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Quality Evaluation of Fresh, Frozen and Canned Snap Beans

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INTRODUCTION

In the processing field there are two Federal Agencies working on quality standards and methods of evaluating quality packs. Standards set forth by both are of importance in considering the quality levels of any fruit or vegetable product. The Food and Drug Administration, a division of the Federal Security Agency, is responsible for setting up "minimum standards of quality" under authority of the Food, Drug and Cosmetic Act of 1938. These minimum standards of quality for processed fruits and vegetables are the lowest level of quality for shipment in interstate commerce without being labeled "below minimum standards of quality ". This division established minimum standards of quality for canned snap beans which became effective on September 30, 1948. These standards set-up three requirements among others that are of value here, namely, (1) "The trimmed pods contain not more than 25% by weight of seeds and pieces of seed", (2) "The deseeded pods contain not more than 0.15% by weight of fibrous material" and (3) "In case there are present pods or pieces of pods 27/64 inch or more in diameter, there are not more than 12 strings per 12 ounces of drained weight which will support ½ pound for 5 seconds or longer" (8).

The other Federal Agency involved in evaluating quality is the Processed Fruit and Vegetable Inspection and Standardization Division of the Fruit and Vegetable Branch of the United States Department of Agriculture. This division is responsible for setting forth and evaluating the levels of quality (i. e. grades) of the different processed fruits and vegetables. On October 2, 1948 the fourth issue of the United States standards for grades of canned green and wax beans became effective. This standard, which was established "after careful consideration of all data and views submitted by individual members of the industry, trade association and from other sources", is "designed to serve as a convenient basis for sale in wholesale transactions, as a basis for determining loan values, and as a basis for the inspection of this commodity by the Federal inspection services". On April 15, 1944 the tentative United States standards for grades of frozen snap beans became effective. These standards are still in effect. Both sets of grade standards deal with the quality levels of snap beans. Quality of canned snap beans is determined by considering the following factors: "Clearness of liquor (10 points); color (15 points); absence of defects (35 points) and maturity (40 points)." The factor "absence of defects" refers to the degree of freedom from harmless, extraneous vegetable material, from units damaged by insect, pathological, mechanical or other injury." These defects are usually due to inadequate supervision or excessive speed in handling the product within the factory. The most important single factor affecting quality is maturity. The factor of maturity refers to the degree of development of pods and seeds and the tenderness of the pods. For each grade level, minimum requirements are set up; however, only at the bottom of Grade C level is the requirement set at a specific amount except for tough strings. As an example, the Grade A requirements are "canned beans that are very young and tender. Very young and tender means that the units are full fleshed for the variety, tender and not fibrous; the seeds are in the early stages of maturity; and not more than 2 percent, by count, of the units possess tough strings." Whereas, the Grade C requirements are "canned beans that are nearly mature and fairly tender. Nearly mature and fairly tender means that the units may have lost to a considerable extent, their fleshy structure, and that the trimmed pods contain not more than 25%, by weight, of seed and pieces of seed; the deseeded pods contain not more than 0.15%, by weight, of fibrous material; and not more than 10%, by count, of the units may possess tough strings except that in case there are present units at least 27/64 inch or more in diameter, there are not more than 12 strings or pieces of strings in 12 ounces drained weight which will support a ½ pound weight for not less than five seconds." (1)

In the frozen product the quality is determined by considering the following factors: color (20 points); absence of defects (40 points) and texture and maturity (40 points). The factors "texture and maturity" represent the most important indices of quality. Here it is interpreted the same as for the canned product, excepting that no minimum standards of quality have been established and thus the bottom levels of quality are not specified clearly. (2)

These brief abstracted facts represent the trade practices in evaluating quality levels of processed snap beans. This should suffice to show that the quality requirements are established on an objective basis only for the minimum Grade C level in the canned product. In the frozen product no specific objective requirements are in effect. Thus it would be preferable to have levels of quality for Grades A, B, and C set-up on an objective basis at least for maturity; and the factors of variety and processing methods (canning and freezing) evaluated objectively for quality retention. With this in mind, experiments were undertaken not only to determine the possibilities of developing objective standards for grades; but, also, to determine some of the effects of freezing and canning operations on the quality and chemical changes in snap beans. The studies reported herein were not restricted to the commonly processed varieties of snap beans but included a total of 47 varieties.

