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Title THE TEXTURE AND APPEARANCE OF DUAL BLANCHED GREEN BEANS

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A quality problem that frequently occurs with frozen green beans is the sloughing of the skin (epidermal tissues) of the cooked, ready-to-serve bean pods. It was found that by giving the beans a pre-blanch (relatively mild heat treatment) prior to the blanch treatment normally used for frozen green beans, on cooking, sloughing was markedly reduced, and furthermore, the bean pods were firmer.

As an additional heat treatment was involved, over and above what is now used for commercial packs of frozen green beans, it was of interest to know the extent to which the color of the beans was affected. Also of interest was the effect of storage at 0° F. for four months on the color of the beans.

The color changes in the dual and single blanched green beans were evaluated by two methods: (1) a physical analysis of the light reflected from the beans (Hunter Color and Color Difference Meter)

and, (2) a physical analysis of the light absorbing properties of the pigments extracted from the beans and subsequent calculation of the per cent conversion of chlorophyll to pheophytin. Texture (firmness), as indicated by resistance to shear, was measured by a modified Kramer Shear Press. A mechanical device was used to determine the amount of sloughing of the skins of the bean pods.

After a statistical analysis of the data collected in the experiment, the following conclusions were drawn:

1. The firmness of the cooked, dual and single blanched, frozen green beans, as measured by the shear press, was found to be highly significantly negatively correlated with sloughing of the skins.

2. There was no change in lightness or darkness of the color of single or dual blanched beans over storage at 0° F. for four months. The Hunter "$-a_L/b_L$" index of color noted a significant change in hue from green towards yellow of the single and dual blanched beans. The conversion of chlorophyll to pheophytin was not significant over storage.

3. The color of those beans receiving the 200° F. - 150 second final blanch (single blanch) was the same as the color of those beans receiving the 210° F. - 105 second final blanch (single blanch).

4. As the time and temperature of the pre-blanch increased, there was a corresponding increase in the amount of chlorophyll converted to pheophytin, and a change in the visual color of the beans

from green towards yellow. The effect of variations of time of pre-blanch was much greater on the color of the dual blanched beans than the effect of variations of temperature of pre-blanch.

5. As the time and temperature of the pre-blanch increased, the texture (firmness) of the cooked dual blanched beans increased. The 200° F. - 150 second final blanch resulted in beans that were firmer than beans receiving the 210° F. - 105 second final blanch.

6. A pre-blanch at 170° F. for 30 seconds followed by a final blanch at 200° F. for 150 seconds was found to result in beans that were similar in color, yet firmer in texture (less sloughing of the skins) than the single blanched beans.

THE TEXTURE AND APPEARANCE OF DUAL BLANCHED FROZEN GREEN BEANS

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I. INTRODUCTION

The single blanch currently used for frozen green beans is a severe one because of the need to inactivate enzymes which would otherwise exert a deliterious effect on the flavor and appearance of the beans during storage. One of the adverse effects of the severe heat treatment that frequently occurs, has been the sloughing of the skin (epidermal tissue) of the cooked, ready-to-serve bean pods.

In studying the sloughing problem, Sistrunk (47) noted that if the beans were given a pre-blanch (relatively mild heat treatment), on cooking, the skins of the bean pods were tight, and consequently, sloughing was markedly reduced. He noted further that the dual blanched beans were firmer than those beans receiving a single blanch.

As an additional heat treatment was involved, over and above what is normally employed for commercial packs of frozen green beans, it was of interest to know the extent to which the color of the beans was degraded, since color is an important index of quality and hence consumer acceptance.

Variations in time and temperature of pre-blanch and of final blanch were selected in hopes of being able to recommend a particular time and temperature of pre-blanch and final blanch that would result in beans that were similar in color, yet firmer in texture than the single blanched beans. Firmer beans would denote less sloughing and consequently an improvement in the appearance of the beans.

As vegetables are frozen primarily for storage until such time as they are to be eaten, a study was made of the effect of storage at 0° F. on the color of the beans, to observe what changes there were, if any, in the color of the beans.

II. LITERATURE REVIEW

Blanching of Green Beans

In 1929, Joslyn and Cruess (24, p. 10) noted the value of blanching (scalding) vegetables destined for freezing. Since that time it has become a standard practice in the frozen food industry to blanch vegetables.

The blanching process involves a heat treatment. The heat treatment is usually effected by means of either steam or hot water. Holmquist et al. (20, p. 437), Lee (31, p. 64), Mackinney and Weast (33, p. 393), and Joslyn and Marsh (22, p. 379) noted several reasons for blanching vegetables prior to freezing: (1) to inactivate enzymes present in the tissues, (2) to shrink the vegetables, (3) to cleanse the vegetables, and (4) to remove undesirable water-soluble and volatile constituents.

Colby and Manning (5, p. 54) have found that there is a close relationship between quality retention during storage of frozen vegetables and the degree of enzyme activity. Consequently the time and temperature of the blanch is determined in most cases by evaluating the activity of the enzymes present in the vegetables.

Masure and Campbell (34, p. 369) stated that the enzymes, peroxidase and catalase, were thought to be the enzymes responsible for the deterioration of the quality of raw vegetables over storage. As a result, numerous enzyme tests have been developed to evaluate the activity or the presence of these enzymes. Colby and Manning (5, p. 160) and Melnick, Hochberg and Orser (36, p. 148) have found that catalase appeared to be more susceptible to heat than peroxidase in green beans.

In a study of the principles of freezing preservation, Joslyn and Marsh (23, p. 435) noted that catalase content did not correlate very well with quality over storage, although the catalase content was found to be lower in those vegetables that maintained a higher quality over storage. Colby and Manning (5, p. 54) concluded that unless a negative catalase test was found, the quality of snap beans would deteriorate over storage. With regards to peroxidase, he noted that the quality of the beans would not deteriorate on storage if a positive peroxidase test was found, providing the catalase test was negative.

Lee (31, p. 23), in a review of literature, noted that if a safety factor of fifty percent of the inactivation time for catalase was used, the quality of frozen vegetables would keep over storage. According to Isaac and Winch (21, p. 23), the higher heat resistance of peroxidase has led to its increasing use as a test for adequacy of blanch.

Joslyn and Marsh (22, p. 379) noted that blanching reduced the volume of the beans and made the beans more pliable due to loss of turgidity. Thus, blanching is necessary to conserve space on packing.

Sistrunk (46, p. 17) noted that soil and other foreign material were removed in blanching. Moyer _et al._ (37, p. 4) found that blanching reduced the bacterial flora.

Joslyn and Marsh (20, p. 379) noted that blanching tended to minimize the degradation of color upon cooking frozen vegetables. Lee (31, p. 82), Mackinney and Weast (35, p. 393) and Moyer _et al._ (37, p. 4) suggested that blanching removed a considerable portion of those constituents of the bean which would react with the chlorophyll upon cooking.

In evaluating the effect of blanching on several varieties of green beans, Woodroof, Heston and Ellis (54, p. 12) found that blanching intensified the green color. They determined that the color was darkened, while at the same time the greenness increased and the yellowness decreased. Joslyn and Marsh (22, p. 379) described the effect of blanching on the color of green beans as a brightening effect.

Lee (31, p. 81) stated that, "It is possible that during this treatment, combinations of chlorophyll with complex substances are altered, which, together with physical changes of the tissues, could perhaps account for the more intense green color." Mackinney and Weast (33, p. 393) remarked that with minor modifications, the physical state of dispersion of the chlorophyll in the plant tissue remained the same upon blanching.

The proper time and temperature for blanching has been a subject of considerable debate since the value of blanching was first observed in 1929. Joslyn and Marsh (27, p. 175) found that blanching in the range of 180° to 195° F. was of utmost importance if quality was to be maintained over storage. They noted further that blanching temperatures around 195° F. were needed for long storage periods. In later studies, Joslyn and Marsh (22, p. 379-381) found that the proper time and temperature of blanching varied with variety, freshness of the product, and growing conditions. They cited several authors who recommended a range of 2-5 minutes in boiling water as the necessary period for blanching.

Sistrunk (46, p. 131) concluded that the size, variety, and field conditions under which the beans were grown had an influence on the proper time and temperature for blanching. Studies by Mundt and McCarty (38, p. 311) showed that the differences in variety of beans were more influential in determining the correct blanch time than variations in the climatic factors of an area.

Dietrich et al. (11, p. 144) reported that when beans were blanched to approximately the same degree of peroxidase inactivation, the lower temperature - longer time blanch caused greater chlorophyll loss than the higher temperature - shorter time blanch. In a more intensive study of blanching, Dietrich _et al_. (10, p. 261) noted that short time (1-2 minutes) blanching in the 200° - 212° F. temperature range resulted in high quality frozen green beans. They noted further that those beans blanched at 190° - 195° F. were tougher.

It is as important not to overblanch as it is not to underblanch. Colby and Manning (5, p. 160) and Joslyn and Marsh (23, p. 436) determined that if snap beans were given a blanch sufficient to obtain a negative peroxidase reaction, the beans would be overblanched and an excessive loss of color would result. Cruess (6, p. 814), Dietrich _et al_. (10, p. 260), Joslyn and Marsh (22, p. 379), and Mundt and McCarty (38, p. 309) noted that overblanching at 212° F. caused extensive softening, sloughing, and a less desirable color as more chlorophyll was converted to pheophytin. Dietrich _et al_. (10, p. 260) noted further that the percent of chlorophyll lost followed a linear relationship with blanching time at a given temperature.

In evaluating the effect of blanching over storage, Caldwell _et al_. (4, p. 13) and Dietrich _et al_. (10, p. 260) found that when green beans for freezing were either overblanched or underblanched, more chlorophyll was lost on storage under identical storage conditions, than samples just adequately blanched according to a peroxidase test.

Dietrich et al. (10, p. 260) noted further that underblanched beans lost more chlorophyll than overblanched beans. In an earlier study, Dietrich et al. (9, p. 111) noted that on storage, frozen beans with excessive chlorophyll degradation due to overblanching, had a greater rate of change of chlorophyll to pheophytin than beans that were properly blanched. In 1959, after further studies, Dietrich et al. (11, p. 139) concluded that the method of blanching was an important factor that influenced the stability of the frozen product over storage.

The reasons why there is no standard time and temperature of blanching were aptly noted by Masure and Campbell (34, p. 369) who remarked that, "Since blanching is influenced by such variable factors as blanching medium and temperature, blancher loading, physical and physiological characteristics of the vegetables, average size of pieces, and uniformity of heat distribution and penetration, one cannot rely on standard blanch time and temperature alone." Thus, while a standard time and temperature is unlikely to come about, the general tendency is towards shorter time - higher temperature blanching as against lower time - lower temperature blanching.

