To the Graduate Council:

I am submitting herewith a thesis written by Beverly Dawn Butler, entitled "Chemical, Physical, and Sensory Attributes of Snap Beans as They Affect Texture." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Science and Technology.

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CHEMICAL, PHYSICAL, AND SENSORY ATTRIBUTES OF SNAP BEANS AS THEY AFFECT TEXTURE

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ABSTRACT

Ten cultivars of snap beans, grown in Tennessee, were evaluated for chemical and physical characteristics before and after processing and to determine the correlation between chemical and physical differences and sensory perception of texture. The beans were processed by canning and freezing.

The proximate composition of the fresh beans was 93% moisture and (on a dry weight basis) 17.1% crude protein, 2.1% ether extract, 7.1% ash and 72.8% NFE. Canned beans increased in moisture (93.5%) and ash (22.4%) (salt added) while frozen beans decreased in moisture (92.5%) and ash (6.3%). Fresh snap beans contained 380 mg/100 g (dwb) calcium and 262 mg/100 g (dwb) magnesium. Canned beans decreased to 259 mg calcium and 136 mg magnesium while frozen beans increased to 505 mg calcium and contained the same amount of magnesium.

Fresh and canned beans contained 32.0 and 31.8 percent total dietary fiber, respectively, and both were significantly lower than frozen beans, (34.0%). The frozen bean also contained significantly more pectin, 5.1 mg/g, than did canned beans, 4.2 mg/g. Both canned and frozen beans contained small amounts of fibrous material, less than 0.03%, which is less than the maximum legal limit of 0.15%.

Canned beans were significantly softer (27 Kg force to shear 100 g sample) than fresh or frozen beans (326 Kg and

340 Kg force, respectively). As pectin content of the beans increased the firmness of the beans also increased (r=0.83). However, the total dietary fiber did not significantly correlate with the firmness. A sensory panel was not able to significantly determine differences in texture between 'BBL-47' and 'FM128' snap beans. These two cultivars had been selected based upon differences in firmness for the frozen products.

None of the snap beans had significant amounts of sloughing (0.1-1.0 ml sediment/ 100 g) and the average seed content of the snap beans was 5.7%. The color of the snap beans was comparable to these cultivars from previous studies.

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CHAPTER I

INTRODUCTION

Snap bean production is an important source of income in Tennessee. In 1984, Tennessee produced 11,340 tons of snap beans for processing which was an increase of over 2,000 tons from 1983. Also, the dollar value of snap beans grown in Tennessee increased 30% over 1983. Tennessee ranked seventh in the nation in the production of snap beans for processing in 1984 (USDA, 1985).

The University of Tennessee Plateau Experiment Station at Crossville, Tennessee has an ongoing research program to evaluate snap bean cultivars for their performance under local growing conditions. Additional investigations are needed to determine the quality attributes of Tennessee-grown snap bean cultivars for canning and freezing.

One quality attribute significantly affecting acceptability of snap beans is texture. It is likely that differences in texture of snap beans are due to differences in bean maturity. As beans increase in maturity, they increase in size and develop more fiberous material. The amount of fiberous material is a quality factor considered when snap beans are graded according to the U.S. Grade Standards (CFR, 1988a). As the amount of fiberous material increases the quality of the snap beans decreases. However, the fiberous material is a part of the total dietary fiber content of the snap beans and an increase in the dietary fiber content may be beneficial when considering the nutritional value a product. A diet high in fiber content has been shown to reduce the risk of colon cancer, lower blood serum cholesterol and glucose levels, as well as provide other health benefits. The type of dietary fiber is also important since not all components of dietary fiber produce the same benefits (Anon., 1979; Normand et al., 1987; Schneeman, 1987). For example, cellulose increases fecal bulk and relieves constipation and may reduce the incidence of colon cancer, but has no effect on the reduction of blood serum cholesterol (Anon., 1979). According to Reiser (1987), pectins have been shown in many studies to reduce blood serum levels of low-density lipoprotein and to reduce blood glucose responses. Fruits and vegetables are the primary source of pectins (Normand et al., 1987) and may be more valuable as a source of dietary fiber than previously believed. It would be desirable to maximize the dietary fiber content of snap beans while simultaneously maximizing desirability in texture or firmness.

Objectives of the study

The objectives of this study were to evaluate ten cultivars of snap beans that have shown satisfactory response to local growing conditions for chemical, physical, and sensory characteristics before and after processing, and to determine the correlation between chemical and physical differences and sensory perception of texture.

CHAPTER II

REVIEW OF LITERATURE

I. Beans

The name "bean" denotes several related plants of the legume family, Leguminosae. Both the edible pods and the seeds of these plants are called beans. Some 100 or more species of beans are cultivated throughout the world. In the United States and Canada, the most important kinds, exclusive of soybeans, are varieties of the common bean, Phaseolus vulgaris (Ensminger et al., 1983). Varieties of the common bean picked at a young immature stage are called "string beans" or "snap beans". Both the immature seeds and the pods of snap beans are eaten. Snap beans may have either green pods (green beans) or yellow pods (wax beans). Snap beans are used as a fresh vegetable, or they may be processed by canning or freezing.

II. History

About 7,000 years ago, beans (Phaseolus vulgaris) were grown by the Indian tribes in the Tehuacan Valley of Mexico and in Callejon de Huaylas, Peru. Apparently, the beans were domesticated independently in each area from a common wild ancestor. The cultivation of the common bean was spread gradually throughout the Americas by migrating bands of Indians. The Spanish explorers of the 15th and 16th centuries found bean crops growing throughout Latin America, and 17th century British colonists of North America found Indians growing beans in both New England and Virginia (Ensminger et al., 1983).

Common beans were spread around the world by Portuguese and Spanish explorers and traders, and they became popular crops in Africa, Asia, and Europe by the early 17th century. Since then, plant breeders have selected plants for large seeds and tender stringless pods.

III. Selection

There are many varieties of both green and wax snap beans. Snap beans may be flat, oval, or round (Ensminger et al., 1983; Luh and Woodroof, 1975). In the western states, the Blue Lake type of cultivar is preferred for canning and freezing (Luh and Woodroof, 1975). Most varieties grown for market are stringless when fully mature, but develop stringiness as they pass the optimum stage for harvest. Overmature pods may become fibrous and tough whether stringless or not.

Ideally, snap beans should be fresh in appearance, clean, firm but tender, crisp, free from scars, and reasonably well shaped (Ensminger et al., 1983; Kramer et al., 1949; Luh and Woodroof, 1975). All beans in a selected lot should be approximately the same stage of maturity so that they will cook uniformly. Firm, crisp, and tender beans will snap readily when broken. Pods in which the seeds are very immature are the most desirable. If the seeds are mature, the pods are likely to be tough or fibrous. A dull or wilted appearance indicates that beans have been held too long after picking. Decayed snap beans become soft, watery, or moldy (Ensminger et al., 1983).

The grades for snap beans according to the United States Standards for Grades of Canned Green Beans and Canned Wax Beans as outlined in the Code of Federal Regulations (CFR, 1988a), part 52.443 are as follows: U.S. Grade A or U.S. Fancy (score of 90 or above), U.S. Grade B or U.S. Extra Standard (score of not less than 80), U.S. Grade C or U.S. Standard (score of not less than 70), and Substandard (fail to meet requirements for grade C). The beans are scored on clearness of liquor (10 points), color (15 points), absence of defects (35 points), and character (40 points). U.S. Grade A beans possess a practically clear liquor, have a bright uniform color, are practically free from defects (blemishes, extraneous vegetable material, or mechanical injury), and have good character (beans are young and tender, seeds are in early stage of maturity, less than 5% possess tough strings, not materially effected by epidermal sloughing). Snap beans are substandard if they contain excessive seed and pieces of seed (>25%) in the trimmed pods, have excessive fiberous material (>0.15%) in deseeded pods, or have excessive tough strings (>20% by count) determined according to the Standard of Quality for Canned Green Beans and Canned Wax Beans as outlined in the Code of Federal Regulations, Title 21 part 155.120(b) (CFR, 1988b).