REVIEW OF LITERATURE

The snap bean (*Phaseolus vulgaris* L.) is a native of South America according to Whittnack in his investigations of seeds of Peruvian tombs (16). It is an important and widely grown vegetable crop with many factors contributing to its wide distribution, such as, adaptability for growth on a wide range of soil types; the period from planting to usable maturity is so short that the crop fits easily into cropping systems; and the varieties that have been developed are well adapted to each great agricultural region in the United States (3).

The term "snap bean" is applied to beans in the tender young stage when the pods are eaten. This class is known also as string beans, although practically all varieties of present importance are stringless (15). Snap beans are of two common types; (1) green podded and (2) yellow podded or wax, with two subdivisions of each type, that is, round or flat. The United States Department of Agriculture (1) classifies round type beans as beans having a width not greater than 1½ times the thickness of the bean. Flat type beans are beans having a width greater than 1½ times the thickness of the bean. Kooiman (11) in his monograph on *Phaseolus* states that the general color of the unripe pod may be either yellow or green, displaying in the latter case different shades from light to bluish green. In the yellow podded beans the color is due to a comparatively early loss of chlorophyll, which loss in other than wax varieties only occurs after the pod is full grown. These wax varieties lose their chlorophyll very early while others never quite lose it before ripening.

Emerson (7) in 1904 stated that the only characters relating to the quality of pods are "toughness" and "stringiness". A stringy pod has strongly developed vascular fibers along both sutures, though in a stringless pod these fibers are entirely or almost entirely wanting. Emerson further states that a tough pod has strong fibers in the walls, which run obliquely across the pods from suture to suture. Tender pods are practically without these fibers, the walls usually being more or less fleshy. Kooiman (11) states "in most wild leguminous plants the pod walls are heavily parchmented. This parchment consists of fibers which run obliquely across the pod wall from suture to suture. In young pods it is at first absent, but develops gradually as the pod matures. In beans this must have been the original condition. There is, however, a wide range of variation in the development of this character. Some varieties are freely parchmented; others are tender, developing no parchment at all or only late. Between these extremes different stages of parchment development occur."

Workers at the University of Maryland (14) have shown that the parchment or fiberous sheath of the side walls, as they call it, are actually in the inner mesocarp. The tissue starts as a one-celled layer of parenchyma and later develops into a region several cells in thickness. These workers have shown that the variety Bountiful differentiates these small close fitting parenchmatous cells (17) to the fibers three days sooner than the variety Giant Stringless Green Pod, but at twenty days after anthesis both varieties show development and thickness of the cells of the fibrillar layer. They further show that cool temperatures and abundant rainfall produce less thickening of these cells and that high temperatures accelerate cell wall thickening. Currence (5) has stated that the fiber of the side wall is associated with the width of the pod; the wider the pod, the greater the fiber content and it is more pronounced in flat pods.

Kooiman (11) states that the seed weight, absolute and relative length, breadth and width of the pods are to a considerable degree subject to variation. Harris (10) has shown that the seed weight is correlated with the relative position in the pod as well as with the number of seeds per pod.

In addition to the above, the pods are classified on the basis of size by the United States Department of Agriculture (1).