Measurement of Color of Green Beans

Color is an important factor in determining the acceptability of a product by the consumer. The importance of color is derived from the fact that the consumer associates certain color characteristics with quality. Color was defined by Judd (26, p. 5), who stated that, "Color is the evaluation of radiant energy (physics) in terms that correlate with visual perception (psychology)."

The color of green beans is due primarily to the presence of chlorophyll A and chlorophyll B. The principal color change in green beans was noted by Siegele (44, p. 97) to be due to the conversion of chlorophyll A and chlorophyll B to pheophytin A and pheophytin B. Mackinney and Weast (33, p. 393) noted that the formation of pheophytin involved the removal of magnesium from the chlorophyll molecule. The conversion can be illustrated by the following equations:

Chlorophyll A to Pheophytin A

$$C_{55}H_{72}O_5N_4Mg + 2H^+ = C_{55}H_{74}O_5N_4 + Mg^{++}$$

Chlorophyll B to Pheophytin B

$$C_{55}H_{70}O_6N_4Mg + 2H^+ = C_{55}H_{72}O_6N_4 + Mg^{++}$$

Thus the change in color of the green beans from green towards yellow involves the loss of magnesium from the chlorophyll molecule.

There are two methods to objectively study the color and color changes in green beans: (1) the physical analysis of the light reflected from the material and, (2) the physical analysis of the light absorbing properties of the pigments extracted from the material.

As a consequence of the above, there are two general categories of instruments used to measure color and color differences. Kramer and Smith (29, p. 15-16) defined these two categories in the following manner: "... (1) psychophysical, that is, instruments which give a numerical value of the color impression as seen by the eye of the observer and, (2) physical, that is, actual physical measures in terms of wavelength and percent of color transmittance at a given wavelength." The data collected from the above two categories of instruments can be expressed by their respective indices as noted by Kramer (27, p. 23):

Physical Measures	Psychophysical Measures
Reflectance	Lightness, value
Dominant wavelength	Hue, color
Purity	Chroma, intensity, strength

These indices are attributes of color and together describe the three dimensional character of color, whether it be physical or psychophysical.

Kramer (27, p. 21-22) noted that in evaluating the lightness or darkness of a particular subject, disregarding the specific wavelength, one is evaluating the amount of light reflected. He noted further that the dominant wavelength is that wavelength at which light is reflected more readily than others, and if that wavelength is in the range between 380 mμ and 770 mμ, the reflected light is seen as a particular color or hue for that particular wavelength. Purity, or chroma, strength, and intensity as discussed by Kramer (27, p. 24), is the amount of light reflected at a given wavelength.

The result of an objective study of color and color differences may be expressed in one of two systems: (1) the Munsell system or, (2) the ICI (International Commission of Illumination) system. The psychophysical measures contain indices used in the Munsell system for assigning numerical values to reflected colors. The ICI system assigns numerical values to reflected colors according to the physical measures indices.

Eastmond (13, p. 7) and Kramer (27, p. 24) noted that the standard system was the ICI system whereby the color of an object illuminated by a standard illuminant and viewed by a standard observer is specified. The standard observer, as described by Kramer (27, p. 24), "... may be thought of as a simulated standard eye, consisting of three primary color filters having exactly specified spectrophotometric curves X, Y. and Z, with X being essentially amber in color; Y, green, and Z, blue."

In order to convert reflectance data to either the physical indices or the psycophysical indices, one must first express the data in terms of the ICI tristimulus values X, Y, and Z, as noted by Judd

(26, p. 42-43). The second step is to compute the chromaticity coordinates x, y, and z, from the tristimulus values as fractions of their total. The various indices are then obtained using the chromaticity coordinates x, and y, and various charts and tables as described by Judd (26, p. 94-132).

The physical analysis of the light reflected from green beans has been accomplished through the use of two types of instruments, the spectrophotometer and the tristimulus colorimeter. Each will be discussed separately.

Judd (26, p. 82) noted that the spectrophotometer measured the fundamental properties of an object responsible for its color by comparing, "...at each wavelength of the visible spectrum the radiant flux leaving the object with some other flux such as that incident on it." Guerrant (17, p. 207) used the General Electric Recording Spectrophotometer to measure the reflected visible light of frozen green beans stored at various temperatures for twelve months. Bennett et al. (1, p. 12) also used the same instrument to study the effect of storage temperatures on the color of frozen green beans. In both cases the beans were blended with water, as this was the only way reproducible results could be obtained. Blending the beans with water is undesirable in that the pigmentation is diluted.

According to Kramer (30, p. 1897), the Hunter Color and Color

Difference Meter, a tristimulus colorimeter, measures the reflectance of an object by use of three filters that approximate the X, Y, and Z functions of the ICI system. The filters cover photocells which receive the light reflected from the object. There is also a comparison cell. The current from the comparison cell is compared with that from the filter-covered photocells. This comparison is evaluated on three scales, "L" or "R_d", "a" and "b". The comparison is made possible because the three scales are set to values of a known standard color and the current between the filter-covered cells and the comparison cell is equilibrated prior to measuring the color of the unknown sample.

There are two types of circuits. Judd (26, p. 260) noted that one circuit yields the quantities "R_d", "a", and "b", which are defined as 100Y, $175f_Y(1.02X - Y)$, and $70f_Y(Y - 0.847Z)$ respectively, where $f_Y = 0.50(21 + 20Y)/(1 + 20Y)$ and X, Y. and Z, are the tristimulus values. The second type of circuit yields the quantities "L", "a_L", "b_L", which are defined as $100Y^{1/2}$, $175(1.02X - Y)/Y^{1/2}$, and $70(Y - 0847Z)/Y^{1/2}$, respectively. As above, X, Y, and Z are the tristimulus values.

The three scales of the Hunter Color and Color Difference Meter may be described in terms of a modification of the color solid. The "a" and "b" scales are laid out in Cartesian Coordinates, while the "R_d" or "L" scale is perpendicular to the plane of the diagram. (As noted by Figure 1, the Hunter "a" values are measures of redness when plus or greenness when minus, while the Hunter "b" values are measures of yellowness when plus or blueness when minus.

Kramer (27, p. 32) noted that, "The a values are functions of X and Y and b values are functions of Z and Y. Together, a and b may provide results equivalent to those obtained with the hue and chroma dimensions of the Munsell system." Thus Hand et al. (19, p. 1209) has noted that in general hue or dominant wavelength can best be represented by "a/b". Robinson et al. (39, p. 270) noted that the values of "a" and "b" determined dominant wavelength, while saturation, purity, and chroma were approximately equal to $(a^2 + b^2)^{1/2}$

The Hunter "R_d" (diffuse reflectance) or "L" (lightness) values are directly comparable to the Y of the ICI system or value of the Munsell system according to Kramer (27, p. 31-32). Robinson et al. (39, p. 270) noted that the "R_d" scale readings were equal to 100 times the Y function of the ICI system. In the same reference it was noted that the "R_d" scale was related to the "L" scale in that $L = 10R_d^{1/2}$.

Since its development in 1952, the Hunter Color and Color Difference Meter has been widely used. Sweeney et al. (49, p. 342) used the instrument to evaluate the color of frozen green beans on the retail market. They found that the "a_L/b_L" values ranged from

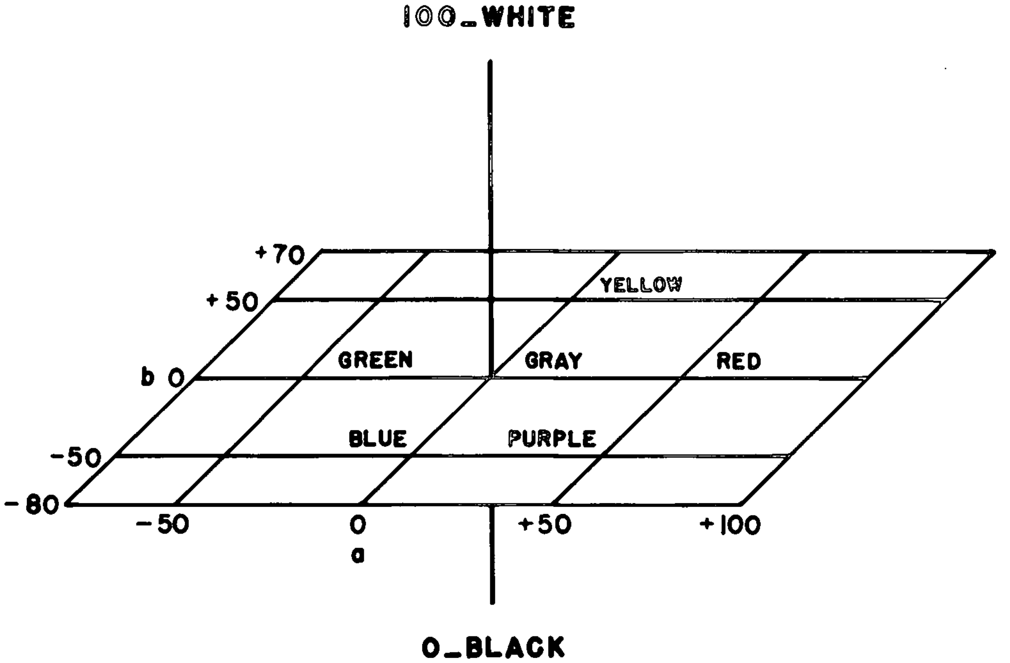

Figure 1. Diagram Showing Dimensions of the Hunter "L", "a", and "b" Color Solid.

0.48 to 1.05.

Dietrich *et al.* (9) and Dietrich *et al.* (11) reported using the Hunter Color and Color Difference Meter in time-temperature tolerance studies of frozen green beans. The 1957 studies (9, p. 113) showed that a loss of green color over storage was best represented by a decrease of Hunter "a_L/b_L" values. It was noted that changes in $(a^2 + b^2)^{1/2}$ were not as consistent as changes in Hunter "a_L/b_L" values when evaluating color changes in green beans. The 1959 report (11) noted the effect of various storage temperatures on the color of frozen green beans as indicated by changes in Hunter "a_L/b_L".

