# THE EFFECTS OF VARIETIES, BLANCHING TECHNIQUES, AND COOKING METHODS ON COLOR, TEXTURE, AND SENSORY CHARACTERISTICS OF FROZEN GREEN BEANS

by

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# INTRODUCTION

In recent years there has been an upsurge in home gardening and home preservation of food. As changes are made in the ways in which our food is grown and prepared, we need to study the consequences of these changes on the nutritive value and eating quality of the food. Some information is available on commercial producing and processing practices in relation to nutritive value and eating quality. Little information is available on practices used by home gardeners and home preparation and/or preservation methods. Additional information is needed on how home preparation procedures such as precooking processes, methods of cooking, and frozen storage influence the eating quality of vegetables that are commonly home grown to make recommendations to home gardeners and consumers.

The handling, storage, and preservation of vegetables often involve changes in the nutritive value, most of which are undesirable. The freezing process (including prefreezing treatments, freezing, frozen storage, and thawing), if properly conducted, generally is recognized as the best method of long-term food preservation when judged on the basis of retention of sensory attributes and nutrients (Fennema, 1975).

Inactivation of enzymes prior to freezing vegetables is necessary if nutritive value and eating quality are to be preserved to the greatest possible extent (Noble and Gordon, 1964). Traditionally, such inactivation has been accomplished almost exclusively by boiling water or steam blanching, but in recent years, interest has arisen in the use of microwaves for this purpose (Drake et al., 1981). Little information is available on the effects of microwave versus boiling water or steam blanching on the eating quality of vegetables. In a recent study, Drake et al. (1981) compared the effects of water, steam, and microwave blanching on asparagus, green beans, green peas, and sweet corn. Drake and co-workers reported in their study that microwave-blanched vegetables were not as acceptable as water- or steam-blanched vegetables. They also reported no significant time was saved by microwave blanching. Eheart (1967) found that rapid blanching of broccoli by microwaves or slow blanching in water at 77°C, was not a satisfactory method as compared to the conventional method of water blanching at 100°C.

Some studies have compared cooking methods for vegetables. Generally, cooking methods using less water result in greater nutrient retention (Cook and Sundaram, 1963; Sweeney et al., 1960; Gordon and Noble, 1959c; Sweeney et al., 1959; Krehl and Winters, 1950).

Contradictory results for nutrient retention and eating quality of microwave cooked vegetables are reported in the literature. Some studies have reported higher retentions of ascorbic acid in vegetables cooked by microwaves compared to conventional methods of heating (Gordon and Noble, 1959b; Campbell et al., 1958). In contrast, other researchers (Eheart and Gott, 1964; Kylen et al., 1961; Stevens and Fenton, 1951) reported no significant differences for ascorbic acid retention in microwave cooked vegetables while Eheart and Gott (1965) indicated less retention after microwave heating.

Little research is found in the literature comparing color retention of green vegetables cooked conventionally and by microwaves. Chapman et al. (1960) compared fresh and frozen broccoli cooked by both microwaves and by boiling in a small amount of water. The color of fresh broccoli cooked electronically was judged slightly better than that cooked by boiling, but the taste panel ranked frozen broccoli cooked by boiling above that cooked electronically.

The influence of freezing rates on the textural quality of commercially frozen vegetables has been considered (Fuster and Prestamo, 1980; Brown, 1973; Brown, 1967). Researchers agree that, in commercial practices, rapid freezing provides the best preservation of the raw product (Fuster and Prestamo, 1980; Brown, 1967). No information could be found in the literature on the effects of the freezing process on home preservation practices on the texture of green vegetables.

The purpose of this study was to compare the effects of varieties, blanching techniques, and cooking methods on color, texture, and sensory characteristics of frozen green beans.

## REVIEW OF LITERATURE

### Processing Variables

Blanching. Blanching prior to freezing vegetables is used primarily to inactivate enzymes which contribute to undesirable changes in color, flavor, and nutritive value during storage (Lund, 1975). The traditional methods of blanching use either boiling water or steam as the heat transfer medium, but recently, microwave heating has been proposed as a blanching method (Drake et al., 1981).

Several investigators have compared boiling water and steam blanching with respect to losses of nutrients in vegetables (Schwerdtfeger, 1971; Noble and Gordon, 1964; Dietrich and Neumann, 1965; Proctor and Goldblith, 1948). Substantially smaller losses of water-soluble vitamins and most minerals occur with steam blanching than with water blanching.

Microwave heating has been suggested for blanching food products. It has been reported that microwave energy has no direct enhancing effect on degradation of food components other than through temperature elevation (Lopez and Baganis, 1971); therefore, Lund (1975) suggested that microwave blanching should result in nutrient retention at least equal to that achieved during steam blanching and better than that achieved during boiling water blanching. Utilizing a commercial processing technique, Dietrich et al. (1970) compared microwave, steam, and boiling water blanching and concluded that microwave blanching resulted in better ascorbic acid retention in Brussel sprouts; however, the best product was achieved with a combination of processes involving microwave and boiling water blanching.

Few research studies have been reported on the effects of microwave versus boiling water or steam blanching on the eating quality of vegetables. In a recent comparative study over a two-year period, Drake et al. (1981) investigated the effects of boiling water, steam, and microwave blanching on asparagus, green beans, green peas, and sweet corn. Vegetables blanched by each technique were evaluated by instrumental tests and sensory preference analysis for color, texture, and taste. Drake and co-workers concluded from their study that microwave-blanched vegetables were not as acceptable as water- or steam-blanched vegetables and no significant time was saved by microwave blanching. Eheart (1967) found that rapid blanching of broccoli by microwaves or slow blanching in water at 77°C, was not a satisfactory method as compared to the conventional method of water blanching at 100°C.

Storage. Although some researchers have reported no significant changes in nutrients during freezer storage (Wells et al., 1963), losses of nutrients can result from physical separation, leaching, or chemical degradation (Fennema, 1975). Data are available for ascorbic acid retention during the entire freezing process from blanching through freezing (Fennema, 1975). These data are based on differences in ascorbic acid contents of fresh products and those that were blanched, frozen, and stored for 6 to 12 months at -18°C. Although losses differed among products and varieties, losses of ascorbic acid averaged about 50% during the freezing process. Comparisons among reported studies indicate blanching is responsible for the major portion of loss of water-soluble nutrients that occurs during the entire freezing process (Fennema, 1975).

Ascorbic acid appears to be the nutrient most frequently studied, probably since it is one of the least stable. The ascorbic acid content of fresh vegetables generally decreases with storage. The loss of this vitamin increases with higher freezer storage temperatures and with longer storage periods (Bennion, 1980).

Early researchers (Harris and Von Loesecke, 1960) reported ascorbic acid losses of 25 to 40 percent in broccoli and 10 to 30 percent in green beans when the vegetables were stored at 46° to 50°F for four days. Eheart and Odland (1972) found that broccoli stored in air for one week at 2°C (30°F) did not lose reduced ascorbic acid whereas green beans lost as much as 88 percent in six days.

Increases in ascorbic acid during storage of vegetables have been reported. Eheart (1970) found that frozen uncooked and cooked broccoli stored for two or four days at 3.3°C (38°F) prior to blanching was higher in reduced and total ascorbic acid than that blanched and frozen immediately after harvest. Payne (1967) measured ascorbic acid in frozen corn and found that this vitamin significantly increased immediately after freezing and after certain periods of storage in the frozen state. Adequate explanations for ascorbic acid increases were not available and such increases have been questioned (Leichsenring and Morris, 1951).

A few studies have dealt with nutrient losses during storage of products at fluctuating storage temperatures as compared to constant temperatures. With respect to frozen peas (Boggs et al., 1960; Gortner et al., 1948), cauliflower (Dietrich et al., 1962), and green beans (Gortner et al., 1948), losses of ascorbic acid did not differ significantly between the two conditions.