IV. Processing

About 16% of the snap beans grown in the United States is marketed fresh, 64% is canned, and 20% is frozen (Ensminger et al., 1983). Beans that are processed by canning or freezing first undergo a blanching treatment. Blanching vegetables for canning serves to expel gases and to soften the product so that more may be filled into the container (Cruess, 1958; Luh and Woodroof, 1975). When blanching green vegetables for freezing, it is necessary to heat them to a minimum of 77 C (170 F) to destroy catalase and peroxidase so that frozen beans do not develop a hay-like flavor in storage (Cruess, 1958). According to Luh and Woodroof (1975), cut beans for canning are usually blanched in 82 C (180 F) water for 1.5 to 2 minutes. Collins (1978) blanched beans for canning at 77 C (170 F) for 3 minutes and beans for freezing at 88 C (190 F) for 3 minutes. Luh and Woodroof (1975) reported that blanching of vegetables may result in losses of water-soluble components including minerals, vitamins, amino acids, and carbohydrates.

According to Souci et al. (1986), canned green beans contain 2.5% more moisture than fresh green beans. The increase in moisture causes changes in the concentration of nutrients (Lamb et al., 1982). Also, the water-soluble nutrients leach out into the canning water (American Can Company, 1949; Lamb et al., 1982). As reported in a study by the American Can Company (1949), canned green beans lose up to 15.4% of the total protein, 37.2% of the total ash, and 27.1% of the total nitrogen-free extract (NFE) into the liquid portion of the canned product. During retorting, green beans lose an appreciable amount of thiamin and vitamin C (Cruess, 1958). Thermal processing tends to soften plant tissues (Fennema et al., 1986) as well as cause very undesirable degradation of color (Francis and Clydesdale, 1975).

Freezing operation are designed to retain, to as great a degree as possible, the properties of the fresh vegetable. However, during freezing and thawing, certain irreversible changes occur in the vegetables that render the frozen and thawed product quite different from the fresh in texture and general appearance (Cruess, 1958). Usually there is considerable collapse of the tissues upon thawing. The thawed product is limp, and liquid is lost from the tissue upon thawing and draining (Cruess, 1958). Fennema (1982) reported that the freezing process had no significant detrimental effect on nutritive values of lipids, carbohydrates, or proteins; although, high amounts of some vitamins are lost during blanching and thawing due to leaching and loss of exudate.

V. Composition

Vegetables are not generally considered to be primary sources of essential amino acids (Luh and Woodroof, 1975). The protein content of many vegetables is 1-2% and generally the essential amino acids are not in the proper proportions for optimal utilization nor in amounts for adequate protein nutrition. However, immature seeds of legumes may be as much as 14% protein and mature dry seeds are still higher in protein (Luh and Woodroof, 1975). Legume seeds provide one of the better quality plant proteins (Luh and Woodroof, 1975). However, legume proteins are of poor nutritional value unless subjected to heat treatment during which anti-nutritional factors are destroyed (Deshpande and Nielsen, 1987). Proteins are denatured when heated, enhancing their digestability by intestinal proteases (Luh and Woodroof, 1975). A decrease in protein digestability occurs during severe heat treatments due to the formation of isopeptide bonds (Fennema et al., 1986).

The lipid content of most vegetables is 0.1%, and the fatty acids in most cases are highly unsaturated (Luh and Woodroof, 1975). Most vegetables are excellent sources of minerals, and dietary fiber. The proximate compositions of canned, frozen, and fresh snap beans as outlined in the Agriculture Handbook 8-11 (Haytowitz and Matthews, 1984) are given in Table 1.

VI. Fiber

Pectic substances along with cellulose, hemicellulose, and lignin components are the major constituents of the plant cell wall, and, collectively, they are part of what is called dietary fiber. Pectic substances and hemicellulose are soluble dietary fiber (Bijlani, 1985; Olson, et al., 1987), whereas cellulose and lignin are insoluble dietary fiber (Bijlani, 1985).

Pectic substances have been reported to have important physiological and nutritional effects such as hypocholesterolemic effect, increased excretion of fecal sterols and lipids, binding of bile salts and polyvalent cations, and increased requirement for vitamin B_{12} (Belo and Lumen, 1981).

Pectin contributes to adhesion between parenchyma cells of vegetables and mechanical strength of tissues. Maceration of vegetable tissues seems to be brought about mainly by the degradation of pectin (Fuchigami, 1987). Softening of vegetables during cooking is considered to be affected considerably by the properties of pectic substances.

Vidal-Valverde et al. (1983) concluded that frozen vegetables had pectic substance contents similar to that found in fresh vegetables and that pectin contents of canned vegetables were lower than those observed for fresh or

Table 1. Proximate composition of canned, frozen, and fresh snap beans from USDA Handbook 8-11.

PROCESSING METHOD	MOISTURE	PROTEIN	FAT	ASH	TOTAL CHO
	%	------------	% [a]	------------	
Canned, drained	93.30	17.2	1.49	14.2	67.2
Frozen	89.88	17.8	2.08	5.2	74.8
Fresh	90.27	18.7	1.23	6.8	73.4

[a] dry weight basis.

(Haytowitz and Matthews, 1984)

frozen vegetables. Vidal-Valverde et al. (1983) quoted values for pectic substances expressed as anhydrogalacturonic acid for green beans as follows: fresh=0.78-1.27%, frozen=1.22%, canned=0.61%.

Cellulose and lignin combined make up 34.48% of the total dietary fiber found in raw vegetables and these components generally increase as the plant matures (Schneeman, 1986). Lintas and Cappelloni (1988) reported that processing had little effect on the insoluble dietary fiber content of vegetables.

VII. Color

Kramer et al. (1949) concluded that color of snap beans is primarily affected by varietal differences. Some varieties are green while others are yellow. However, as beans mature their color generally tends to fade.

The green color of vegetables is attributable to the presence of chlorophylls a and b. Chlorophylls, which are magnesium complexes, are the most widely distributed plant pigments. The loss of the bright green color of vegetables during heat processing has long been a concern of food processors and scientists. The problem of retaining the green color of processed vegetables has been that of keeping the chlorophyll molecule intact. During processing, the green color often changes to a dull olive-green through replacement of magnesium by hydrogen in the chlorophylls with the formation of pheophytins (Fennema et al., 1986; Luh and Woodroof, 1975). When the phytol group is removed from chlorophylls, water-soluble chlorophyllides are formed; the latter are green and have essentially the same light-absorption qualities as chlorophylls (Luh and Woodroof, 1975). However, when hydrogen replaces magnesium in chlorophyllides, dull brown pheophorbides form which have spectral characteristics similar to pheophytins.

The inactivation of enzymes such as peroxidases, lipases, and lipoxygenases by blanching prevents color changes associated with the conversion of chlorophylls to pheophytins. According to Dietrich and coworkers, who reported on research in 1959, under- or over-blanched green beans lost more chlorophyll than those just adequately blanched (one minute at 93-100 C) (Luh and Woodroof, 1975).