Cain, Sidwell, and Frazier (3, p. 2) used the Hunter Meter in collecting data on the effect of canning and freezing on different varieties of Blue Lake Pole Beans. In an intensive study of the effects of nitrogen, potassium and phosphorous fertilizers on the quality and chemical composition of pole beans, Sidwell (43, p. 24) used the Hunter Color and Color Difference Meter. Woodroff, Heston, and Ellis (54, p. 24) reported on the color of different varieties of beans and their change in color over storage as measured by the Hunter Meter.

Siegele (44, p. 68) used the Hunter ΔE index $(\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2}$ which represents total color change to follow the effect of heat on the pigments of green beans. He concluded that the ΔE index did not prove to be very satisfactory for showing color changes which took place.

In all of the above experiments involving the Hunter Color and Color Difference Meter, whole pieces were used and water or liquid from canned beans was used to fill the interstices. One case was noted, however, where the beans were chopped up prior to color measurement (42, p. 406). In that study it was noted that the Hunter "a" value was a satisfactory means of evaluating the color of canned green beans.

The second method of objectively studying the color and color changes in vegetables is to extract the pigments that contribute to the color of the plant material and measure their light absorbing properties. Siegele (44, p. 5-6) reviewed the literature regarding the separation and determination of pigments by paper and column chromatography, and subsequent quantitative estimation of the pigments by use of a spectrophotometer. The quantity measured by the spectrophotometer for the light absorbing properties of the extracted pigment of green beans was spectral transmittance. Spectral transmittance, according to Judd (26, p. 82), is the, "...ratio of transmitted to incident flux for one part of the spectrum..."

Guyer, Kramer, and Ide (18), and Kramer, Guyer, and Ide (28) used a Beckman spectrophotometer to measure chlorophyll and carotene in an acetone extract of the pigments of green beans at 665 mμ and 450 mμ respectively. In an earlier study, Kramer and Smith (29) used a Coleman Universal Spectrophotometer to measure the color of different varieties of green beans, extracted with hot alcohol and measured at 680 mμ.

In a series of studies on green beans, Ross, Murphy, and Devlin (40), Ross and Roberts (41), and Ross, Brekke, and Moore (42), measured acetone extracts of chlorophyll at 660 mμ with a Beckman Spectrophotometer. The height of the peak at 660 mμ was assumed to be proportional to the concentration of chlorophyll and thus providing a quantitative measure of the green color. However, in the last report,it was concluded that using one wavelength to measure color changes was not satisfactory due to variable factors in the extraction method and the presence of color constituents other than chlorophyll.

In 1940, Mackinney and Weast (33) proposed the use of chlorophyll and its degradation product pheophytin for measuring color changes in frozen vegetables, and described a method for determining the ratios of concentration of these two compounds in the same extract. The pigments of the beans were extracted by acetone and then measured at two wavelengths, 560 mμ and 535 mμ. At 535 mμ, the specific absorption coefficients of chlorophyll and pheophytin were equal, and at 560 mμ, both chlorophyll and pheophytin showed a maximum in their specific absorption coefficient curves. Dietrich (8) noted that the wavelength at which these two phenomena occurred varied with spectrophotometer and should be determined in preliminary studies. The advantage of the procedure of Mackinney and Weast (33) lies in the fact that a change in concentration of the extract does not affect the ratio of chlorophyll to pheophytin, providing the change is not too great.

In the analysis of Mackinney and Weast (33, p. 394), the carotenoid pigments were assumed to be unaffected in calculating the percent conversion of chlorophyll. Furthermore, it was concluded that no serious error was introduced in regarding pheophytin A and pheophytin B as a single component. It was also found that in the region where the specific absorption coefficients of chlorophyll and pheophytin were equal, and where both chlorophyll and pheophytin showed a maximum in their specific absorption coefficient curves, the rates of conversion of chlorophyll A and chlorophyll B were similar.

Sweeney et al. (49, p. 342-343) studied the percent conversion of chlorophyll of retail packages of frozen green beans by a modification of the procedure of Mackinney and Weast (33). The conversion of chlorophyll to pheophytin was found to vary from 0 to 53 percent after processing.

Dietrich et al. (9) modified the extraction procedure of Dutton, Bailey, and Kohake (12), in which the method of Mackinney and Weast (33) was used for the spectrophotometric measurement of the pigments of green beans. The extraction procedure was further modified in 1958 (8) for further studies of the loss of chlorophyll of frozen green beans under various conditions, Dietrich et al. (10), and Dietrich et al. (11). In 1957, Dietrich et al. (9, p. 112-113) concluded that it was not necessary to determine the absolute amount of chlorophyll or pheophytin present as the color changes could be followed using a ratio of these two compounds. Furthermore, Dietrich et al. (9) concluded that the loss of chlorophyll appeared to be an excellent quality index for frozen green beans. It appears that the relative amounts of chlorophyll and pheophytin, rather than total chlorophyll as measured at a particular wavelength might be more effective in following the color changes of green beans.

Measurement of Sloughing and Texture of Green Beans

During variety studies by Woodroof, Heston, and Ellis (54, p. 27) it was noted that sloughing of the bean pods was one of the most common causes of poor appearance. Other have noted the deleterious effect of sloughing on appearance: Enzie (15), McConnell (35), Singleton (45), Sistrunk (46, p. 2), Strohmaier (48), and Van Buren et al. (53).

Sloughing is a factor in the USDA grading standards for both canned beans (53, p. 6-7) and frozen beans (52, p. 5). In order for frozen green beans to meet the requirements for US Grade A and B, the pods must not be more than slightly affected in appearance by sloughing of the epidermis, and not materially affected in appearance by sloughing of the epidermis, respectively. US Grade A and B canned beans must not be materially affected in appearance by sloughing of the epidermis.

Strohmaier (48, p. 602) made a histological study of thawed frozen beans and cooked frozen beans with respect to sloughing. She noted that in both cases the break occurred in the region of largest thin-walled parenchyma cells. In the thawed frozen sample, the break occurred nearer the vascular region than in the cooked frozen sample.

Several objective means of evaluating the sloughing of green beans have been developed. McConnell (35, p. 1) evaluated sloughing of blanched beans by noting the time needed to rub, with gentle pressure of the fingers, the skin from the sides of the beans taken from a 200° F. soft water bath (20-50 ppm hardness as $CaCO_3$) at different time intervals. He found that the three and four sieve size beans were more resistant to sloughing than the one and two sieve sizes. He noted further, though, that where there was sloughing with the more mature beans, this was more objectionable than with the less mature beans.

Van Buren _et al_. (53, p. 233) objectively measured the amount of material rubbed off of canned beans under controlled conditions. The beans were shaken mechanically in water and then the amount of sediment suspended in the water was measured in a 100 ml graduated cylinder after allowing the sediment to settle. In using the dual blanch for canned green beans, Van Buren _et al_. (53, p. 234) noted that sloughing was reduced if the beans were first blanched at 170° F. for 2 minutes and then blanched at 190° F. for 2 minutes. They also found that the skin-tightening process did not take place if the beans were first blanched at the higher temperature.

A method similar to that developed by Van Buren _et al_. (53, p. 233) was used by Sistrunk (46, p. 34) to evaluate the effect of field and processing factors on the sloughing of canned Blue Lake beans. The beans were agitated in water and then the sediment suspended in the water was filtered, dried, and weighed. The results indicated that the sloughing of canned beans was influenced by irrigation practices, harvest date, time and temperature of the blanch, and the size and variety of the beans.

Singleton (45, p. 52) working with bean varieties for freezing observed that sloughing was not successfully reduced by trying different variations of time and temperature of blanching. Enzie (15, p. 61) noted that some varieties of frozen green beans appeared to slough more than others when cooked.

Various methods have been used to measure texture objectively by physical means. Up until recently, most methods consisted of instruments with calibrated springs and scales to which was attached a blunt pointed needle or knife. Guyer, Kramer, and Ide (18) used a modified fruit pressure tester in evaluating the texture of various varieties. The instrument was modified in that the plunger normally found was replaced with a blunt cutting edge. They found that there was a highly significant difference between varieties at all stages of maturity.

Van Buren et al. (53, p. 233) studied the firming effect of dual blanching using a texturometer which evaluated firmness in terms of force required to compress the beans to a certain level. They found a -0.90 correlation coefficient between pounds of pressure and ml. of sediment (sloughed skins). It was concluded that blanching conditions have a marked effect on the physical character of the beans as noted by the sloughing and texture data.

The effect of various storage temperatures on the texture of frozen green beans as noted by Woodroof and Shelor (55), was measured by a tenderometer adjusted so that the number of grams required for a needle to pierce the sample being tested could be recorded. A similar instrument was used by Gould (16, p. 9) which measured the number of pounds required for a needle to pierce the bean. Culpepper (7, p. 359) used a blunt pointed needle to evaluate the changes in texture of green beans with increase in maturity.

A more recent means of measuring texture is by use of the shear press. The shear press simulates the action of chewing where the teeth first compress and then shear through the food. The instrument has been found to be highly versatile in that with the proper modifications it could measure the texture of a wide variety of foods, and give results that were reproducible. Sistrunk (46, p. 33) measured the texture of canned beans using the old model Maryland Shear Press. He found that the shear press measurement of texture was highly significantly negatively correlated with sloughing. Cain, Sidwell, and Frazier (3, p. 3) used the same instrument to study the effect of canning and freezing on different varieties of Blue Lake beans. More recently, Sweeney et al. (49, p. 342-343) evaluated the texture of cooked frozen green beans purchased in retail markets, using a Lee-Kramer Shear Press with a standard cell and a 3000 pound proving ring. He found that the shear press readings, in pounds of force, ranged from 8 to 172.

Storage of Frozen Green Beans

As the commercial importance of frozen vegetables grew, there was a corresponding increase in interest in the effects of various storage temperatures on the quality of specific vegetables, green beans for one. In 1940, Caldwell et al. (4, p. 22) noted that beans stored at 15° F. for six months lost more chlorophyll than those stored at 0° F. for the same length of time.

Tressler (50, p. 75) found that those beans stored at -10° F. could be held three to four times longer without a noticeable change in quality than those beans stored at 10° F. He held beans at 0° F. for eight to twelve months without noticeable change in quality.

In 1948, Woodroof and Shelor (55, p. 517) observed that as the temperature of storage of frozen green beans rose from -15 to 15° F., the quality of the beans decreased, after four months storage. He noted further that loss of green color occurred quite extensively at 15° F. as the storage time increased after four months storage. At -15° F. there was only slight loss of blue and an increase in yellow color, under the same circumstances. With regards to texture, Woodroof and Shelor (55, p. 517) noted that there was no consistent relationship between the storage temperature and the firmness of the thawed frozen beans, although there was a continuous loss of texture the longer the beans were stored.