Cooking Methods. Some studies have compared cooking methods for vegetables. Charles and Van Duyne (1954) cooked asparagus, broccoli, Brussel sprouts, cabbage, cauliflower, peas, and snap beans in waterless aluminum cookware. They also cooked the vegetables in tightly covered aluminum pans with water equivalent to half the weight of the vegetables. The vegetables cooked in the waterless cookware retained from 72 to 91 percent of the ascorbic acid present in the raw vegetables, while those cooked in the tightly covered pans with a small amount of water retained from 73 to 88 percent ascorbic acid. However, these differences were not significant. Charles and Van Duyne (1954) concluded that vegetables cooked in small amounts of water were superior in appearance, color, and flavor to those prepared in waterless cookware, but both products were considered satisfactory.

Other researchers have found that, in general, cooking methods using less water result in greater nutrient retention (Sweeney et al., 1960; Gordon and Noble, 1959c; Sweeney et al., 1959; Krehl and Winters, 1950).

Overcooking has been reported by Noble (1967) to result in reduced retention of ascorbic acid. Noble cooked green beans, broccoli, Brussel sprouts, cabbage, cauliflower, onions, rutabagas, and turnips in boiling water until they were tender. These vegetables also were cooked for 5, 10, and 50 minutes beyond the tender stage. The retention of ascorbic acid, in comparison to the raw state, ranged from 33 to 56 percent, with a mean of 44 percent. Overcooking for 5 minutes reduced the mean retention to 41 percent.

Contradictory findings for nutrient retention and eating quality of microwave cooked vegetables are reported in the literature. Kylen et al. (1961) reported no differences in the amounts of ascorbic acid retained in seven fresh and three frozen vegetables cooked by conventional and microwave methods. Microwave cooking of broccoli and green beans resulted in less retention of ascorbic acid than cooking conventionally in a minimum amount of water (Eheart and Gott, 1965). However, Campbell et al. (1958) reported that ascorbic acid retention in cabbage, peas, and broccoli was greater with microwave cooking than with conventional methods of heating.

Little information is found in the literature on color retention of green vegetables cooked conventionally and by microwaves. Chapman et al. (1960) compared fresh and frozen broccoli cooked by both microwaves and boiling in a small amount of water. Cooking times for one pound of fresh broccoli to achieve optimum tenderness in the stem were 6 minutes by microwaves and 13 minutes by boiling. Comparable cooking times for 20 ounces of frozen broccoli were 13 minutes by microwaves and 11 minutes by boiling. Color of fresh broccoli cooked electronically was judged slightly better than that cooked by boiling, but the sensory panel ranked frozen broccoli cooked by boiling above that cooked electronically. Gordon and Noble (1964) reported that several vegetables cooked in boiling water sufficient to cover them were greener than those cooked by a waterless method. Gilpin et al. (1959) and Sweeney et al. (1959) found that cooking broccoli in large amounts of water caused some loss of color and flavor. Color and flavor deteriorated also when broccoli was cooked beyond the tender stage.

## Quality Attributes

Color. Color has been considered as one of the most important quality attributes of a food product. To the consumer, color is associated with freshness and maturity of fresh foods, and in processed foods, color is used as an indication of the quality of both the raw product and the preservation method used. Thus, color is an important factor in consumer acceptance (Sweeney and Martin, 1961).

Color retention has been used as a measure of quality in green vegetables. Considerable research has been conducted in an effort to improve the quality of cooked green vegetables (Dietrich et al., 1957, 1959; Gilpin et al., 1959; Sweeney and Martin, 1958). Fresh green vegetables change from a bright green to a dull olive green color during processing. The kinetics of this reaction were studied extensively by Joslyn and MacKinney (1938) and MacKinney and Joslyn (1940, 1941). The authors found the color change was a result of the conversion of chlorophyll to pheophytin in an acidic medium. Magnesium in the chlorophyll molecule was replaced by two hydrogen ions supplied by the plant tissue and the corresponding pheophytin was produced. The reaction was found to be irreversible. Two chlorophylls were isolated and designated as chlorophyll a and b. Both chlorophylls were found to be very similar chemically, but MacKinney and Joslyn (1940) reported that chlorophyll a was converted to pheophytin a eight to ten times as rapidly as chlorophyll b was converted to pheophytin b. Similar results have been reported by Sweeney and Martin (1961). They showed that the destruction of chlorophyll a was the principle factor responsible for the loss of color in cooked green vegetables. Tan and Francis (1962) concurred with these results in their work on spinach puree.

Several factors may influence the speed and extent of change in color. These include: heating time, pH of the vegetable, and the blanching process. The heating time may influence the alteration of the pigment. Sweeney and Martin (1958) measured loss of chlorophyll a and b with the Gardner Color Difference Meter when broccoli was cooked for periods of 5, 10, 15, and 20 minutes. Chlorophyll a was degraded more rapidly than chlorophyll b. After 5 minutes of heating, retention of chlorophyll a was approximately 80 percent and of chlorophyll b, 90 percent. After 10 minutes of heating, retentions were 45 percent and 87 percent, respectively. After 20 minutes, less than one third of the chlorophyll remained, and the ratio of chlorophyll a to chlorophyll b had decreased from 1.77 in broccoli heated for 5 minutes to 0.65 in that heated for 10 minutes. These results were in agreement with early findings by MacKinney and Joslyn (1940).

The speed and extent of conversion of chlorophylls to pheophytins may be influenced by the hydrogen ion concentration of the vegetable. Sweeney and Martin (1961) measured chlorophyll retention with the Gardner Color Difference Meter and reported a high retention of chlorophyll in cooked frozen spinach of 72.2 percent and in cooked frozen peas of 67.6 percent, with both vegetables having high pH values of 6.8 and 9.0, respectively. Retention in cooked green beans was 26.7 percent and in

Brussel sprouts 20.9 percent, those vegetables having pH values of 6.2 and 6.3, respectively. Furthermore, when green beans were heated in water buffered to elevate the pH, better chlorophyll retention was found as pH was increased to 7.

The effect of blanching on the retention of chlorophylls in green beans during subsequent frozen storage was reported by Walker (1964). Beans were blanched in boiling water for periods of 20, 30, 45, and 60 seconds up to 10 minutes. Conversion of chlorophylls to pheophytins increased up to 3 minutes blanching time, after which the conversion leveled. Blanched beans were held in frozen storage at -10°C for 20 days. Loss of chlorophylls during storage varied with the blanching treatment. Blanching times of 45 seconds and 1 minute resulted in the greatest retention of chlorophylls. Loss of chlorophylls in unblanched and in underblanched (times less than 45 seconds) green beans was attributed in part to conversion of chlorophylls to pheophytins but primarily to oxidation of chlorophylls as a result of peroxidation of lipids in the beans. The two blanching times that produced the greatest retention of chlorophylls (45 seconds and 1 minute) were sufficient to completely inactivate catalase and peroxidase in the green beans. Loss of chlorophyll in overblanched (times greater than 1 minute) beans was attributed to "heat inactivation of other systems," which resulted in oxidation of the chlorophylls (Walker, 1964).

Texture. The influence of freezing rate on the textural quality of frozen vegetables has been considered (Fuster and Prestamo, 1980; Brown, 1973; Brown, 1967). Except for a few studies, the freezing rates studied in relation to texture have been those in commercial practices.

Brown (1967) studied the effect of freezing rate on the texture of green beans. Texture was measured with a L.E.E.-Kramer recording shear press and by sensory analysis. Results of the instrumental tests showed rapid freezing of beans by immersion in liquid nitrogen prevented tissue damage and reduced the texture degradation caused by cell wall rupture accompanying slow freezing. Sensory evaluation by a trained panel showed texture differences in beans frozen at various rates where there were no visible differences in the amounts of cell wall damage.

Fuster and Prestamo (1980) determined the effects of freezing rates on the cell structure of green beans. Samples of raw green beans, beans blanched in the laboratory in boiling water for different times (1, 2, and 3 minutes) and in steam at atmospheric pressure (5 and 7 minutes), and samples industrially blanched in boiling water for 3 to 4 minutes, were used. For comparison of freezing rates, the beans blanched in the laboratory were stored at -30°C in a chest freezer (slow freezing) and the beans industrially blanched were stored at -30°C in a tunnel freezer (rapid freezing). Histological changes were determined by microscopic observation and photomicrographs of the tissue structure. The results indicated the rate of freezing is the most critical factor affecting the cell structure. The authors concluded that freezing injury is inversely related to the rate of freezing. In samples frozen slowly, the cell wall of the parenchyma was damaged.