Normal sterilization processes can result in sulfur loss from proteins with accompanying alterations in color and flavor (Basel, 1982). Basel also reported that the color of green beans as determined by the Hunter Colorimeter was improved by acidified bulk storage. The color of acidified beans (L=30.42, 'a'=-1.70, 'b'=12.70) was more acceptable than that of conventionally canned products (L=21.67, 'a'=-0.68, 'b'=7.89). L value indicates lightness where 0 = black and 100 = white, 'a' value indicates degree of greenness where smaller numbers (more negative) are more green, and 'b' value indicates degree of yellowness where larger numbers are more yellow. Collins (1978, 1979) and Collins and Mullins (1984) reported Hunter Colorimeter values for canned, frozen, and fresh snap beans as follows: the mean L, 'a' and 'b' values for canned snap beans were 32.2, -0.7, and 15.0, respectively; for frozen snap beans were 30.6, -11.4, and 15.1, respectively; and for fresh snap beans were 44.8, -9.7, and 17.5, respectively.

VIII. Texture

Texture is an important sensory attribute of foodstuffs and in certain products it may even be more important than flavor (Szczesniak and Kahn, 1971). Texture is the attribute of a substance resulting from a combination of physical properties and perception by the senses of touch, sight, and hearing (Jowitt, 1974). Texture, or firmness, is an important factor in evaluating the quality of processed snap beans (Van Buren et al., 1962). For fresh beans, if the seeds are mature the pods are considered to be overmature and are likely to be tough or fibrous (Ensminger et al., 1983).

Modern varieties of snap beans have been selected for tenderness. Plant tissues can be softened or firmed by thermal processing. Typical heat processes tend to soften plant tissues through the action of heat on pectic substances. In contrast, mild heat treatments may activate endogenous pectin methyl-esterase which will partially demethylate pectic substances allowing calcium to affect crosslinking of pectic polymers with a resulting increase in tissue firmness (Fennema et al., 1986). Moderate heating of proteins in the presence of water usually results in protein denaturation which may cause alterations in texture. Severe heating of proteins in water can result in protein crosslinking (formation of isopeptide bonds) causing alterations in texture (Fennema et al., 1986). Van Buren (1983) found that firmness of thermally processed snap beans is affected by the presence of salts in the cooking media. Monovalent salts, such as NaCl and KCl, soften snap beans, while divalent salts, such as $CaCl_2$, firm the beans. Blanching vegetables in water containing calcium or magnesium salts will increase their firmness (Cruess, 1958).

The firmness of snap beans was found to be closely related to sloughing (Van Buren et al., 1960). Sloughing is a quality defect found frequently in canned beans and has been encountered in frozen beans as well. Sloughing is a tendency for the epidermal layer of cells to separate from the pericarp portion or main part of the pod (Kaczmarzyk et al., 1963). This leads to a downgrading of the product and serious economic loss. According to Van Buren et al. (1960) calcium plays a role in preventing sloughing. The tendency for beans to slough was decreased by soaking in a calcium chloride solution.

Blanching temperature also had an effect on bean texture. Canned beans that were blanched at 77-82 C (170-180 F) were firmer than those blanched at 88 C (190 F). As blanching temperature was increased from 66 C (150 F) to 99 C (210 F), the tendency to slough and split increased and the firmness decreased (Van Buren et al., 1960). Gullet et al. (1984) found that increased blanch times tended to soften snap beans.

IX. Sensory

Researchers can learn about the texture of a product by measuring certain chemical and physical properties. However, these measurements must ultimately be related to the manner in which the product behaves in the human mouth. Reliable sensory data must be collected to obtain correct interpretation and correlation of human evaluations with instrumental analysis (Civille and Szczesniak, 1973). Gullet et al. (1984) reported that, for texture, the sensory panel seemed to be more sensitive than peak height (OTMS-Ottawa Texture Measurement System) measurement.

In any organized study of food texture it is essential for terms describing textural attributes to have generally accepted and rational meanings (Jowitt, 1974). Texture may be defined as firmness or softness of tissues according to the feeling or sensation in the mouth (Luh and Woodroof, 1975) or as the behavior of the material under stress or strain using such terms as "firm", "hard", "soft", "tough", or "tender" (Jowitt, 1974). Firmness is one of the most positively regarded textural characteristics and suggests biting and very moderate chewing (Szczesniak and Kahn, 1971). "Firm" is often named as the ideal texture of many prepared natural foods. To the consumer the term "firm" describes foods which do not fall apart but are readily disintegrated by chewing and is mentioned often when talking about the texture of fruits and vegetables (Szczesniak and Kahn, 1971). Vanseveld et al. (1985) reported "fibrous" as the term most closely linked to preference scores of texture for canned green beans. The terms "fibrous" and "coarse" were negatively correlated while "crisp and "tender" were positively correlated.

An ideal working texture profile panel as described by Civille and Szczesniak (1973) usually consists of six members. Candidates for training should not wear artificial dentures. A screening test for a texture profile panel is as follows: present each candidate with the last four examples from the hardness scale, which are peanuts, carrots, almonds, and rock candy. Present them in random order and ask each candidate to arrange them in increasing order of hardness. Each potential panelist should rank all four in the proper order of actual hardness.

CHAPTER III

MATERIALS & METHODS

I. Source of Snap Beans

Beans were grown at the Plateau Agricultural Experiment Station, Crossville, Tennessee. Ten cultivars were mechanically harvested, refrigerated, and transported to the processing lab in McLeod Food Technology Building, Knoxville, Tennessee. Beans were held at 8-10 C (45-50 F) until processed. The cultivars processed were 'Shamrock', 'Trophy', 'Blue Jay', 'Sentry', 'Goldkist', 'H531-5-1', 'FM128', 'FM103', 'Pod Squad', and 'Bush Blue Lake 47'. All of the cultivars were the green type except 'Goldkist' which was a wax bean.

II. Preparation of Snap Beans

Thirty-five pounds of pods of each cultivar were fed through a commercial-size snipper. Snipped pods were weighed to determine the percentage of pods recovered and sorted by a commercial-size grader into three lots as follows (CFR, 1988a):

Group	Sieve Size	Measurement of Thickness (in 64ths of an inch)
Small	1	less than 14.5
Medium	2,3,4	14.5 to < 24.0
Large	5,6	> or = 24.0

III. Procedure for Processing Snap Beans

Pods from each group were cut into lengths of 3.4 cm with a commercial-size cutter. Cut pods of the medium group of sieve sizes were processed by canning or freezing according to the method of Collins (1978).

One lot of cut pods from each cultivar was prepared for canning by blanching in water at 77 C (170 F) for 3 minutes. Ten 303x406, fruit enamel cans, filled with 295 g beans/can plus 6 g salt/can, were processed at 116 C (240 F) for 20 minutes in a still retort. The canned beans were held for 4 months before evaluation.

An additional lot of cut pods from each cultivar, for which adequate medium sized beans were available, was prepared for freezing by blanching in water at 88 C (190 F) for 3 minutes. The pods were packaged in plastic bags, frozen at -23 C (-10 F), and held at -23 C (-10 F) for 4 months before evaluation.

IV. Chemical Tests

Chemical evaluations were conducted on the snap beans from each fresh group size (small, medium, and large) and the canned and frozen beans.

a. Proximate Composition

Proximate analysis was determined according to AOAC (1984) methods and included moisture, ash, fat, and protein by methods 7.003, 7.009, 7.062, and 7.015 and 2.057, respectively. Nitrogen-free extract (NFE) was determined by the following calculation: 100 - (moisture + ash + fat + protein) = NFE

b. Mineral Analysis

Calcium and magnesium content was determined for all medium snap bean samples for the cultivars and processes utilized. One gram of each dried sample was weighed into a 250 ml beaker and 60 ml of concentrated nitric acid added. Samples were boiled to near dryness and cooled. To each sample, 7 ml of reagent grade perchloric acid were added and a watch glass was placed over the beaker until the reaction subsided. The watch glass was removed, and the samples were heated and boiled to approximately 1 ml in volume. Measurements of calcium and magnesium were performed using an Instrumentation Laboratories atomic absorption-emmision spectrophotometer (model IL551).

c. Pectin Determination

All samples for pectin determination were freeze-dried and ground. The methods of Dekker and Richards (1972) and Belo and de Lumen (1981) were used. A 1 gram sample (weighed to the nearest 0.1 mg) was dispersed in 20 ml of 0.25% aqueous solution of ammonimum oxalate (oxalic acid) and heated in a boiling water bath (100 C) for 2 minutes to inactivate the enzymes. After being cooled, the suspension was homogenized for 5 minutes in a VirTis homogenizer set at 30. The homogenate was then refluxed in a boiling water bath for 1 hour, cooled, and centrifuged at 48,000 X g (Sorvall Superspeed RC2-B) for 20 minutes. The supernatant was collected and the residue was subjected to further extraction for a total of 3 extractions per sample. All extracts were stored under refrigeration (2 C) prior to pectic substance analysis.

