above their temperature gradually declined. Seldom did the food temperature drop below 140° F within a two-hour holding period provided the steam was not turned off during holding. If food is to be held at these temperatures during transportation to a satellite service, or before and during a serving period, then food service managers should know the changes occurring in the food attributes indicating quality in the food, nutritional values, and consumer acceptance of these changes.

An objective standard correlated with sensory evaluation that would indicate the quality of the food as desired by consumers would be of value to the food service industry in training personnel and in maintaining quality control.

The need for objective quality control standards prepared for food held over heat for periods of time before serving was the basis for planning this research study. The objectives of the research were:

1. To investigate changes in texture and color of two varieties of fully prepared, frozen Grade A green beans held heated for varying periods of time.

2. To study relationships among holding times for fully prepared frozen green beans held heated, consumer acceptability, sensory tests, and objective measurements for texture and color to discern texture and color objective measurement values acceptable to the consumer that could be used as objective standards for quality control.

CHAPTER II

REVIEW OF THE LITERATURE

There are perhaps 30 or more distinct types of food service organizations within the food service industry, each of which is concerned with the feeding of different portions of the population (Livingston et al., 1973). Naturally, not only the methods of food handling used by these various kinds of establishments but also their menus, type of equipment, quality and quantity of food purchased, and professional skills of personnel vary greatly. The quality of the food in each food service depends upon the handling of raw materials, food preparation, and service of prepared food.

Now that the average American is consuming more than one meal out of four away from home, there is an increased emphasis on research in quality control of food and on the application of the concept developed to the food prepared and served in volume. For quality control, it is important to identify, measure, and control independently each of the significant components of quality (Finney, 1969).

I. Need for Quality Control Standards

Quality in food has been defined by Kramer and Twigg (1970) as "the composite of those characteristics that differentiate individual units of a product and have significance in determining the degree of acceptability of that unit by the buyer." West et al. (1966a) state that "although the terms 'best' or 'high quality' are difficult to define

and mean different things to different people, certain common characteristics of food give some basis for judgment. Nutritive value, color, texture, and flavor are possible to evaluate by various methods and help give meaning to the words 'quality foods'." Francis (1970) gives the three major attributes of food quality as color, flavor, and texture. Szczesniak and Kahn (1971) classify the food attributes as flavor, texture, color, and form or temperature. A more definitive classification of quality attributes is shown by Kramer and Twigg (1970) in Fig. 1. Although specific classifications vary, there is general agreement that color, flavor, and texture are sensory attributes of food quality.

Sensory attributes have been considered by mankind for centuries. Amerine et al. (1965) report that flavor distinctions and food preferences developed rapidly, especially along class and status lines during the Neolithic period, and many of our present-day food taboos and food habits undoubtedly were developed at that time. However, for quality control standards, objective tests should be made. Dawson and Harris (1951) indicate that advantages of using objective tests are evident. The objective test could be rapid and accurate. One test may not reflect overall quality, but one attribute which is the most important or the worst offender could be measured to indicate overall quality. The more clearly an attribute can be defined and measured, the more chance there is for the success of an objective test to relate to sensory tests for same attribute. If there is an apparent relationship between sensory evaluation of an attribute and the objective test, the objective test could be used to replace sensory evaluation.

A visible standard based on objective measurements of a quality

I. Quantitative

Yield
Proportion of ingredients
Net weight
Drained weight

II. Hidden

Nutritive value
Harmless adulterants
Toxic substances

III. Sensory

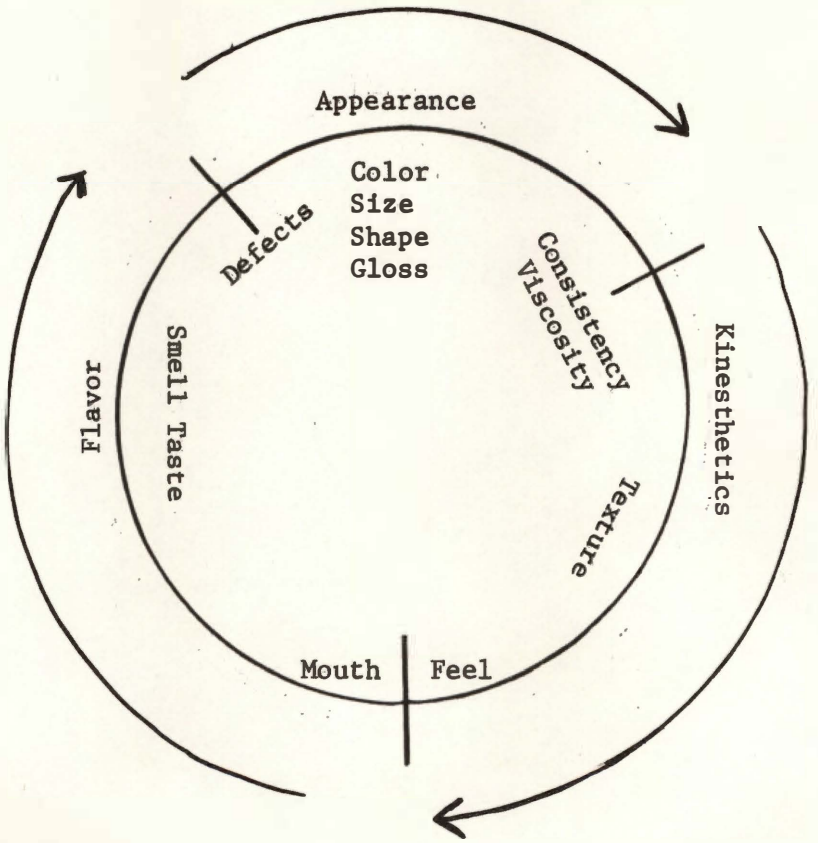


Fig. 1--Classification of quality attributes (Kramer and Twigg, 1970).

attribute that has met these requirements could be used by food service employees to control the quality of the food.

Francis (1970) reports that in past years most of the tests for quality attributes have been subjective, but research to develop objective methods has been encouraged in recent years by the food industry. Two main reasons have been given for this. First, producers and processors of food desire objective tests of consumer acceptability in order to control the quality of their products. Second, valid judgments of product quality are important in financing inventories of seasonal food products through banks, brokers, and other financial institutions.

Kramer and Twigg (1970) state that data obtained by objective methods of evaluating a quality attribute may be correlated with test-panel scores. The higher the correlation coefficient the greater the accuracy of the objective test in reflecting human evaluation. An objective test identifying a particular quality parameter in physical terms is meaningless until such measurement is correlated with human response to the entire food when purchased or consumed under usual conditions.

II. Consumer Preferences

Surveys of college students (Anon, 1973; Stasch et al., 1970) and of a cross section of the adult population (Anon, 1970b) indicate that green beans are a favorite vegetable for adult age groups, and they are preferred especially in the southern region of the United States. On this basis, beans were selected as the food to be used for the

development of a quality control standard. Two other considerations contributed to the selection of beans: (1) A comparison by Walker et al. (1973) stating findings of the Department of Agriculture's Food Consumption Surveys in 1955 and 1965 showed that the average quantity of fruits and vegetables consumed per person was appreciably smaller in 1965 than in 1955. Within the fruit and vegetable group, the greatest difference was in the amount of dark green and deep yellow vegetables, and the decline in consumption was reflected in less vitamin A and ascorbic acid available in the diets. (2) Clydesdale et al. (1970) and Sweeney (1970) stated that color is one of the major problems in cooked green vegetables, particularly when held on a steam table prior to serving. A quality control standard could consist of the color parameters within which a food is most acceptable to the consumer. Color within the parameters could conceivably relate to other quality attributes as nutritive value and texture (Clydesdale et al., 1970; Gordon and Noble, 1959; Walker et al., 1973).

III. Texture as an Attribute of Quality

Corey (1970) has stated:

> Whereas color recognition is essentially an instantaneous event so that color can be considered (in this sense) a "simple" quality, texture cognition extends in time, different aspects continuously developing and being sensed until the foodstuff is swallowed. In its fullest sense the textural experience during chewing is a dynamic integration of mouthfeel, the prior tactile responses while handling the foodstuff and a psychic anticipatory state arising from the visible perception of the food's overall geometry and surface features. Texture may be defined as the forces and feelings other than flavor sensed in the mouth while chewing a piece of food.

> Proper study of texture is actually the study of the food/man interface, i.e., of how the human transforms texturogens into those sensory feelings recognized as texture. (Psychorheology --concerned with anatomy, mechanics, physiology and psychology of chewing and the neurophysical and psychic basis of mouth-feel.) It will inevitably also have to be concerned with questions of language and even with socio-religious attitudes toward foodstuffs, with the interaction between personality and product properties and the role of subconscious desires in what the consumer prefers or what he thinks he prefers.

Kramer (1972) states that problems arose, during the 1920's and 1930's, in defining food texture as an awareness developed that more than one attribute contributed to the sensory quality of food. The USDA was one of the first government agencies to recognize that objective measurement values were needed for the development of grades and standards of quality for raw and processed food. The term "texture," one of the three accepted primary properties of food, relates entirely to the sense of touch or feel. Therefore, texture can be measured objectively and precisely in units of mass or force by mechanical means.

Objective measurement of the textural changes in food also could be used as the basis for development of quality control standards for food during preparation and service in volume.

IV. Objective Measurement of Texture

Finney (1969) reports that some of the problems associated with measuring food texture arise because foods are complex systems exhibiting various degrees of elasticity, viscosity, and plasticity. Because of the complex structure and mechanical behavior of food, objective measurements of food texture may be influenced by a variety of deformations

imposed upon the material, geometry of the loading surface, localized yielding within the product tested and definitions of the parameters of food texture.

Szczesniak et al. (1963) developed standard rating scales for these parameters by comparing objective measurements with the judgments of nine taste-panel members. Each point on the rating scales was represented by a food product, and the scales covered the entire range of texture intensity common in food products. These studies by Szczesniak et al. (1963) were some of the first to stress the importance of determining the sensory textural characteristics of a food, defining the characteristics in terms acceptable to researchers and relating the sensory characteristics to objective measurements. Continuing studies have expanded the knowledge pertaining to texture in food and instrumental evaluation of texture characteristics. Szczesniak and Bourne (1969) studied methods used by consumers for testing firmness of foods without eating the food. Four basic properties were most commonly used to measure firmness subjectively: viscosity/consistency, deformation, puncture, and flexure.

The kinds of sensory tests applied by the respondents in the above study are shown schematically in Fig. 2. The results of the study not only contribute to a better understanding of the sensory evaluation of food firmness, but also can be used as a valuable guide to the selection of proper objective methods for evaluating food firmness (Table 1).

Voisey (1971) believes that the studies mentioned have evolved into a sophisticated measuring tool. The techniques of Szczesniak and

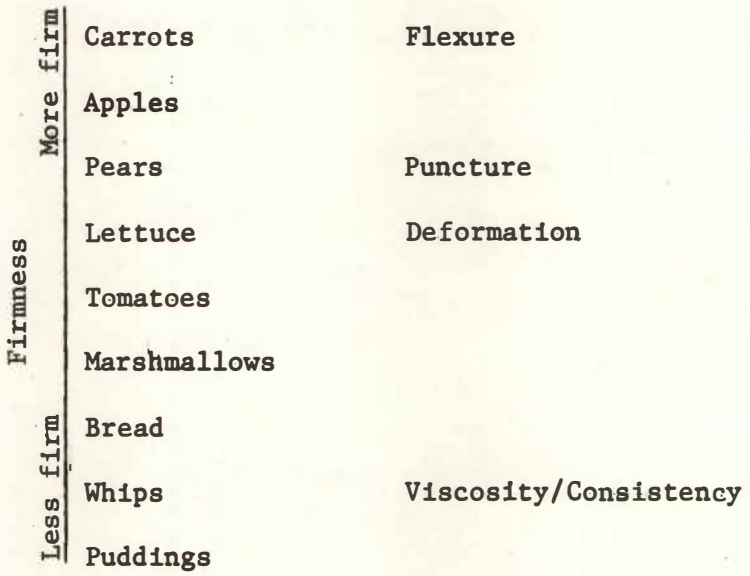


Fig. 2--Schematic representation showing how the sensory method used to measure firmness depends upon the firmness of that food (Szczesniak and Bourne, 1969).

Table 1--Correctness of judgment for sensory test of food firmness related to objective characterization by Instron machine

Firmness scale	Deformability (mm/100g)	Bioyield (kg)	Sensory test	Equivalent objective test
Very firm	0.01	>26	Bending	Stiffness of a beam
	0.03-0.01	>2-21	Puncture	Force to reach bioyield point
Increasing firmness	7.00-0.03	--	Deformability	Amount to compress under arm force
Very soft	>51	0.008	Resistance to flow	Apparent viscosity consistency

Szczesniak and Bourne, (1969)

Bourne (1969), however, are time consuming and require the use of considerable amounts of trained labor. Thus, in recent years, interest has accelerated in objective measurement of textural characteristics of foods to provide efficient and precise quantitative description in research, product development, and quality control for the food industry.

Because food texture is composed of so many variables, it is not possible to obtain an overall index in a single measurement. In general, therefore, only those properties which have the greatest influence on consumer acceptance are measured. The mechanical properties are the most critical for many foods. The mechanical properties of food encompass the reaction of the material to applied forces. Since foods are viscoelastic, both time-dependent and time-independent measurements are required. To measure the texture of foods in terms of elastic or viscoelastic parameters, the product is deformed in some arbitrarily selected but defined manner, and the force and time required to produce a given deformation or flow are recorded.

A great variety of instruments have been developed for measuring food texture (Voisey, 1971). All these systems have a common concept and common requirements. Samples of food are subjected to compression, tension, or shear (in combination or as a single operation), and force, deformation, and time are recorded. A texture measuring system, thus, consists of five components: (a) a mechanical mechanism for deforming the sample, (b) a means of recording the force, (c) a means of recording the deformation, (d) a method of recording time during deformation, and (e) a test cell to hold the sample. The first four components are

readily available since these items have already been developed for other purposes, as, for example, the textile industry. The test cell should, therefore, be considered as the most critical component of the system. The cell may be a single or a multiblade shearing device, a pair of grips to apply tension, a flat surface to apply compression, a probe to puncture the sample or a container and paddle used in a viscometer. The design of the cell determines the manner in which forces are applied to the food, how they are distributed throughout the specimen and which type (tensile, compressive, or shearing) predominates in the resulting reaction.

In measuring the force and deformation of test samples, the data must be expressed in a rational set of units. Units used in testing engineering and other materials are, therefore, being adopted for textural studies.

When a material is subjected to a tensile, compressive, or shearing force, its original length will deform by an amount. The results can be recorded in two ways: (a) force and deformation, and (b) stress and strain using metric or English systems of measure. Simple classical elastic stress theory analysis is based on two assumptions: (a) the material is homogeneous, and (b) the deformations are small. Sherman (1969) has pointed out that "classical elastic theory deals with very small strains so that when considering the much larger strains involved in mastication, the accepted definition of strain may not be valid."

In designing texture tests, two approaches can be used in the selection of specimens: (a) make all the specimens the same size and

report either force and deformation or stress and strain, (b) use specimens of a defined shape (but not necessarily the same size), measure the size of each sample and report stress and strain. The method selected depends primarily on practical considerations in preparing samples of each specific product.

The speed at which the test material is deformed must be considered critical because foods are viscoelastic and their reaction to force is time dependent. Also, the speed of deformation governs the rate of force rise which must not exceed the response rate of the recorder. Two types of deformation control are used in material testing: constant rate of force increase and constant rate of deformation. The latter is used for testing foods because it is simpler and less expensive than the automatic controls required to achieve a constant rate of force increase. The load capacity of the mechanism must also be adequate to handle the resistance forces generated in the deformed samples. Control of deformation speed is affected if this is not the case.

Szczesniak (1972) indicates one of the significant trends in instrumental texture measurements is instrumental-sensory correlation. Five separate lines of endeavor are worth noting here: (1) a general study of stress/strain relationships during the process of mastication; (2) equating instrumental testing conditions for specific products with those occurring during sensory testing; (3) translating sensory reactions into basic rheological parameters; (4) performing objective texture measurements under strictly defined conditions, thus permitting calculations of basic rheological parameters; and (5) a critical

re-examination of the meaning of the correlation coefficient and application of more adequate techniques of mathematical treatment of the data.

These current trends are applicable to the development of quality control standards as the research would be principle oriented with elucidated principles being applied to measurement of a specific product. The test cell chosen for the research would be one with a probe in contact with the food, and one that has given accurate test results in previous research. "Multiple-point" measurements would give a more detailed evaluation of the texture changes occurring in food when prepared and held for volume feeding. An instrumental sensory relationship would be essential for the establishment of objective quality control standards.

Bourne et al. (1966) studied the use of the Instron (Instron Universal Testing Machine) which measures compressive and tensile properties of materials when adopted as a research tool to study the rheological properties of food materials. They found that every instrument that uses a linear vertical motion in measuring food texture can be duplicated in a single universal testing machine which has been fitted with the appropriate working parts or test cells. A strip-chart recorder that is an integral part of the machine draws a force-distance curve for every test at a set time rate. Metric units are used to express the three fundamental parameters of force, distance, and time.

One of the test cells used is the Kramer Shear Compression Cell, named after the head of the research team who developed it. Most recently it has been referred to as the FTC Texture Test System by its

present manufacturer, Food Technology Corporation.

Szczesniak et al. (1970) studied and compared the behavior of 24 foods in a cell of this type attached to an Instron. Each food was tested at a variety of weight levels representing the range between the weight needed to just barely cover the bottom to that required to completely fill the cell. Maximum "force" values and "shear peak" areas were determined from the recorded force-distance curves. Results of the research were that for most foodstuffs, pounds of force per gram of sample weight is not a constant but decreases as sample weight increases. Many products attained a constant force independent of sample weight, within the range of sample weights investigated. When extrusion took place, the force was independent of sample weight. The easier it became to extrude a product, the earlier the maximum force reached a constant value.