The findings by Fuster and Prestamo (1980) and Brown (1967) support the observation by Fennema (1975) that rapid freezing provides the best preservation of the textural characteristics of the raw product. However, the value of such rapid freezing has been questioned because the resulting textural improvement could be destroyed by slight overcooking (Brown, 1973). In a study to determine if the textural improvement brought about by freezing at fast rates is lost by prolonged cooking, Brown (1973) selected three vegetables (zucchini squash, carrots, and green beans) which were frozen at various rates, cooked for three different lengths of time, and presented to a sensory panel for texture comparison. The results indicate that the texture improvement brought about by freezing at rapid rates is not lost by prolonged cooking. Instead the improved texture either remained or became more obvious as the cooking time was increased.

Some information has been reported on the effects of blanching, freezing, and cooking on the texture of green beans in commercial practices. Brown (1967) studied the effect of the processing steps on cell wall damage and tissue degradation. The texture of green beans after boiling water blanching, freezing, and cooking was measured with a L.E.E.-Kramer recording shear press. Shear resistance of blanched beans was measured 2 hours after blanching, that of frozen beans was measured after 1 or 2 days storage at -20°F and either cooking for 7 minutes or thawing. Brown (1967) found that shear resistance of the beans was reduced in steps of approximately equal magnitude by the successive processes of boiling water blanching, freezing, and cooking. Visible damage to the green bean tissue was caused by freezing, but not blanching or cooking.

No information could be found in the literature concerning the effects of the freezing process on home preservation practices on the texture of green vegetables.

# MATERIALS AND METHODS

## Treatments

Twelve treatment combinations were studied--two varieties of green beans (Contender and Provider), three blanching techniques (boiling water, steam, and microwave), and two cooking methods (conventional and microwave) after freezer storage. A randomized complete block design with four replications of each treatment combination was used.

Varieties. Two varieties of fresh green beans (Contender and Provider), locally grown, were obtained weekly. The green beans were held overnight at 4-7°C prior to preparation for frozen storage.

Blanching Techniques. Green beans were washed, trimmed, cut into 2.5 cm - 3.8 cm lengths, and weighed into 454 g quantities. Conventional and microwave blanching methods were used to simulate home preservation practices.

For blanching in boiling water, 3.8 l of water were used for each 454 g sample of green beans. The beans were placed in the blanching kettle with boiling water, covered, and boiled for 3 minutes. The blanched beans were cooled in an ice-water bath for the same amount of time that they had been exposed to heat.

For steam blanching, 1000 ml of water were used for each 454 g sample of green beans. The water was added to the bottom of a steam kettle and heated, tightly covered, to boiling. The beans were placed in the steam kettle, covered, and steam blanched for 5 minutes. The blanched beans were cooled in an ice-water bath for 5 minutes.

For microwave blanching, 120 ml of water were used per 454 g of green beans. The water and the green beans were placed in a 3-quart (2.85 l) pyrex casserole, covered tightly, and heated in a Sharp Carousel Microwave Oven (Model R-8200) on the highest setting for 3 minutes with stirring at 1½ minute intervals. The blanched beans were placed in a collander and cooled in an ice-water bath for 3 minutes.

Blanched green beans were packaged in 1-quart (0.95 l) freezer bags, frozen, and stored at -18°C for 12 weeks.

Cooking Methods. Two cooking methods, conventional and microwave, were used to prepare the beans for sampling.

To cook the frozen green beans by the conventional method, 120 ml of water were used for each 454 g package. The water was placed in the bottom of a 2-quart (1.9 l) covered stainless steel saucepan and brought to a boil. The frozen beans were placed in the boiling water and the pan covered. Cooking time began immediately after the pan was covered and the beans were allowed to cook for 10 minutes with stirring after the first 3 minutes of heating.

To cook the frozen green beans by microwaves, the green beans were placed in a 3-quart (2.85 l) pyrex covered casserole and heated in an Amana Radarange Microwave Oven (Model RR-7DA) on the highest setting for 8 minutes with stirring at 4 minute intervals and after heating.

## Evaluation and Measurements

Color. Color was determined for each of four replications on fresh and frozen, cooked samples. Color measurements were made using the Hunter Lab Spectrophotometer (Model S54P-5). For both fresh and frozen, cooked samples, slurries of 50 g green beans and 100 ml distilled water were blended for 1 minute in a one-speed Waring blender. In addition, cooked samples were prepared for color evaluation by chopping 50 g green beans into fine pieces. Samples were placed in optically clear cells (5.6 cm diameter, 3.8 cm depth) and filled to depths of approximately 2.5 cm for presentation to the spectrophotometer. Four color determinations were made on each sample and the average L,a,b values were reported. Instrumental values were reduced to the color functions, hue angle ($\tan^{-1} b/a$) and saturation index $[(a^2 + b^2)^{\frac{1}{2}}]$. Hue angle and saturation index values were based on the Hunter a,b diagram (Figure 1, Appendix) using the area of the diagram from 90° to 180°, which indicates the direction of change in hue from yellow to green (Little, 1975).

Texture. Texture was determined for each of four replications on fresh and frozen, cooked samples. For textural analysis of the green beans, an Instron Universal Testing Machine (Model 1122) with the Ottawa Texture System, extrusion cell, was used with a crosshead speed of 100 mm/min and a chart speed of 200 mm/min. A 50 kg load was used for fresh beans and a 100 kg load was required for cooked samples. For each product evaluation, three green beans were placed horizontally in the center of the extrusion cell. Samples were compressed to approximately 70% in one compression cycle. Hardness was determined as maximum peak force and measured in kilograms.

Sensory Analysis. A twelve member semi-trained taste panel evaluated the cooked samples for color, aroma, firmness, toughness, sweetness, and presence of off-flavor on a 13-cm linear intensity scale (Form 1, Appendix). A discussion of terms, individual conceptions of color, aroma, texture, and flavor, and practice with the scorecard were conducted in two formal orientation sessions to familiarize the panelists with the samples and procedures.

Cooked green bean samples were placed in a 30-ml plastic cup and covered with a watchglass or petri dish for presentation to the panelists. Color of the green beans was evaluated under the MacBeth Skylight (North sky daylight). Color differences were masked with green lighting for evaluation of aroma, texture, and flavor characteristics.

## Analysis of Data

Instrumental data for fresh green beans were subjected to analysis of variance using the following:

| Source of Variation | D/F |
|---|---|
| Replication | 3 |
| Variety | 1 |
| Error | 3 |
| Total | 7 |

Instrumental and sensory data for frozen, cooked green beans were subjected to analysis of variance using the following:

| Source of Variation | D/F |
|---|---|
| Replication | 3 |
| Variety | 1 |
| Blanching Technique | 2 |
| Cooking Method | 1 |
| Variety × Blanching Technique | 2 |
| Variety × Cooking Method | 1 |
| Blanching Technique × Cooking Method | 2 |
| Variety × Blanching Technique × Cooking Method | 2 |
| Error | 33 |
| Total | 47 |

Least square means were compared to determine treatment effects. When F-values were significant, probability of differences were calculated to determine the level of significance.

Correlation coefficients also were determined on instrumental and sensory data for color and texture of frozen, cooked green beans.

## RESULTS AND DISCUSSION

### Effects of Variety

Physical Measurements. Color and Instron data for two varieties of fresh green beans are presented in Table 1. Color measurements were made on fresh green bean samples that had been slurried. No significant differences were found between the Contender and Provider varieties tested for either color or hardness.

Instrumental data for color and texture of two varieties of frozen, cooked green beans are reported (Table 2). Since it had been hypothesized that the presentation of samples for instrumental analysis should simulate those presented to the sensory panel, cooked samples were prepared for color evaluation by slurrying or by chopping into fine pieces. No significant differences were found between varieties for color regardless of the method of presentation, slurried or chopped. Although no differences were indicated for hardness in the raw beans, the Provider variety were harder than Contender after cooking ($p \leq 0.05$).