Bennett *et al.* (1, p. 19), in a study of the effect of storage temperatures on various foods, noted that green beans stored at 10° F. lost more color than those stored at 0° F. and -20° F. In 1955, Siegele (44, p. 66) reported that for frozen beans stored at -20° F. for five months, there was but a small change in the color of the beans. Guerrant (17) noted that beans stored at 10° F. were darker in color than those stored at 0° F. or at -20° F., as shown by a decrease in reflectance values. He noted further, that the peak of maximum reflectance shifted to higher wavelengths as the storage temperature increased.

In preliminary studies by Dietrich *et al.* (11, p. 112), it was found that there was an increase in percent conversion of chlorophyll to pheophytin in bush beans as the storage time and temperature increased; as the storage temperature increased from 0° F. to 30° F., the loss of chlorophyll and hence the green color decreased markedly.

Dietrich *et al.* (11, p. 111) noted further that different varieties lost chlorophyll at different rates. The amount of chlorophyll lost was also found to vary with the year. However, in a more intensive study of the effects of storage temperatures on green beans reported by Dietrich *et al.* (11, p. 144) in 1959, it was concluded that the variety, growing area, and harvest year were not important in following the rate of deterioration of chlorophyll over storage at temperatures ranging from 0° to 30° F. for 120 days.

Dietrich et al. (11, p. 144) observed that there was a two fold increase in deterioration of the color of frozen green beans with a 5° F. increase in temperature in the 0° to 25° F. range. He noted further that the higher the initial chlorophyll retention, the slower was the rate of chlorophyll deterioration in subsequent storage at any given temperature. With regards to the rate of deterioration of chlorophyll over storage, Dietrich et al. (10, p. 259) concluded that this phenomenon occurred at a rate always equal to a fixed percentage of the initial chlorophyll.

The fact that the loss of color of frozen green beans stored at -20° F. was negligible, and that there was a loss of only two percent of the initial chlorophyll of beans stored for 120 days at 0° F. was noted by Dietrich et al. (11, p. 144).

Dietrich et al. (11, p. 136-137) stated that textural changes were not found to be related to storage conditions for adequately blanched beans. In another study, Dietrich et al. (10, p. 261) noted that there was no change in texture of beans over six weeks storage at 20° F. As this temperature is comparable to a much longer storage period at a lower temperature, it appears that texture change over storage is not noticeable.

In 1962, Woodroof, Heston, and Ellis (54, p. 35) reported that there was little change in the color of frozen green beans stored at -15° F., 0° F., and 15° F. for four months, but that there was progressive deterioration as the length of storage increased. He noted that the beans stored at -15° F. were superior to those stored at the higher temperature. Furthermore, the beans stored at 0° F. were slightly better in color than those stored at 15^{0} F.

III MATERIALS AND METHODS

Raw Material

The green beans used in the experiment were grown at the Vegetable Crops Farm of the Horticulture Department. All of the beans were of the variety FM-1, Blue Lake Pole Beans.

Preparation and Processing

Two harvests were made in 1961 and a third in 1962. The beans were harvested in the morning and delivered to the food processing pilot plant in the afternoon.

Three replications of the experiment were taken from the first two harvests. Sloughing and texture measurements, and the statistical relationship between them were accomplished on beans taken from the third harvest in 1962.

The beans were graded for size, snipped and cut to one inch lengths using commercial size equipment. In the experiment, only sieve size three and four beans were used. The range in diameter for sieve size three and four beans is 18.5 - 21.0 and 21.0 - 24.0 sixty-fourths of an inch respectively. These sieve sizes were combined during the snipping and cutting operations. After thoroughly mixing the lot of cut beans, the individual treatments were prepared.

There were eighteen treatments and two controls (single blanches). The eighteen treatments consisted of variations in the pre-blanch and final blanch. The two controls were the final blanches, which were previously found to adequately inactivate the peroxidase enzymes by the method of Masure and Campbell (34). The pre-blanch variations consisted of all possible combinations of three temperatures, 162^{o} F., 170^{o} F., and 177^{o} F., with three periods of time, 30 seconds, 90 seconds, and 300 seconds. These nine treatments were increased to eighteen after the application of the two final blanches, 200^{o} F. - 150 seconds, and 210^{o} F. - 105 seconds, to each of the above time and temperature combinations. Thus, the treatments formed a 3 x 3 x 2 factorial experiment with three replications. As each replication was done as a unit, the experiment was of random block design.

The beans were blanched in two large stainless steel steam jacketed kettles which had a capacity of water to beans of approximately fifty to one by volume. The cut beans were placed in small stainless steel baskets and then placed in the kettles for blanching. The temperature was maintained at $\pm 2^{o}$ F. manually by observing a thermometer placed in the water. A uniform temperature was assured by keeping the small baskets in motion during the blanch period. One kettle was used for the pre-blanch and the other for the final blanch. After each blanch period the baskets of blanched beans were placed in cold running tap water ($60-65^{o}$ F.). All of the treatments involving

162^{o} F. pre-blanch temperature were done first, followed by the 170^{o} F. and 177^{o} F. pre-blanch treatments. In between the just mentioned divisions, the blanching water in both kettles was changed.

The cooled beans were filled into 16 ounce metal-end cartons and frozen at -18^{o} F. for twenty-four hours. The frozen samples were stored at 0^{o} F. until evaluation.

Analysis and Evaluation of the Frozen and Cooked Green Beans

The beans processed in 1961 were measured for color after freezing and after four months storage. At the end of the four months storage period the beans were cooked and subsequently measured for color and texture. An unsuccessful attempt was made to measure the amount of sloughing of the cooked beans in 1961. However, in 1962 the method for measuring sloughing was modified and data was successfully obtained. The day after the beans from the 1962 harvest were frozen they were cooked and the sloughing determinations were made, along with texture measurements.

The frozen green beans were cooked using the following method: A sample of 250 grams of beans, 250 ml of tap water and thirty grains of salt were placed in ten 401 x 411 cans, two of which were fitted with thermocouples. The cans were placed on trays in a steam box and the thermocouples were attached to an automatic recorder. The temperature at which the water began to boil was previously found to be 209° F. Consequently the samples were cooked for ten minutes after the temperature had reached 209° F. as indicated by the recorder.

Color

Color was measured by two methods. In one method the visual color of the green beans was measured by the Hunter Color and Color Difference Meter, Model 106 (Figure 2). In the second method the chlorophyll, pheophytin and carotenoid pigments were extracted from the plant tissues and were measured by a Beckman Model DU Spectrophotometer.

In measuring the visual color of the bean samples, the Hunter Color and Color Difference Meter was standardized to the values of the SKC - 15 "Kitchen Green" color plaque: "L" = 57.4, "a" = -17.7, and "b" = 14.0. The SKC - 15 "Kitchen Green" color plaque was used because it was similar in color to the green beans. The bean sample was placed in the exposure position and the difference between the plaque and the sample was measured by the instrument in terms of the "L", "a", and "b" values.

The frozen samples were thawed for three hours at room temperature before being measured for color. The cooked samples were drained and then measured for color. The beans were filled into a clear, rigid, Polystyrene container, 3 1/4 x 2 5/8 x 1 3/8 inches and the

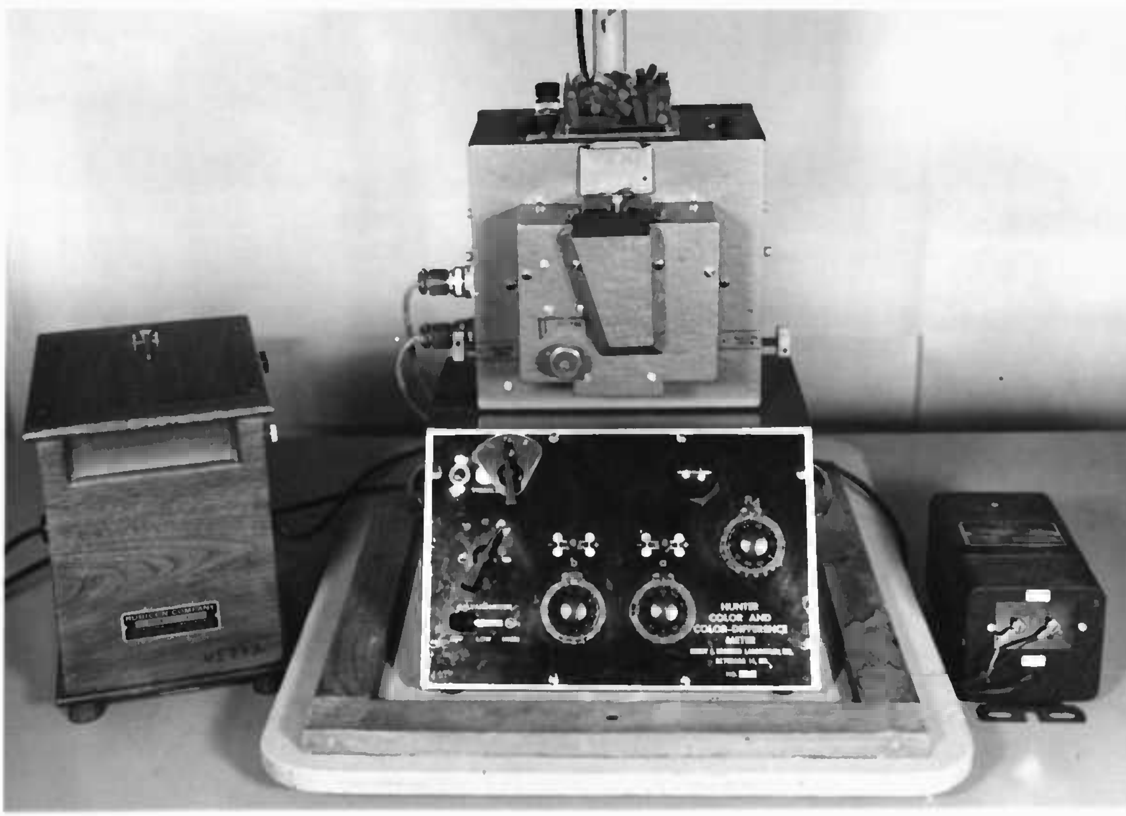

Figure 2. The Hunter Color and Color Difference Meter.

air spaces were filled with tap water. The container was then placed in the exposure position. An average of two readings was taken as the color of the sample.