Szczesniak et al. (1970) found that for all samples tested "shear peak" areas increased with increasing sample weights. The effect of the sample weight on maximum force and on peak areas appeared to be an inherent characteristic of the test material and not of the manner in which is was arranged in the test cell. Two tested rates of force applications, 24 cm/minute and 9 cm/minute, showed very little, if any, difference in exponent values.

For instrumental-sensory correlation, emphasis is on knowing what sensory characteristic is being studied and on choosing the instrument or test cell to measure that characteristic. Howard and Heinz (1970) measured shear and compression strengths of individual raw carrots with the Instron. Compression correlated highly, but shear

poorly, with sensory hardness as judged by compressing and flexing the carrots. Sensory analysis requiring the judge to bite or break carrot slices may yield a better correlation with shear analysis.

Voisey and Larmond (1971) used five different test cells with an Instron: Kramer shear-compression, back extrusion, FMC Pea Tenderometer, a plate extrusion, and a wire extrusion cell. An objective test was required to evaluate baked beans from plant breeders' selection. Such a test was needed to evaluate textural qualities as well as agronomic performance of developing varieties. Because of the large number of samples involved, convenience and minimal labor were requisites of the test. The objective results were highly correlated with each other and with sensory ratings for hardness and cohesiveness. It was concluded, therefore, that the selection of an objective test could be based on practical considerations and the equipment at hand.

Pectic substances control to a large degree the firmness of fruits and vegetables. During ripening of fruit, for example, changes in the pectin produce softening. To study the relationship between firmness and the pectic substances, a plunger with a 0.04-inch-diameter tip tapering to a 0.02-inch-diameter shaft was attached to a crosshead on an Instron (Holt, 1970). It penetrated the tomato at 1 cm/minute. Distinct peaks were observed on the force-displacement trace which are related to the four anatomical parts of the tomato. The method can be used to follow changes in firmness during ripening, to detect ripening abnormalities, to measure differences between varieties, and to detect variations in firmness over the surface of individual tomatoes.

Breene et al. (1972, 1973) devised for cucumbers a procedure

for objectively determining Texture Profile Analysis (TPA) parameters using the Instron. The procedure is an important criterion of quality for any new variety of pickling cucumber. Both growers and processors want a cucumber that is a firm, crisp-textured product when processed, cured, or fermented. The TPA parameters include hardness, cohesiveness, chewiness, gumminess, elasticity, and brittleness (crispness).

The TPA parameters were determined by the method described by Bourne et al. (1966). Force-distance curves were produced by twice compressing a 1-cm-thick center slice from a 1-inch-diameter cucumber to 0.25 cm on the Instron TM equipped with load cell CTM. Crosshead speed was 0.5 cm/minute. Chart speed was 5 cm/minute.

Objective measurements of vegetable texture have an economic value to producers, packers, and the food service industry when related to food quality as perceived by consumer acceptance. Extensive research will be needed to determine what consumers regard as quality in food, and how this quality in food is related to the food attributes and to mechanical properties of food attributes that can be measured objectively. Development of instruments to measure the mechanical properties of food effectively must continue to keep pace with the demand for objective measurements as quality control standards.

V. Color as an Attribute of Quality

Clydesdale et al. (1970) believe that the single most important quality attribute of a food is color. This is based on the fact that no matter how nutritious, flavorful, or well textured a food is, it will not be eaten unless it is an acceptable color. This does not

apply to food for the blind or food eaten in the dark. Francis (1970) states that color is becoming one of the most important attributes to consider as the self-service trend accelerates in the food service industry. If the visual impact of the food is negative, the consumer may never get to evaluate the flavor and texture. The product may remain on the food service counter or on the retailer's shelf. Birren (1963) stated, "Color is forever a part of food, a visual element to which human eyes, minds, emotions and palates are very sensitive. Perhaps, through eons of time, man has come to build up strong and intuitive associations between what he sees and what he eats. A good meal is always a beautiful sight to behold. . . . There is a definite art of color in food. It is important to those who merchandise it and to those who willingly or reluctantly consume it. What may not be appreciated properly is the fact that a sizable fund of research has been devoted to the matter of color and food, and much of it has a direct and practical application."

Walker et al. (1973) found, in a study to determine factors in acceptance of fruits and vegetables by children 8 to 18 years of age, that colors associated with fruits were strongly linked to favorable taste expectations, whereas the colors associated with some vegetables were considered unappetizing. The pervasive greenness of some vegetables aroused mixed sensory reaction. A light or medium green seemed more acceptable than a dark green. Color was more likely to be a negative influence when combined with other unfavorable sensory impressions such as the liquid consistency of tomato sauce.

Bowman et al. (1971) reported that in the evaluation of frozen

and raw vegetables cooked by three different methods, the panel indicated by their scoring that they considered the color of the majority of the vegetables more important to them than flavor, tenderness, or texture.

Mackinney and Little (1962) state that an important application for color measurements is in the specifications of color for establishing grade standards of food and food products. As of July 15, 1960, 143 standards for grades of processed fruits, vegetables, and certain other products had been issued by the Agricultural Marketing Service, Fruit and Vegetable Division of the United States Department of Agriculture (USDA). With few exceptions, color is one of the important factors in establishing grade standards. Evaluation score points are assigned according to the importance of color relative to other factors in a given case. As color evaluation has been used in standards during initial steps of processing food, color could be used as the basis for the development of quality control standards during preparation and service in volume.

VI. Green Bean Pigmentation

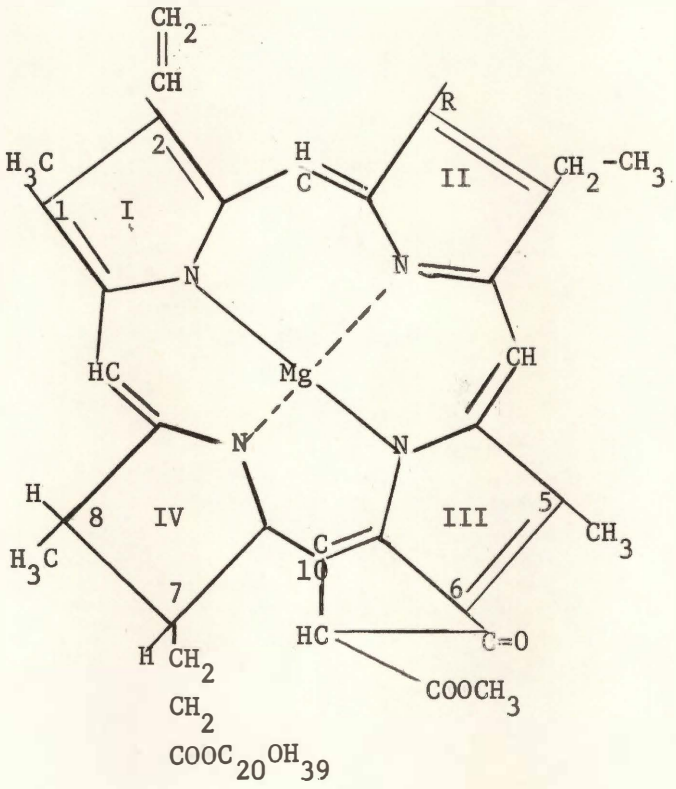
Green beans (Phaseolus vulgaris L.) have been an important part of man's diet for centuries. Remains found at various New World sites show that they were cultivated as early as 5000 B.C. (Brothwell and Brothwell, 1969). At harvest time green beans have tissues at different stages of maturity (Reeve and Brown, 1966). The cells of the embryonic parchment layer or fiber sheath of the young pod are very thin walled. The parenchyma cells of the center of the pod have thin walls, while

cells of the outer parenchyma have relatively thick walls, and often separate from each other with no breakage of the cell walls. The pigment within the cells is chlorophyll, and thickness and maturity of the cell walls affect the perceived color of chlorophyll in the cells. "Chlorophylls are located within plastid bodies in plants called chloroplasts, which have an ordered fine structure, and appear in the light microscope as green saucer-shaped bodies. Chlorophyll molecules are held together in the chloroplast both by their mutual attraction and by the affinity of each molecule's phytol 'tail' for lipids and by the affinity of each molecule's hydrophilic portion for proteins. . . . The chlorophyll molecule is imbedded between a layer of protein and lipid with a carotenoid positioned alongside the phytol chain of the chlorophyll" (Clydesdale et al., 1970). Charley (1972) states that chlorophylls and carotenoids constitute 5 to 6 percent of the chloroplast. Chloroplasts are approximately half protein and one-third fat.

The Structure of Chlorophyll

"A molecule of chlorophyll consists of four five-membered pyrrole groups arranged to form a porphyrin ring. An atom of magnesium in the center of the molecule is chelated by the four nitrogens of the pyrrole groups. The numbering system used to designate the carbon atoms in this part of the molecule, sometimes referred to as the prophyrin head, is given (Fig. 3). . . . The phytyl group which is twice as long as the dimensions of the porphyrin ring is visualized as being positioned at an angle to the plane of the porphyrin ring" (Charley, 1972).

The color of the unsaturated chlorophyll is dependent on the



R=CH_3; chlorophyll a

R=CHO; chlorophyll b

Fig. 3--Schematic representation of chlorophyll. The central metal, Mg, is linked with the 4 pyrrole nitrogens. Ring IV is hydrogenated. Substituents are methyl groups at positions 1, 5, 8; vinyl at position 2; ethyl at 4; formyl at 6; propionic phytyl ester at 7 (Aurand and Woods, 1973).

resonance of the conjugated double bond system. In addition to the porphyrin head, chlorophyll is a methyl, phytyl ester. The acetic methyl ester is at position 10 and the propionic phytyl ester at position 7. Two forms of chlorophyll are found in vegetables and fruits (Clydesdale et al., 1971). Chlorophyll a has a methyl group on carbon 3, while in chlorophyll b an aldehyde group (-CHO) replaces this methyl group. The two forms of the pigment differ in hue, chlorophyll a being bright blue-green and chlorophyll b, yellow-green. Chlorophylls a and b occur in plants in the ratio of about 3:1 and are responsible for the green color of vegetables.

Physical and Chemical Reactions of Chlorophyll

Charley (1972) reports the "phytyl portion of the chlorophyll is responsible for the solubility of chlorophyll in fat and in such fat solvents as acetone, benzene, and alcohol. . . . An esterase enzyme, chlorophyllase, which is specific for catalyzing the hydrolysis of the phytyl ester linkage of chlorophyll has been identified in spinach but is . . . absent from beans and peas. The optimum temperature for the activity of this enzyme is 75° C. The chlorophyllides (Phytyl-free chlorophylls) resemble their parent chlorophylls in color, but they have become soluble in water."

Little and Mackinney (1972b) indicate that weak acids, particularly carboxylic acids such as are present in fruits and vegetables, will degrade chlorophyll. In fresh, raw tissue, acids and pigments are in separate compartments within the cell; but heat treatment alters the permeability of cell membranes and permits contact of acid and pigment.

The effect of the weak acid is to replace the magnesium with two hydrogens. Magnesium-free chlorophyll a and b are referred to as pheophytins a and b. Pheophytin a is a gray-green, and chlorophyll b is a dull yellowish green. Charley (1972) reports that yellow-green becomes the dominant color during heating of chlorophyll as the blue-green chlorophyll a degrades more rapidly to a pheophytin than the yellow-green chlorophyll b. Clydesdale et al. (1971) state that chlorophyll a is converted to pheophytin 5.5 to 10 times faster than chlorophyll b is converted to pheophytin b.

The hydrogen ion concentration of the vegetable influences the speed and extent of conversion of chlorophylls to pheophytins (Sweeney and Martin, 1961). Retention of chlorophyll in cooked green beans was 26.7 percent with a pH of 6.2 and 50 percent with a pH of 6.9. Alkaline cooking water will saponify both the phytyl and the methyl ester groups of chlorophyll. The salt of the free carboxylic acid that results, called chlorophyllin, is soluble in water and is a brilliant green color. Vegetables cooked in alkaline water may have a mushy texture because of the breakdown of hemicelluloses and a loss of ascorbic acid if overcooked. Shortened cooking times with a higher pH cause no adverse effect on ascorbic acid retention. Cooking green vegetables in large amounts of water to dilute the acid and cooking with the pan uncovered to eliminate volatile acids are treatments that reduce the deleterious effect of acid on green color (Charley, 1972).

Little and Mackinney (1972b) report that color change in frozen food is controlled fairly successfully by a preliminary blanching treatment prior to freezing. The blanching process causes the frozen

green beans to be bright green in color. The gas is expelled from the intercellular spaces which, in the raw vegetable, refract light and dull the color. Eheart and Odland (1973) blanched 300 g samples of green beans at 200° F for 4 minutes.

The destruction of chlorophyll by photo-oxidation appears to proceed by way of attack on the methine bridges (Little and Mackinney, 1972b). Dehydrated products packed in clear containers will undergo photo-oxidation with a loss of desirable color (Clydesdale and Francis, 1970). Many other reactions may occur, such as the oxidation of isocyclic ring to form allomerized chlorophyll or the rupture of the tetrapyrrole ring to form colorless end products.

As indicated by Charley (1972), Little and Mackinney (1972b), and Clydesdale and Francis (1970), the color of the chlorophyll pigment is difficult to maintain during food processing. A study of the color changes in chlorophyll during preparation and service of green beans should indicate the changes in quality.

VII. Objective Measurement of Color

Tristimulus colorimeters consist of a light source, an object to be measured, a set of filters (red, green, blue) which duplicate the responses of the three types of receptors in the cones of the retina of the human eye, and a photocell (Clydesdale and Francis, 1969b). The character of the light used in a colorimeter is of little importance provided that when modified by a filter and a detector, it approximates the response obtained by the human eye (as defined by a standard observer) when the eye views an object under standard sources of

illumination. Little and Mackinney (1972a) report that a relationship between the psychological data obtained from visual observation and the instrumental (psychophysical) measurements must be established. The definition of this relationship enables food scientists to use instrumental measurements to predict visual experience. Measurements are meaningless without definition of relationship, as a colorimeter does not see, it analyzes.

When a sample presentation of food is made to the colorimeter, the light reflected from the food surface constitutes a stimulus. Three other stimuli, chosen with some degree of care, e.g., a red, a green, and a blue (which are called primaries), can be mixed in such proportions that they will match the stimulus from the food. Successive readings of the reflectance from the food by use of the three filters are designated X, Y, and Z. With these figures, a new set of values is derived based on the transformation to C. I. E. space (Commission Internationale de L'Eclairage, formerly called International Commission on Illumination). It is only with the transformation to C. I. E. space that the dominant wavelength of the reflected light can be derived, and from the dominant wavelength the color is determined.

The C. I. E. and the Munsell systems are the two most widely accepted systems for characterizing color. The attributes of spectral color, saturation, and brightness have been designated by different terms (Jacobson, 1972). Munsell and C. I. E. interrelations have been studied resulting in Munsell renotations with an instrumentation reading for each Munsell color (Mackinney and Little, 1962). The C. I. E. system uses dominant wavelength (x) to indicate spectral color,

purity (y) to indicate degree of saturation, and (Y or L) to indicate lightness of the color (Jacobson, 1972).

Methods of sample presentation and physical attributes of the sample influence the color measurement of reflected light (Clydesdale and Francis, 1969c). Foods of irregular shape, size, and color are problems in presentation. Mackinney and Little (1962) state that optimum results are obtained with flat, opaque, uniformly colored surfaces where visual appearance relates directly to color measurement. Foods seldom meet these criteria.

Various colorimeters have been used to study the reflected light from food containing chlorophyll. An investigation was made of the quality of frozen green vegetables both as received from the local retail market and after cooking (Sweeney et al., 1961). Reflected color was measured with a Gardner Automatic Color Difference Meter. Color conversion of chlorophyll was highest in green vegetables purchased in the summer than in fall, winter, or spring, and may reflect a longer storage period between packing and sale of the vegetables. Sweeney (1970) used the Gardner Automatic Color Difference Meter to measure the chlorophyll retention of green beans held on a steam table. Unconverted chlorophyll and Gardner aL/bL values for beans held on a steam table increased significantly when a mixture of two parts by weight of magnesium carbonate and one part calcium acetate was used in the cooking water. Clydesdale et al. (1971), in an experiment similar to Sweeney's, measured with a Hunter Lab Model D25 Difference Meter the retention of chlorophyll color in spinach, green peas, and beans after phosphate buffer and $MgCO_3$ had been added to the vegetables during cooking. The use of both phosphate buffer and $MgCO_3$ reduced the discoloration in

beans and peas. Extremely good results were obtained with spinach. This was accomplished without a disproportionate decrease in ascorbic acid. Unfortunately, textural changes were such that this method of maintaining color in cooked whole frozen green vegetables cannot be recommended. It could be considered for use with pureed vegetables. Ross et al. (1959) determined with a Hunter Color Difference Meter that color value variations along the length of individual beans and on the two sides are small compared with bean-to-bean variation. Clydesdale and Francis (1969a) obtained color readings for spinach puree with the General Electric Recording Spectrophotometer, a Hunter Lab Model D 25 Color Difference Meter, and a Color Master Differential Colorimeter, Model V. Experiments were carried out on each of three different sets of 11 samples to obtain tristimulus values from each instrument. These values were mathematically transferred to the tristimulus values of the other two color systems. Tristimulus values from the instruments also were reduced to common color functions, and all data were correlated with visual rankings. Good correlations of instrument versus visual rank were obtained. Absolute values obtained from the transformation equations were very different from instrumental values. However, the transformations resulted in only a slight decrease in correlation with visual preference.

Primo et al. (1970) achieved color measures of green beans with the Hunter Lab Model D 25 Difference Meter and the Beckman DU Spectrophotometer with the objective of finding simple instrumental values to correlate with visual acceptance of samples. The selected parameters were the Hunter values, L, Y, and L + a, measured in whole beans. The

Beckman color measures did not correlate as well as the Hunter with visual acceptance of the samples.

Colorimeter objective measurements related to subjective evaluation of color could be an objective quality control standard.

VIII. Sensory Evaluation of Quality Attributes in Food

If objective measures that correlate highly with human response and are meaningful as quality indicators are to be developed, then the nature of sensory stimuli and sensory evaluation must be thoroughly understood. Amerine et al. (1965), Anon (1968), and Larmond (1970) generally agree that these factors must be considered when obtaining accurate sensory evaluation data: (1) method used for sensory evaluation; (2) panel; (3) material evaluated; (4) statistical design; (5) environmental conditions for test; and (6) data analysis.