Sensory Characteristics. Sensory data for the effects of variety on frozen, cooked green beans are presented in Table 3. No significant differences were found between varieties for the sensory attributes of color, aroma, sweetness, and presence of off-flavors. The sensory panel

Table 1. Mean[a] and F values for color and texture of two varieties of fresh green beans.

| Physical Measurement | Variety: Contender | Variety: Provider | F-value |
|---|---|---|---|
| Color | | | |
| L | 53.600 | 53.547 | $0.00^{NS}$ |
| a | -14.050 | -13.955 | $0.08^{NS}$ |
| b | 19.342 | 19.527 | $0.09^{NS}$ |
| Hue angle | 120.042 | 119.638 | $2.09^{NS}$ |
| Saturation index | 23.909 | 24.005 | $0.02^{NS}$ |
| Hardness (kg) | 9.425 | 9.300 | $6.82^{NS}$ |

[a]Each value is a mean for 4 determinations.

$^{NS}$ $p > 0.05$

Table 2. Mean[a] and F values for color and texture of two varieties of frozen, cooked green beans.

| Physical Measurement | Variety | | F-value |
|---|---|---|---|
| | Contender | Provider | |
| Color | | | |
| Slurry | | | |
| L | 44.774 | 45.040 | 1.12[NS] |
| a | -9.949 | -9.978 | 0.01[NS] |
| b | 17.132 | 16.935 | 0.18[NS] |
| Hue angle | 113.310 | 113.702 | 0.44[NS] |
| Saturation index | 19.860 | 19.711 | 0.07[NS] |
| Chopped | | | |
| L | 42.565 | 43.149 | 3.25[NS] |
| a | -8.603 | -8.430 | 0.21[NS] |
| b | 14.824 | 14.779 | 0.01[NS] |
| Hue angle | 112.989 | 112.822 | 0.04[NS] |
| Saturation index | 17.201 | 17.051 | 0.06[NS] |
| Hardness (kg) | 41.770 | 49.183 | 5.88* |

[a]Each value is a mean for 24 determinations.

* $p \leq 0.05$

NS $p > 0.05$

Table 3. Mean[a] and F values for sensory analysis of two varieties of frozen, cooked green beans.

| Sensory Characteristic | Variety: Contender | Variety: Provider | F-value |
|---|---|---|---|
| Color | 6.098 | 6.002 | 0.06[NS] |
| Aroma | 5.543 | 5.763 | 0.55[NS] |
| Firmness | 6.041 | 7.135 | 9.29** |
| Toughness | 6.136 | 7.298 | 8.12** |
| Sweetness | 4.934 | 4.532 | 4.12[NS] |
| Off-flavor | 5.487 | 5.305 | 0.54[NS] |

[a]Each value is a mean for 24 determinations.

** $p \leq 0.01$

NS $p > 0.05$

results supported the physical hardness values from the Instron in that Provider beans were judged to be firmer and tougher ($p \leq 0.01$) than Contender beans.

Effects of Blanching Technique

Physical Measurements. Color data for green beans blanched by boiling water, steam, and microwaves are presented in Table 4. Significant differences for L values were found between microwave and steam blanched beans that were chopped and those slurried. Inconsistencies were noted between L values in chopped beans versus those that were slurried. The microwave blanched beans that were slurried were darker in color than the steam blanched beans. However, the microwave blanched beans were lighter than those blanched by conventional methods after chopping. Thus, the lightness or darkness of the samples was affected by the method of presentation. No other color differences were attributed to blanching technique. Similar results were reported by other researchers (Drake et al., 1981; Noble and Gordon, 1964) who found no significant differences between the color of boiling water and steam blanched beans immediately after blanching or after frozen storage. Eheart (1967) reported no differences between total chlorophyll retention in broccoli blanched in boiling water or by microwaves, but samples blanched by microwaves retained more chlorophyll a. Drake and co-workers (1981) reported no differences in instrumental tests for color of water, steam, and microwave blanched green beans prior to cooking; sensory panel scores based on personal preference were better, however, for water and steam blanched beans.

Table 4. Mean[a] and F values for color and texture of frozen, cooked green beans blanched by three different methods.

| Physical Measurement | Blanching Technique | | | |
|---|---|---|---|---|
| | Boiling Water | Microwave | Steam | F-value |
| Color | | | | |
| Slurry | | | | |
| L | 44.980[ab] | 42.297[b] | 44.459[a] | $3.53^{*}$ |
| a | -10.095 | -10.332 | -9.464 | $2.20^{NS}$ |
| b | 17.019 | 17.369 | 16.713 | $0.67^{NS}$ |
| Hue angle | 113.802 | 114.078 | 112.637 | $2.22^{NS}$ |
| Saturation index | 19.855 | 20.273 | 19.229 | $1.19^{NS}$ |
| Chopped | | | | |
| L | 42.656[a] | 43.561[b] | 42.347[a] | $5.13^{*}$ |
| a | -8.399 | -8.764 | -8.387 | $0.43^{NS}$ |
| b | 14.701 | 15.107 | 14.598 | $0.37^{NS}$ |
| Hue angle | 112.720 | 113.193 | 112.803 | $0.12^{NS}$ |
| Saturation index | 16.978 | 17.516 | 16.884 | $0.43^{NS}$ |
| Hardness (kg) | 40.037[a] | 54.725[b] | 41.669[a] | $9.25^{***}$ |

[a]Each value is a mean for 16 determinations.

[b]Means in a row bearing different letters (a,b) differ significantly.

* $p \leq 0.05$

*** $p \leq 0.001$

NS $p > 0.05$

Results of the textural analysis of green beans blanched by three different methods are reported (Table 4). Instron values were higher, indicating microwave blanched samples were firmer than the beans blanched by the other treatments. Similar results were reported by Drake et al. (1981) in their work on asparagus. These authors found that shear values for microwave blanched asparagus were higher than the values for water or steam blanched asparagus. No differences were found in texture among the three blanching techniques for green beans, green peas or sweet corn.

Sensory Characteristics. Results of the sensory panel evaluation for color, aroma, firmness, toughness, sweetness, and presence of off-flavors in frozen green beans blanched by three different methods are presented in Table 5. The sensory panel found no significant differences among blanching techniques for color or sweetness of frozen, cooked samples. Drake and co-workers (1981) found that sensory scores for color were low for microwave blanched green beans as compared to those conventionally blanched. Color evaluation in the Drake et al. study (1981) was based on personal preference rather than an intensity scale.

For aroma, firmness, and presence of off-flavors, no significant differences were found between boiling water and steam blanched beans. However, microwave blanched beans were firmer and had a more grassy aroma and stronger off-flavors ($p \leq 0.001$) than either boiling water or steam blanched beans. Off-flavors detected by the panelists in microwave blanched samples included grassy, bitter, and stored. Microwave blanched beans were tougher than those blanched by other methods ($p \leq 0.001$). In addition, steam blanched beans were judged to be tougher than boiling water blanched beans ($p \leq 0.001$). Drake et al. (1981) reported sensory

Table 5. Mean[a] and F values for sensory analysis of frozen, cooked green beans blanched by three different methods.

| Sensory Characteristic | Blanching Technique | | | |
|---|---|---|---|---|
| | Boiling Water | Microwave | Steam | F-value |
| Color | 5.827 | 6.765 | 5.559 | 3.24[NS] |
| Aroma | 5.001[a] | 6.861[b] | 5.098[a] | 16.68*** |
| Firmness | 5.348[a] | 8.257[b] | 6.160[a] | 23.32*** |
| Toughness | 5.265[a] | 8.309[c] | 6.577[b] | 18.71*** |
| Sweetness | 4.972 | 4.712 | 4.517 | 1.77[NS] |
| Off-flavor | 4.782[a] | 6.636[b] | 4.749[a] | 25.84*** |

[a]Each value is a mean for 16 determinations.

[b]Means in a row bearing different letters (a,b,c) differ significantly.