The second method used to measure the color of the green beans was essentially that developed by Dietrich (8, p. 428). A 65 gram sample of either cooked or frozen beans was blended with 50 ml of 100 per cent acetone for three minutes. Forty grams of the resultant slurry was combined with 130 ml. of 100 per cent acetone. After the solution had been stirred for three minutes, one gram of Hyflow Super Cel filter aid was added. The solution was agitated for an additional thirty seconds and filtered through a seven cm (M) sintered glass funnel with the aid of light suction. The paste of insoluble solids was washed with 100 ml of 80 per cent acetone (v/v). The acetone extract was then transferred to a 250 ml. volumetric flask and made up to volume with 80 per cent acetone (v/v). The optical density of the solution was determined in a Beckman Model DU at 553 mμ and 536 mμ. Zero adjustments were made with 90 per cent acetone (v/v) in the reference cell.

In calculating the per cent conversion it was necessary to determine the ratios of optical density readings found at 536 mμ and 553 mμ for chlorophyll with zero conversion (R_o), for the unknown sample (R_x) and for an extract where the chlorophyll was 100 per cent converted to pheophytin (R_{100}). The sample for zero conversion was extracted from a fresh sample of beans taken from the master lots.

The procedure for extracting the chlorophyll from the raw material was somewhat different than described above due to the presence of enzymes. It was reported by Dietrich (8, p. 428) that an acetone concentration of 80 per cent or above was found to be sufficient to inhibit the enzyme activity. Thus a 50 gram sample of the raw beans was blended with 250 ml. of 100 per cent acetone and the solution was stirred for three minutes. Then 125 grams of the resulting slurry was combined with 50 ml of 100 per cent acetone and the solution was stirred for three minutes. The remaining procedure follows that noted above for the frozen or cooked beans.

The extract containing all pheophytin and no chlorophyll (R_{100}) was prepared using an acetonic solution of oxalic acid (saturated solution of oxalic acid in 90 per cent acetone). One ml. of the acetonic solution of oxalic acid was made up to 100 ml volume with the chlorophyll extract and allowed to stand from twenty-two to twenty-four hours, and then the optical density was read.

The calculations for per cent conversion of chlorophyll to pheophytin were made by the formula:

$$\% \text{ conversion } = \frac{R_x - R_o}{R_{100} - R_o} \times 100$$

Shear Press

Texture as indicated by resistance to shear was measured by a modified Kramer Shear Press (Figure 3), the basic hydraulic system and ram assembly of which were manufactured by the Bridge Food Machinery Company. The modifications include a 1000 pound pressure ring, transducers, exciter demodulator, displacement indicator and an automatic XY recorder. As the steel blades of the ram assembly sheared through the beans placed in the cup of the standard cell, the compression of the 1000 pound pressure ring was measured electrically by the use of transducers connected to the automatic XY recorder. In going from the transducers to the recorder, the current passed through the exciter demodulator and displacement indicator.

The instrument was electronically balanced so that a full scale reading by the displacement indicator would be obtained from a 400 pound load, while at the same time the XY recorder would give a five inch deflection on the Y axis. The resistance to shear was recorded on the XY recorder for a 150 gram sample placed in the cup of the standard cell through which the ram assembly passed. For the work curve which was automatically recorded by the instrument, the area and the height of the curve was measured and subsequently converted to work area (in.-pounds) and maximum force (pounds) respectively.

Figure 3. The Modified Kramer Shear Press.

Sloughing

An especially designed apparatus (46, p. 34) was used to measure sloughing (Figure 4). A cooked sample of 50 grams of beans was placed in a 6" x 6" wire drum made from 1/4 inch galvanized mesh screen. The drum was connected to a motor through a variable speed reduction gear which was set so that the drum rotated at 60 rpm.

A pan containing 750 ml. of tap water was placed under the reel. The water level was such that the bottom of the reel was covered to a height of 1/2 inch, a height just sufficient to keep the beans rinsed during the rotation. After one minute the drum was drained and shaken to remove adhering water and material from the beans. The material in the water was rapidly filtered with the aid of a Buchner funnel attached to a filter flask and water aspirator. The material trapped on a silk filter (43 threads per inch) was considered to be tissue from the bean that had become loose and sloughed off. The silk filters were dried at 176^{o} F. and weighed before the filtration. The grams of dry material were obtained after re-drying for five hours at 176^{o} F., cooling in a desiccator and re-weighing.

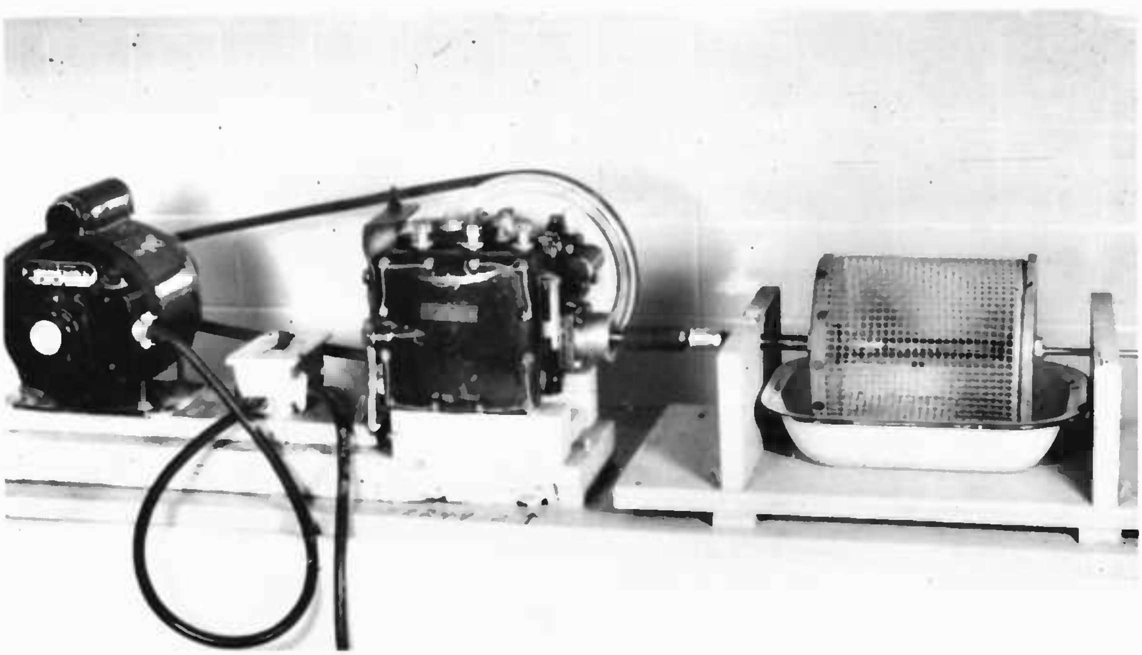

Figure 4. The Machine for Determining Sloughing.

IV RESULTS AND DISCUSSION

All of the data collected in the experiment was analyzed by the statistical designs and methods of Li (32). The significance of the main effects was tested by means of analysis of variance. Where the main effects were found to be significant by the magnitude of the "F value" the Least Significant Difference (LSD) between means was calculated.

Texture and sloughing were found to be highly significantly negatively correlated by Sistrunk (46, p. 133) and Van Buren (53, p. 233), with regards to canned green beans. The evaluation of sloughing and texture of frozen green beans harvested and processed in 1962 led to the same conclusion. The amount of sloughing per 50 gram sample ranged from 7.7 mg. to 108.2 mg. The maximum force indice of texture, in pounds of force, ranged from 123.2 to 256.0. The range in work area (inch-pounds) was from 144.0 to 284.0. A correlation coefficient of -0.922 (standard error of estimate = ±0.202) was found between work area and the amount of sloughed material. Between the maximum force index of texture, as measured by the shear press, and sloughing, a correlation coefficient of -0.930 (standard error of estimate = ±1.789) was calculated. In other words when the shear press measurements of texture indicated that the beans were relatively soft, the same beans were also found to have a relatively large amount of sloughing.

In order to conserve space in the tables, the following abbreviations were used:

SD	-	Significantly different (0.05)
NSD	-	Not significantly different
HSD	-	Highly significantly different (0.01)
(0.01)	-	1% level of significance
(0.05)	-	5% level of significance
LSD	-	Least significant difference
HCM	-	Hunter Color and Color Difference Meter
%CC	-	Per cent conversion of chlorophyll

The Effects of Variation in Dual Blanch Treatments on the Color of Frozen Green Beans After Processing

The effect of dual blanching on the color of the green beans is discussed in terms of the effect of the temperatures of the pre-blanch, the effect of the times of the pre-blanch and the effect of the final blanches.

Hunter Color and Color Difference Meter

A statistical analysis of the effect of variations of the temperature of the pre-blanch on the color of the beans as measured by the Hunter

"L" value showed that there was no change in lightness of the beans (Table 1). The same was true for the effect of variation of the time of the pre-blanch on the color of the dual blanched green beans as noted by the Hunter "L" value (Table 2). Furthermore, the effect of the two final blanches was found to be the same with regard to the lightness of the green beans as measured by the Hunter "L" value (Table 4).

The effect of time and temperature of the pre-blanch on the color of the beans was significant at the 1% and 5% levels respectively, as measured by the Hunter "$-a_L$" value (Tables 1, 2 and 3). A significant interaction existed between these two effects (Table 3). The 170° F. pre-blanch temperature appeared to intensify the green color of the beans when the pre-blanch time was either 30 seconds or 90 seconds (Table 3). For those beans having pre-blanch times of 30 and 90 seconds, the 177° F. pre-blanch temperature degraded the color of the green beans to the point where the color, as measured by the Hunter "$-a_L$" value, equaled that of beans having a pre-blanch temperature of 162° F. (Table 3). At a pre-blanch time of 300 seconds, the Hunter "$-a_L$" values decreased, indicating a loss of greenness, as the temperature of the pre-blanch increased from 162° F. to 177° F. (Table 3). The low temperature - long time final blanch resulted in lower Hunter "$-a_L$" values than the high temperature - short time final blanch (Table 4).

The effect of the three pre-blanch temperatures was found to be the same with regards to the color of the beans as measured by the Hunter "b_L" value (Table 1). The same was true for the effect of variation of the time of the pre-blanch on the color of the dual blanched green beans as measured by the Hunter "b_L" value (Table 2). Furthermore, the effect of variations of the final blanches on the color of the beans as measured by the Hunter "b_L" values was found to be the same.