Hoffman (1968) presents principles of psychological test methods for appearance. The visual appearance of a surface or volume is related to the illumination by which it is viewed, the conditions under which it is viewed, and the visual response characteristics of the observer. The appearance characteristics of greatest interest are those relating to:

1. Luminance (brightness, lightness)
2. Specular reflectance (gloss, luster, sheen)
3. Chromaticity (hue and saturation)
4. Transparency (translucence)
5. Nonuniformity (texture, pattern, contrasting areas such as those caused by flaws or foreign substances, etc.)

Amerine et al. (1965) report that panel members may be recruited from employees in an organization or out of it; or the panel may be composed of members chosen by a random sampling of a specific population. Members can be inexperienced or experienced at sensory judgment; and they can be of any age, race, or sex. However, they should be in good physical health, free of respiratory problems and preferably not heavy smokers. The panel members should be interested in the test results, intelligent, alert, and unbiased in reporting what has been determined from the samples presented.

Material should be evaluated according to the method of its preparation and presentation. A sample may present one appearance when steamed and another when it is boiled in a large amount of liquid. The time of the day when the sensory panel evaluates the food is important. Szczesniak and Kahn (1971) found that the average consumer will accept and enjoy a wide range of textures and aggressive flavor in food at dinner time but not at breakfast. The acceptance of varying textures and flavors in food increases gradually from breakfast to dinner.

Larmond (1970) states the accuracy of sensory evaluation tests for food and the reliance that can be placed on the results depend on standardization of testing conditions and use of statistical methods of experimental design and analysis. Experimental design may make the test efficient and saves time and material.

Hoffman (1968) gives four methods for appearance evaluation: (1) threshold methods, as the degree of embossing can be expressed in terms of illumination level necessary for perception; (2) comparison methods, a comparison of the test surface or volume with a standard of

known value (Munsell Book of Color, the Container Corporation Color Harmony Manual, Moerz and Paul Dictionary of Color, and Villalobos Color Atlas); (3) ranking methods, because of the remarkable sensitivity of the eye and the nondestructive nature of visual judgment it is possible to rank with accuracy large numbers of samples with regard to an appearance attribute; (4) numerical counting methods, number of flaws in an area, as errors in printing a newspaper.

A consideration of these principles and techniques has to be considered in planning the research for developing objective standards for sensory attributes indicating quality in food.

CHAPTER III

PROCEDURES

The purpose of this study was to investigate changes in color and texture of prepared frozen green beans held heated for different time intervals. Relationships among holding times for fully prepared frozen green beans, consumer acceptability, sensory evaluation, and objective measurements for color and texture were studied in order to recommend a range of color and texture values for objective standards of quality control.

Two varieties of frozen Grade A whole green beans, Slender White and Peco, grown in Tennessee, harvested, and blast frozen as described by Reeve (1970), were obtained. Before cooking, 12 lb of each variety were randomly chosen, removed from the freezer and package, mixed together, then divided into seven 735 g portions. Portions were placed in seven half-size shallow stainless steel steam table inset pans marked with holding times of 0, 10, 20, 30, 40, 50, and 60 minutes.

All pans of green beans were steamed at one time for 30 minutes under 5 lb pressure in an upright stack steamer. Six of the pans then were placed on improvised steam tables and held for the specified times. Internal temperature of the beans was held above 140° F. The pan of beans for zero holding time was covered and allowed to cool to room temperature.

Five replications of objective measurements for Peco and Slender White beans, cooled to room temperature, were obtained for the seven

holding periods with the Kollmorgen Color Eye for dominant wavelength, Munsell color (hue, value, and chroma) and Hunter a and b. Instron measurements were used to obtain "force," "shear peak area," and "work." Moisture control and pH of the beans also were determined.

A seven-member trained sensory panel evaluated both varieties of beans for texture, overall acceptability and color for the first four replications. A consumer panel evaluated each bean variety for overall acceptability during the fifth replication. Evaluation of consumer panel scores was by analysis of contingency tables using chi-square values as test statistics to test no difference in preference of the two varieties. Orthogonal comparisons and an analysis of variance of mean values for objective measurements and trained sensory panel scores were performed.

I. Source of Green Beans

One-hundred-twenty lb of Peco variety and 122 lb of Slender White variety Grade A frozen whole green beans were obtained.[1] The Slender White and Peco varieties were blast frozen and packaged on July 25 and August 2, 1973. All frozen green beans were packaged in 2 lb capacity, wrapped, waxed cardboard cartons. They were held in storage which did not exceed 0° F until shipped to Knoxville, Tennessee, on June 13, 1974.

The frozen green beans were stored in a Victory two-door upright

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[1] Winter Garden, Incorporated
P.O. Box 119
Bells, Tennessee 38006

freezer (Model FA 206) from the time received until removed for preliminary studies and research. The thermostat of the freezer was set at 0° F. The actual temperature range inside the freezer was 0-5° F. It was assumed that the standards for quality for USDA Grade A frozen whole green beans were maintained during storage at this temperature after freezing and packaging (Rasmussen, 1968).

II. Preparation of Green Beans for Testing

The cartons of green beans for each variety were numbered consecutively. These numbers were duplicated on slips of paper which then were placed in two containers, one for each variety. Prior to each preparation period, the variety to be used was selected by randomly drawing from slips in a third container, then six numbers indicating the cartons of green beans to be used were drawn from the container representing that variety. This procedure was followed each day until five replications of testing had been made for each variety.

Six packages (12 lb) of frozen green beans were removed from the freezer and emptied into a large mixing bowl. After mixing thoroughly, the following amounts were removed for objective measurements: 30 g (Fig. 4) were placed in a covered dish to protect them from light and air until measurements were made with the Signature Model D-1 Kollmorgen Color Eye; two 100 g portions were packaged in plastic bags until measurements could be made with the Instron Universal Testing Machine; 20 g were kept in a covered plastic container until the beans were cut finely, weighed, and placed in a vacuum oven for moisture determinations; and 30 g were used for pH measurement. The remaining green

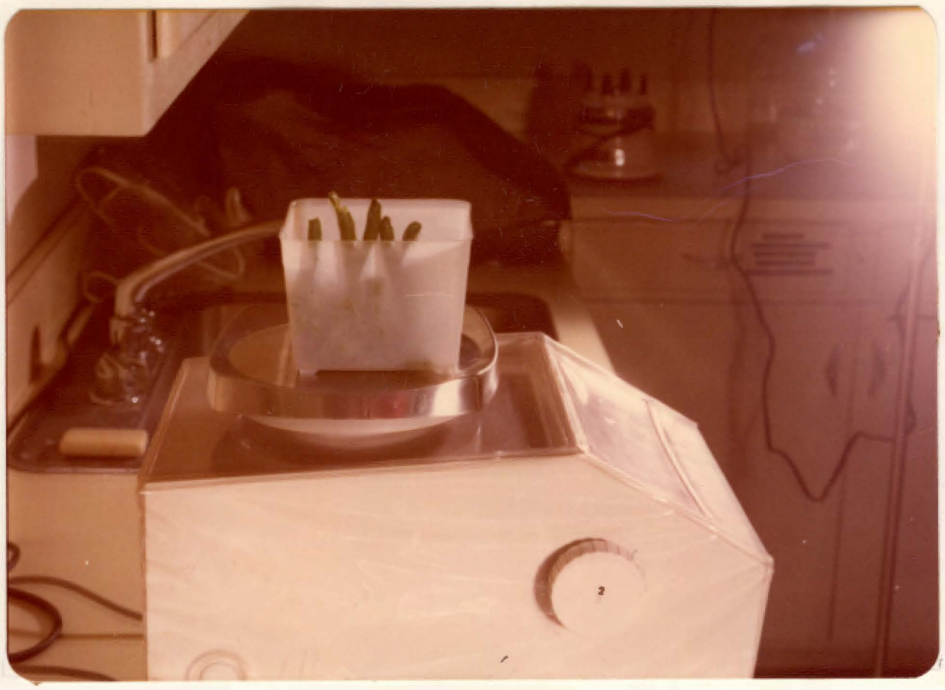


Fig. 4--Sartorious Werke AG Scale and plastic container used to weigh green beans.

beans were divided into seven equal portions (735 g) and placed in seven half size, 2 1/2-inch-deep stainless steel standard steam table inset pans (West et al., 1966b).

The seven pans were placed on two shelves within one compartment of an upright self-generating Market Forge Steamer (Model No. MF2AEWT403). The beans were cooked at 5 lb pressure from the frozen state until just tender in 30 minutes, according to an automatic timer on the steamer. Immediately after cooking, one pan was covered and allowed to cool, and six pans were placed on three improvised steam tables and covered with stainless steel lids. One pan was removed from the steam table at each 10-minute interval for one hour. Holding times were 0, 10, 20, 30, 40, 50, and 60 minutes. The temperature of the steam tables was set to

maintain the temperature of the green beans above the minimum of 140° F (Longreé).

The improvised steam tables were three 4-inch-deep stainless steel, standard size steam table inset pans, each placed over two small electric burners. Water was placed in the pans to the depth of 1 inch and brought to a boil before the pans of beans were placed in the large inset. Heat was reduced to half way between low and medium low during the holding period and water temperature was maintained at 212° F.

No water or seasoning was added to the green beans during the cooking or holding period. The beans were kept covered before and after cooking to reduce the effects of light and air on their color and texture (Charley, 1972).

At the end of each holding period over steam, the beans were removed from the steam table and stirred gently but thoroughly with a spoon. Quantities stated previously for raw green beans were removed from each of the seven pans and held for objective measurements. The green beans left in the pans were covered and allowed to cool to room temperature, then used for sensory evaluation by a panel of graduate students.

III. Sensory Evaluation

Three volunteer sensory panels assisted in the research. Two were consumer panels and one was a trained panel. The consumer panels were composed of undergraduate and graduate students, staff, and faculty in the College of Home Economics. Both men and women participated. Forty consumers sampled the Peco variety and 31 consumers

sampled the Slender White variety of beans for overall acceptability. Each variety was presented on a separate day. Panel members came in to taste the samples throughout the day from 9:00 a m until 4 p m. The beans were cooled, after preparation, to room temperature (70° F) and were held covered until time for sampling. A few consumers participated on both panels but most consumers sampled only one variety of bean.

Seven graduate students from the Department of Food Science, Nutrition, and Food Systems Administration served as members of the trained panel. Panel members were informed as to the general conditions of the study and the specific holding times. However, they were not shown the effect of the holding time on the two varieties of beans used prior to their evaluation of them.

Panel members were trained for five days before the initiation of the research with an unknown variety of frozen green beans that was distinctly different from the varieties used. They first identified the most obvious changes in texture, overall acceptability, and color with holding times of 0 to 60 minutes. Then they learned to judge the smaller differences. During the last days of training, the panelists evaluated the samples under the same conditions and with the same sensory tests that were to be used in actual testing. A seven-point descriptive texture scale was used with terms for firmness ranging from very firm to very soft (Appendix A, Fig. 21). For overall acceptability, a seven-point hedonic scale was used. Terms for acceptability ranged from "like very much" to "dislike very much" (Appendix A, Fig. 22). The color scale was a seven-point descriptive scale. Terms for green color ranged from dark green to dark olive green (Appendix A, Fig.23).

Panelists came to the laboratory at 9:00 a.m. each day during training and research periods.

Panelists evaluated the green beans for texture under red lights in the individual booths after they first entered the laboratory. After texture evaluation was completed, they turned off the red lights and turned on natural white colored fluorescent lights. Then the same samples of beans were evaluated for overall acceptability. Evaluation of color in green beans was the last sensory test completed. For this evaluation, the samples were placed in a separate booth.

Consumer Panel for Overall Acceptability

The same seven-point hedonic scale for overall acceptability which would be used for evaluation of green beans by trained panel members was used by a consumers' panel composed of undergraduate and graduate students, staff, and faculty at the College of Home Economics. Both men and women participated. The beans were placed on 6-inch white paper plates for presentation to the panel under normal room lighting. Code numbers were selected from the random digit table in Snedecor and Cochran (1967).

Each variety of green bean was prepared as stated previously. The same objective measurements were made as for green beans prepared for the trained panel. Each variety was presented on a separate day. Panel members came in to taste the samples throughout the day from 9:00 a.m. until 4:00 p.m. Most of the consumers sampled only one variety of green beans. There were 40 consumers to sample the Peco variety and 31 to sample the Slender White variety.

Texture Scale

A seven-point descriptive texture scale (Finney, 1971; Mackey et al., 1973) was used by panelists to evaluate the texture change in the green beans held for seven time periods under heated conditions.

The trained panel members were instructed to feel the bean, then bite through it once before chewing (Brandt et al., 1963; Sherman, 1969; Szczesniak and Bourne, 1969; Szczesniak et al., 1963).

One-third cup of green beans, from each of the pans held for the seven time periods under heated conditions, was removed from the covered pan and placed in a coded glass custard cup. The code numbers were selected from the random digit table in Snedecor and Cochran (1967).

The custard cups were placed on a brown plastic tray (Fig. 5). A napkin and a glass of water were added; then the tray was placed in a booth under a red light (Fig. 6).

Overall Acceptability Scale

A seven-point hedonic scale (Kramer and Twigg, 1970; Pilgrim, 1957) was used by panelists to evaluate the overall acceptability of the green beans held for seven time periods under heated conditions. Panelists also were requested to check whether they liked or disliked the color, flavor, and texture of each sample.

The same tray of samples presented for the Texture Scale Test was used by the panelists (Fig. 7). Immediately after the texture test, the panelists turned off the red fluorescent light and turned on a natural white colored fluorescent light to evaluate the degree of



Fig. 5--Tray prepared with coded sample dishes for panel evaluation of texture and overall acceptability.



Fig. 6--Prepared tray placed under red light in the individual booth for testing texture.



Fig. 7--Panelist testing the coded samples of green beans for overall acceptability.

acceptance of the samples and to mark like or dislike of differences noted in the three quality attributes of color, flavor, and texture for overall acceptability. Because of the difference in the color of the green beans under the natural white light and under the daylight of the Color Booth and the different code numbers, panelists' transfer of preference for a color between the two tests was avoided.

Color Scale

A seven-point descriptive color scale (Jeremiah et al., 1972) was used by the panel to evaluate the color change in the green beans held for seven time periods under heated conditions. One-third cup of green beans was removed from each of the seven pans and placed in a white plastic dish randomly coded (Snedecor and Cochran, 1967). The

Munsell Color Charts (Anon., 1952) were used for panel reference (Appendix B, Table 5) and were placed in order around the three inside walls of the Macbeth Color Booth, Executive Model (BBX 324) (Fig. 8). The dishes were placed in random order in front of the color charts. Daylight fluorescent light was used in the color booth to provide controlled color background and illumination for samples during the test period (Amerine et al., 1965). Panel members checked the green beans for texture and overall acceptability before checking the color scale.

Descriptive terms for texture, overall acceptability, and color were transposed to numerical data by using the following procedure: (1) the actual number of trained panel members who checked each scale term of the three scales for each replication was counted; (2) the total number of members checking each scale term of the three tests for all replications was divided by four to determine an average mean; (3) an average mean was determined by adding means of Slender White and Peco beans together and dividing by two; (4) to convert the mean for each term to a numerical score, the seven term means for each of the three scales were multiplied by a number. The mean of trained panel members for the first term farthest to the left was multiplied by seven. This procedure was continued, decreasing the multiplier by one for each column until the mean for number of members who checked column seven at the far right was multipled by one. The values obtained were used in analyses of variance for panel scores of texture, overall acceptability, and color.



Fig. 8--Macbeth Color Booth with the Munsell reference charts and sample dishes of green beans placed for panel evaluation of color.

IV. Objective Measurements

Objective measurements for color with the Kollmorgen Color Eye for "force," "shear peak area," and "work" with the Instron for pH and moisture were made on the same day as the sensory evaluation for each replication.

Texture Related Measurements

Values of "force," "shear peak area," and "work" were measured with an Instron for each 100 g sample of green beans that was obtained during five replications for each of the two varieties of green beans raw and held heated for seven varying periods of time.

Measurement of the force in kilograms required to shear a 100 g sample of green beans (Szczesniak et al., 1970) placed in a Kramer Shear Compression Cell attached to an Instron Universal Testing Machine (TM1132) was used to indicate the firmness of the beans. The work to shear beans or work function was determined from the area under the peak. Calculations for both "force" and "work" functions reported by Mackey et al (1973) are:

1. Maximum force--Number of divisions at highest peak of curve on Instron Chart graph x kilograms force per division. Full scale on the chart paper equals 10 divisions of 1 cm each; if a 100 kilogram load is applied as force, then one division represents 10 kilograms of force.

2. Work function to shear--Area under the curve in square cm x force per cm in kilograms = work to shear in kilogram-centimeters ^{2}. The area under the curve was measured with a compensating polar

planimeter (Keuffel and Esser Company, Model 4236M).

For the measurement of the force required to shear 100 gm of green beans, a full Kramer shear compression cell load, a 500 kilogram load cell, was used. A loading rate or force of 500 kilograms was applied to the raw beans and 200 kilograms to the cooked beans. Crosshead speed was 10 cm/minute synchronized with chart speed of 10 cm/minute. Gears were 26 AX/26 AX (Anon, 1970a). A sample of the Instron Chart with calculated values for force is shown in Fig. 9.

The chart from the Instron shows the force distance curves obtained for the green beans. The initial steep slope represents the rapid increase in force as the blades contact the green beans. The measure of the "force" required to shear the beans with the blades is the height of the peak. There is a rapid decrease in force as the blades press the beans through the precision blade-sized slits in the bottom of the Kramer shear compression cell (Fig. 10).

Color Related Measurements

Light reflectance was measured with a Kollmorgen Color Eye for each 30 g sample of green beans that was obtained during five replications for each of the two varieties of green beans raw and held for seven time periods over heat.