*** $p \leq 0.001$

NS $p > 0.05$

preference scores were lower for texture of microwave blanched green beans as compared to those blanched by conventional methods. The undesirable quality attributes of firmness, toughness, grassy aroma, and strong off-flavors in the microwave blanched samples may have been caused by the presence of enzymes that were not inactivated during the blanching process. Joslyn (1946) reported that, in general, if the blanching treatment is not sufficient to inactivate catalase and peroxidase, frozen vegetables will develop off-flavors. Bedford and Joslyn (1939) reported that blanching may cause profound modifications in texture and the formation of undesirable cooked flavors, and recommended that considerable attention be given to blanching procedures that are adequate to inactivate enzymes and result in a minimum of the undesirable changes.

Bennion (1980) stated that two results of chemical changes which may occur during frozen storage of foods are "off-odors" and "off-flavors." Although these changes may be controlled by pre-freezing blanching of vegetables, underblanching may result in either of these changes. Campbell et al. (1979) noted that one of the principle reasons for off-flavors is rancidity of the fatty material in unblanched frozen vegetables. Noble and Winter (1952) reported that in unblanched frozen green beans marked off-flavors developed rapidly by the end of three weeks storage and they were practically inedible by the end of four weeks. Off-flavor descriptions for unblanched frozen green beans were reported by Moriarty (1966) to include earthy, sour, and bitter.

Bennion (1980) suggested that "off-odors" in frozen raw or insufficiently blanched vegetables may be attributed to the accumulation of volatile carbonyl compounds during frozen storage. Chow and Watts

(1969) reported that rancid odors in frozen green beans were related to malonaldehyde values, used as an index of unsaturated fatty acid oxidation. These authors concluded that both lipid oxidation as determined by the thiobarbituric acid test and acetaldehyde formation from anaerobic fermentation contributed to flavor deterioration in frozen green beans. Woodruff et al. (1966) in a review article on blanching techniques suggested that the development of haylike flavors, bitterness, and odors in unblanched frozen vegetables may be due to amino-aldehyde reactions. They further stated the speed of the reactions were dependent on the relationship of enzyme-time-temperature-oxygen. Therefore, it appears that inactivation of enzymes is only one factor of importance to the quality of frozen vegetables.

## Effect of Cooking Method

Physical Measurements. Color and Instron data for frozen green beans cooked conventionally and by microwaves are presented in Table 6. No significant differences were found in L or b values for beans cooked conventionally and by microwaves. However, saturation indexes ($p \leq 0.05$) indicated the color of beans cooked by microwaves was a brighter, more pure color than the beans conventionally cooked. Hue angle values were significantly different ($p \leq 0.001$). The hue angle indicated more greenness in both the chopped and the slurried microwave cooked samples than those conventionally cooked, which follows since the Hunterlab a values also showed that microwave cooked beans were greener in both chopped and slurried samples. Contradictory results have been reported by other researchers (Chapman et al., 1960; Gordon and Noble, 1959a) who used different products and methods of evaluation. Chapman et al. (1960)

Table 6. Mean[a] and F values for color and texture of frozen green beans cooked conventionally and by microwaves.

| Physical Measurement | Cooking Method | | |
|---|---|---|---|
| | Conventional | Microwave | F-value |
| Color | | | |
| Slurry | | | |
| L | 44.757 | 45.067 | 1.42[NS] |
| a | -8.913 | -11.015 | 36.24*** |
| b | 16.817 | 17.251 | 0.89[NS] |
| Hue angle | 110.816 | 116.196 | 82.29*** |
| Saturation index | 19.051 | 20.520 | 6.99* |
| Chopped | | | |
| L | 42.677 | 43.037 | 1.24[NS] |
| a | -7.341 | -9.692 | 38.54*** |
| b | 14.528 | 15.075 | 1.16[NS] |
| Hue angle | 109.499 | 116.312 | 64.86*** |
| Saturation index | 16.311 | 17.941 | 7.35* |
| Hardness (kg) | 37.646 | 53.308 | 26.26*** |

[a]Each value is a mean for 24 determinations.

*** $p \leq 0.001$

[NS] $p > 0.05$

found that Gardner Color Difference Meter values showed little differences in frozen broccoli cooked by boiling and by microwaves. Gordon and Noble (1959a) measured color by the Nickerson whirling disc method and found that cabbage boiled in the saucepan was greener than that cooked in the electronic range.

Measurements taken from Instron curves after compressing frozen, cooked samples are presented (Table 6). Microwave cooked samples were firmer than those conventionally cooked ($p \leq 0.001$) as shown in higher hardness values. Bowman et al. (1971) reported that microwave cooking resulted in undesirable effects on textural and/or epidermal tissues of broccoli, cabbage, green beans, peas, onions, and parsnips. The authors stated a possible explanation of this phenomenon is that "application of high energy in the form of microwaves may cause some compositional factor(s) in these vegetables to combine, interact, or undergo molecular rearrangement, or polymerization. This modified or new constituent(s) may not soften during cooking as does the native plant substance(s)." Bollman et al. (1948) recommended cooking broccoli, cabbage, green beans or peas for the shortest time possible to provide reasonable tenderness and to minimize objectionable "skin effects" of prolonged cooking. Chapman and co-workers (1960) pointed out that in cooking the stems of broccoli to optimal texture by the electronic method, the heads of fresh broccoli would be undercooked, whereas heads of frozen broccoli would be overcooked.

Sensory Characteristics. Sensory panel scores for frozen green beans cooked conventionally and by microwaves are presented in Table 7. Significant differences were found between green beans cooked

Table 7. Mean[a] and F values for sensory analysis of frozen green beans cooked conventionally and by microwaves.

| Sensory Characteristic | Cooking Method | | F-value |
|---|---|---|---|
| | Conventional | Microwave | |
| Color | 3.338 | 8.762 | 178.59*** |
| Aroma | 4.172 | 7.135 | 100.30*** |
| Firmness | 4.688 | 8.489 | 112.10*** |
| Toughness | 4.609 | 8.825 | 106.99*** |
| Sweetness | 4.314 | 5.131 | 17.95*** |
| Off-flavor | 4.546 | 6.246 | 46.99*** |

[a]Each value is a mean for 24 determinations.

*** $p \leq 0.001$

conventionally and by microwaves for all quality attributes measured. Microwave cooked samples were judged to have the following characteristics when compared to those conventionally cooked: a brighter green color, a stronger grassy aroma, a firmer and tougher texture, a sweeter flavor, and more predominant off-flavors. Gordon and Noble (1959a) reported that vegetables of the Brassica genera (cabbage, cauliflower and broccoli) were judged by sensory panelists to be milder in flavor when cooked in boiling water than when cooked in the electronic range. The findings by Gordon and Noble (1959a) were supported by Bowman et al. (1971) who also noted that the flavor of cabbage was milder after boiling in the saucepan than in the electronic range. Contradictory results for color and flavor were reported by Chapman et al. (1960) who found that in their study, taste panel color scores of frozen broccoli cooked by boiling were higher than those for broccoli cooked electronically. The authors also compared flavor scores for broccoli cooked electronically and by boiling and found no flavor superiority for one method over the other. The undesirable quality attributes (grassy aroma, firm and tough texture, and presence of off-flavors) that were observed in our study may have been caused by the presence of enzymes that were not inactivated during the blanching process or other reactions involved in off-flavor development that have been explained in the previous section on sensory characteristics.

## Significant Treatment Combination Interactions

Color of the slurried samples was affected significantly by the interaction between varieties and cooking methods (Table 8). Significant differences were found between b values and saturation indexes ($p \leq 0.05$) for the Contender variety beans that were cooked by conventional and

Table 8. Mean[a] and F values for physical measurements of frozen, cooked green beans for variety × cooking method interactions.

| Physical Measurement | Contender | | Provider | | F-value |
|---|---|---|---|---|---|
| | Conventional | Microwave | Conventional | Microwave | |
| Color | | | | | |
| Slurry | | | | | |
| L | 44.635 | 44.914 | 44.879 | 45.221 | $0.01^{NS}$ |
| a | -8.667 | -11.232 | -9.159 | -10.797 | $1.76^{NS}$ |
| b | $16.338^{a}$ | $17.926^{b}$ | $17.295^{ab}$ | $16.576^{a}$ | $6.25^{*}$ |
| Hue angle | 110.940 | 115.679 | 110.691 | 116.713 | $1.17^{NS}$ |
| Saturation index | $18.501^{a}$ | $21.219^{b}$ | $19.600^{a}$ | $19.821^{ab}$ | $5.04^{*}$ |
| Chopped | | | | | |
| L | 42.662 | 42.468 | 42.692 | 43.606 | $2.93^{NS}$ |
| a | -7.076 | -10.131 | -7.607 | -9.254 | $3.45^{NS}$ |
| b | 14.062 | 15.587 | 14.995 | 14.563 | $3.72^{NS}$ |
| Hue angle | 109.300 | 116.679 | 109.698 | 115.945 | $0.45^{NS}$ |
| Saturation index | 15.786 | 18.617 | 16.837 | 17.265 | $3.99^{NS}$ |
| Hardness (kg) | 35.975 | 47.567 | 39.317 | 59.050 | $1.77^{NS}$ |

[a]Each value is a mean for 12 determinations.