Total pectic substances in the oxalate extracts were first hydrolyzed with polygalacturonase (Sigma Chemical Company, St. Louis, MO; EC 3.2.1.15) according to the method of Dekker and Richards (1972). Five mg of each sample were dissolved in 10 ml of 0.1M sodium acetate buffer (pH 4.4-4.5) and polygalacturonase (1 mg) was added, followed by a few drops of toluene. The samples were incubated at 30 C for 24 hours. The enzyme was inactivated by heating each sample to 100 C for 2 minutes. The galacturonic acid produced was determined by the modified carbazole method of Bitter and Muir (1962). Five ml of sulfuric acid reagent (2.3838 g borax in 250 ml sulfuric acid) were placed into test tubes fixed in a wire rack and placed in an ice water bath. One ml of each sample was carefully layered onto the acid. The tubes were closed with teflon coated screw caps and the rack was shaken gently at first, then vigorously maintaining constant cooling in the ice water bath. The tubes were then heated for 10 minutes in a boiling water bath and cooled to room temperature. Carbazole reagent (0.2 ml of 0.125g/100ml absolute ethanol or methanol) was added to each tube. The tubes were shaken and heated in a boiling water bath for 5 minutes then cooled to room temperature. The absorbance was then read at 530nm in a 1-cm cell.

A standard of pure pectin was made by dissolving 5 mg of pure pectic acid (Sigma) in 0.1M sodium acetate buffer and following the above described enzymatic hydrolysis and Carbazole procedures. Galacturonic acid standards of 4-40 ug/ml were prepared by dilution of the above standard with deionized water saturated with benzoic acid. Blank determinations contained the pectinase hydrolysis and carbazole reagents except for the pectic substance extracts which were replaced by oxalate solution.

d. Fibrous Material

Deseeded pods were weighed (100 grams), transferred to a metal cup, and ground with a pestle. Material adhering to the pestle was washed back into the cup with 200 ml of boiling water. The mixture was heated to just below the boiling point and 25 ml of 50% by weight sodium hydroxide solution was added. The mixture was boiled for 5 minutes and stirred for 5 minutes at 7200 rpm (CFR, 1988). The material was transferred to a previously weighed 30-mesh monel metal screen. The fiber was washed with a stream of water until the remaining material did not show any red color when moistened with phenophthalein solution. Screens containing the fibrous material were dried for 2 hours at 100 C, cooled, and weighed.

e. Total Dietary Fiber

The total dietary fiber content was determined for each cultivar for each process treatment and for each sieve size using an enzymatic method and FiberTech system as outlined in Appendix A.

V. Physical Properties

Physical evaluations were conducted on the snap beans from fresh (groups small, medium, and large), canned, and frozen.

a. Firmness

Firmness of canned, frozen, and fresh beans was measured using the Instron Food Testing Machine equipped with a Kramer Shear-Compression Cell. The 500kg capacity load cell was used and the crosshead speed was 10 cm per minute. Firmness is expressed as kilograms of force required to shear a 100g sample of beans. A composite sample of beans was prepared and three measurements were made from each sample.

b. Sloughing

Epidermal sloughing was determined according to the method of Collins and Mullins (1984) for canned and frozen beans. Twenty pieces of cut pods were placed into a flask with 100ml of water. After shaking with a mechanical shaker for five minutes, the bean pieces were removed from the flasks and the liquid was transferred into a 100ml graduated cylinder. After standing for one hour, the height of the sediment was recorded and used as the measurement of degree of sloughing.

c. Seed Percentage

Samples of 100g of sieve size 3 beans were obtained to determine seed-to-pod ratio. The seeds were removed, weighed and percentage of seed was calculated.

d. Color

The color was evaluated for each cultivar of snap beans for each process using a Hunter Colorimeter (model D25-2). The instrument was standardized using a white tile No. C2-21125 with L =91.03, 'a'=-1.3 and 'b'=1.6. Cut pods were placed across the bottom of a cuvette with an optical glass bottom, and L, a, and b values were measured and recorded.

VI. Sensory Analysis

'BBL-47' and 'FM128' cultivars were selected for a sensory difference test based on results of physical and chemical tests. Canned and frozen snap beans were prepared by boiling in water for 15 minutes. Thirty-two panelists were presented with two pairs of snap bean samples, one pair of either canned or frozen at a time. The panelists were asked to indicate which snap bean was the most tender or to indicate that there was no difference.

VII. Experimental Design and Statistical Analysis

Statistical evaluation of proximate analysis, mineral analysis, total dietary fiber, fibrous material, pectin determination, instron measurements, color measurements, seed percentage, and sloughing were performed following Randomized Incomplete Block designs. A 10 x 3 x 2 (cultivar x process x replication) design was utilized for evaluating medium sieve size snap beans. A 10 x 3 x 2 (cultivar x sieve size x replication) design was utilized for evaluating fresh snap beans.

The determination of any significant changes in the chemical or physical components due to cultivar, process, or sieve size was performed by Analysis of Variance (ANOVA) (Bender et al., 1982). Significance among the means of each component was determined by the Student-Newman-Kuel (SNK) mean separation technique (Neter et al., 1985). The statistical analysis was performed using the Statistical Analysis System (SAS, 1986) programs available through the IBM-CMS computer at the University of Tennessee-Knoxville.

CHAPTER IV

RESULTS AND DISCUSSION

I. Proximate Analysis

Table 2 shows the proximate composition of medium sieve size snap beans for each cultivar and process treatment. The snap beans were mostly water with all samples being greater than 90%. The majority of the solid content was carbohydrate material and less than 4% lipid material. When the values for canned, frozen, and fresh were averaged, differences between the cultivars and processes become evident as indicated by the analysis of variance (Table 3).

'Goldkist', the wax bean cultivar, and 'BBL-47' contained the highest average moisture content with 93.7%. 'FM128' contained the lowest moisture content with 91.9%. 'Trophy' and 'Sentry' contained the highest protein with 18.5% and 18.1%, respectively, while 'H531-5-1' (15.3%), 'FM103' (15.2%), and 'Blue Jay' (15.0%) contained the lowest. 'FM103' had the highest average fat content, 3.7%, and 'Pod Squad' and 'Sentry' contained the lowest with 1.5% and 1.3%, respectively. 'Trophy' was also the highest in ash content at 16.7%, and 'FM128' was the lowest at 10.1%. 'FM128' had the highest NFE content with 71.2%, while 'Trophy' and 'H531-5-1' had the lowest with 61.9% and 60.2%, respectively.

Table 4 compares the average proximate composition for

Table 2. Proximate composition of canned, frozen, and fresh snap beans by cultivar.