The Hunter "$-a_L/b_L$" value was highly significantly affected by the temperature of the pre-blanch (Table 1). As the temperature of the pre-blanch increased from 162° F. to 177° F., the Hunter "$-a_L/b_L$" values decreased. The same was found to be true as the pre-blanch time increased from 30 to 300 seconds (Table 2). The 210° F. - 105 second final blanch resulted in a highly significantly larger Hunter "$-a_L/b_L$" value than the 200° F. - 150 second final blanch (Table 4). The decrease in Hunter "$-a_L/b_L$" values indicated a change in hue from green towards yellow as noted by Dietrich _et al._ (9, p. 111). The adverse effect of the lower temperature - longer time blanch as compared to the high temperature - short time blanch (Table 4) was also noted by Dietrich _et al._ (11, p. 144).

Per Cent Conversion of Chlorophyll

No significant difference was noted between the three pre-blanch temperatures with respect to the per cent conversion of chlorophyll to pheophytin (Table 1). However, as the temperature increased, the amount of pheophytin formed also increased. The effect of time of the pre-blanch on the per cent conversion of chlorophyll to pheophytin was highly significant (Table 2). As the time of the pre-blanch increased from 30 seconds to 300 seconds, the amount of chlorophyll converted to pheophytin increased. The effect of the variation of the final blanch was not significant (Table 4). There was no significant interaction among any of the main effects.

The Effect of Four Months Storage at 0^{o} F. on the Color of the Dual and Single Blanched Beans

Hunter Color and Color Difference Meter

No significant effect on the lightness or darkness of the beans, as measured by the Hunter "L" value, was noted over storage for the dual and single blanched beans (Table 5). However, at the end of the storage period, the beans appeared to be darker in color.

The decrease in the Hunter "$-a_L$" value (loss of greenness) over the four months storage period at 0^{o} F. was not significant (Table 5). A statistical analysis of the effect of the variation in the final blanch on the color of the dual blanched beans after four months storage, as noted by the Hunter "$-a_L$" value, showed that there was no significant difference (Table 6). This is contrary to the results found after

TABLE 1. THE EFFECT OF TEMPERATURE OF PRE-BLANCH ON THE COLOR OF DUAL BLANCHED FROZEN GREEN BEANS AFTER PROCESSING

Color Indices	Means of Main Effects Pre-Blanch Temperature (° F.) 162	 170	 177
HCM "L"[1]	33.36	31.89	32.83
HCM "-a_L"[2]	13.09	14.02	13.32
HCM "b_L"[3]	11.22	12.50	12.28
HCM "-a_L/b_L"[4]	1.171	1.122	1.083
%CC[5]	26.92	29.31	30.21

1 NSD
2 SD: LSD (0.05) 0.582
3 NSD
4 HSD: LSD (0.01) 0.0333
5 NSD

TABLE 2. THE EFFECT OF TIME OF PRE-BLANCH ON THE COLOR OF DUAL BLANCHED FROZEN GREEN BEANS AFTER PROCESSING

Color Indices	Means of Main Effects Pre-Blanch Time (sec) 30	 90	 300
HCM "L"[1]	33.41	33.08	33.31
HCM "-a_L"[2]	14.64	14.08	11.69
HCM "b_L"[3]	11.93	12.06	12.01
HCM "-a_L/b_L"[4]	1.231	1.169	0.976
%CC[5]	19.76	27.33	39.39

1 NSD
2 HSD: LSD (0.01) 0.781
3 NSD
4 HSD: LSD (0.01) 0.0333
5 HSD LSD (0.01) 4.726

TABLE 3. THE EFFECT OF TIME AND TEMPERATURE OF PRE-BLANCH ON THE COLOR OF DUAL BLANCHED FROZEN GREEN BEANS, AS MEASURED BY THE HUNTER COLOR AND COLOR DIFFERENCE METER "$-a_L$" VALUE AFTER PROCESSING

Pre-Blanch Temperature (°F.)	Means of Main Effects Pre-Blanch Time (sec) 30	90	300	Means of Temperatures
162	13.93	13.30	12.05	13.09
170	15.15	15.08	11.82	14.02
177	14.85	13.88	11.22	13.32
Means of Times	14.64	14.09	11.70	

Effect of Times - HSD: LSD (0.01) 0.781
Effect of Temperatures - SD: LSD (0.05) 0.582
Interaction - SD

TABLE 4. THE EFFECT OF FINAL BLANCH ON THE COLOR OF DUAL BLANCHED FROZEN GREEN BEANS AFTER PROCESSING

Color Indices	Means of Main Effects Final Blanch (°F. - sec) 200-150	210-105
HCM "L"[1]	32.81	33.72
HCM "$-a_L$"[2]	13.04	13.91
HCM "b_L"[3]	11.78	12.22
HCM "$-a_L/b_L$"[4]	1.111	1.139
%CC[5]	28.60	29.05

1 NSD
2 HSD: LSD (0.01) 0.639
3 NSD
4 HSD: LSD (0.01) 0.0272
5 NSD

processing (Table 4). It appears that the 210° F. - 105 second final blanched beans decreased in greenness over the storage period while the 200° F. - 150 second final blanched beans changed very little in color as measured by the Hunter "$-a_L$" value (Tables 4 and 6).

A statistical analysis of the effect of storage at 0° F. for four months on the color of the dual and single blanched frozen green beans showed that the loss of yellowness, as measured by the Hunter "b_L" value, was not significant (Table 5).

The Hunter "$-a_L/b_L$" value, a mathematical means of evaluating the color changes of green beans, decreased significantly over storage at 0° F. for four months. Thus, while the Hunter "$-a_L$" and "b_L" did not show the effect of storage on the color of the beans separately, together, a change in hue from green towards yellow was noted.

In evaluating color changes over storage, as measured by the Hunter Color and Color Difference Meter, there was no significant interaction between the treatment effects (pre-blanch and final blanch) and the storage effects.

Per Cent Conversion of Chlorophyll

The loss of chlorophyll over the four months storage period for the dual and single blanched beans was not significant (Table 5). Dietrich et al. (11, p. 144) reported a loss of 2% chlorophyll over storage at 0° F. for four months. A similar loss (3.24%) was noted in Table 5.

TABLE 5. THE EFFECT OF FOUR MONTHS STORAGE AT 0° F. ON THE COLOR OF THE DUAL AND SINGLE BLANCHED FROZEN GREEN BEANS

Color Indices	Means of Main Effects Storage (mo) 0	4
HCM "L"[1]	33.38	32.53
HCM "$-a_L$"[2]	13.75	13.33
HCM "b_L"[3]	12.11	12.01
HCM "$-a_L/b_L$"[4]	1.137	1.107
%CC[5]	27.62	30.86

1 NSD
2 NSD
3 NSD
4 SD: LSD (0.05) 0.0253
5 NSD

TABLE 6. THE COLOR OF DUAL AND SINGLE BLANCHED FROZEN GREEN BEANS AFTER FOUR MONTHS STORAGE AT 0° F.

Color Indices	Means of Main Effects Blanch Temperature and Time (° F.-sec) 200-150	210-105
HCM "L"[1]	32.69	32.37
HCM "$-a_L$"[2]	13.06	13.09
HCM "b_L"[3]	12.09	11.79
HCM "$-a_L/b_L$"[4]	1.074	1.109
%CC[5]	33.27	30.83

1 NSD
2 NSD
3 NSD
4 NSD
5 NSD

The Effects of Variation in Dual Blanch Treatments on the Texture and Color of Frozen Green Beans, Stored for Four Months at 0^{o} F. and Then Cooked

The effect of dual blanching on the texture and color of the cooked frozen green beans is discussed in terms of the effect of the temperatures of the pre-blanch, the times of the pre-blanch and the effect of the final blanches.

Texture Measurements

The "F" value for the variation due to the temperature of the pre-blanch was significant at the 5% and 1% levels for the maximum force and work area indices respectfully (Table 7). Those beans pre-blanched at 162^{o} F. were softer in texture than those beans with pre-blanch temperatures of 170^{o} F. and 177^{o} F. as indicated by both indices of texture.

The effect of variations of pre-blanch time was significant at the 1% level. As the time of pre-blanch increased from 30 to 300 seconds, the pounds of maximum force and the inch-pounds of work area increased as noted in Table 8. All three pre-blanch times were significantly different from each other.

The effect of the final blanch on the maximum force and work area indices of texture was highly significant. The longer time, lower temperature final blanch produced firmer beans than the shorter time, higher temperature blanch (Table 9).

There was no interaction between the temperature and time of the pre-blanch and the final blanch.

Color Measurements

Hunter Color and Color Difference Meter

The Hunter "L" values for the three pre-blanch temperatures were found to be significantly different. Those beans receiving the 162^{o} F. pre-blanch were lighter in color than those pre-blanched at either 170^{o} F. or 177^{o} F. (Table 10). The "F" value for the variation due to the time of pre-blanch was significantly different with regards to the Hunter "L" value. The color of those beans pre-blanched for either 90 or 300 seconds were darker than those beans pre-blanched for 30 seconds (Table 11). After cooking, the effect of variations of time and temperature of pre-blanch on the lightness or darkness of the color of the beans was found to be significant, whereas, before cooking (Tables 1 and 2), this was not so. Apparently the pre-blanch treatment had some effect on the cooking properties of the color of the beans, as there was no effect of storage noted on the beans (Table 5).

The variation in the temperature of the pre-blanch did not significantly effect the color of the beans as analyzed by the Hunter "$-a_L$"

TABLE 7. THE EFFECT OF TEMPERATURE OF PRE-BLANCH ON THE TEXTURE OF COOKED DUAL BLANCHED FROZEN GREEN BEANS

Shear Press Indices of Texture	Means of Main Effects Pre-Blanch Temperature (° F.) 162	 170	 177
Maximum Force (lbs)[1]	229.11	251.51	249.42
Work Area (inch - lbs)[2]	272.27	295.11	298.31

1 SD: LSD (0.05) 16.10
2 HSD: LSD (0.01) 15.955

TABLE 8. THE EFFECT OF TIME OF PRE-BLANCH ON THE TEXTURE OF COOKED DUAL BLANCHED FROZEN GREEN BEANS

Shear Press Indices of Texture	Means of Main Effects Pre-Blanch Time (sec) 30	 90	 300
Maximum Force (lbs)[1]	197.78	232.76	299.51
Work Area (inch-lbs)[2]	238.22	277.02	350.44

1 HSD: LSD (0.01) 21.61
2 HSD: LSD (0.01) 15.96

TABLE 9. THE EFFECT OF FINAL BLANCH ON THE TEXTURE OF COOKED DUAL BLANCHED FROZEN GREEN BEANS

Shear Press Indices of Texture	Means of Main Effects Final Blanch (° F. - sec) 200-150	 210-105
Maximum Force (lbs)[1]	378.44	351.60
Work Area (inch-lbs)[2]	446.31	419.38

1 HSD
2 HSD

values for the three pre-blanch times were found to be highly significantly different. Each pre-blanch time was significantly different from the other two (Table 11). As the time of pre-blanch increased, there was a progressive loss of greenness. The interaction between the time and temperature of the pre-blanch, noted in Table 3 for the Hunter "$-a_L$" index of color changes in frozen green beans, disappeared on cooking. However, the effect of variations of temperature on the color of the beans as measured by the Hunter "$-a_L$" value, noted in Table 1 for frozen green beans, also disappeared on cooking (Table 10).