[b]Means in a row bearing different letters (a,b) differ significantly.

* $p \leq 0.05$

NS $p > 0.05$

microwave methods. Significant differences also were found between b values for the two varieties that were microwave cooked ($p \leq 0.05$) and differences for saturation indexes ($p \leq 0.05$) were observed between the Contender variety beans that were microwave cooked and the Provider beans cooked by a conventional method. The interactions between variety and cooking methods noted in our study possibly may be related to differences in pigment concentrations between varieties that are affected by cooking.

No additional interactions were found among the remaining treatment combinations that were studied; therefore, tables for nonsignificant interactions are found in the appendix.

Relationship Between Physical Measurements and Sensory Characteristics for Frozen, Cooked Green Beans

Correlation coefficients were calculated to study the relationships between physical measurements and sensory characteristics for frozen, cooked green beans (Table 9). Falkner (1962) considered the relationship between variates low when the correlation coefficient, regardless of sign, falls within the range of 0.00 to 0.39, moderate for 0.40 to 0.79, and high for 0.80 and above. For 47 degrees of freedom, a coefficient of at least 0.28 is required for a significant ($p \leq 0.05$) relationship between two measurements; a coefficient of 0.36 is required for the relationship to be significant at $p \leq 0.01$ (Snedecor and Cochran, 1980), or a coefficient of 0.45 for a significant relationship of $p \leq 0.001$ (Dayton, 1983).

Correlation coefficients calculated for color measurements using our data indicated that there was a significant relationship ($p \leq 0.001$) between sensory scores for color and Hunterlab a values for both the

Table 9. Correlation coefficients for physical measurements and sensory characteristics for frozen, cooked green beans.

| | |
|---|---|
| Sensory color score vs. | |
| L, slurry | 0.05 |
| a, slurry | -0.63*** |
| b, slurry | 0.19 |
| Hue angle, slurry | 0.82*** |
| Saturation index, slurry | 0.36* |
| Sensory color score vs. | |
| L, chopped beans | 0.13 |
| a, chopped beans | -0.61*** |
| b, chopped beans | 0.20 |
| Hue angle, chopped beans | 0.76*** |
| Saturation index, chopped beans | 0.35* |
| Physical hardness value vs. | |
| Firmness | 0.69*** |
| Toughness | 0.83*** |

* $p \leq 0.05$

*** $p \leq 0.001$

chopped samples and the slurry. High sensory scores for color were interpreted as bright green. Increasing negative Hunterlab a values relate to increasing intensity of green. Therefore, an inverse relationship between these two color measurements is warranted. A significant relationship was observed between sensory color scores and hue angle values ($p \leq 0.001$) and between sensory color scores and saturation indexes ($p \leq 0.05$). According to Falkner's analysis (1962) the correlations between sensory scores for color and Hunterlab a values would be classified as moderate. High correlations were observed between sensory color scores and hue angle values in the slurried samples. However, moderate correlations were found between sensory color scores and hue angle values in the chopped green beans. As expected, correlations were low between sensory color scores and Hunterlab L values and for sensory color scores and Hunterlab b values. Correlations were also low between sensory color scores and saturation indexes. Since the saturation index indicates intensity (brightness or dullness) of the samples and panelists scored color on a scale from dull green to bright green, higher correlations than observed were expected.

Correlation coefficients for the Instron physical hardness values and sensory scores for both firmness and toughness were positively related ($p \leq 0.001$). A moderate positive relationship was found between physical hardness values and firmness scores; the positive relationship was high between physical hardness values and toughness scores. These results show that the instrumental assessment of hardness was appropriate and that the instrument and sensory panel were measuring similar quality factors.

# CONCLUSIONS

Under the conditions of our study, we concluded:

1. Provider beans were firmer than the Contender variety following freezer storage and cooking when evaluated instrumentally and by a sensory panel.

2. Microwave blanched beans were harder according to Instron measurements, and sensory scores for firmness and toughness were higher than those for beans blanched by conventional methods.

3. Green beans blanched by microwaves were characterized by a grassy aroma and the presence of off-flavors.

4. Microwave cooked beans were greener and firmer than those conventionally cooked as indicated by physical measurements and sensory analysis.

5. Microwave cooking resulted in flavor descriptors of grassy aroma, sweetness, and presence of off-flavors.

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# APPENDIX

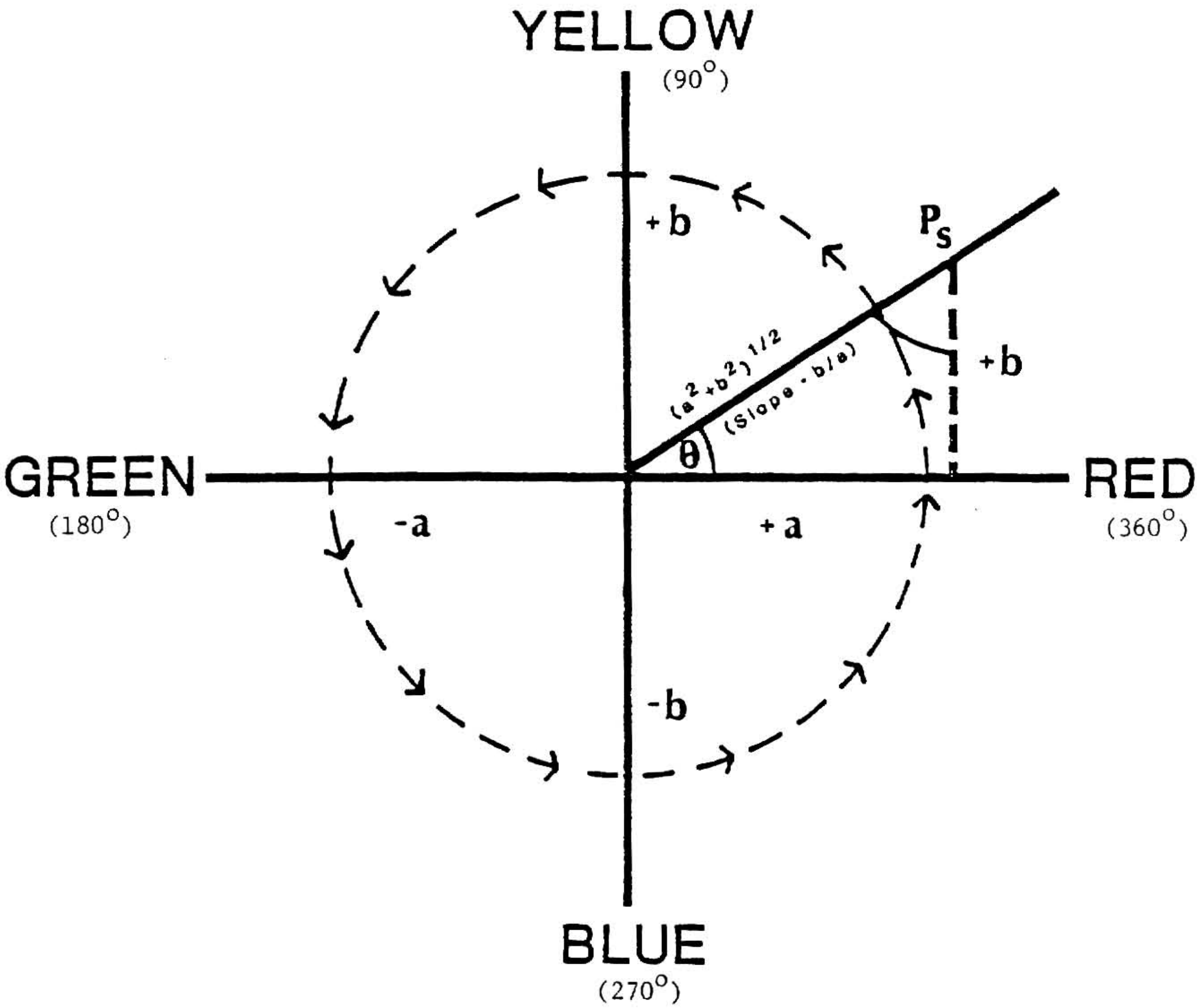


Figure 1. Depiction of hue angle (θ) and saturation index $(a^2 + b^2)^{1/2}$ in the Hunter a,b diagram (Little, 1975).