CULTIVAR	PROCESS	MOISTURE	PROTEIN[a]	FAT[a]	ASH[a]	NFE[a,b]
		%				
Goldkist	Canned	93.76	14.71	2.20	24.42	58.67
	Frozen	93.39	17.79	1.98	6.50	72.99
	Fresh	93.90	16.89	1.63	7.15	75.06
Shamrock	Canned	93.53	13.82	0.96	23.96	61.27
	Frozen	92.93	17.06	3.52	5.79	73.63
	Fresh	92.85	16.32	1.71	6.17	73.57
Trophy	Canned	93.85	16.59	1.88	25.75	55.78
	Frozen	-----	-----	----	-----	-----
	Fresh	93.33	20.36	2.59	7.73	68.07
Blue Jay	Canned	93.74	14.42	1.34	22.01	61.60
	Frozen	-----	-----	----	-----	-----
	Fresh	92.87	15.58	2.84	7.12	74.47
Sentry	Canned	93.37	16.47	1.25	20.73	60.66
	Frozen	91.70	19.60	0.83	6.82	72.76
	Fresh	92.69	18.21	1.21	7.83	72.03
H531-5-1	Canned	93.73	15.30	1.86	21.95	60.18
	Frozen	-----	-----	----	-----	-----
	Fresh	93.05	-----	1.65	7.61	-----
FM128	Canned	92.68	14.09	1.88	18.35	65.68
	Frozen	90.89	16.31	2.05	5.49	75.56
	Fresh	92.08	16.38	1.95	6.40	73.43
FM103	Canned	93.71	14.02	3.43	22.35	60.20
	Frozen	-----	-----	----	-----	-----
	Fresh	92.83	16.37	3.91	6.86	72.86
Pod Squad	Canned	92.33	14.97	1.26	20.62	62.44
	Frozen	-----	-----	----	-----	-----
	Fresh	92.58	16.64	1.79	6.82	73.75
BBL-47	Canned	94.13	14.49	1.85	23.34	60.32
	Frozen	93.52	17.27	1.41	6.68	73.44
	Fresh	93.39	17.45	2.32	7.03	73.33

[a] Dry weight basis.
[b] 100-(protein+fat+ash).

Table 3. Mean squares for the analysis of variance of mean proximate compositions of medium sieve size snap bean cultivars.

SOURCE	DF	MOISTURE	PROTEIN	FAT	ASH	NFE
		Mean Squares				
Cultivar	9	1.97*	6.06*	2.21 NS	17.79*	37.31*
Process	2	3.28*	32.69*	0.92 NS	1395.44*	713.30*
Error		(38ᵃ)0.15	(32ᵃ)0.19	(63ᵃ)1.34	(38ᵃ)1.20	(29ᵃ)1.41

NS Not significant at the P > 0.05 level.
* Significant at the P < 0.01 level.
ᵃ degrees of freedom for mean square term.

Table 4. Mean proximate compositions of medium sieve size snap beans by process.

PROCESS	MOISTURE	PROTEIN[a]	FAT[a]	ASH[a]	NFE[a,b]
	-----------------------	-----------	----% ----	-----------	-----------
Canned	93.48x	14.89z	1.69x	22.35x	60.68z
Frozen	92.48z	17.60x	1.90x	6.25z	73.91x
Fresh	92.95y	17.10y	2.10x	7.07y	72.75y

[a] Dry weight basis.
[b] 100-(protein+fat+ash).
x-z Means within each column followed by different letters are significantly different at $p<0.05$ level.

medium sieve size snap beans among the three processes, canned, frozen, and fresh. The composition of the snap beans varied significantly ($p<0.05$) between each of the processes except among the fat percentages. As expected, canned snap beans had the highest moisture content with 93.5% since the snap beans could absorb some of the liquid in which they were packed. The frozen snap beans lost water and had the lowest moisture content with 92.5%. The protein, fat, ash, and NFE percentages were calculated on a dry weight basis (dwb). The canned snap beans had more than three times as much ash content (22.4%) as the frozen (6.3%) or fresh (7.1%) snap beans because salt was added before canning. This also resulted in significantly lower protein and NFE percentages ($p<0.05$) in the canned beans. Loss of ash content from the frozen samples was likely caused by the water blanch which would allow for leaching of some soluble components into the blanching water. This significant decrease in ash resulted in increased protein and NFE contents compared to the fresh snap beans. The results of the proximate analysis study were comparable to values reported by Haytowitz and Matthews (1984) (Table 1) for canned snap beans. Frozen and fresh snap beans had higher moisture contents and lower NFE than samples analyzed by Haytowitz and Matthews (1984). These differences may be due to the handling practices and cultivar differences.

Moisture, protein, ash and NFE percentages were significantly influenced by snap bean sieve sizes (Table 5). The proximate composition by sieve size for fresh snap beans of all the cultivars is shown in Table 6. In general, moisture, protein, and ash all decreased as snap bean size increased. NFE increased as snap bean size increased. There was no significant difference ($P>0.05$) in the fat content of the three sizes of snap beans; although, there was a trend for fat percentage to decrease as the snap beans became larger.

II. Minerals

The analysis of variance (Table 7) of calcium and magnesium contents indicated highly significant ($p<0.01$) differences in both the cultivars and process treatments. Table 8 presents the mean calcium content of medium sized snap beans for the ten cultivars and three process treatments. Among the cultivars, 'Trophy' contained the highest amount of calcium and magnesium in the fresh and canned beans but was not processed as a frozen bean. 'Sentry' also contained the highest amount of calcium and magnesium for fresh beans and for frozen beans but contained the least amount of calcium and magnesium in the canned beans along with 'Pod Squad' and 'FM128'. The reason 'Sentry' lost more minerals in the canned beans may have been the result of a more severe blanch than the other cultivars. The beans were water blanched which does increase

Table 5. Mean squares for the analysis of variance of mean proximate compositions of fresh snap bean cultivars.

SOURCE	DF	MOISTURE	PROTEIN	FAT	ASH	NFE
		------------------	------------------Mean	Squares------------------	------------------	------------------
Cultivar	9	1.14**	3.32*	1.57^{ns}	1.16**	8.15*
Sieve Size	2	11.93**	5.23*	2.79^{ns}	31.43**	69.51**
Error		(48^{a})0.32	(28^{a})1.08	(81^{a})1.81	(48^{a})0.27	(26^{a})3.48

^{ns} Not significant at the $p>0.05$ level.
* Significant at the $p<0.05$ level.
** Significant at the $p<0.01$ level.
^{a} degrees of freedom for mean square term.

Table 6. Mean proximate compositions of fresh snap beans by sieve size.

SIEVE SIZE	MOISTURE	PROTEIN[a]	FAT[a]	ASH[a]	NFE[ab]
	----------	----------	%	----------	----------
Small	93.31x	17.96x	2.52x	8.80x	69.21y
Medium	92.95x	17.10y	2.10x	7.07y	72.75x
Large	91.83y	16.77y	1.84x	6.36z	74.22x

[a] Dry weight basis.
[b] 100-(protein+fat+ash).
x-z Means within each column followed by different letters are significantly different at $p<0.05$ level.

Table 7. Mean squares for the analysis of variance of mean mineral contents of medium sieve size snap beans.

SOURCE	DF	CALCIUM	MAGNESIUM
		---------Mean	Squares--------
Cultivar	9	5956.54**	1360.83**
Process	2	194481.42**	92946.33**
Error	38	304.62	142.90

** Significant at the $p<0.01$ level.

Table 8. Mean calcium and magnesium contents of canned, frozen, and fresh medium sieve size snap bean cultivars.