There was a significant change in Hunter "b_L" values as the temperature of the pre-blanch varied. The 162° F. pre-blanch resulted in yellower beans than the 170° F. or the 177° F. pre-blanch (Table 10). The effect of the pre-blanch time was also significant at the 5% level. Those beans receiving the 90 and 300 second pre-blanch had a lower Hunter "b_L" value than the 30 second pre-blanch (Table 11).

There was no significant difference between the variations in time and temperature of the pre-blanch on the color of the frozen green beans, as measured by the Hunter "b_L" value, after processing (Tables 1 and 2). No significant effect was noted over storage for four months at 0° F. (Table 5). However, the pre-blanch time and temperature did have a significant effect on the cooking properties of the color of the beans as noted by the Hunter "b_L" index of color changes in green beans (Tables 10 and 11). The lower temperature - shorter time pre-blanch (162^{o} F. - 30 second) apparently aided in retaining the yellowness of the frozen green beans on cooking.

The Hunter "$-a_L/b_L$" values decreased as the temperature of the pre-blanch increased (Table 10). The change was significant in that the Hunter "$-a_L/b_L$" value for the 162^{o} F. pre-blanch was significantly different from the 177^{o} F. pre-blanch. The change in hue (Hunter "$-a_L/b_L$") of the cooked, frozen, dual blanched green beans over time of pre-blanch was highly significant. All of the Hunter "$-a_L/b_L$" values were highly significantly different from each other (Table 11).

The variation in time and temperature of pre-blanch were highly significantly different with respect to the effect on the color of frozen green beans, as measured by the Hunter "$-a_L/b_L$" index after processing (Tables 1 and 2). Over a period of four months storage at 0^{o} F., there was a significant change in the hue (Hunter "$-a_L/b_L$") from green towards yellow of the frozen green beans, irregardless of blanching treatments (Table 5). The significant change in color over storage, coupled with the effects of cooking, blurred the significance between the temperatures of the pre-blanch (Table 10). The difference between the times of the pre-blanch was still highly significant however (Table 11).

The variation of the final blanch had no effect on the color of the cooked frozen green beans as analyzed by the Hunter Color and Color Difference Meter (Table 13). The highly significant difference between the 200° F. - 150 second and 210° F. - 105 second final blanches, with respect to the frozen green beans as measured by the Hunter "$-a_L$" and "$-a_L/b_L$" indices after processing (Table 4), was obscured by the effect of storage (Table 5). While there was no change in the color of the beans over storage, as measured by the Hunter "$-a_L$" value, a sufficient change must have occurred to eliminate the significant difference between the final blanches.

No significant interaction was involved in analyzing the effects of variation in time and temperature of pre-blanch and of final blanch on the color of dual blanched, cooked, frozen green beans, as analyzed by the Hunter Color and Color Difference Meter.

Per Cent Conversion of Chlorophyll

The increase in per cent chlorophyll converted to pheophytin with increase in the temperature of the pre-blanch was not found to be significant (Tables 10 and 12). The 177° F. pre-blanch temperature appeared to have a more adverse effect on the chlorophyll of the beans than the other temperatures. The effect of the pre-blanch temperatures interacted significantly with the effect of the pre-blanch times (Table 12). Regardless of the interaction, the effect of the times of pre-blanch on the per cent conversion of chlorophyll was highly significant (Tables 11 and 12). The 300 second pre-blanch time converted more chlorophyll to pheophytin than the 30 or the 90 second pre-blanch times. The 200° F. - 150 second final blanch appeared to cause a greater loss of chlorophyll than the higher temperature - shorter time, 210° F. - 105 second, final blanch, although the difference was not found to be significant (Table 13).

No interaction was noted between the time and temperature of the pre-blanch with respect to the per cent of chlorophyll converted to pheophytin as measured in frozen green beans after processing. Apparently, either the pre-blanch or final blanch treatments had some effect on the cooking properties of the chlorophyll of the beans, which would account for the interaction between the time and temperature of the pre-blanch upon cooking.

A Comparison of Dual and Single Blanched Green Beans After Four Months Storage at 0° F.

Color Measurements of Frozen and Cooked Green Beans

It was previously noted that the effect of the variation of the final blanch on the color of the frozen and cooked dual blanched green beans, as measured by the Hunter Color and Color Difference Meter and per cent conversion of chlorophyll, was not significant (Tables 6 and 13).

TABLE 10. THE EFFECT OF TEMPERATURE OF PRE-BLANCH ON THE COLOR OF COOKED DUAL BLANCHED FROZEN GREEN BEANS

Color Indices	Means of Main Effects Pre-Blanch Temperature (° F.)		
	162	170	177
HCM "L"[1]	32.88	31.86	31.79
HCM "-a_L"[2]	3.98	3.69	3.27
HCM "b_L"[3]	11.66	11.02	10.94
HCM "-a_L/b_L"[4]	0.346	0.328	0.296
%CC[S]	83.79	84.13	88.3S

1 SD: LSD (0.0S) 0.849
2 NSD
3 SD: LSD (0.0S) 0.578
4 SD: LSD (0.05) 0.033
5 NSD

TABLE 11. THE EFFECT OF TIME OF PRE-BLANCH ON THE COLOR OF COOKED DUAL BLANCHED FROZEN GREEN BEANS

Color Indices	Means of Main Effects Pre-Blanch Time (sec)		
	30	90	300
HCM "L"[1]	32.84	31.73	31.9S
HCM "-a_L"[2]	4.68	4.03	2.23
HCM "b_L"[3]	11.77	10.98	10.87
HCM "-a_L/b_L"[4]	0.403	0.364	0.202
%CC[S]	82.02	83.39	90.87

1 SD: LSD (0.0S) 0.849
2 HSD: LSD (0.01) 0.SS7
3 SD: LSD (0.0S) 0.776
4 HSD: LSD (0.01) 0.044
S HSD: LSD (0.01) 5.S83

TABLE 12. THE EFFECT OF TIME AND TEMPERATURE OF PRE-BLANCH ON THE COLOR OF DUAL BLANCHED, COOKED, FROZEN GREEN BEANS, AS PERCENT CONVERSION OF CHLOROPHYLL

Pre-Blanch Temperature (° F.)	Means of Main Effects Pre-Blanch Time (sec) 30	60	300	Means of Temperatures
162	76.73	83.05	91.60	83.79
170	78.82	85.15	88.43	84.13
177	90.50	81.97	92.57	88.35
Means of Times	82.02	83.39	90.87	

Effect of Times - HSD: LSD (0.01) 5.583
Effect of Temperatures - NSD
Interaction - SD

TABLE 13. THE EFFECT OF FINAL BLANCH ON THE COLOR OF DUAL BLANCHED, COOKED, FROZEN GREEN BEANS

Color Indices	Means of Main Effects Final Blanch (° F. - sec) 200-150	210-105
HCM "L"[1]	32.34	32.01
HCM "$-a_L$"[2]	3.59	3.71
HCM "b_L"[3]	11.30	11.12
HCM "$-a_L/b_L$"[4]	0.316	0.330
%CC[5]	85.69	85.16

1 NSD
2 NSD
3 NSD
4 NSD
5 NSD

As a consequence of this, only the pre-blanch times and temperatures were noted in Tables 14 and 15.

Hunter Color and Color Difference Meter

It was noted previously (Tables 1, 2 and 5), that the color of the frozen green beans, as perceived by the Hunter "L" value, was not significantly affected by the variations in pre-blanch treatments or by the storage period. Yet Table 14 indicates that all of the means of the Hunter "L" values were not equal. Li (32, p. 237) noted that the LSD was to be used to test the significance of the difference between two particular treatment means, and not to be distorted into the difference between two extreme sample means, as erroneous conclusions might be drawn in the latter situation. Such was the case when the single blanched beans were compared to the 170^{o} F. - 300 second pre-blanched beans.

Tables 10 and 11 noted that the variations of the time and temperature of the pre-blanch significantly affected the lightness or darkness of the color of the cooked dual blanched frozen green beans. However, in comparing the Hunter "L" value of the cooked, single blanched beans with the cooked dual blanched beans (Table 15), no significant difference was noted.

The adverse effect of heat on the color of frozen green beans, as measured by the Hunter "$-a_L$" value, was noted in Tables 1, 2, 3 and

4. It is not surprising then, to find the Hunter "$-a_L$" value for the single blanched beans significantly higher than the dual blanched beans, except for those beans pre-blanched at 170° F. for 30 seconds (Table 14). After cooking (Table 15) the differences between the single blanched and dual blanched beans were smaller (Table 15). As a result, the dual blanched beans receiving pre-blanches at 162° F. and 170° F. for 30 and 90 seconds, were similar in color to the single blanched beans, as measured by the Hunter "$-a_L$" value.

The discussion regarding the Hunter "L" value in comparing the dual blanched beans with the single blanched beans, also pertains to the Hunter "b_L" value. In Table 14, Hunter "b_L" values for those beans pre-blanched at 170° F. and 177° F. for 300 seconds were compared with the Hunter "b_L" value for the single blanched beans, and were found to be not as yellow as the single blanched beans. However, after cooking, the single blanched beans were of the same yellowness (same Hunter 'b_L" value) as the dual blanched beans (Table 15).

The degradation of the color of the beans due to the adverse effect of heat, as indicated by the decrease in Hunter "$-a_L/b_L$" value, was previously noted in Tables 1, 2 and 4. Thus the single blanched beans which received the least amount of heat were significantly different in the Hunter "$-a_L/b_L$" values than the dual blanched beans except for those beans pre-blanched at 170° F. for 30 seconds (Table 14). Upon cooking (Table 15), the differences between the color of single and dual blanched beans, as measured by the Hunter "$-a_L/b_L$" value. As a result, the dual blanched beans receiving a 162° F. pre-blanch for 30 and 90 seconds and a 170° F. pre-blanch for 30 seconds were of the same color as the single blanched beans (Table 15).