Prior experiments with various procedures had indicated that with the procedure used there was a consistent thickness of green beans; the beans were in the same form as when presented to panelists for evaluation; and horizontal and vertical lines and shape of food were merged into solid mass. The glass cuvette was designed specifically for use with the Color Eye.

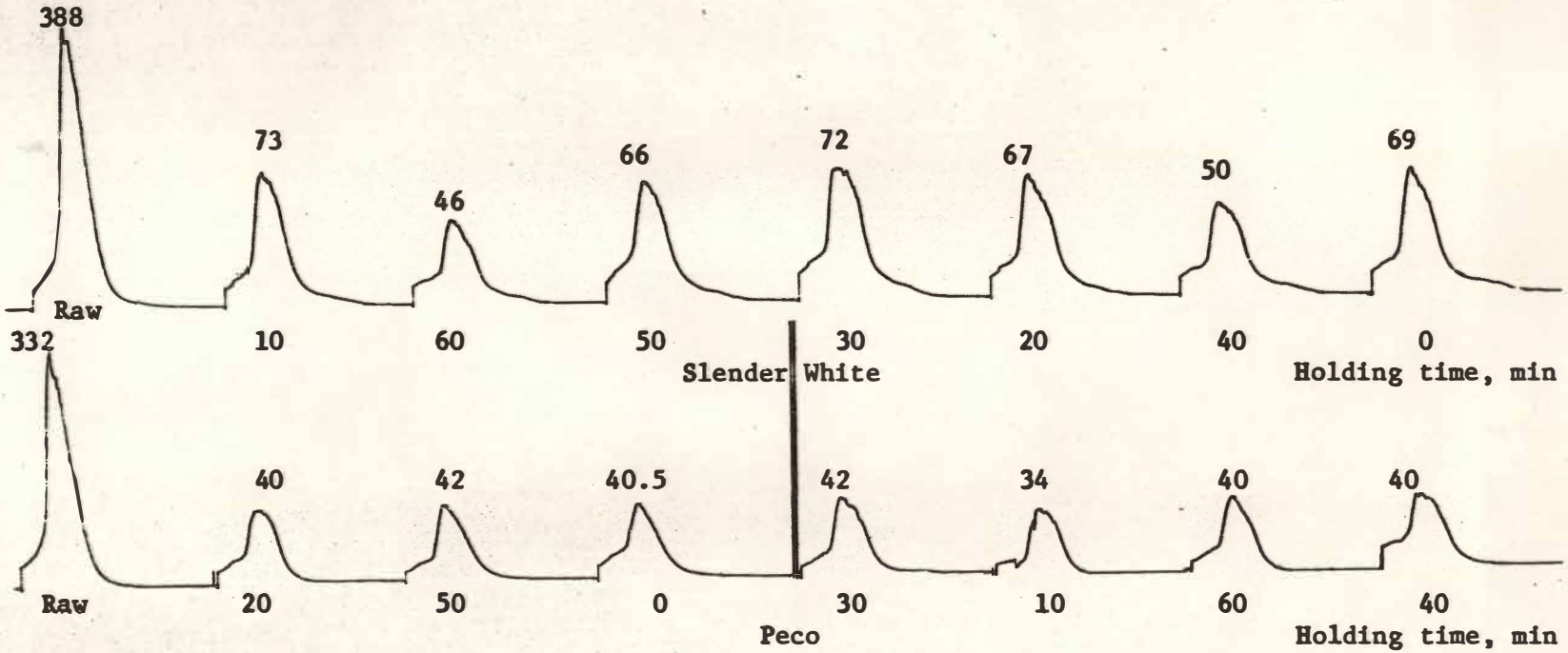


Fig. 9—"Force" curves on Instron charts of Peco and Slender White beans, raw and held heated, for varying intervals (fourth replication).

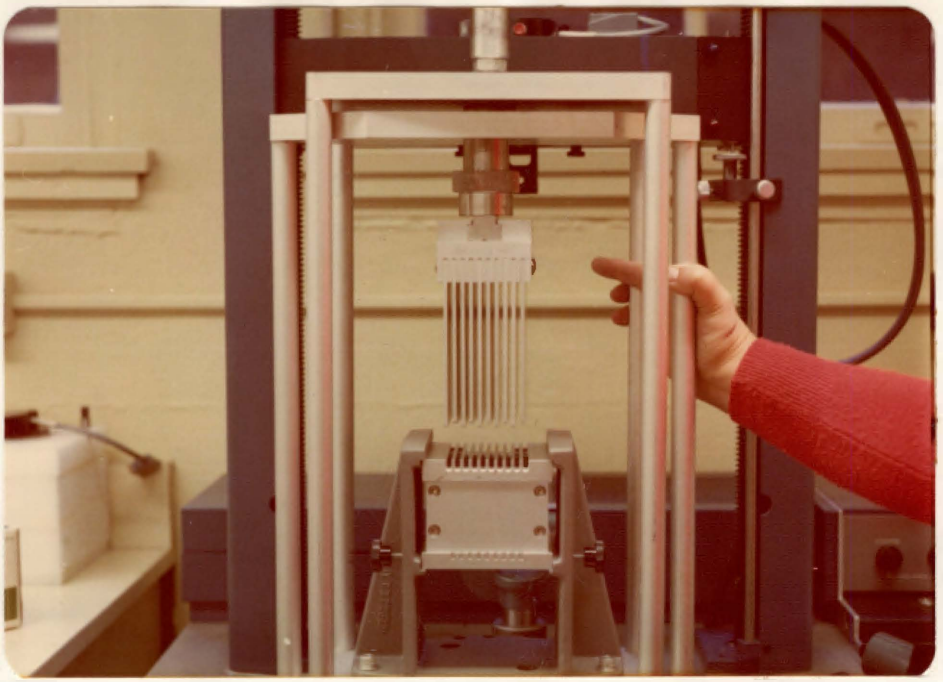


Fig. 10--Instron with Kramer shear compression cell used for shearing green beans.

Measurements were made with the Kollmorgen Color Eye (Signature Model D-1). White vitrolite standards were used at ports A and B for standardization before measurements were made for each replication series of samples. The standard procedure (Anon, 1972) was followed. The green beans were left as whole as possible and packed tightly, without air bubbles or empty space, in a cut glass cuvette (Fig. 11) for Color Eye presentation at porthole B (Fig. 12). A two-fold thickness of tightly woven black cloth was placed over both ports of the Color Eye, when reflectance readings were made, to prevent laboratory lights from affecting the readings.

Kollmorgen Color Eye readings for the settings of X, Y, Z, and X' (Appendix B, Fig. 24) were converted (Appendix B, Fig. 25) to C. I. E.

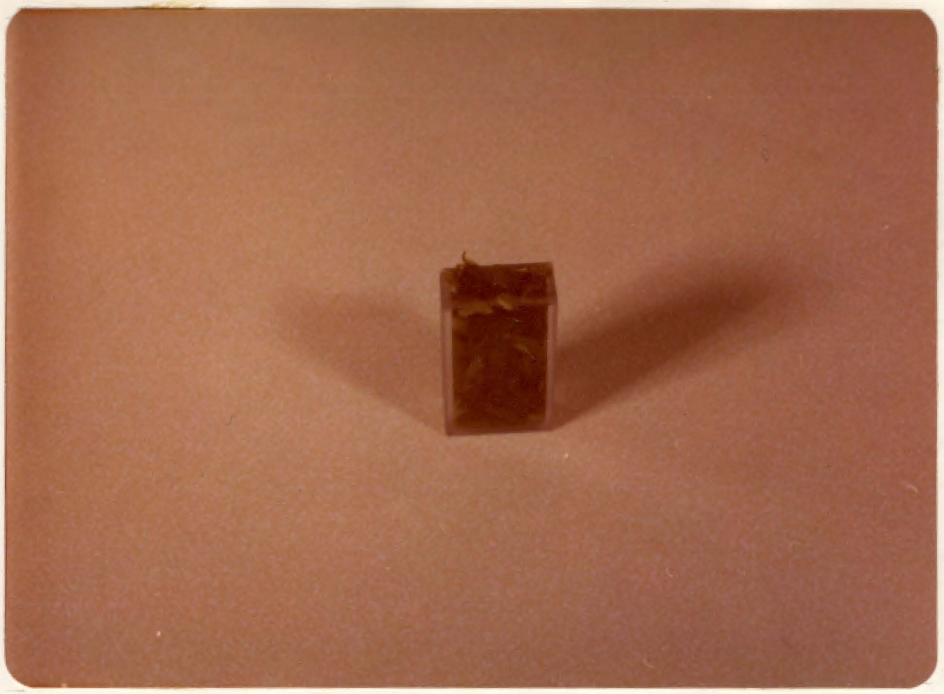


Fig. 11--Cut glass cuvette, packed with green beans, ready for presentation at porthole B.



Fig. 12--Sample presentation of green beans at the porthole of the Kollmorgen Color Eye for measuring the reflectance of light.

readings for X, Y, Z, coordinates, x and y, yellow index, lightness, Hunter *a* and *b*, Hue Angle, and Saturation Index by a program for the Olivetti Desk Computer. Formulas (Anon, 1972) used to convert Color Eye readings (ce) to C. I. E. notation (cie) were:

Xcie = Xce reading x (0.6333) + X'ce reading x (0.1711)

Ycie = Yce reading x (0.8560)

Zcie = Zce reading x (1.0109)

$$\text{Coordinate } x = \frac{\text{Xcie}}{\text{Xcie} + \text{Ycie} + \text{Zcie}}$$

$$\text{Coordinate } y = \frac{\text{Ycie}}{\text{Xcie} + \text{Ycie} + \text{Zcie}}$$

$$\text{Yellow Index} = \frac{\text{Xcie} - \text{Zcie}}{\text{Ycie}}$$

$$\text{Lightness} = \sqrt{\text{Ycie}}$$

$$\text{Hunter } a = \frac{(\text{Xcie} - \text{Zcie})}{\text{Xcie} + 2\text{Ycie} + \text{Zcie}} \times 100$$

$$\text{Hunter } b = \frac{0.4\ (\text{Ycie} - \text{Zcie})}{\text{Xcie} + 2\text{Ycie} + \text{Zcie}} \times 100$$

$$\Phi = \frac{\text{Hunter } b}{\text{Hunter } a} = \text{Hue Angle}$$

$$S = (a^2 + b^2)\ \sqrt{\text{Ycie}} = \text{Saturation Index}$$

Clydesdale and Francis (1969d) gave the following formulas to convert C. I. E. X, Y, Z readings expressed as Hg0-100 to Hunterlab L, *a* and *b* units:

$$L = 10\ \sqrt{\text{Ycie}}$$

$$a = \frac{17.5\ (1.02 \times \text{cie} - \text{Ycie})}{\sqrt{\text{Ycie}}}$$

$$b = \frac{7.0\ (\text{Ycie} - 0.847\ \text{Zcie})}{\sqrt{\text{Ycie}}}$$

Both methods were used in calculating the Hunterlab values.

Coordinates x and y were used to plot lines on a chromaticity diagram of the C. I. E. system. A line through the center C on the chart and through the intersection of lines for the x and y coordinates to the outer curve of the chart indicated the dominant wavelength (Appendix B, Fig. 26).

Coordinates x and y also were used in the ASTM standard method of specifying color by the Munsell system (Anon., 1968). Forms were used to obtain Munsell Color Notation from C. I. E. data (Appendix B, Table 6 and Fig. 27, Fig 28).

Other Related Measurements

The pH of the raw and cooked samples for the two varieties was determined to observe the relationship between pH and color change (Clydesdale et al., 1970; Sweeney, 1970). A 30 g sample from the raw beans and beans from each of the pans held for seven time periods under heated conditions for the two varieties was taken for pH determination. Fifty ml of distilled water were poured into a Waring Blender. The blender was set on high speed, and the green beans were slowly added and mixed to make a thick puree. The purees were placed in labeled 4 oz custard cups (Fig. 13). pH readings were obtained with a Corning Model 10 pH meter. The instrument was standardized with pH 7.00 buffer at 24° C., the temperature of the green beans (AOAC, 1970).

To determine the moisture content, each 20 g sample of green beans, reserved during each replication from the raw beans and from the seven holding periods was removed from its small covered plastic container and placed on a wooden cutting board. The green beans were cut

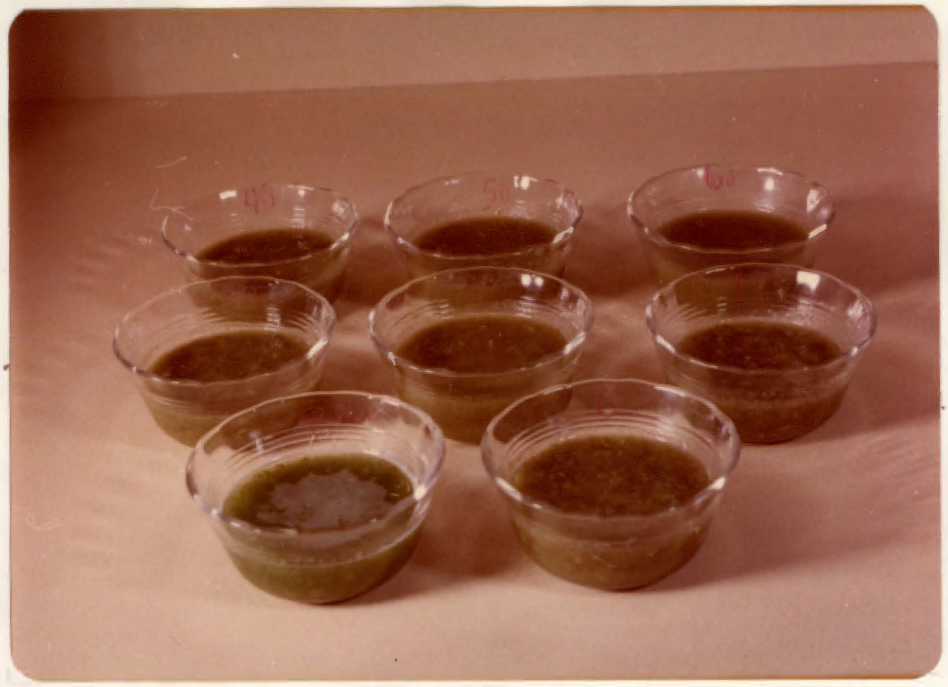


Fig. 13--Dishes of pureed green beans, prepared for pH determination.

finely and replaced in the container. The container was weighed to the nearest 0.001 g on the Mettler P120 Balance. After weighing, duplicate 5-8 g samples were transferred to two numbered preweighed aluminum weighing dishes with a small stainless steel spatula. Weight of the green beans in the weighing dishes was obtained by difference.

The duplicate sets of metal pans were placed on separate shelves in a preheated vacuum oven (Precision Scientific Company) at a controlled temperature of 68° C. Preliminary tests indicated that 15 hours were required to dry the beans to constant weight.

After drying, the pans (Fig. 14) were removed with forceps and placed in two desiccators to cool for 30 minutes. Prior to the first use, the desiccant had been heated in a 350° F. oven for 1 hour. The

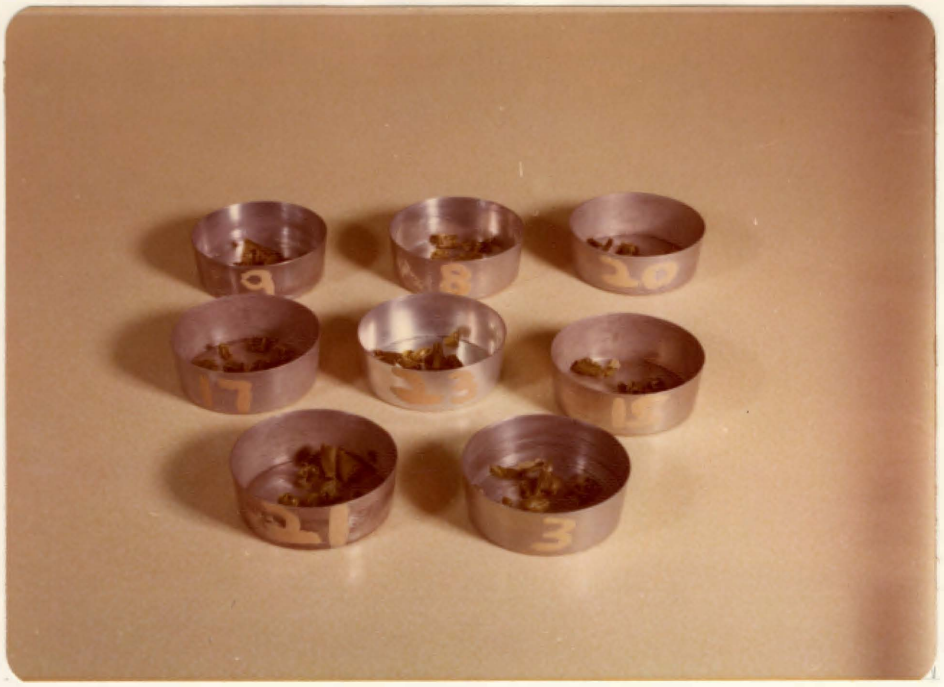


Fig. 14--Coded pans of green beans, after drying.

aluminum pans were placed on the Mettler P120 balance with forceps and reweighed to the nearest 0.001 g. Moisture content (Appendix B, Fig. 29) was calculated as loss of sample weight expressed as percent of undried weight. The values for the duplicates were averaged and the means are given in Appendix B, Table 7.

V. Experimental Design and Statistical Analysis

A split plot design with five replications of two varieties (whole plots) was chosen. Seven holding periods (split plots) were assigned randomly within each replication for the objective measurements. Four replications of each variety were presented to seven members of a trained panel for variables of sensory evaluation. The

analysis of variance used is shown in Table 2.

A panel composed of female and male students and faculty, The University of Tennessee, Knoxville, evaluated each variety of bean for acceptability.

An analysis of contingency tables using chi-square values (Snedecor and Cochran, 1967) as test statistics was employed to test the hypothesis of no difference in preference between the two varieties across holding time.

The effects of heated holding time on mean of trained panel scores for texture, color, and acceptability were partitioned into single degree of freedom contrasts by the use of orthogonal polynomials.