	CALCIUM CONTENT			MAGNESIUM CONTENT		
CULTIVAR	CANNED	FROZEN	FRESH	CANNED	FROZEN	FRESH
	----mg/100g beans[a]----			----mg/100g beans[a]-----		
Goldkist	281.0c	502.5d	384.5d	148.5bc	275.5b	265.5c
Shamrock	276.5c	498.0d	331.5h	146.5bc	240.0c	229.5g
Trophy	298.0b	-----	418.0b	153.5b	-----	287.0b
Blue Jay	250.5e	-----	382.5d	129.5d	-----	264.5c
Sentry	238.5f	529.0b	425.5b	124.5d	278.5b	286.0b
H531-5-1	249.0e	-----	405.5c	131.0d	-----	281.5b
FM128	232.5f	478.0e	347.5g	124.0d	226.5d	239.0f
FM103	254.5e	-----	370.5ef	131.5d	-----	255.5d
Pod Squad	236.5f	-----	364.0f	123.5d	-----	248.5e
BBL-47	265.5d	519.5c	377.5de	143.0c	279.0b	260.5c
Average	258.3z	505.4x	380.7y	135.6y	259.9x	261.7x

b-h Means within each column followed by different letters are significantly different at $p<0.05$ level.
x-z Means within each column followed by different letters are significantly different at $p<0.05$ level.

mineral loss (Luh and Woodroof, 1975) and a slightly higher blanch temperature or longer blanch time could have resulted in a greater mineral loss. The mineral loss during canning is indicated in Table 8 with the average calcium and magnesium contents significantly lower ($p<0.05$) than the fresh or frozen snap beans. The calcium content of the frozen beans was significantly higher than the fresh which may have been due to the loss in moisture content in the frozen beans. These results are supported by Haytowitz and Matthews (1984) who reported calcium content (dwb) of canned, frozen and fresh snap beans as 288.1mg, 415.0mg, and 380.3mg and magnesium content (dwb) as 194.0mg, 217.4mg, and 256.9mg, respectively. The variations in calcium and magnesium may cause differences in the texture of the snap beans since divalent salts firm plant products (Fennema et al., 1986).

III. Total Dietary Fiber

There was no significant difference ($p>0.05$) between snap bean cultivars for total dietary fiber content (Table 9). The means for total dietary fiber ranged from 30.34 to 33.73% (dwb) (Table 10). The mean total dietary fiber contents for canned, frozen and fresh beans are presented in Table 11. The frozen beans were significantly higher ($p<0.05$) in total dietary fiber which may be due to the greater NFE content found in these beans (Table 4). There

Table 9. Mean squares for the analysis of variance of mean total dietary fiber, fibrous material, and pectin contents of medium sieve size snap bean cultivars.

SOURCE	DF	TOTAL DIETARY FIBER	FIBROUS MATERIAL	PECTIN
		----------------Mean	Squares----------------	
Cultivar	9	2.63[ns]	0.005*	0.33**
Process		(2[a]) 8.14*	(1[a]) 0.000[ns]	(1[a]) 4.06**
Error		(13[a]) 1.52	(18[a]) 0.001	(19[a]) 0.09

ns Not significant at the $p>0.05$ level.
* Significant at the $p<0.05$ level.
** Significant at the $p<0.01$ level.
a degrees of freedom for mean square term.

Table 10. Mean total dietary fiber, fibrous material, and pectin contents of medium sieve size snap beans by cultivar.

CULTIVAR	TOTAL[a,b] DIETARY FIBER	FIBROUS[c,d] MATERIAL	PECTIN[c,d,e]
	------------%	------------	(mg/g)
Goldkist	33.24x	0.01y	4.66x
Shamrock	33.70x	0.02y	4.57x
Trophy	33.73x	0.04xy	3.71y
Blue Jay	31.87x	0.01y	4.53xy
Sentry	32.10x	0.02y	4.59x
H531-5-1	30.34x	0.05xy	4.13xy
FM128	31.57x	0.03xy	4.94x
FM103	31.72x	0.05xy	4.22xy
Pod Squad	32.72x	0.07x	4.07xy
BBL-47	31.95x	0.02y	4.49xy

[a] Means include canned, frozen, and fresh snap beans.
[b] Dry weight basis.
[c] Means include canned and frozen snap beans.
[d] Fresh weight basis.
[e] mg/g of freeze dried sample.
x-y Means within each column followed by different letters are significantly different at $p<0.05$ level.

Table 11. Mean total dietary fiber, fibrous material, and pectin contents of snap beans by process.

CULTIVAR	TOTAL[a] DIETARY FIBER	FIBROUS[b] MATERIAL	PECTIN[c]
	------------%------------		(mg/g)
Canned	31.82y	0.03x	4.17y
Frozen	33.97x	0.02x	5.10x
Fresh	32.04y	-----	-----

[a] Dry weight basis.
[b] Fresh weight basis.
[c] mg/g of freeze dried sample.
xy Means within each column followed by different letters are significantly different at $p<0.05$ level.

was no significant difference ($p>0.05$) between the fresh and canned beans total dietary fiber contents.

IV. Fibrous material

The fibrous material varied significantly ($p<0.05$) among cultivars but not processes (Table 9). 'Pod Squad' contained the highest amount of fibrous material (0.07% on a fresh weight basis) and was significantly higher ($P<0.01$) than 'BBL-47', 'Sentry', 'Shamrock', 'Blue Jay' and 'Goldkist'. None of the cultivars contained more than 0.15% by weight of fibrous material which is the maximum allowable level in the Standard of Quality for Canned Green or Wax Beans (CFR, 1988). Therefore all the cultivars would be acceptable in character (texture) when evaluated by this factor. Fibrous material and total dietary fiber were not correlated ($P>0.05$). This could be expected since fibrous material analysis is a much more severe chemical treatment and small fiber particles are not trapped in the screen used for filtering the sample.

V. Pectin content

Pectin content of the medium sieve size snap beans significantly varied ($p<0.01$) among cultivars and processes (Table 9). 'FM128', 'Sentry', 'Goldkist' and 'Shamrock' contained significantly higher ($p<0.05$) pectin contents than 'Trophy'. The pectin content of frozen snap beans was significantly higher ($p<0.05$) than canned snap beans (Table 11). Vidal-Valverde et al. (1983) also found that the pectin content of canned snap beans was lower than that of frozen or fresh snap beans. Pectin content was not determined for fresh snap beans; however, the pectin content should be similar for fresh and frozen snap beans (Vidal-Valverde et al., 1983). An increase in pectin content contributed to an increase in total dietary fiber content ($r=0.67$). This would be expected since pectin is a component of dietary fiber. Pectin also contributes to the firmness of vegetable products.

It may be possible to develop cutivars of beans with greater amounts of pectin and total dietary fiber without producing an unacceptable snap bean since the fibrous material content was less than one-half the maximum legally permitted level in canned beans. The concern would be producing snap beans that have acceptable texture.

VI. Instron measurement of firmness

The firmness of medium sieve size snap beans varied among the cultivars and process treatments (Table 12). 'FM128' was consistently the firmest of all the cultivars regardless of the process method (Table 13). It also contained the greatest amount of pectin. 'Trophy' was the most tender for canned and fresh and it contained the least amount of pectin. No samples of 'Trophy' were frozen and

Table 12. Mean squares for the analysis of variance of mean instron values of medium sieve size snap bean cultivars.

SOURCE	DF	MEAN SQUARE
Cultivar	9	6750.22**
Process	2	524591.50**
Error	37	576.33

** Significant at the p<0.01 level.

Table 13. Mean values for the force (Kg) required to shear 100g samples of canned, frozen and fresh medium sieve size snap beans by cultivar

CULTIVAR	CANNED	FROZEN	FRESH
Goldkist	25.5x	332.0y	307.6w
Shamrock	25.6x	347.4xy	364.9w
Trophy	22.7y	------	298.1w
Blue Jay	28.3w	------	316.3w
Sentry	29.1w	367.3x	339.9w
H531-5-1	26.1x	------	317.4w
FM128	30.6w	402.2w	367.1w
FM103	28.3w	------	323.0w
Pod Squad	29.8w	------	319.4w
BBL-47	28.3w	249.7z	315.3w

w-z Means within each column followed by different letters are significantly different at p<0.05 level.