Per Cent Conversion of Chlorophyll

As the time of the pre-blanch increased, there was a highly significant increase in the amount of chlorophyll of the frozen beans converted to pheophytin (Table 14). Thus, only the less severe pre-blanch treatments, 162° F. for 30 and 90 seconds, and 170° F. for 30 seconds, resulted in beans with color comparable to the single blanched beans, as measured by the per cent of chlorophyll converted to pheophytin. Cooking the beans produced some erratic results (Table 12) among the pre-blanch treatments in that, as the amount of heat applied to the raw beans increased, there was not a consistent corresponding increase in the amount of chlorophyll converted to pheophytin (Table 20). In any event, the following pre-blanch treatments were similar in color to the control samples: 162° F. for 30 and 90 seconds; 170° F. for 30, 90 and 300 seconds; 177° F. for 90 seconds (Table 15).

The range of values for the per cent conversion of chlorophyll to pheophytin for the dual blanched beans, as noted in Table 14, was from 23.10 to 41.58. Using an industry panel, Dietrich et al.

TABLE 14. A COMPARISON OF SINGLE AND DUAL BLANCHING ON THE COLOR OF FROZEN GREEN BEANS AFTER FOUR MONTHS STORAGE AT 0° F.

Color Indices	Means of Pre-Blanch Treatments Over Final Blanch Treatments — Pre-Blanch Temperature and Time (° F.-sec) 162-30	162-90	162-300	170-30	170-90	170-300	177-30	177-90	177-300	Single Blanch
HCM "L"[1]	33.67	32.40	32.30	32.55	32.10	31.23	33.22	32.53	32.03	33.25
HCM "$-a_L$"[2]	14.42	13.38	11.65	15.17	14.02	10.13	14.38	13.32	10.73	15.65
HCM "b_L"[3]	12.45	11.97	11.74	12.17	12.08	11.07	12.40	12.30	11.55	12.52
HCM "$-a_L/b_L$"[4]	1.162	1.157	0.993	1.247	1.162	0.918	1.162	1.093	0.930	1.250
%CC[5]	23.10	26.85	42.75	23.83	29.20	41.58	28.23	32.25	40.63	20.13

1 LSD (0.05) 1.359
2 LSD (0.05) 0.705
3 LSD (0.05) 0.812
4 LSD (0.05) 0.0419
5 LSD (0.05) 7.473

TABLE 15. A COMPARISON OF THE EFFECT OF SINGLE AND DUAL BLANCHING ON THE COLOR OF COOKED FROZEN GREEN BEANS

Color Indices	Means of Pre-Blanch Treatments Over Final Blanch Treatments — Pre-Blanch Temperature and Time (° F. - sec) 162-30	162-90	162-300	170-30	170-90	170-300	177-30	177-90	177-300	Single Blanch
HCM "L"[1]	33.30	32.48	32.75	32.08	32.07	31.05	33.27	31.02	31.56	32.55
HCM "$-a_L$"[2]	4.70	4.48	4.27	5.07	4.12	3.50	2.77	1.88	2.05	4.82
HCM "b_L"[3]	11.85	11.60	11.87	11.35	11.27	10.33	11.78	10.20	10.63	11.08
HCM "$-a_L/b_L$"[4]	0.403	0.442	0.363	0.395	0.360	0.338	0.238	0.183	0.185	0.440
%CC[5]	76.73	83.05	91.60	78.82	85.15	88.43	90.50	81.97	92.50	80.17

1 LSD (0.05) 1.551
2 LSD (0.05) 0.731
3 LSD (0.05) 1.091
4 LSD (0.05) 0.055
5 LSD (0.05) 6.893

(9, p. 141) concluded that when the conversion of chlorophyll to pheophytin was equal to or greater than 50 per cent, the color of the frozen green beans would draw complaints from the consumers. As the per cent conversion of chlorophyll of the dual blanched beans was not in the critical region indicated above, it is conceivable that the dual blanched beans had not lost their appeal to the consumer as far as color is concerned.

Texture Measurements of Cooked Green Beans

It was previously noted in Table 9 that the two final blanches were highly significantly different from each other, with respect to their effect on the texture of the dual blanched cooked frozen green beans, as measured by the shear press. It is interesting to note in Tables 16a and 16b, the effect of the final blanch on the dual blanched green beans in comparison with the effect of the same heat treatment on the single blanched beans. Whereas, the firmness of the former was decreased by the higher temperature - shorter time (210° F. - 105 second) blanch, the firmness of the latter was increased by the same blanch. Thus, it is not surprising that the dual blanched beans receiving the 210° F. - 105 second final blanch were similar in texture to the 210° F. - 105 single blanched beans, and that just the opposite was true of the 200° F. - 150 second final and single blanched beans.

As a consequence of the above, the work area index of texture indicated that those dual blanched beans receiving the 200° F. - 150 second final blanch were all significantly different from the single blanched beans (Table 16a). The maximum force index of texture indicated that only the 162° F. - 30 second pre-blanch, and 200°F.-150 second final blanch resulted in beans that were similar in firmness to the single blanched beans (Table 16b). With respect to those beans receiving the 210° F. - 105 second final blanch, both indices of texture, as measured by the shear press, indicated that those beans pre-blanched for 30 seconds, irregardless of pre-blanch temperature, were similar to the single blanched beans in firmness (Tables 16a and 16b).

TABLE 16. A COMPARISON OF THE EFFECT OF SINGLE AND DUAL BLANCHING ON THE TEXTURE OF COOKED FROZEN GREEN BEANS

a. Work Area Index of Texture

Final Blanch	Means of Individual Treatments Pre-Blanch Temperature and Time (° F. - sec)									Single
(° F. - sec)	162-30	162-90	162-300	170-30	170-90	170-300	177-30	177-90	177-300	Blanch
200-150[1]	224.27	269.60	335.73	261.87	278.93	368.80	265.33	304.80	368.53	115.73
210-105[1]	212.80	262.13	329.07	232.27	264.27	364.53	232.80	282.40	336.00	201.07

1 LSD (0.05) 37.158

b. Maximum Force Index of Texture

Final Blanch	Means of Individual Treatments Pre-Blanch Temperature and Time (° F. - sec)									Single
(° F. - sec)	162-30	162-90	162-300	170-30	170-90	170-300	177-30	177-90	177-300	Blanch
200-150[1]	180.00	228.00	290.67	220.00	241.33	320.00	221.33	248.00	321.33	140.00
210-105[1]	177.33	217.33	281.33	198.67	225.33	303.73	189.33	236.53	280.00	162.13

1 LSD (0.05) 50.222

V SUMMARY AND CONCLUSIONS

A study was made of color and texture (firmness-sloughing) changes of dual and single blanched frozen green beans. Texture (firmness) and sloughing measurements were made on cooked, dual blanched and single blanched, frozen green beans after processing. The color of the beans was analyzed after processing, after four months storage at 0° F. Texture (firmness) and color measurements were made on dual and single blanched beans stored for four months at 0° F. and then cooked.

The results indicate the following conclusions:

1. The firmness of the cooked, dual and single blanched, frozen green beans, as measured by the shear press, was found to be highly significantly negatively correlated with sloughing of the skins. When the shear press indices of texture indicated that the beans were relatively soft, the same beans were also found to have a relatively large amount of sloughing.

2. There was no change in lightness or darkness of the color of single or dual blanched beans over storage at 0° F. for four months. The Hunter "$-a_L/b_L$" index of color noted a significant change in hue from green towards yellow of the single and dual blanched beans. The conversion of chlorophyll to pheophytin was not significant over storage.

3. In evaluating the effect of dual blanching on the color of frozen green beans stored for four months and then cooked, the effect of the variation of the final blanch (single blanch) was not found to be significant. The color of those beans receiving the 200° F. - 150 second final blanch (single blanch) was the same as the color of those beans receiving the 210° F. - 105 second final blanch (single blanch).

4. As the time and temperature of the pre-blanch increased, there was a corresponding increase in the amount of chlorophyll converted to pheophytin, and a change in the visual color of the beans from green towards yellow. The effect of variations of time of pre-blanch was much greater on the color of the dual blanched beans than the effect of variations of temperature of pre-blanch.

5. The lightness of the frozen dual blanched green beans was found to be the same as the single blanched beans, except for those beans pre-blanched at 170° F. for 300 seconds. After cooking, all of the beans, treated (dual blanched) and control (single blanched) were found to be of the same lightness.

6. Before cooking, those frozen green beans (stored at 0° F. for four months) receiving a 170° F. pre-blanch for 30 seconds were similar in color to the single blanched beans as indicated by Hunter "$-a_L/b_L$" value. After cooking, those beans pre-blanched at 162° F. for 30 and 90 seconds, and 170° F. for 30 seconds were of the same hue (Hunter "$-a_L/b_L$" value) as the single blanched beans.

7. Those dual blanched beans with an amount of chlorophyll converted to pheophytin equal to that of the single blanched beans, were pre-blanched at 162° F. for 30 and 90 seconds, and 170° F. for 30 seconds. Upon cooking, the following pre-blanch treatments were similar to the single blanched beans: 162° F. for 30 and 90 seconds; 170° F. for 30, 90 and 300 seconds; and 177° F. for 90 seconds.

8. As the time and temperature of the pre-blanch increased, the texture (firmness) of the cooked dual blanched beans increased. The 200° F. - 150 second final blanch resulted in beans that were firmer than beans receiving the 210° F. - 105 second final blanch.

9. The maximum force index of texture indicated that the 162° F.-30 second pre-blanch, 200° F. - 150 second final blanch, resulted in beans that were similar in firmness to the single blanched beans.

10. The work area index of texture indicated that those dual blanched beans receiving the 200° F. - 150 second final blanch were all significantly different from the single blanched beans.

11. The work area and maximum force indices of texture as measured by the shear press indicated that those beans receiving a pre-blanch of 30 seconds irregardless of temperature of pre-blanch, and a final blanch of 210° F. for 105 seconds, were similar to the single blanched beans in firmness.

On the basis of the foregoing conclusions, a pre-blanch at 170° F. for 30 seconds followed by a final blanch at 200° F. for 150 seconds is recommended for dual blanching, to obtain beans that are similar in color, yet firmer in texture (less sloughing of the skins) than the single blanched beans.

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