Table 2--Analysis of variance

Sources	Objective	Sensory
	Degrees of freedom	Degrees of freedom
Variety	1	1
Time	6	6
Linear	1	1
Quadratic	1	1
Cubic	1	1
Rest	3	3
Variety x time	6	6
Replication (varieties)	8	6
Residual	48	36
Total	69	55

CHAPTER IV

RESULTS AND DISCUSSION

Samples of Peco and Slender White beans held at temperatures above 140° F for seven periods of time were evaluated by consumer panels for overall acceptability. A trained sensory panel evaluated samples of the green beans for texture, overall acceptability, and color. Objective measurements of the green beans for values of "force," "shear peak area," "work," dominant wavelength, Munsell color, Hunter a and b, pH, and percent moisture content also were made. Data were subjected to chi-square, orthogonal comparison, and analysis of variance. Means of trained panel scores and means for objective measurement values are presented in Appendix C, Tables 8 and 9.

I. Sensory Evaluation

Consumer Panel Evaluation of Overall Acceptability

A seven-point hedonic scale was used which enabled the consumers to check the degree to which they liked or disliked a sample of Peco or Slender White beans. In addition, the consumers were requested to check whether they found a difference in the sample from other samples for texture, flavor, and color. A "D" for dislike, or an "L" for like was placed in the same square as the check mark. Comments were also made about likes and dislikes (Stewart and Amerine, 1973).

Consumer preference has been determined accurately by panels of 20 to 40 sensory panelists (Kramer et al., 1963). For this research, 31

consumers evaluated Slender White beans and 40 consumers evaluated the Peco beans. Consumers were male and female students and faculty from The University of Tennessee, Knoxville. The consumer panel data were arranged into contingency tables and chi-square was used for testing no difference in varietal preference. Variety did not affect difference significantly for overall acceptability. Both varieties were equally acceptable to the consumer panels.

The greatest difference between the two varieties of green beans for consumer acceptability with holding time was for the scale term "dislike slightly." Peco beans were disliked more during the first 20 minutes of holding time than Slender White beans. This finding corresponds to the trained panels' mean scores for texture and color. The panelists evaluated the Peco bean as being greener in color and firmer in texture over the first 20 minutes. Both attributes possibly are least acceptable to persons with southeastern regional food preferences.

Trained Panel Evaluation of Texture

Variety did not affect texture significantly. Holding time affected sensory scores for texture significantly ($P<0.0001$, Appendix C, Table 10). A significant interaction between variety and heated holding time was not found. Softening of the green beans as detected by the trained panel was linear (Fig. 15). The change from very firm to very soft, as discerned by the panelists, was in agreement with objective measurement values for "force" and "work."

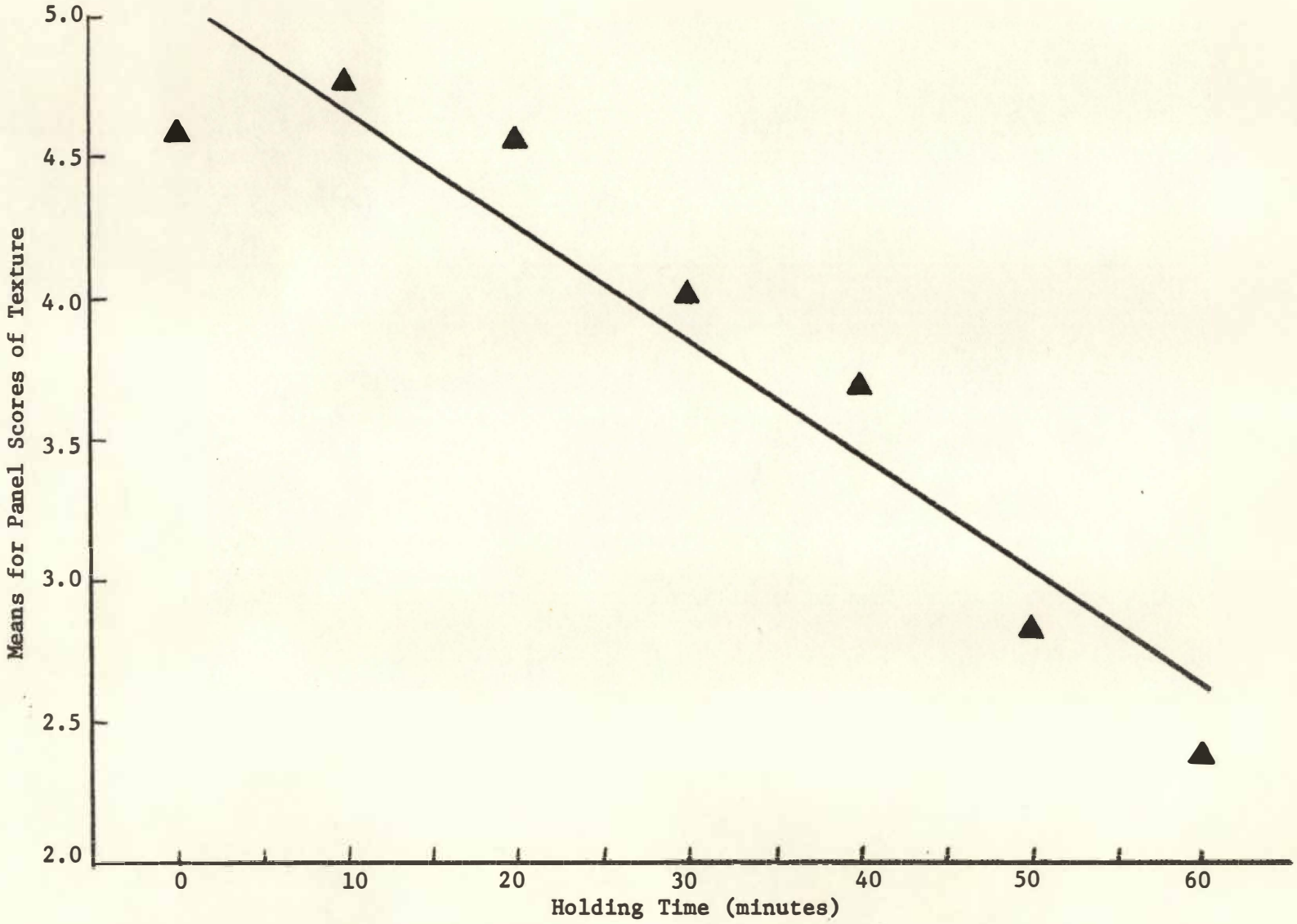


Fig. 15--Mean sensory scores averaged for texture of Peco and Slender White beans at 10-minute intervals of holding time.

Trained Panel Evaluation of Overall Acceptability

Overall acceptability was not affected significantly by variety, but it was affected significantly ($P<0.05$) by holding time (Appendix C, Table 11). A significant interaction between variety and holding time was not found. As indicated by the cubic component (Fig. 16), acceptability was highest after beans were held heated for 30 minutes, and lowest when held 10 minutes.

The cubic component for acceptability was attributed to the bimodal preference by the panel for the green beans based on the attributes of texture, flavor, and color. Five panel members had been reared in the southeastern region. Four of these panelists had a similar consistent pattern of acceptance for beans that were less firm and more yellow green than beans accepted by the other three members. Two members of the panel had been reared in states out of the southeastern region, and one panel member from the southeastern region followed their pattern of acceptance for beans that were green and barely tender. In the southeastern region, green beans are frequently cooked with smoked or fresh pork, vinegar, and sugar over low heat for relatively long periods of time (Lane, 1956). A blended flavor and a soft cohesiveness of the bean develops that is different from the flavor and texture of green beans cooked quickly in rapidly boiling water.

Panelists' comments regarding color included the opinion that Peco green beans were too green in color at 0- and 10-minute holding times. However, the panelists considered the color of Peco beans to remain more even and acceptable over a longer range of holding times than that of Slender White beans. The Slender White beans were

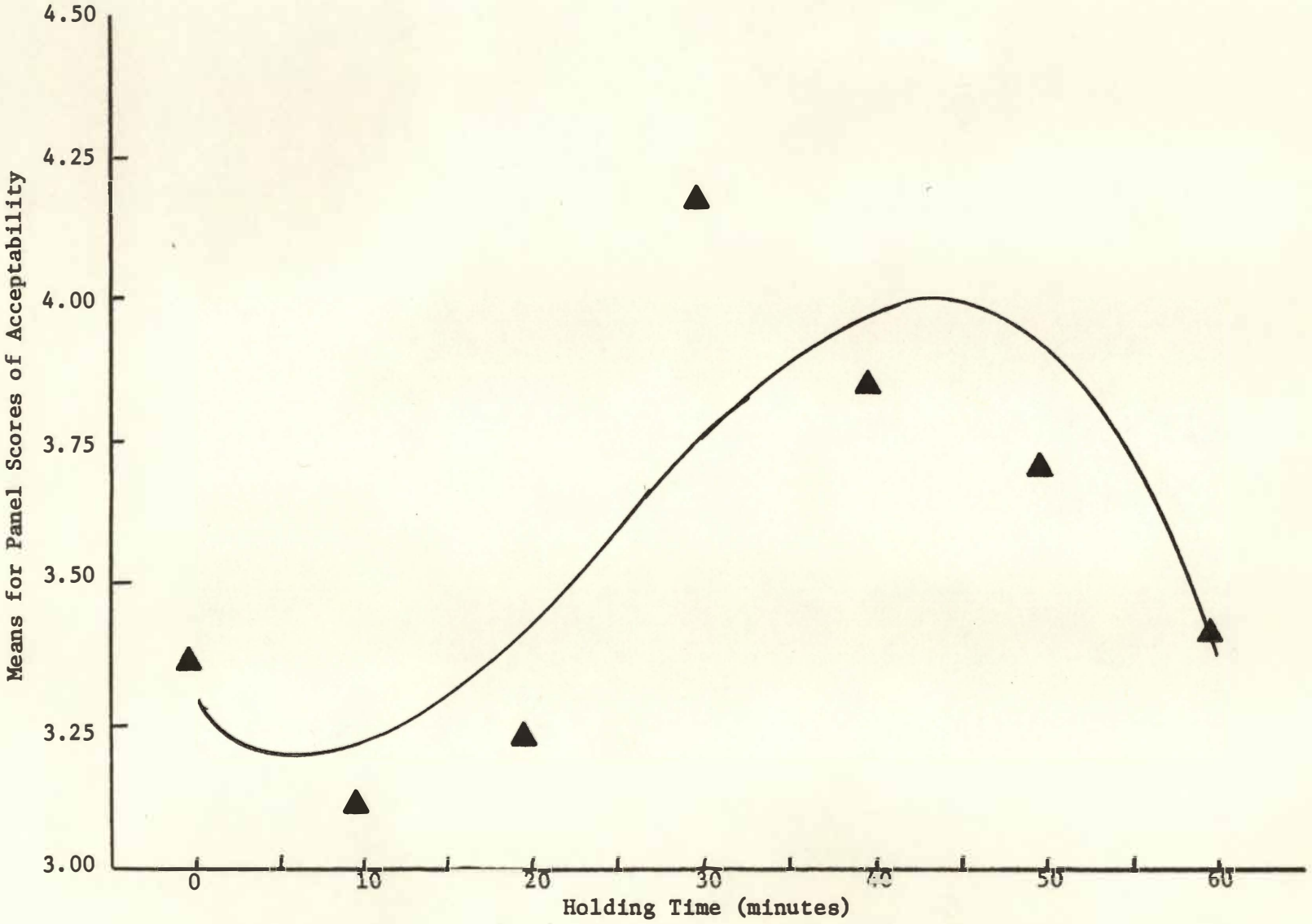


Fig. 16--Mean sensory scores averaged for overall acceptability of Peco and Slender White beans at 10-minute intervals of holding time.

considered non-uniform in color at every holding period and their color was more yellow and and more unacceptable after 40 minutes that that of the Peco beans. The most acceptable color for both varieties of beans was at 30 minutes' heated holding time. The range of holding times within which panelists preferred the texture was narrower than that for color.

Comments regarding texture changes with holding time were directed largely toward the Slender White beans. Even though the majority of the panel members preferred a softer bean, they objected to what they considered excessive softness. Comments about Slender White beans at 50- and 60-minute holding times included the following: "I like beans soft, but I don't like them mushy. Too soft. Don't like skin, or strings; slightly tough. Skin--ick! Too mushy! Beans have heavy strings. Mushy after chewing. Overcooked--mushy."

Texture of the Slender White bean generally was acceptable at an earlier holding time than the Peco bean and less acceptable at the later holding times. Texture change was uniform in all of the Peco beans but not in the Slender White beans.

Panel members stated that Peco green beans tasted raw, green, or grassy for the first 10 minutes of heated holding time. After 40 minutes, some panel members indicated the Slender White beans were flat and tasteless while the Peco beans tasted overcooked. Flavor was most acceptable for the 30 minute holding period for both varieties of beans. The range of holding times within which flavor was liked was nearly as restricted as that for texture.

Trained Panel Evaluation of Color

Variety affected sensory scores (Appendix C, Table 12) for color significantly ($P<0.05$), indicating that panelists discerned the genetic difference in color of the Slender White and Peco beans. Color was affected significantly ($P<0.0001$) by holding time. The effect was linear (Fig. 17). The color change as described by the trained panel was from dark green to dark olive green over the 60 minutes of holding time. A significant interaction between variety and holding time was not found.

II. Objective Measurements

Texture Related Measurements

Variety did not affect "force" significantly (Appendix C, Table 13). "Force" was significant with holding time ($P<0.05$). From Fig. 18, it can be seen that the effects were linear. A significant interaction between variety and holding time was not found.

"Force" measurements for the initial shearing of the beans were comparable to the force required to bite through the bean for the first time. The "force" values probably reflected the effects of heat on the pectic substances, hemicelluloses and cellulose, all of which contribute to firmness of the green beans. The shearing forces for both Peco and Slender White beans were similar to those reported by Sweeney (1970) both as to magnitude and as to effect of holding over steam.

"Shear peak area" was not affected significantly by variety, holding time, or by interaction between variety and holding time (Appendix C, Table 14). The green beans retained nearly their same

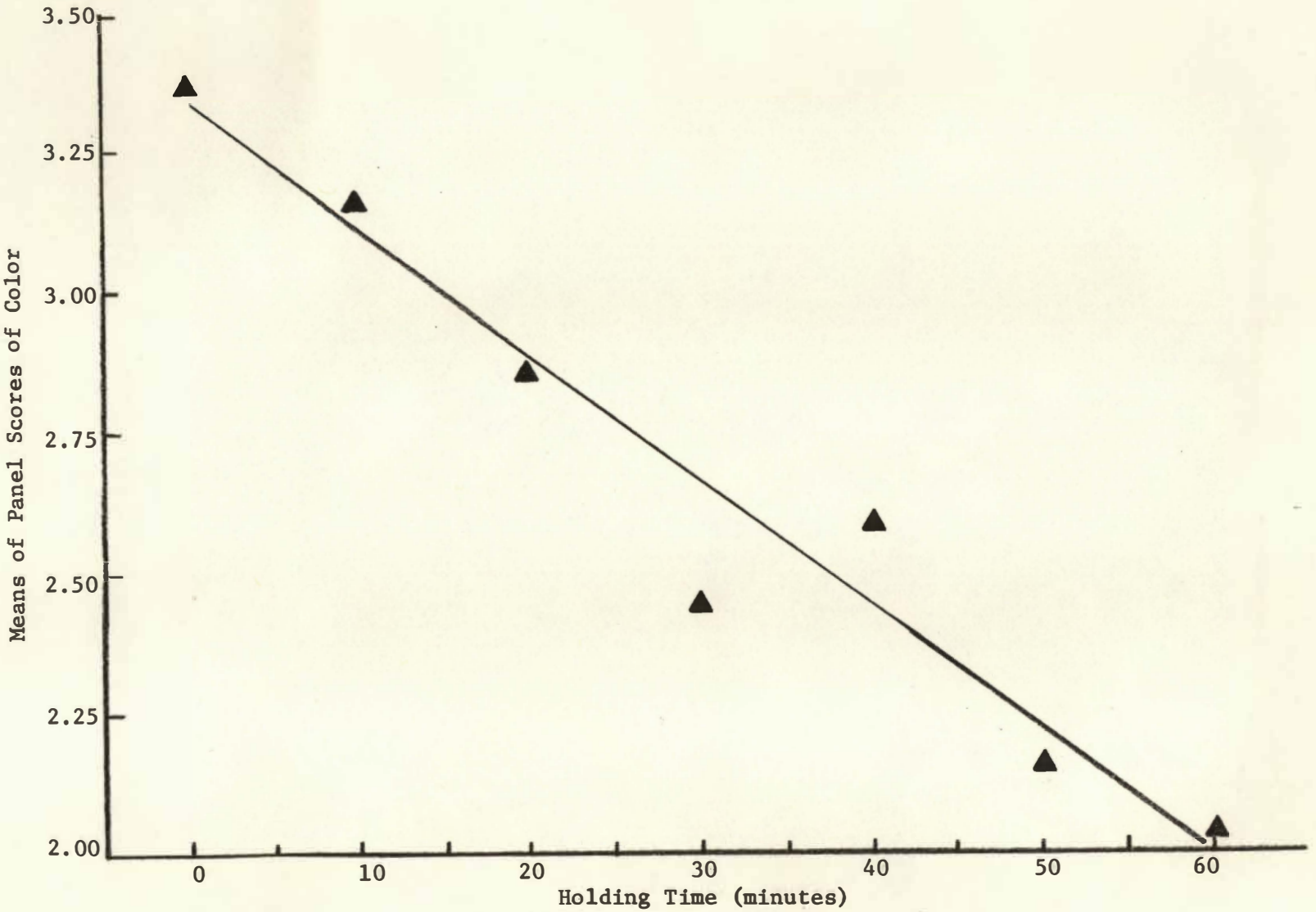


Fig. 17--Mean sensory scores averaged for color of Peco and Slender White beans at 10-minute intervals of holding time.