As Culpepper has so ably stated, "the value of any vegetable as a food product depends primarily upon its composition and palatability. Both are generally greatly influenced by the stage of maturity at which the material is prepared for use" (4). This is the basis of his study completed in 1936 in which he has shown that the best stage for canning was when the beans were 15 days old, that is, 15 days after the flowers were in full bloom. "At this stage the pods had reached their full length, but the seed had developed so little as to make up an insignificant portion of the total weight of the pod , however, a fairly acceptable canned product was obtained from about the 10- to the 20-day stage or a comparatively long period in the development of the snap bean." His work dealt with two varieties, namely, Burpee Stringless Green Pod and Refugee Wax. Some chemical analyses were made of the Burpee Stringless Green Pod by taking samples at five day intervals throughout the growing period. He analyzed the pericarp, the seed and the whole pod for solids, both soluble and insoluble; sugar, titratable acidity; total astringency and total nitrogen. On this variety he found that the total solids decreased somewhat from the 5- to 10-day stage, then increased slowly to the 20-day stage and at the 20-day stage a rapid increase sets in and continued to the 40-day stage. In the pericarp, the soluble solids decrease somewhat from the 15-day stage onward, while the insoluble solids increase considerably. "This would indicate that the increase in total solids of the hull (pericarp, as referred to in this paper) is due largely to accumulation of fiber. The soluble solids in the seed decrease from the 15-day stage onward while the insoluble solids fraction increases tremendously. The insoluble solids always made up a greater portion of the total than the soluble solids and in the older samples the soluble portion constitutes a very minor part. It is evident that the rapid rise in total solids in the entire bean beginning at the 15-day stage is due largely to growth of the seed and to the changes occurring in its compostion. Most of the substance of the pericarp is obviously transferred to the seed in the final stage of development." He also showed that the sugar content was very low at all stages of maturity with a sharp decline in amount after the 20-day old period. The titratable acidity values "may be open to question" due to the presence of interfering coloring substances. He reported that the values might be slightly lower at the 15-day and at the 40-day stages than at other times. "It is very clear that changes in the acidity during the growth and development of the snap beans are too small to greatly affect the quality of the product or the methods employed in preserving it in different ways." The nitrogen content increased with maturity being most marked at the 15-day stage onward.

Gould (9) in 1947 gave data on solids content, sugars and reserve polysaccharides for 16 varieties of frozen snap beans that had been stored for six months. No consistent relationship was found since there were 16 different varieties and each variety was at a different stage of maturity. However, one variety (Giant Stringless Green Pod) was analyzed at eight day intervals to show the effect of maturity. These data show that the more mature snap beans had a higher total solids content, primarily due to the insoluble portion and this being reflected in the total reserve polysaccharides. The increase being slightly more than 33 percent in each case. This would indicate the value of using total reserve polysaccharides or alcohol insoluble solids content as a measure of maturity in snap beans. However, these data are for only one variety and the stages of maturity represent Top Grade A and Top Grade B quality snap beans.

Kramer (12) in a study of the "Nutritive Value of Canned Foods" has given the proximate composition of the solid and liquid portion of canned green beans. These data show that approximately 36% of the solids are found in the liquid portion of the canned samples. This value should emphasize the importance of using the liquid portion of canned samples when making a complete approximate analysis or when using it as food. In addition, the data shows that 15% of the protein, 37% of the ash and nearly 22% of carbohydrates are in the liquid though only 4% of the crude fiber is found in this portion of the canned product.

EXPERIMENTAL PROCEDURES AND RESULTS

A total of forty-seven varieties of snap beans were grown according to accepted commercial practices without replication. The varieties were not restricted to the most commonly processed varieties (Blue-Lake, Refugee, Stringless Green Pod and Tendergreen), but included the most prominent varieties listed by the Seedsmen. Each variety was harvested at three stages of maturity. Maturity was based on percent by weight seeds, that is, the pods were deseeded and the seeds weighed. Samples with 8% or less seeds were considered Grade A or immature, 8 to 16% were Grade B or optimum and those with seed content from 16 to 25% were Grade C or mature. One hundred plants were pulled at each harvest from each variety and the usable pods stripped from these plants. The percent by weight seeds, the number of pods per 100 gram samples, the color, shape, length, texture and ascorbic acid contents were determined. The percent by weight seeds was determined by deseeding 100 grams of pods and weighing the seeds obtained. Since 100 grams were used, the value was recorded as percent by weight seeds.

The number of pods per 100 grams was determined by counting the number of pods in a 100 gram sample and recorded as number of pods per 100 grams of sample.

The color of the pods was determined subjectively with the aid of the Maerz and Paul's Dictionary of Color (12b). The sample was compared to a plate in the dictionary. A sample with a reading of 21J7 means Plate 21, Column J and Row 7. With some of the wax varieties the minimum and maximum color was recorded since they were not as uniform in color as the green varieties.

The shape of the pods was determined subjectively by evaluating the variety as to whether or not it was straight, curved, round, and/or flat.

Texture was determined with the Texture Meter (manufactured by the Wm. F. Christel Co., Valders, Wisconsin). The beans were cut into ¼ to ⅜ inch lengths and three 50 gram samples were used for the determinations. The readings were averaged and this value is used for each variety at each stage of maturity. The range on the instrument is from 0 to 300 and it reads directly in pounds. Some of the samples were too tough and gave readings at 300 plus, consequently, the data is given as such and in those cases may not be reflecting the true tenderness of the beans in this range of the instrument for texture. The lower the reading, the more tender the sample. Most varieties gave readings that varied less than 15 pounds at the different stages of maturity, that is, the three samples varied within this range of 15 pounds to each other.