Form 1. Scorecard Used for Sensory Analysis of Green Beans.

Name ______________________________ Date ____________________

Place a mark perpendicular to the point which describes your evaluation of the characteristics listed. Label each mark with a sample code number.

COLOR

Dull Green — Bright Green

AROMA

Mild "Grassy" — Strong "Grassy"

TEXTURE

Soft — Firm

Tender — Tough

FLAVOR

Not Sweet — Very Sweet

No Off-flavor — Strong Off-flavor

Write the code number of the description of the off-flavor.

_________ grassy

_________ bitter

_________ stored

_________ other (describe)

COMMENTS:

Table 10. Mean[a] and F values for physical measurements of frozen, cooked green beans for variety × blanching technique interactions.

| Physical Measurement | Contender | | | Provider | | | |
|---|---|---|---|---|---|---|---|
| | Boiling Water | Microwave | Steam | Boiling Water | Microwave | Steam | F-value |
| Color | | | | | | | |
| Slurry | | | | | | | |
| L | 44.712 | 44.980 | 44.631 | 45.247 | 45.615 | 44.287 | $1.43^{NS}$ |
| a | -9.800 | -10.169 | -9.880 | -10.390 | -10.496 | -9.049 | $1.56^{NS}$ |
| b | 16.771 | 17.129 | 14.497 | 17.267 | 17.610 | 15.929 | $2.21^{NS}$ |
| Hue angle | 113.429 | 114.044 | 112.456 | 114.175 | 114.111 | 112.819 | $0.11^{NS}$ |
| Saturation index | 19.526 | 19.941 | 20.114 | 20.184 | 20.606 | 18.343 | $2.13^{NS}$ |
| Chopped | | | | | | | |
| L | 42.577 | 43.025 | 42.094 | 42.734 | 44.111 | 42.601 | $0.70^{NS}$ |
| a | -8.181 | -8.765 | -8.864 | -8.617 | -8.764 | -7.910 | $1.17^{NS}$ |
| b | 14.211 | 14.891 | 15.371 | 15.190 | 15.322 | 13.825 | $2.28^{NS}$ |
| Hue angle | 112.691 | 113.538 | 112.738 | 112.750 | 112.849 | 112.867 | $0.10^{NS}$ |
| Saturation index | 16.466 | 17.337 | 17.801 | 17.491 | 17.694 | 15.967 | $2.06^{NS}$ |
| Hardness (kg) | 35.962 | 51.462 | 37.887 | 44.112 | 57.987 | 45.450 | $0.02^{NS}$ |

[a]Each value is a mean for 8 determinations.

$^{NS}$ $p > 0.05$

Table 11. Mean[a] and F values for sensory analysis of frozen, cooked green beans for variety × blanching technique interactions.

| Sensory Characteristic | Contender | | | Provider | | | F-value |
|---|---|---|---|---|---|---|---|
| | Boiling Water | Microwave | Steam | Boiling Water | Microwave | Steam | |
| Color | 5.717 | 6.802 | 5.776 | 5.936 | 6.727 | 5.341 | $0.22^{NS}$ |
| Aroma | 5.045 | 6.655 | 4.930 | 4.958 | 7.066 | 5.266 | $0.27^{NS}$ |
| Firmness | 4.700 | 7.602 | 5.822 | 5.996 | 8.912 | 6.498 | $0.34^{NS}$ |
| Toughness | 4.296 | 8.148 | 5.965 | 6.234 | 8.470 | 7.188 | $1.31^{NS}$ |
| Sweetness | 5.149 | 4.878 | 4.776 | 4.794 | 4.545 | 4.257 | $0.09^{NS}$ |
| Off-flavor | 4.950 | 6.899 | 4.612 | 4.614 | 6.413 | 4.886 | $0.88^{NS}$ |

[a]Each value is a mean for 8 determinations.

$^{NS}$ $p > 0.05$

Table 12. Mean[a] and F values for sensory analysis of frozen, cooked green beans for variety × cooking method interactions.

| Sensory Characteristic | Contender | | Provider | | |
|---|---|---|---|---|---|
| | Conventional | Microwave | Conventional | Microwave | F-value |
| Color | 3.698 | 8.499 | 2.978 | 9.025 | $2.36^{NS}$ |
| Aroma | 4.025 | 7.062 | 4.318 | 7.209 | $0.06^{NS}$ |
| Firmness | 4.504 | 7.579 | 4.873 | 9.398 | $4.08^{NS}$ |
| Toughness | 4.433 | 7.840 | 4.786 | 9.810 | $3.93^{NS}$ |
| Sweetness | 4.639 | 5.230 | 3.988 | 5.076 | $1.58^{NS}$ |
| Off-flavor | 4.732 | 6.242 | 4.359 | 6.249 | $0.59^{NS}$ |

[a] Each value is a mean for 12 determinations.

$^{NS}$ $p > 0.05$

Table 13. Mean[a] and F values for physical measurements of frozen, cooked green beans for blanching technique × cooking method interactions.

| Physical Measurement | Conventional | | | Microwave | | | F-value |
|---|---|---|---|---|---|---|---|
| | Boiling Water | Microwave | Steam | Boiling Water | Microwave | Steam | |
| Color | | | | | | | |
| Slurry | | | | | | | |
| L | 44.992 | 44.824 | 44.455 | 44.967 | 45.771 | 44.464 | $1.50^{NS}$ |
| a | -9.174 | -9.156 | -8.409 | -11.016 | -11.509 | -10.520 | $0.18^{NS}$ |
| b | 16.855 | 17.077 | 16.517 | 17.184 | 17.661 | 16.909 | $0.03^{NS}$ |
| Hue angle | 111.344 | 116.261 | 111.263 | 116.892 | 109.840 | 115.434 | $0.15^{NS}$ |
| Saturation index | 19.208 | 20.501 | 19.404 | 21.143 | 18.541 | 19.917 | $0.06^{NS}$ |
| Chopped | | | | | | | |
| L | 42.965 | 42.589 | 42.077 | 42.346 | 44.147 | 42.617 | $2.59^{NS}$ |
| a | -7.189 | -7.436 | -7.399 | -9.610 | -10.092 | -9.375 | $0.28^{NS}$ |
| b | 14.390 | 14.801 | 14.394 | 15.011 | 15.412 | 14.802 | $0.02^{NS}$ |
| Hue angle | 109.253 | 116.817 | 109.478 | 116.909 | 109.766 | 115.839 | $0.22^{NS}$ |
| Saturation index | 16.097 | 17.860 | 16.599 | 18.432 | 16.238 | 17.530 | $0.08^{NS}$ |
| Hardness (kg) | 33.125 | 47.787 | 32.025 | 46.950 | 61.662 | 51.312 | $0.35^{NS}$ |

[a]Each value is a mean for 8 determinations.