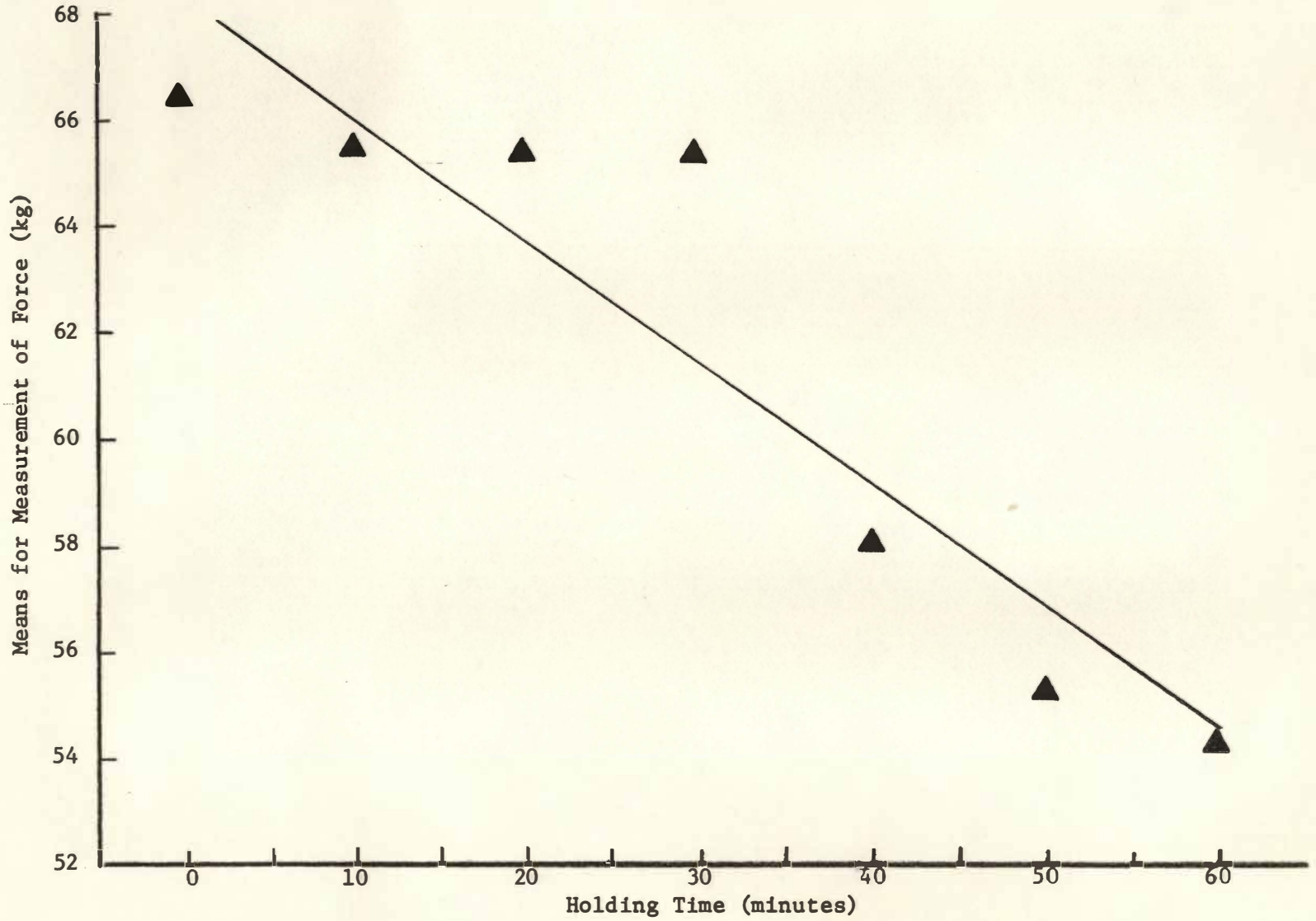


Fig. 18--Mean of "force" values averaged for Peco and Slender White beans at 10-minute intervals of holding time.

shape and percent moisture content throughout the 60 minutes when held heated. This was reflected by "shear peak areas" that only approached significance ($P<0.09$).

Variety did not affect "work" significantly (Appendix C, Table 15). "Work" was significant ($P<0.05$) with holding time. From Fig. 19 it can be seen that the effects were linear. A significant interaction between variety and holding time was not found. "Work" measurements for the total force required to shear, press, and extrude beans from the Kramer shear compression cell were comparable to the "work" required to chew the beans to the swallowing point.

Color Related Measurements

Dominant wavelengths differed significantly ($P<0.01$) for the two bean varieties (Appendix C, Table 16). Holding time also affected significantly the dominant wavelengths ($P<0.01$). The dominant wavelengths increased linearly with holding time (Fig. 20). A significant interaction between variety and holding time was not found. The difference in dominant wavelengths for Peco and Slender White beans was attributed to inherent characteristics affecting coloration of the green beans. The Slender White beans were large, long, and had a heavy string. The beans within the mature pods were nearly twice as large as the beans within the Peco pods. Slender White beans have a rapid maturing rate at harvest. Picking them before they become too mature results in the beans having varying degrees of maturity, color, and size. The Peco beans were stringless. They mature slowly and at an even rate, and are uniformly green and small in size.

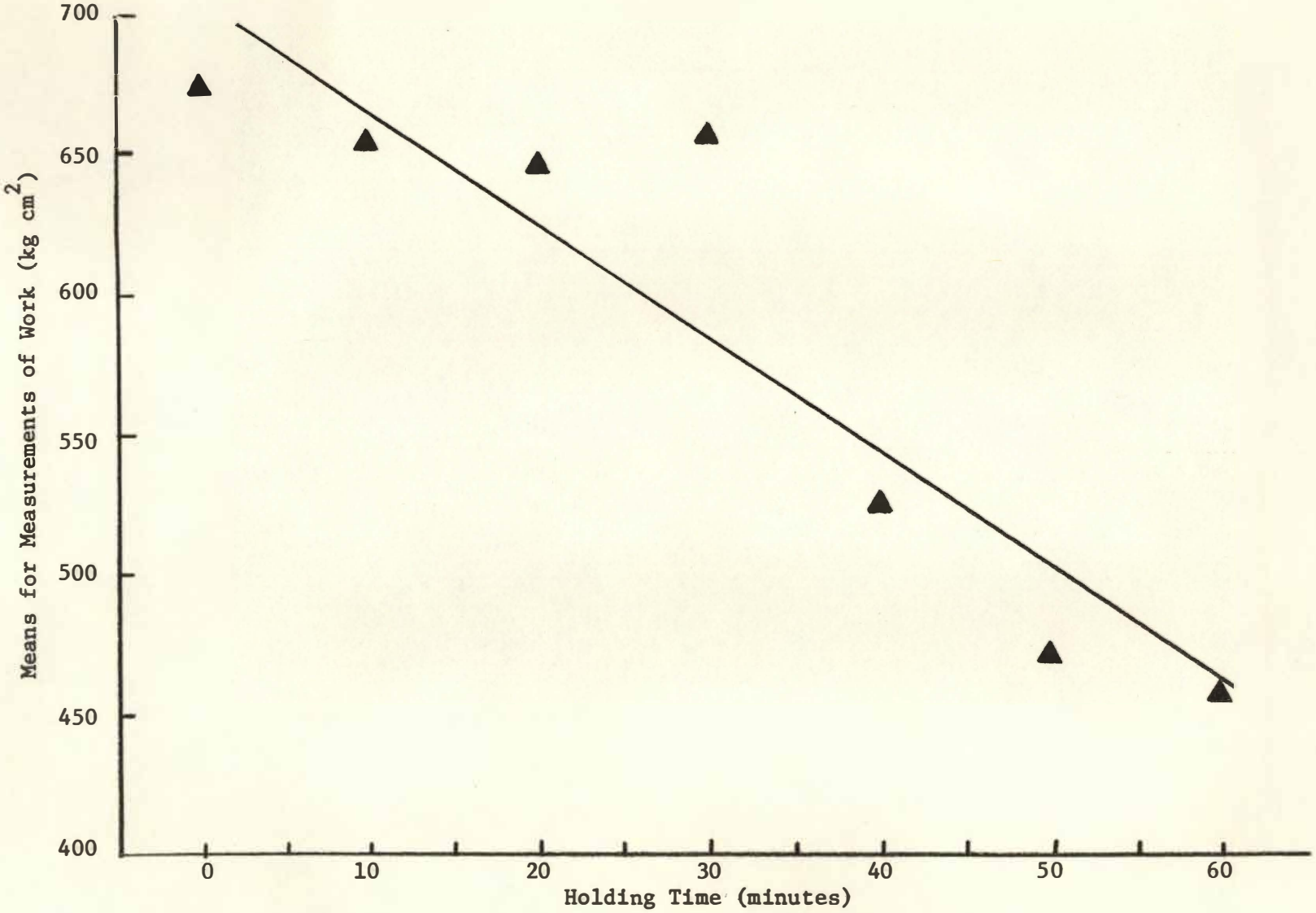


Fig. 19--Mean of "work" values averaged for Peco and Slender White beans at 10-minute intervals of holding time.

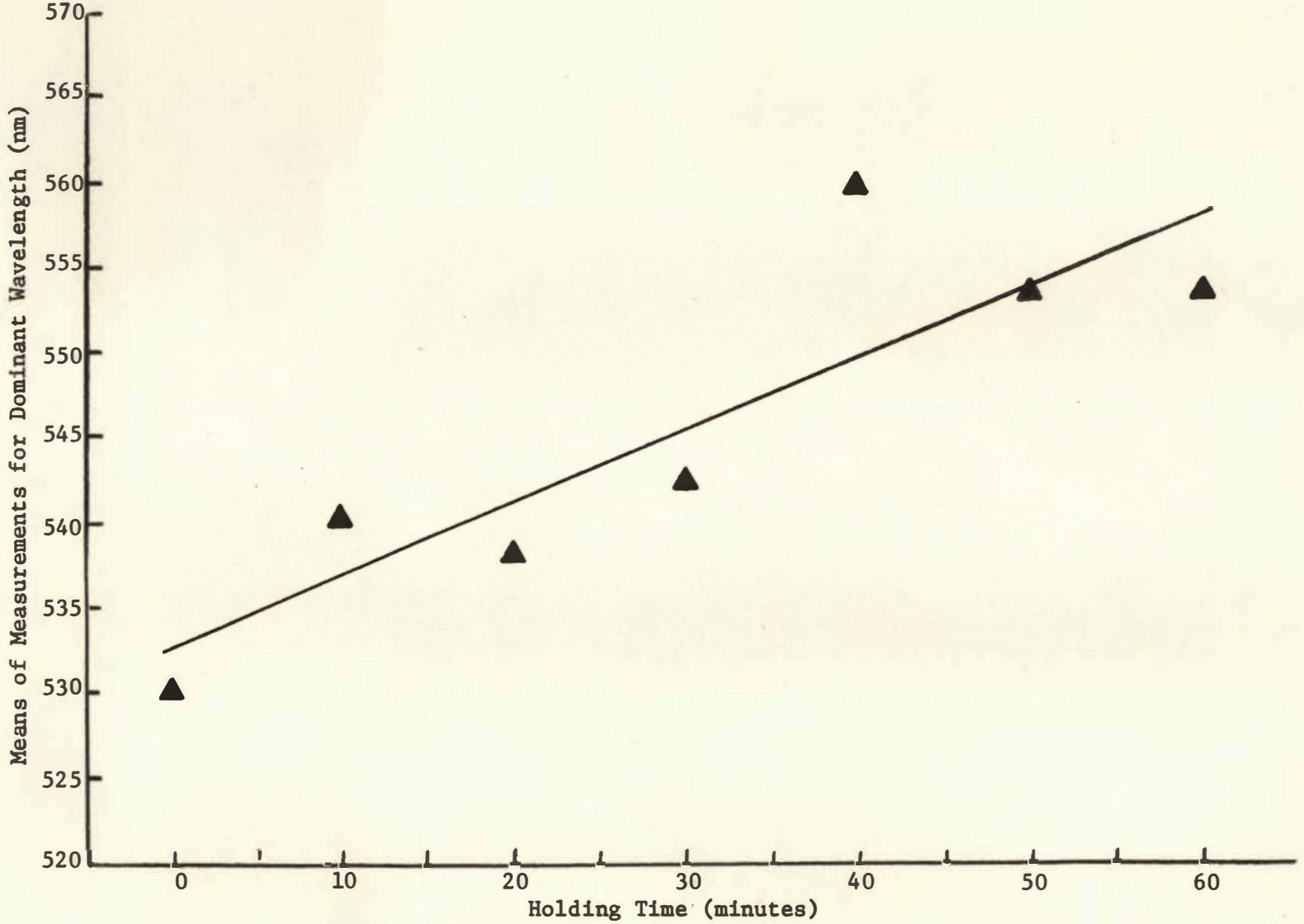


Fig. 20--Dominant wavelengths averaged for Peco and Slender White beans at 10-minute intervals of holding time.

Color change of dominant wavelength with holding time as indicated by the significance of the linear component (Fig. 20) proceeded at a rather uniform rate from green toward yellow over the 60 minutes of heated holding time. Both varieties changed from green to yellowish green in the first 10 minutes, then became more yellowish green within the next 30 minutes of holding times. The dominant wavelength mean values for Peco beans ranged from 528.00 to 551.20 nm and the dominant wavelength mean values for Slender White beans ranged from 532.4 to 556.2 nm. The colors for the dominant wavelengths in Table 3 are according to the (xy) chromaticity diagram of the ICI system (Appendix A, Fig. 26).

Munsell color values (Appendix C, Table 17) were affected significantly ($P<0.0001$) by variety. Holding time did not affect significantly the Munsell color nor was there a significant interaction between variety and holding time. The difference in Munsell color was attributed to the same characteristics affecting varietal means for dominant wavelength.

Variety did not affect Hunter a values significantly (Appendix C, Table 18). Hunter a was not affected significantly by holding time, nor was there a significant interaction between variety and holding time. Hunter b was not significantly affected by variety nor by holding time (Appendix C, Table 19). There was a significant interaction between variety and holding time for Hunter b when converted from C. I. E. values by the method given in Anon., 1972. Conversion values by the procedures given by Clydesdale and Francis (1969d) were not significant.

The conversion of C. I. E. values to Munsell color values and

Table 3--Colors for dominant wavelengths from green to yellow

Dominant wavelengths, nm	Color
491 to 497	Bluish green
497 to 527	Green
527 to 558	Yellowish green
558 to 570	Yellow green
570 to 575	Greenish yellow
575 to 580	Yellow

Hunter a and b values were not as significant as dominant wavelength values. This may be attributed, as Clydesdale and Francis (1969c) reported, to the fact that transformation to x, y, z values from other systems resulted in very different absolute values than those obtained when x, y, z readings were obtained directly from a system.

Other Related Measurements

The pH values for the Peco and Slender White green beans decreased with heating time. Mean pH values for the heated holding periods are given in Table 4. The values were not analyzed statistically.

Eheart and Odland (1973) reported the pH of raw green beans after frozen storage for six months as 6.12 and that of cooked as 6.11.

Clydesdale et al. (1970) observed a pH of 6.1 for fresh uncooked green beans, and a pH of 5.8 for green beans cooked until just tender. At 180 ± 5° F. for the equivalent of steam table periods of 20, 45, and 60 minutes, Clydesdale et al. (1970) found pH values of 5.6, 5.5, and 5.5. Sweeney (1970) noted a pH of 6.21 for frozen uncooked green beans and of 6.14 for frozen green beans cooked 10 minutes in a steam-jacketed kettle. When these beans were drained and held on a conventional steam table in steam table inset pans for 10, 20, and 30 minutes, the pH values were 5.84, 5.84, and 5.80.

The color of the green beans in this study changed similarly to Charley's (1972) description from green to yellowish green and to an increasingly yellow green as pH values decreased with increased heated

Table 4--pH values for Slender White and Peco beans when raw and held heated for varying holding periods

Raw and holding periods (minutes)	pH Slender White	pH Peco
Raw	5.90	6.18
0	5.68	5.71
10	5.70	5.87
20	5.67	5.81
30	5.70	5.68
40	5.57	5.75
50	5.50	5.69
60	5.47	5.66

holding time. Change in color indicates the breakdown of chlorophyll to pheophytins *a* and *b* as volatile acids accumulate in the moisture within and around the green beans.

The percent moisture content varied slightly in the green beans from the raw state to the end of the 60 minute holding time. Appendix B, Table 7, shows the change in percent moisture content for both varieties of beans. Peco beans varied from 91.83 to 91.53 percent moisture content. Slender White had a variation from 89.69 to 89.02 percent moisture content. The difference in percent moisture content between the two varieties was attributed to the Slender White bean being a larger and more fully developed bean.

III. Conclusions

Variety of green beans did not affect overall acceptability. This was evidenced by both panel scores for acceptability (Appendix C, Table 11) and by the chi-square analysis of consumer preference data. Acceptability was affected significantly by holding time as indicated by panel scores for acceptability. The cubic component of the orthogonal comparisons in Fig. 16, page 62, reflects the bimodal preference of the panelists for green beans at different heated holding periods. Panelists of the southeastern region preferred green beans that were a more yellowish green and had a slightly softer texture than those preferred by the other panelists. The highest level of overall acceptability at 30-40 minutes for the trained panel corresponded to the following ranges in the objective measurements: dominant wavelength,

542-559 nm; "force" 65.33-57.99 kg; "work" 657.38-525.27 kg cm^2.

Peco and Slender White green beans did not differ significantly in texture as evidenced by trained panel scores for texture and objective measurement values of "force," "shear peak area," and "work" (Appendix C, Tables 10, 13, 14, 15). Holding time significantly affected trained panel scores for texture and for "force" and "work." The green beans became less firm at a linear rate over the 60 minutes of heated holding time (Fig. 18 and Fig. 19, pages 66 and 68 respectively). The linear component of the panel scores for texture (Fig. 15, page 60) showed that the panelists detected the change in firmness of the beans. A significant interaction between varieties and holding time for trained panel scores of texture, "force," "shear peak area," and "work" was not found. Instron measurements for "force" and "work" could be used as objective quality control standards; both trained panel scores for texture and objective measurements of "force" and "work" were affected significantly and linearly by holding time.