'BBL-47' was the most tender frozen snap bean. Instron values increased as the pectin content of the snap beans increased (r=0.83). This agrees with other researchers (Fennema et al., 1986; Cruess, 1958). There was no significant difference (P>0.05) in firmness between the cultivars of fresh medium sieve size snap beans.

Table 14 presents mean Instron values of all the cultivars by process. Frozen snap beans were the firmest although not significantly different from fresh snap beans. As expected, canned beans were significantly more tender (less than 1/10 the force to shear canned versus frozen or fresh) than fresh or frozen. Canned snap beans were softer in this study than in previous studies by Collins (1978, 1979), and Collins and Mullins (1984). This may be due to the growing conditions and resulting composition of the beans or the process treatment which could have varied slightly from one year to the next.

There were significant differences among the cultivars and sieve sizes for texture measurements of fresh snap beans (Table 15). Large sieve size snap beans required more force to shear than medium or small sieve sizes (Table 16). The sieve size of snap beans is a primary indicator of maturity and texture. Snap beans are typically sorted by size before processing to determine the type of process necessary. Large sieve size beans are cut lengthwise or crosswise to reduce the particle size and therefore reduce the perceived texture

Table 14. Mean values for the force (Kg) required to shear 100g samples of medium sieve size snap beans by process.

PROCESS	FORCE
Canned	27.4y
Frozen	339.7x
Fresh	326.2x

xy Means within each column followed by different letters are significantly different at $p<0.05$ level.

Table 15. Mean squares for the analysis of variance of mean instron values of fresh snap bean cultivars.

SOURCE	DF	MEAN SQUARE
Cultivar	9	2288.78**
Sieve Size	2	2944.50**
Error	47	347.73

** Significant at the $p<0.01$ level.

Table 16. Mean values for the force (Kg) required to shear 100g samples of fresh snap beans by sieve size.

SIZE	FORCE
Small	320.42y
Medium	326.23y
Large	343.87x

xy Means within each column followed by different letters are significantly different at $p<0.05$ level.

by the consumers. The cultivars of fresh beans were significantly different in the force required to shear when all three sieve sizes were included. The force required to shear the beans were similar to those presented in Table 13. 'FM128' and 'Shamrock' were significantly firmer than 'BBL-47'. None of the other cultivars were significantly different from each other.

VII. Sloughing

Sloughing was determined for canned and frozen snap beans. For frozen snap beans there was no measurable sloughing. Analysis of variance of mean sloughing for the canned snap beans is shown in Table 17. There was no significant difference ($P>0.05$) in sediment height between the cultivars (Table 18); although, 'FM103' had the highest sediment reading with 1.0ml and 'Pod Squad' had the lowest sediment reading with 0.1ml. The average sediment height was 0.6 ml in this study compared to 2.7 ml - 4.3 ml in studies by Collins (1978) and Collins and Mullins (1984). A greater amount of sediment indicates a softer bean however as discussed above the beans in this study were softer than those in the earlier studies. Within this study, however, an increased tendency for the snap beans to slough correlated ($p<0.05$) with decreased pectin content ($r=-53$). Also, an increased tendency for sloughing correlated ($p<0.05$) to a decrease in Instron values or softer snap beans ($r=-0.67$).

Table 17. Mean squares for the analysis of variance of mean sloughing of canned snap beans.

SOURCE	DF	Mean Square
Cultivar	9	0.26[NS]
Error	20	0.43

[NS] Not significant at the $p>0.05$ level.

Table 18. Mean epidermal sloughing of canned snap beans by cultivar.

CULTIVAR	HEIGHT OF SEDIMENT (ml)
Goldkist	0.25x
Shamrock	0.75x
Trophy	0.75x
Blue Jay	0.50x
Sentry	0.50x
H531-5-1	0.75x
FM128	0.88x
FM103	1.00x
Pod Squad	0.10x
BBL-47	0.38x

x Means within each column followed by different letters are significantly different at $p<0.05$ level.

VIII. Seed Percentage

The percentage of seed was calculated for the fresh snap beans in the sieve size 3 category. An analysis of variance of the seed percentages for the ten snap bean cultivars showed a significant difference ($P<0.01$) among the cultivars (Table 19). The average seed percentages are given in Table 20. There was a significant difference ($P<0.01$) in seed percentage between cultivars. 'FM128' had the highest seed percentage, while 'Shamrock', 'BBL-47', and 'Blue Jay' contained the lowest. The differences in the seed percentages are mainly due to cultivar characteristics since only sieve size 3 snap beans were analyzed. The overall average seed percentage was 5.5%, which is within the range reported by Collins (1978, 1979) (3.3%-7.2%). The seed percentage did not significantly correlate ($P>0.5$) with any of the proximate composition components for the snap beans.

IX. Color

Analysis of variance (Table 21) indicated significant differences among cultivars for the L, 'a' and 'b' values and among sieve sizes for L and 'b' values. The Hunter Color values of fresh snap beans are given in Table 22. 'Goldkist' is a wax bean and all other cultivars are green beans. 'Goldkist' had L, 'a, and 'b' values that were signficantly ($P<0.01$) different from all other cultivars which was

Table 19. Mean squares for the analysis of variance of mean seed percentages of fresh sieve size 3 snap beans.

SOURCE	DF	Mean Square
Cultivar	9	21.90**
Error	20	0.18

** Significant at the p<0.01 level.

Table 20. Mean seed percentage of fresh sieve size 3 snap beans.

CULTIVAR	SEED (%)
Goldkist	5.11y
Shamrock	3.00z
Trophy	4.95y
Blue Jay	2.70z
Sentry	8.01x
H531-5-1	4.85y
FM128	10.93w
FM103	4.58y
Pod Squad	8.06x
BBL-47	2.77z

w-z Means within each column followed by different letters are significantly different at p<0.05 level.

Table 21. Mean squares for the analysis of variance of mean Hunter Colorimeter L, 'a', and 'b' values for fresh snap bean cultivars.

SOURCE	DF	L	a	b
		------------Mean Square------------		
Cultivar	9	253.21**	41.62**	56.98**
Size	2	171.58**	4.67[NS]	21.22**
Error	47	2.91	7.30	1.09

[NS] Not significant at the p>0.05 level.
** Significant at the p<0.01 level.

Table 22. Mean Hunter Colorimeter "L", "a", and "b" values[a] for fresh medium-sizes snap bean cultivars.

CULTIVAR	L	'a'	'b'
Goldkist[b]	60.73x	-1.62x	26.27x
Shamrock	39.75z	-10.02y	17.08yz
Trophy	39.80z	-10.23y	16.87yz
Blue Jay	38.60z	-10.08y	16.20yz
Sentry	40.75yz	-10.38y	17.47y
H531-5-1	40.80yz	-9.65y	15.33z
FM128	42.50y	-10.05y	17.15yz
FM103	42.23y	-9.55y	17.15yz
Pod Squad	43.07y	-9.50y	17.32y
BBL-47	38.73z	-9.65y	16.05yz

[a] Hunter L (100=white, 0=black);
'a' ('a'=redness, '-a'=greenness);
'b' ('b'=yellowness, '-b'=blueness).
[b] Wax type snap bean.
x-z Means within each column followed by different letters are significantly different at p<0.05 level.

expected since it is a wax bean. 'Goldkist' had the highest L value (60.73) indicating that it is the lightest cultivar, the greatest 'a' value (-1.62) indicating that it is the least green, and the highest 'b' value (26.27) indicating that it is the most yellow.

There were significant (P<0.01) differences between the green snap bean cultivars for the L value. 'Pod Squad' had the highest L value (lightest) and 'Blue Jay' had the lowest L value (darkest). There was no significant difference (P>0.05) between the green cultivars for the 'a' value (greenness). There were significant differences (P<0.01) between some cultivars for 'b' value. 'Sentry' had the highest 'b' value (most yellow) and 'H531-5-1' had the lowest 'b' value (least yellow). Mean Hunter Color L, 'a', and 'b' values in this study are comparable to previous studies (Collins, 1978 and 1979; Collins and Mullins, 1984).