$^{NS}$ $p > 0.05$

Table 14. Mean[a] and F values for sensory analysis of frozen, cooked green beans for blanching technique × cooking method interactions.

| Sensory Characteristic | Conventional | | | Microwave | | | |
|---|---|---|---|---|---|---|---|
| | Boiling Water | Microwave | Steam | Boiling Water | Microwave | Steam | F-value |
| Color | 3.232 | 3.788 | 2.993 | 8.421 | 9.741 | 8.124 | $0.43^{NS}$ |
| Aroma | 3.787 | 5.061 | 3.667 | 6.216 | 8.660 | 6.529 | $1.33^{NS}$ |
| Firmness | 3.216 | 6.805 | 4.045 | 7.481 | 9.709 | 8.276 | $1.56^{NS}$ |
| Toughness | 3.223 | 6.320 | 4.285 | 7.308 | 10.298 | 8.868 | $0.21^{NS}$ |
| Sweetness | 4.400 | 4.409 | 4.132 | 5.543 | 5.015 | 4.902 | $0.64^{NS}$ |
| Off-flavor | 4.144 | 5.584 | 3.910 | 5.420 | 7.728 | 5.589 | $1.02^{NS}$ |

[a]Each value is a mean for 8 determinations.

$^{NS}$ $p > 0.05$

Table 15. Mean[a] and F values for physical measurements of frozen, cooked green beans for variety × blanching technique × cooking method interactions.

| | Contender | | | | | | Provider | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Conventional | | | Microwave | | | Conventional | | | Microwave | | | |
| Physical Measurement | Boiling Water | Microwave | Steam | Boiling Water | Microwave | Steam | Boiling Water | Microwave | Steam | Boiling Water | Microwave | Steam | F-value |
| Color | | | | | | | | | | | | | |
| Slurry | | | | | | | | | | | | | |
| L | 44.492 | 44.892 | 44.420 | 44.832 | 45.067 | 44.842 | 45.392 | 44.755 | 44.490 | 45.102 | 46.475 | 44.085 | $2.06^{NS}$ |
| a | -8.375 | -8.862 | -8.762 | -11.225 | -11.475 | -10.997 | -9.972 | -9.450 | -8.055 | -10.807 | -11.542 | -10.042 | $0.62^{NS}$ |
| b | 15.802 | 16.090 | 17.122 | 17.740 | 18.187 | 17.872 | 17.907 | 18.065 | 15.912 | 16.627 | 17.155 | 15.945 | $0.75^{NS}$ |
| Hue angle | 111.016 | 115.842 | 112.009 | 116.079 | 109.796 | 115.116 | 111.671 | 116.680 | 110.517 | 117.706 | 109.885 | 115.752 | $0.61^{NS}$ |
| Saturation index | 17.884 | 21.167 | 18.377 | 21.505 | 19.243 | 20.986 | 20.532 | 19.835 | 20.430 | 20.782 | 17.838 | 18.847 | $0.73^{NS}$ |
| Chopped Beans | | | | | | | | | | | | | |
| L | 43.147 | 42.557 | 42.282 | 42.007 | 43.492 | 41.905 | 42.782 | 43.420 | 41.872 | 42.685 | 44.802 | 43.330 | $0.39^{NS}$ |
| a | -6.475 | -7.102 | -7.650 | -9.887 | -10.427 | -10.077 | -7.902 | -7.770 | -7.147 | -9.332 | -9.757 | -8.672 | $0.17^{NS}$ |
| b | 13.010 | 13.897 | 15.277 | 15.412 | 15.885 | 15.465 | 15.770 | 15.705 | 13.510 | 14.610 | 14.940 | 14.140 | $1.45^{NS}$ |
| Hue angle | 109.168 | 116.213 | 110.038 | 117.039 | 108.693 | 116.783 | 109.338 | 116.161 | 108.919 | 116.779 | 110.838 | 114.896 | $0.77^{NS}$ |
| Saturation index | 14.547 | 18.384 | 15.670 | 19.004 | 17.139 | 18.463 | 17.646 | 17.336 | 17.528 | 17.860 | 15.336 | 16.597 | $1.02^{NS}$ |
| Hardness (kg) | 32.425 | 45.500 | 30.000 | 39.500 | 57.425 | 45.775 | 33.825 | 50.075 | 34.050 | 54.400 | 65.900 | 56.850 | $0.21^{NS}$ |

[a]Each value is a mean for 4 determinations.

$^{NS}$ $p \geq 0.05$

Table 16. Mean[a] and F values for sensory analysis of frozen, cooked green beans for variety × blanching technique × cooking method interactions.

| Sensory Characteristic | Contender | | | | | | Provider | | | | | | F-value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Conventional | | | Microwave | | | Conventional | | | Microwave | | | |
| | Boiling Water | Microwave | Steam | Boiling Water | Microwave | Steam | Boiling Water | Microwave | Steam | Boiling Water | Microwave | Steam | |
| Color | 3.548 | 4.377 | 3.168 | 7.886 | 9.223 | 8.385 | 2.916 | 3.199 | 2.818 | 8.957 | 10.255 | 7.864 | $0.79^{NS}$ |
| Aroma | 3.863 | 4.733 | 3.479 | 6.226 | 8.578 | 6.380 | 3.711 | 5.390 | 3.854 | 6.205 | 8.742 | 6.678 | $0.10^{NS}$ |
| Firmness | 3.115 | 6.509 | 3.889 | 6.285 | 8.696 | 7.756 | 3.316 | 7.101 | 4.201 | 8.676 | 10.722 | 8.796 | $0.35^{NS}$ |
| Toughness | 2.752 | 6.538 | 4.008 | 5.840 | 9.757 | 7.922 | 3.694 | 6.102 | 4.562 | 8.775 | 10.839 | 9.815 | $0.06^{NS}$ |
| Sweetness | 4.928 | 4.419 | 4.571 | 5.370 | 5.337 | 4.982 | 3.872 | 4.399 | 3.693 | 5.716 | 4.692 | 4.822 | $2.26^{NS}$ |
| Off-flavor | 4.394 | 6.000 | 3.804 | 5.507 | 7.798 | 5.421 | 3.895 | 5.168 | 4.017 | 5.334 | 7.658 | 5.756 | $0.11^{NS}$ |

[a]Each value is a mean for 4 determinations.

$^{NS}$ $p > 0.05$

# THE EFFECTS OF VARIETIES, BLANCHING TECHNIQUES, AND COOKING METHODS ON COLOR, TEXTURE, AND SENSORY CHARACTERISTICS OF FROZEN GREEN BEANS

by

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Microwave heating has been suggested for blanching vegetables prior to freezer storage. Two varieties of green beans (Contender and Provider), three blanching techniques (boiling water, steam, and microwave), and two cooking methods (conventional and microwave) were used to compare their effects on the color, texture, and sensory characteristics of frozen green beans. A randomized complete block design with four replications of each treatment combination was used. Color was determined on fresh (slurried) and frozen, cooked samples (slurried and chopped), using the Hunter Lab Spectrophotometer; average L,a,b values were reported. Instrumental values were reduced to the color functions, hue angle ($\tan^{-1} b/a$) and saturation index $[(a^2 + b^2)^{\frac{1}{2}}]$. The Instron Universal Testing Machine was used to evaluate hardness of fresh and frozen, cooked green beans. Sensory characteristics were analyzed by a twelve member semi-trained panel using a 13 cm intensity scale. Correlation coefficients were calculated to study the relationships between physical measurements and selected sensory characteristics for frozen, cooked green beans.

Analysis of variance of physical and sensory data revealed no significant differences between varieties for color of fresh or frozen, cooked green beans. Although no differences were indicated for hardness in the raw beans, the Provider variety beans were firmer ($p \leq 0.05$) than the Contender variety following freezer storage and cooking when evaluated instrumentally and by a sensory panel. Microwave blanched beans were harder ($p \leq 0.001$) according to Instron measurements, and sensory scores for firmness and toughness were higher ($p \leq 0.001$) than those for beans blanched by conventional methods. Microwave blanched beans had grassy aromas and strong off-flavors ($p \leq 0.001$) that were not detected in those conventionally blanched. Panelists described off-flavors in microwave blanched samples as grassy, bitter, and stored. Microwave cooked beans were greener and firmer ($p \leq 0.001$) than those conventionally cooked. Flavor attributes for microwave cooked samples were grassy aroma, sweetness, and off-flavors that were not found in conventionally cooked beans.