The two varieties of beans differed significantly in color as evidenced by trained panel scores for color, dominant wavelength and Munsell color (Appendix C, Tables 12, 16, 17). Color was affected significantly by holding time as indicated by dominant wavelengths and panel scores for color. The change in color proceeded from green to yellow at a linear rate over the 60 minute period (Fig. 17, page 65, and Fig. 20, page 69). There was no significant interaction between variety and holding time for dominant wavelength, Munsell color, panel scores for color or Hunter a values. Only one method of conversion gave a significant difference for interaction between variety and holding time for Hunter b values.

Under the conditions of this study, a relationship apparently existed among holding time of fully prepared green beans held over steam, color and texture measured objectively, and color, texture, and overall acceptability determined by sensory evaluation. The objective measurements in combination with the sensory evaluation resulted in objective parameters that could be predictive of acceptability to this particular group of panelists.

The methodology presented in this study could be used in other regions of the United States to indicate consumer preference and to help to establish objective quality control standards for the food service industry.

CHAPTER V

SUMMARY

Grade A frozen Peco and Slender White beans, after preparation and when held heated during 10 minute intervals (0. 10, 20, 30, 40, 50, 60) were evaluated for overall acceptability by a consumer panel. A trained sensory panel evaluated the two varieties of beans, for the seven holding periods, for texture, overall acceptability, and color. Texture and color were measured objectively. Instron measurements were used for obtaining values for "force," "shear peak area," and "work." Measurements from the Kollmorgen Color Eye were transformed to dominant wavelength, Munsell color, and Hunter a and b values. The relationship among consumer acceptability, trained panel evaluation of texture, overall acceptability, and color during the seven holding periods and the objective measurements were studied to ascertain objective measurement values that could be recommended as standards of quality control.

The consumer panel data, obtained during the fifth replication of objective measurements, were arranged into contingency tables and chi square was used for testing no difference in varietal preference. The sensory panel evaluation data for texture, overall acceptability, and color obtained during the first four replications of objective measurements were subjected to orthogonal comparisons and an analysis of varience, as were those for the five replications of objective measurements.

The consumer panel showed no significant varietal preference as

to overall acceptability. The trained panel scores for overall acceptability were not affected significantly by variety but were affected significantly by holding time; panelists found both varieties of bean most acceptable between 30 and 40 minutes. A significant cubic component for overall acceptability was attributed to the bimodal preference of the panel for the green beans.

Texture was not affected by the variety of green beans as evidenced by trained panel scores for texture and objective measurement values of "force" and "work." Holding time affected texture significantly as evidenced by trained panel scores and by objective measurement values of "force" and "work." Softening of the green beans was linear with holding time as shown by orthogonal comparisons for the trained panel scores and objective measurement values.

Color was affected significantly by the variety of bean as evidenced by trained panel scores and objective measurement values of dominant wavelength and Munsell color. Holding time also affected color significantly as shown by trained panel scores and values of dominant wavelength. Dominant wavelength increased linearly with holding time representing a color change from dark green to dark olive green. The only significant interaction between variety and holding time was for Hunter b, from the Kollmorgen readings, indicating that although color was different in the beans, the color changes in the two varieties of beans followed a similar linear change with holding time.

Under the conditions of this study, a relationship apparently existed among holding time of fully prepared green beans held over steam, consumer overall acceptability, trained panel evaluation of

texture, overall acceptability, and color and objective measurement values for texture and color. The sensory evaluation, showing maximum acceptability at 30-40 minutes of holding time, in combination with the corresponding objective measurement values, resulted in mean objective parameters that could be predictive of acceptability to this particular group of trained panelists. The parameters were 65.33-57.99 kg for "force," 657.38-525.27 kg cm^2 for "work," and 542-559 nm for dominant wavelength. The methodology presented in this study could be used in other regions of the United States to indicate consumer preference and to help establish objective quality control standards for the food service industry.

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APPENDIXES

APPENDIX A

SENSORY DATA

NAME:

DATE:

PRODUCT:

Feel the bean, then bite through it before chewing. Please place a check mark in the space opposite the sample which best represents your judgment as to the texture.

Sample	Very firm	Firm	Slightly firm	Neither firm nor soft	Slightly soft	Soft	Very soft

Comments:

Fig. 21--Descriptive texture scale.

NAME:

DATE:

PRODUCT:

Taste each of the test samples presented. Place a check mark in the space opposite the sample which best represents your judgment as to liking or disliking the sample.

Sample	Like very much	Like moder-ately	Like slightly	Neither like nor dislike	Dislike slightly	Dislike moder-ately	Dislike very much

Difference in samples was detected due to: (Check one or more and write L or D in the same space to indicate like or dislike).

Sample	Texture	Color	Flavor	Other (specify)

Fig. 22--Hedonic scale for overall acceptability.

NAME:

DATE:

PRODUCT:

Please place a check mark in the space opposite the sample which best represents your judgment as to the color.

Sample	Dark green	Medium green	Pale green	Slightly yellow green	Pale olive green	Medium olive green	Dark olive green

Comments:

Fig. 23--Descriptive color scale.

APPENDIX B

OBJECTIVE DATA

Table 5--Munsell color charts with hue and ranges of values and chroma, used as reference charts for descriptive color scale terms

Hue	Values	Chroma	Descriptive color scale terms
2.5 Y	5,6,7	4,6,8	Dark olive green
5.0 Y	5,6,7	4,6,8	Medium olive green
2.5 GY	5,6,7	4,6,8	Pale olive green
5.0 GY	4,5,6	4,6,8	Slightly yellow green
7.5 GY	4,5,6	4,6,8	Pale green
2.5 G	4,5,6	4,6,8	Medium green
5.0 G	4,5,6	4,6,8	Dark green

Minutes of time green beans held raw and heated after cooking	X	Y	X	X'
Raw				
0				
10				
20				
30				
40				
50				
60				

Fig. 24--Readings for X, Y, Z, X' from Kollmorgen Color Eye.

Minutes of time green beans held raw and heated after cooking	C. I. E. X	C. I. E. Y	C. I. E. Z	L	x	y	Dominant wave length
Raw							
0							
10							
20							
30							
40							
50							
60							

Fig. 25--Transformation of Kollmorgen Color Eye readings to C. I. E. readings and dominant wavelengths.

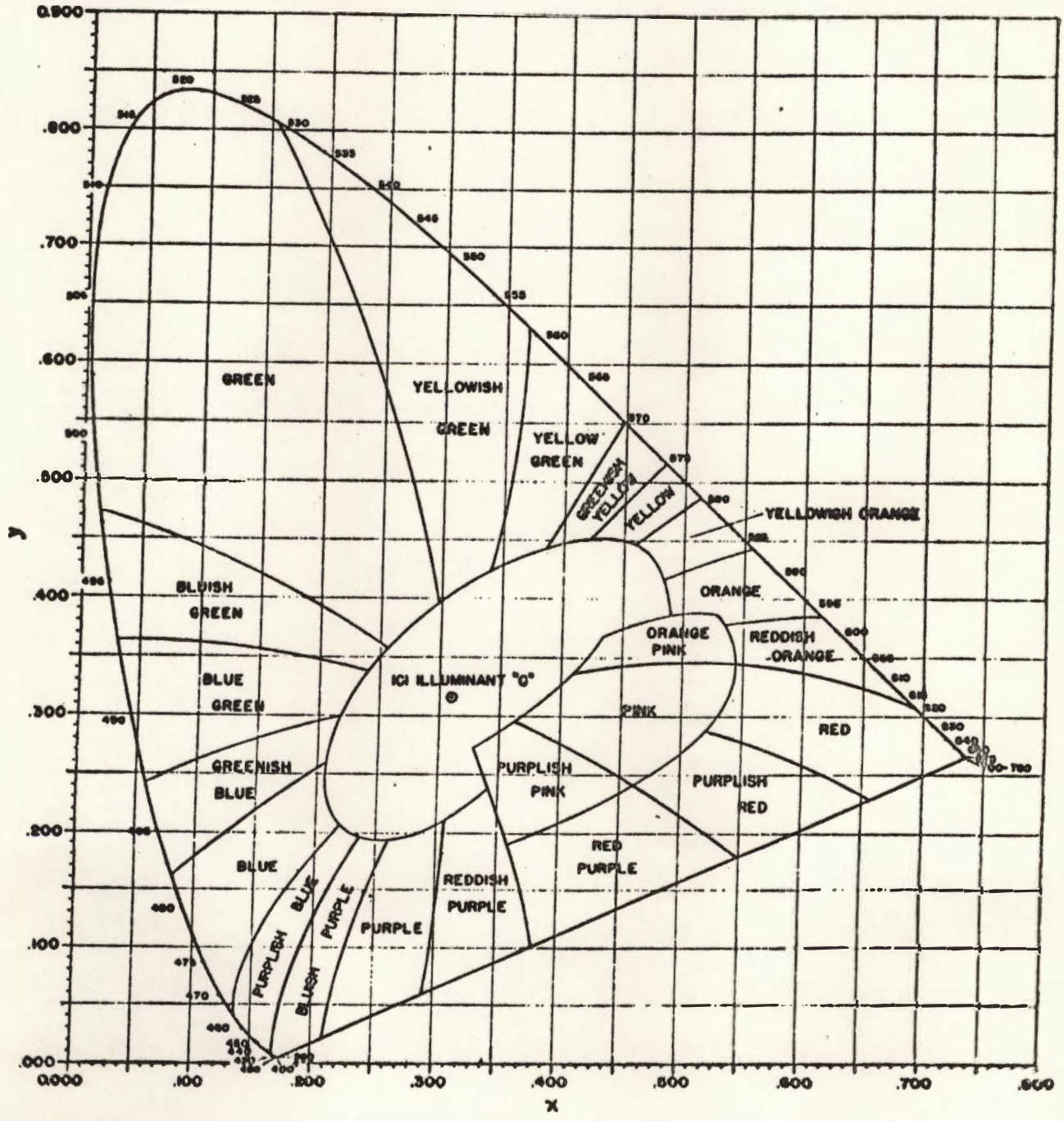


Fig. 26--The (x,y) chromaticity diagram of the C. I. E. system.

Table 6--Luminous reflectance, Y, in percent relative to M_gO, equivalent to Munsell renotation value, V (2)

V_T	Y	V_T	Y	V_T	Y	V_T	Y	V_T	Y	V_T	Y	V_T	Y	V_T	Y	V_T	Y
10.00	102.57																
9.99	102.30	8.99	78.45	7.99	58.92	6.99	42.92	5.99	29.94	4.99	19.68	3.99	11.935	2.99	6.511	1.99	3.100	0.99	1.196
8	102.04	8	78.23	8	58.74	8	42.77	8	29.82	8	19.59	8	11.870	8	6.468	8	3.075	8	1.182
7	101.78	7	78.02	7	58.57	7	42.63	7	29.71	7	19.50	7	11.805	7	6.425	7	3.050	7	1.168
6	101.52	6	77.80	6	58.39	6	42.49	6	29.59	6	19.41	6	11.740	6	6.382	6	3.025	6	1.154
5	101.25	5	77.59	5	58.22	5	42.34	5	29.48	5	19.32	5	11.675	5	6.339	5	3.000	5	1.141
9.94	100.99	8.94	77.38	7.94	58.04	6.94	42.20	5.94	29.36	4.94	19.23	3.94	11.611	2.94	6.296	1.94	2.975	0.94	1.128
3	100.73	3	77.16	3	57.87	3	42.06	3	29.25	3	19.14	3	11.547	3	6.254	3	2.950	3	1.114
2	100.47	2	76.95	2	57.69	2	41.92	2	29.13	2	19.06	2	11.483	2	6.212	2	2.925	2	1.101
1	100.21	1	76.74	1	57.52	1	41.77	1	29.02	1	18.97	1	11.419	1	6.170	1	2.901	1	1.087
0	99.95	0	76.53	0	57.35	0	41.63	0	28.90	0	18.88	0	11.356	0	6.128	0	2.877	0	1.074
9.89	99.69	8.89	76.32	7.89	57.17	6.89	41.49	5.89	28.79	4.89	18.79	3.89	11.292	2.89	6.086	1.89	2.853	0.89	1.060
8	99.44	8	76.11	8	57.00	8	41.35	8	28.68	8	18.70	8	11.229	8	6.045	8	2.829	8	1.047
7	99.18	7	75.90	7	56.83	7	41.21	7	28.57	7	18.62	7	11.167	7	6.003	7	2.805	7	1.034
6	98.92	6	75.69	6	56.66	6	41.07	6	28.45	6	18.53	6	11.104	6	5.962	6	2.781	6	1.021
5	98.66	5	75.48	5	56.48	5	40.93	5	28.34	5	18.44	5	11.042	5	5.921	5	2.758	5	1.008
9.84	98.41	8.84	75.27	7.84	56.31	6.84	40.79	5.84	28.23	4.84	18.36	3.84	10.980	2.84	5.881	1.84	2.735	0.84	0.995
3	98.15	3	75.06	3	56.14	3	40.65	3	28.12	3	18.27	3	10.918	3	5.841	3	2.712	3	.982
2	97.90	2	74.85	2	55.97	2	40.51	2	28.01	2	18.19	2	10.856	2	5.800	2	2.688	2	.969
1	97.64	1	74.64	1	55.80	1	40.37	1	27.90	1	18.10	1	10.795	1	5.760	1	2.665	1	.956
0	97.39	0	74.44	0	55.63	0	40.23	0	27.78	0	18.02	0	10.734	0	5.720	0	2.642	0	.943
9.79	97.14	8.79	74.23	7.79	55.46	6.79	40.09	5.79	27.67	4.79	17.93	3.79	10.673	2.79	5.680	1.79	2.620	0.79	.931
8	96.88	8	74.02	8	55.29	8	39.95	8	27.56	8	17.85	8	10.612	8	5.641	8	2.598	8	.918
7	96.63	7	73.82	7	55.12	7	39.82	7	27.45	7	17.76	7	10.551	7	5.602	7	2.575	7	.906
6	96.38	6	73.61	6	54.95	6	39.68	6	27.34	6	17.68	6	10.491	6	5.563	6	2.553	6	.893
5	96.13	5	73.40	5	54.78	5	39.54	5	27.23	5	17.60	5	10.431	5	5.524	5	2.531	5	.881
9.74	95.88	8.74	73.20	7.74	54.62	6.74	39.40	5.74	27.12	4.74	17.51	3.74	10.371	2.74	5.485	1.74	2.509	0.74	.868
3	95.63	3	72.99	3	54.45	3	39.27	3	27.02	3	17.43	3	10.311	3	5.447	3	2.487	3	.856
2	95.38	2	72.79	2	54.28	2	39.13	2	26.91	2	17.34	2	10.252	2	5.408	2	2.465	2	.844
1	95.13	1	72.59	1	54.11	1	39.00	1	26.80	1	17.26	1	10.193	1	5.370	1	2.443	1	.832
0	94.88	0	72.38	0	53.94	0	38.86	0	26.69	0	17.18	0	10.134	0	5.332	0	2.422	0	.819
9.69	94.63	8.69	72.18	6.69	53.78	6.69	38.72	5.69	26.58	4.69	17.10	3.69	10.075	2.69	5.295	1.69	2.401	0.69	.807
8	94.38	8	71.98	8	53.61	8	38.59	8	26.48	8	17.02	8	10.017	8	5.257	8	2.380	8	.795
7	94.14	7	71.78	7	53.45	7	38.45	7	26.37	7	16.93	7	9.959	7	5.220	7	2.359	7	.783
6	93.89	6	71.57	6	53.28	6	38.32	6	26.26	6	16.85	6	9.901	6	5.183	6	2.338	6	.771
5	93.64	5	71.37	5	53.12	5	38.18	5	26.15	5	16.77	5	9.843	5	5.146	5	2.317	5	.759
9.64	93.40	8.64	71.17	7.64	52.95	6.64	38.05	5.64	26.05	4.64	16.69	3.64	9.785	2.64	5.109	1.64	2.296	0.64	.747
3	93.15	3	70.97	3	52.79	3	37.92	3	25.94	3	16.61	3	9.728	3	5.072	3	2.276	3	.735
2	92.91	2	70.77	2	52.62	2	37.78	2	25.84	2	16.53	2	9.671	2	5.036	2	2.256	2	.723
1	92.66	1	70.57	1	52.46	1	37.65	1	25.73	1	16.45	1	9.614	1	5.000	1	2.236	1	.711
0	92.42	0	70.37	0	52.30	0	37.52	0	25.62	0	16.37	0	9.557	0	4.964	0	2.216	0	.699
9.59	92.18	8.59	70.17	7.59	52.13	6.59	37.38	5.59	25.52	4.59	16.29	3.59	9.501	2.59	4.928	1.59	2.196	0.59	.687
8	91.93	8	69.97	8	51.97	8	37.25	8	25.41	8	16.21	8	9.445	8	4.892	8	2.176	8	.675
7	91.69	7	69.78	7	51.81	7	37.12	7	25.31	7	16.13	7	9.389	7	4.857	7	2.156	7	.663
6	91.45	6	69.58	6	51.64	6	36.99	6	25.20	6	16.05	6	9.333	6	4.822	6	2.136	6	.651
5	91.21	5	69.38	5	51.48	5	36.86	5	25.10	5	15.97	5	9.277	5	4.787	5	2.116	5	.640
9.54	90.97	8.54	69.18	7.54	51.32	6.54	36.72	5.54	25.00	4.54	15.89	3.54	9.222	2.54	4.752	1.54	2.097	0.54	.628
3	90.73	3	68.99	3	51.16	3	36.59	3	24.89	3	15.81	3	9.167	3	4.717	3	2.078	3	.617
2	90.49	2	68.79	2	51.00	2	36.46	2	24.79	2	15.74	2	9.112	2	4.682	2	2.059	2	.605
1	90.25	1	68.59	1	50.84	1	36.33	1	24.69	1	15.66	1	9.058	1	4.648	1	2.040	1	.593
0	90.01	0	68.40	0	50.68	0	36.20	0	24.58	0	15.57	0	9.003	0	4.614	0	2.021	0	.581