X. Sensory Analysis

The sensory analysis found no difference in tenderness between 'BBL-47' and 'FM128' when processed by canning or freezing. From the 32 panelists, 11 panelists selected 'BBl-74' as the most tender canned product, 8 selected 'FM128' and 13 could not detect any difference. For the frozen product, 12 panelists selected 'BBL-74' as the most tender, 8 selected 'FM128' and 12 could not detect any difference. This indicates that the firmness difference detected between these two cultivars for the frozen beans by the Instron could not be detected by an untrained consumer panel. This also suggests that it may be possible to increase pectin content in snap bean cultivars without detectable texture differences.

CHAPTER V

SUMMARY AND CONCLUSIONS

All the cultivars of snap beans were acceptable for processing according to the quality grade standards outlined in the CFR (1988a,b). All cultivars had less than 25% seed, less than 0.15% fibrous material in the deseeded pods, sloughing was minimal indicating a clear liquor, and no splitting of the beans was observed.

The major constituent in the snap beans was water, 93%, with the solid content mainly consisting of carbohydrate material. Canned beans contained more water and ash (NaCl), less calcium and magnesium and require significantly less force to shear than did the fresh beans. There was no significant difference in the total dietary fiber contents between these two types of processed beans. Frozen beans contained less water and ash, more calcium and total dietary fiber than fresh beans. There was no significant difference in magnesium content and it took the same force to shear as the fresh beans. The frozen beans, also, contained more pectin than did canned beans.

As the pectin content of the snap beans increased, the Instron values increased indicating that snap beans with a higher pectin content tend to be firmer. An increase in pectin content also correlated with a decreased tendency for snap beans to slough. Conversely, an increase in sloughing correlated to a decrease in Instron value, or softer snap beans. Total dietary fiber is also negatively correlated with sloughing. Fibrous material was not an acceptable indicator of total dietary fiber, probably because the insoluble fiber content of the snap beans was relatively low. In addition, the total dietary fiber measurement included both the beans and the pods, whereas the fibrous material measurement was taken on deseeded pods.

It would be desirable to maximize total dietary fiber (mainly pectin) content of snap beans to minimize sloughing as well as to increase the total dietary fiber in the diet, as long as texture is not affected adversely. The sensory panel was unable to detect any differences in texture of BBL-47 and FM128, although, physical and chemical differences were found between the cultivars. Further study of detectable levels of increased dietary fiber content of snap beans is needed. Canned snap beans are much softer than fresh and frozen so that increased levels of dietary fiber in beans used for canning would be very acceptable. It may also be possible to increase pectin content without increasing the fibrous material significantly.

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APPENDIX

DIETARY FIBER ANALYSIS PROCEDURE

a. Reagents:

1. 95% Ethanol(v/v), technical grade
2. 78% Ethanol: placed 207 ml of distilled water into a one liter volumetric flask. Diluted to volume with 95% ethanol.
3. Phosphate buffer, 0.05M, pH 6.0: Dissolved 0.875 g of Na_2HPO_4, anhydrous and 5.26 g of NaH_2PO_4, anhydrous in approximately 700 ml of water in a one liter volumetric flask. Diluted to volume with distilled water. Checked pH and adjusted if necessary with either NaOH or H_3PO_4.
4. Sodium hydroxide solution, 0.171 N: Dissolved 6.84 g NaOH in approximately 700 ml of distilled water in a one liter volumetric flask. Diluted to volume with distilled water.
5. Phosphoric acid solution, 0.205 M: Dissolved 23.64 g H_3PO_4 (85%) in distilled water in a one liter volumetric flask. Diluted to volume with distilled water.
6. alpha-Amylase, heat stable: Sigma Product No. A 0164.
7. Protease: Sigma Product No. P 3910.
8. Amyloglucosidase: Sigma Product No. A 9913.
9. Celite, acid washed: Sigma product No. C 8656.

b. Sample analysis:

1. Weighed dry, ground sample (approximately 0.8500 g), recorded Sample Weight (SW) and placed sample into 400 ml tall form beaker.
2. Added 50 ml of phosphate buffer (pH=6.0).
3. Added 0.2 ml alpha-Amylase and mixed well.
4. Covered beaker with aluminum foil and placed in boiling water bath for 30 minutes, shaking beaker gently at 5 minute intervals.
5. Removed beaker from the water bath and allowed solution to cool to room temperature.
6. Adjusted pH to 7.5$\pm$0.1 by adding 10 ml of 0.171 N NaOH to beaker. (Checked pH and adjusted if necessary with either NaOH or H3PO4.)
7. Added 5 mg of protease.
8. Covered beaker with aluminum foil and incubated at 60 C for 30 minutes in a continuously agitating water bath.
9. Removed beaker from the water bath and allowed solution to cool to room temperature.
10. Added 10 ml of 0.205 M H_3PO_4 to beaker to adjust the pH of the solution to 4.5$\pm$0.2 (Checked pH and adjusted if necessary.)
11. Added 0.3 ml of Amyloglucosidase.
12. Covered beaker with aluminum foil and incubated for 30

minutes at 60 C in a continuously agitating water bath.

13. Added 280 ml of 95% ethanol, preheated to 60 C (volume measured before heating).
14. Held solution at room temperature for 3 hrs to allow precipitate to form.
15. Prepared crucibles as follows: cleaned thoroughly, heated one hour at 525 C and cooled. Soaked and rinsed in distilled water and air dried. Added 0.5 gram of Celite to each crucible, dried at 130 C for one hour or more, cooled in desiccator and weighed to nearest 0.1 mg. Recorded as "Celite + Crucible Weight" (CW). Stored crucibles in desiccator until needed.
16. Filtered solution through crucible as outlined in fiber tech manual.
17. Dried crucible overnight in a 70 C vacuum oven.
18. Cooled crucible in a desiccator and weighed to the nearest 0.1 mg. Recorded weight as "Residue + Celite + Crucible Weight." (RCW)
19. Calculated Residue Weight (RW) = RCW - CW
20. Protein content of residue from each of two samples and two blanks was analyzed utilizing the Kjeldahl analysis as specified in "Official Methods of Analysis" of the AOAC (1984). A factor of 6.25 was used in all cases to convert ammonia determined in the Kjeldahl to protein. Protein residue was recorded as Protein Weight (PW).
20. Ash content of residue from two samples and two blanks

was analyzed (AOAC, 1984). The crucible was placed in the ashing furnace for 5 hours at 525 C. Crucibles were cooled in a desiccator and weighed to the nearest 0.1 mg. This weight was recorded as "Ash + Celite + Crucible Weight." (ACW)

21. Calculated Ash Weight (AW) = ACW - CW
22. Calculation of Total Dietary Fiber:

$$\frac{RW - (AW + PW)}{SW} * 100 = \%\ \text{Total Dietary Fiber}$$

VITA

Beverly Dawn Buckner was born in Knoxville, Tennessee on January 5, 1962. Her parents are Mr. Glenn P. Buckner of Maynardville, Tennessee and Mrs. Wanda F. Murray of Niota, Tennessee. Beverly received a Bachelor of Science in Agriculture majoring in Animal Science from the University of Tennessee in December of 1984. Beverly received a Master of Science Majoring in Food Technology and Science from the University of Tennessee in August of 1990. Beverly has been a member of the UT meats Judging Team, Secretary of the UT Food Technology and Science Club, and is a member of Gamma Sigma Delta Honorary Society of Agriculture, and a professional member of the Institute of Food Technologists professional society.