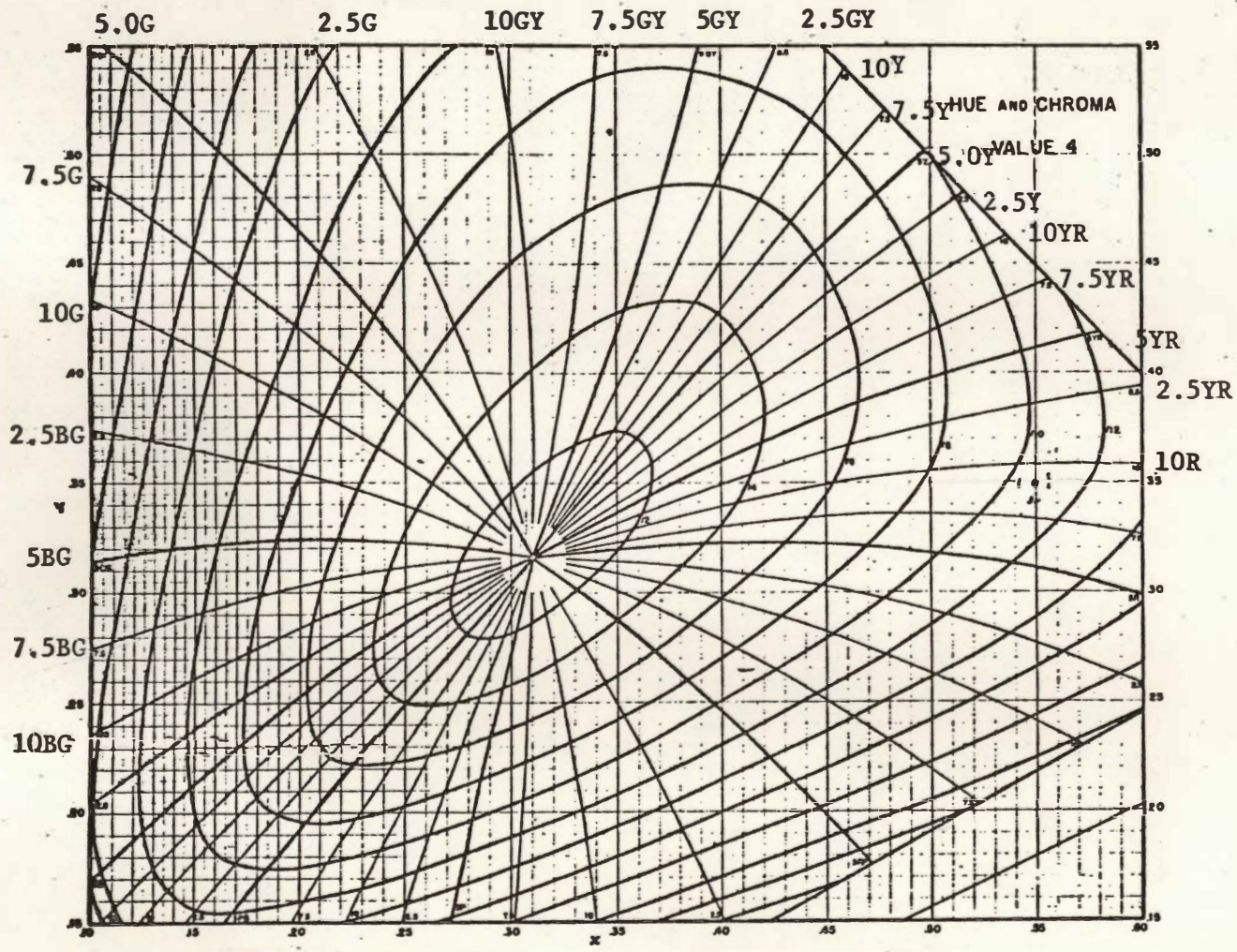


Fig. 27--Munsell value 4-loci of constant hue and constant chroma in C. I. E. (x,y) coordinates (2).

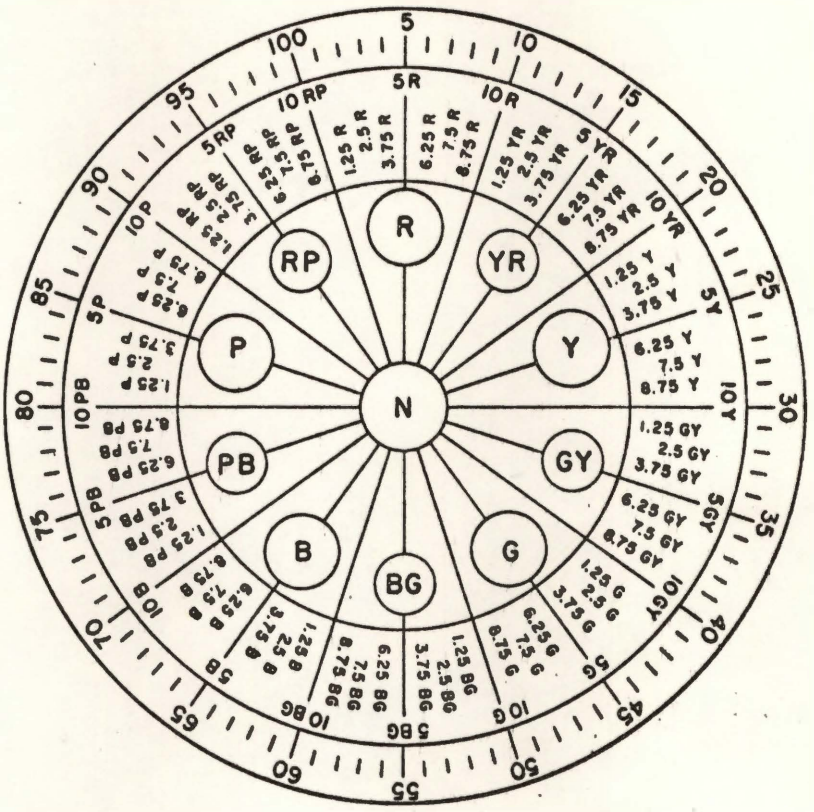


Fig. 28—Designation systems for Munsell hue.

Project No. _____ Replication _____

Date Begun _____ Variety _____

Identity of sample				
Dish number				
Dish weight				
Weight of dish and beans before transfer				
Weight of dish and beans after transfer				
Sample weight				
Weight after drying _____ hours _____ hours _____ hours				
Sample weight				
Dry weight				
% Dry weight				
% Moisture				
Mean weight % Dry				
% Difference				

Calculations _____ Date _____

Checked by _____ Date _____

Fig. 29--Determination form of percentage of moisture of Peco and Slender White beans through raw and intervals held heated.

Table 7--Means of measurements for moisture content of Peco and Slender White beans

Raw through intervals held heated	Peco	Slender White
	% Moisture	% Moisture
Raw	91.83	89.69
0	91.46	89.07
10	91.26	88.65
20	91.42	89.23
30	91.26	89.58
40	91.68	88.89
50	91.21	89.26
60	91.53	89.02

APPENDIX C

STATISTICAL DATA

Table 8--Means of sensory scores for texture, overall acceptability, and color of Slender White and Peco beans

Variety	Holding times	Replications	Color	Overall acceptability	Texture
1 and 2	0	8	3.37	3.35	4.60
1 and 2	10	8	3.16	3.10	4.78
1 and 2	20	8	2.85	3.23	4.57
1 and 2	30	8	2.44	4.17	4.01
1 and 2	40	8	2.58	3.85	3.69
1 and 2	50	8	2.16	3.71	2.82
1 and 2	60	8	2.03	3.42	2.37
1		28	2.33	3.32	3.53
2		28	2.98	3.78	4.14
Overall means		56	2.66	3.55	3.83

Table 9--Means of objective measurement values for two varieties of green beans

Varieties	Holding time	Replications	Dominant wavelength nm	Hunter b[1]	"Force" kg	"Shear peak area" cm^2	"Work" kg cm^2	Munsell color		
								hue	value	chroma
1 and 2	0	10	530.20	0.02	66.44	9.58	675.12	8.34	3.42	0.15
1 and 2	10	10	540.20	0.03	65.50	9.16	654.61	8.50	3.54	0.14
1 and 2	20	10	538.20	0.01	65.41	9.42	646.56	7.87	3.58	0.14
1 and 2	30	10	542.50	-0.02	65.33	9.30	657.38	8.70	3.46	0.10
1 and 2	40	10	559.80	-0.02	57.99	8.67	525.27	8.14	3.51	0.10
1 and 2	50	10	553.50	0.01	55.18	8.10	470.31	7.87	3.59	0.10
1 and 2	60	10	553.70	0.02	54.18	8.04	457.07	7.49	3.61	0.10
1[a]		35	548.54	0.02	58.63	8.52	531.49	6.52	3.88	0.10
2[b]		35	542.34	-0.02	64.24	9.27	636.02	9.73	3.21	0.13
Overall means		70	545.44	0.02	61.43	8.90	583.76	8.13	3.54	0.11

[a]Slender White

[b]Peco

[1]Anon (1972)

Table 10--Analysis of variance for sensory texture scores

Source	Degrees of freedom	Mean squares	F values
Variety	1	5.33	
Replication (variety)	6	4.81	
Time	6	7.00	
Linear	1	37.78	44.76[a]
Quadratic	1	3.38	4.01
Cubic	1	0.49	0.58
Variety x time	6	0.58	
Residual	36	0.84	
Corrected total	55	2.00	
Tests and source			
Numerator: variety	1	5.33	1.10
Denominator: rep (variety)	6	4.81	
Numerator: time	6	7.00	8.29[b]
Denominator: residual	36	0.84	
Numerator: variety x time	6	0.58	0.69
Denominator: residual	36	0.84	

[a]Significant difference at the 1 percent level

[b]Significant difference at the .01 percent level

Table 11--Analysis of variance for sensory overall acceptability scores

Source	Degrees of freedom	Mean squares	F values
Variety	1	2.88	
Replication (variety)	6	0.81	
Time	6	1.15	
Linear	1	1.20	3.15
Quadratic	1	1.56	4.09
Cubic	1	1.79	4.69[a]
Variety x time	6	0.46	
Residual	36	0.38	
Corrected total	55	0.56	
Tests and source			
Numerator: variety	1	2.88	3.52
Denominator: rep (variety)	6	0.81	
Numerator: time	6	1.15	3.01[a]
Denominator: residual	36	0.38	
Numerator: variety x time	6	0.46	1.21
Denominator: residual	36	0.38	

[a]Significant difference at the 5 percent level

Table 12--Analysis of variance for sensory color scores

Source	Degrees of freedom	Mean squares	F values
Variety	1	5.87	
Replication (variety)	6	0.70	
Time	6	1.98	
Linear	1	1.41	11.28[a]
Quadratic	1	0.01	0.08
Cubic	1	0.13	0.06
Variety x time	6	0.11	
Residual	36	0.20	
Corrected total	55	0.54	
Tests and source			
Numerator: variety	1	5.87	8.28[b]
Denominator: rep (variety)	6	0.70	
Numerator: time	6	1.98	9.77[c]
Denominator: residual	36	0.20	
Numerator: variety x time	6	0.11	0.56
Denominator: residual	36	0.20	

[a]Significant difference at the 1 percent level

[b]Significant difference at the 5 percent level

[c]Significant difference at the .01 percent level

Table 13--Analysis of variance for "force"

Source	Degrees of freedom	Mean squares	F values
Variety	1	551.60	
Time	6	293.62	
Linear	1	1,501.50	15.60[a]
Quadratic	1	96.15	0.99
Cubic	1	50.05	0.52
Variety x time	6	62.16	
Replication (variety)	8	1,436.47	
Residual	48	96.20	
Corrected total	69	272.40	
Tests and source			
Numerator: variety	1	551.60	0.38
Denominator: rep (variety)	8	1,436.47	
Numerator: time	6	293.62	3.05[b]
Denominator: residual	48	96.20	
Numerator: variety x time	6	62.16	0.64
Denominator: residual	48	96.20	

[a]Significant difference at the 1 percent level

[b]Significant difference at the 5 percent level

Table 14--Analysis of variance for "shear peak area"

Source	Degrees of freedom	Mean squares	F values
Variety	1	9.88	
Time	6	3.98	
Variety x time	6	2.05	
Replication (variety)	8	25.47	
Corrected total	69	5.05	
Tests and source			
Numerator: variety	1	9.88	0.38
Denominator: rep (variety)	8	25.47	
Numerator: time	6	3.98	1.94
Denominator: residual	48	2.06	
Numerator: variety x time	6	2.05	0.99
Denominator: residual	48	2.06	

Table 15--Analysis of variance for "work"

Source	Degrees of freedom	Mean squares	F values
Variety	1	191,198.43	
Time	6	91,787.42	
Linear	1	467,585.50	13.29[a]
Quadratic	1	27,929.12	0.79
Cubic	1	12,754.58	0.36
Variety x time	6	28,106.56	
Replication (variety)	8	315,975.95	
Residual	48	35,169.97	
Corrected total	69	74,297.51	
Tests and source			
Numerator: variety	1	191,198.43	0.60
Denominator: variety	8	315,975.95	
Numerator: time	6	91,787.42	2.60[b]
Denominator: residual	48	35,169.97	
Numerator: variety x time	6	28,106.56	0.79
Denominator: residual	48	35,169.97	

[a]Significant difference at the 1 percent level

[b]Significant difference at the 5 percent level

Table 16--Analysis of variance for dominant wavelength

Source	Degrees of freedom	Mean squares	F values
Variety	1	672.70	
Time	6	1,100.29	
Linear	1	5,032.03	20.86[a]
Quadratic	1	235.74	0.97
Cubic	1	216.60	0.89
Variety x time	6	324.53	
Replication (variety)	8	38.28	
Residual	48	241.15	
Corrected total	69	305.84	
Tests and source			
Numerator: variety	1	672.70	17.57[a]
Denominator: rep (variety)	8	38.28	
Numerator: time	6	1,100.29	4.56[a]
Denominator: residual	48	241.15	
Numerator: variety x time	6	324.53	1.34
Denominator: residual	48	241.15	

[a]Significant difference at the 1 percent level

Table 17--Analysis of variance for Munsell hue

Source	Degrees of freedom	Mean squares	F values
Variety	1	180.32	
Time	6	1.76	
Variety x time	6	1.52	
Replication (variety)	8	1.63	
Residual	48	1.10	
Corrected total	69	3.85	
Tests and source			
Numerator: variety	1	180.32	110.07[a]
Denominator: rep (variety)	8	1.63	
Numerator: time	6	1.76	1.59
Denominator: residual	48	1.10	
Numerator: variety x time	6	1.52	1.38
Denominator: residual	48	1.10	

[a]Significant difference at the .01 percent level

Table 18--Analysis of variance for Hunter a

Source	Degrees of freedom	Mean squares	F values
- - - - - - Computations according to Anon. (1972) - - - - - -			
Variety	1	0.03	
Time	6	0.07	
Variety x time	6	0.07	
Replication (variety)	8	0.07	
Residual	48	0.07	
Corrected total	69	0.07	
Tests and source			
Numerator: variety	1	0.03	0.49
Denominator: rep (variety)	8	0.07	
Numerator: time	6	0.07	1.07
Denominator: residual	48	0.07	
Numerator: variety x time	6	0.07	1.07
Denominator: residual	48	0.07	
- - Computations according to Clydesdale and Francis (1969d) - -			
Variety	1	0.13	
Time	8	0.35	
Variety x time	6	0.42	
Replication (variety)	6	0.41	
Residual	48	0.25	
Corrected total	69	0.29	
Tests and source			
Numerator: variety	1	0.13	0.37
Denominator: rep (variety)	8	0.35	
Numerator: time	6	0.42	1.62
Denominator: residual	48	0.25	
Numerator: variety x time	6	0.41	1.59
Denominator: residual	48	0.25	

Table 19--Analysis of variance for Hunter b

Source	Degrees of freedom	Mean squares	F values
- - - - - - Computations according to Anon. (1972) - - - - - -			
Variety	1	0.00	
Time	6	0.00	
Variety x time	6	0.00	
Replication (variety)	8	0.00	
Residual	48	0.00	
Corrected total	69	0.00	
Tests and source			
Numerator: variety	1	0.00	0.16
Denominator: rep (variety)	8	0.00	
Numerator: time	6	0.00	1.07
Denominator: residual	48	0.00	
Numerator: variety x time	6	0.00	2.71[a]
Denominator: residual	48	0.00	
- - Computations according to Clydesdale and Francis (1969d) - -			
Variety	1	0.04	
Time	8	0.01	
Variety x time	6	0.02	
Replication (variety)	6	0.04	
Residual	48	0.02	
Corrected total	69	0.02	
Tests and source			
Numerator: variety	1	0.04	2.58
Denominator: rep (variety)	8	0.01	
Numerator: time	6	0.02	0.96
Denominator: residual	48	0.02	
Numerator: variety x time	6	0.04	1.41
Denominator: residual	48	0.02	

[a]Significant difference at the 5 percent level

VITA

Anna Mae Brenner was born in Culver, Kansas, on July 9, 1922. She received her education in the Culver Rural Grade and High schools, graduating in 1940. She was graduated from Kansas State Teachers College of Emporia in 1948 with a Bachelor of Science in Education degree, majoring in Biological Science. She completed a dietetic internship at Grasslands Hospital in 1954. In 1955, she received a Master of Science degree from Kansas State University with a major in Institutional Management. She has done graduate work at Colorado State University.

Included in her professional experiences are positions as a dietitian at Mary Lanning Memorial Hospital, Osawatomie State Hospital, and Purdue University Women's Residence Halls. She was a faculty member at Paola Junior High School, Culver Rural High School, and at the University of Wyoming. Professional societies in which she holds membership are the American Dietetic Association (Registered Dietitian), American Home Economics Association, and Food Service Systems Management Education Council. Her honor societies are Gamma Sigma Delta and Omicron Nu.

She is the daughter of Grace McKean Brenner and Willis Franklin Brenner of Culver, Kansas.