Ascorbic acid was determined on two 50 gram samples using the method of Loeffler and Ponting (12a). In addition to the above, yield data, heat units and percent sieve size at each stage of maturity were determined (9a). Immediately after harvest, the samples were processed, one-half of each lot being used for canning and one-half for freezing. Both processes were those used in good commercial practices (Flow Sheet I). After nine months storage the canned products were opened and color of liquor, sediment in liquor, percent by weight seeds, fiber content, flavor, tenderness and tough strings were determined. Color of the liquor, flavor and tenderness were evaluated subjectively by a panel of 5 judges. Color of the liquor was scored on a scale of 1 to 5 with 1 being considered very cloudy and 5 very clear. Flavor and tenderness were scored from 1 to 10, with 1 being considered off-flavor or tough and 10 being scored as excellent in flavor and/or very tender.

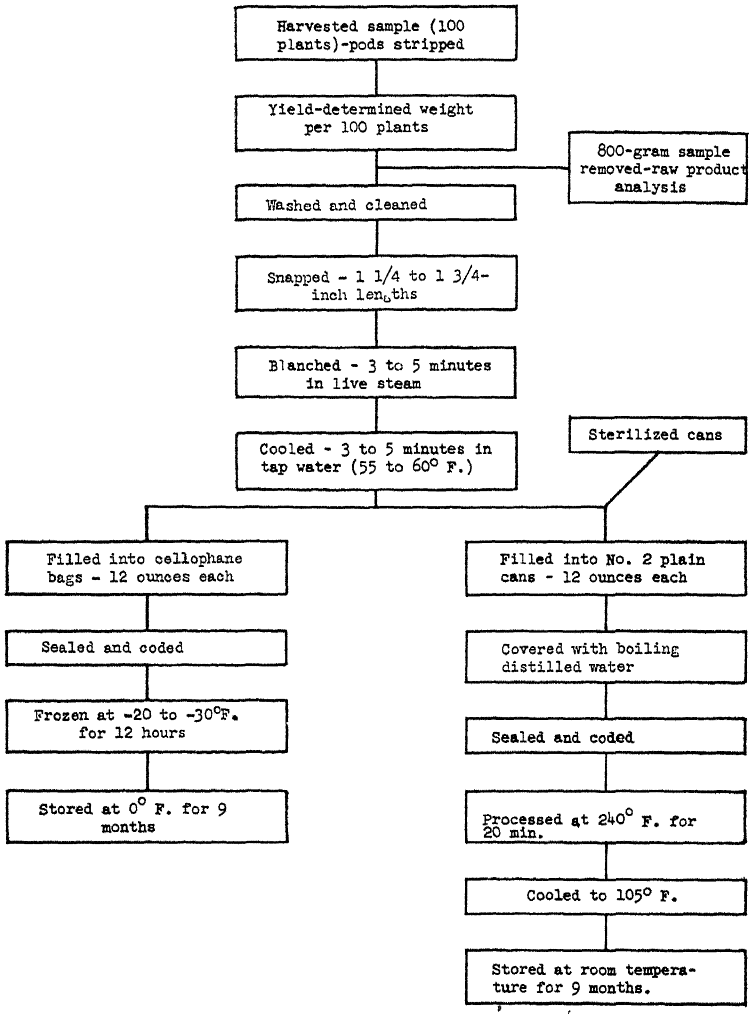
Sediment in the liquor was measured as cubic centimeter of sediment per can. This was determined by draining the liquor from the can into a graduated cylinder and allowing the sediment to stand for one hour.

Fiber content and tough strings were determined according to the Food and Drug Administrations' method (8). The frozen products were likewise removed from storage after nine months and analyzed the same as the canned product. In addition to the above factors for the canned product, seed color, pod width and thickness, seed length and width were evaluated on the frozen product.

The color of the seeds was evaluated subjectively by scoring the seeds as to whether or not they were green, gray, purple, or shades between green, gray or purple in color. They were recorded as such.

Flow Sheet No. I

PROCESSING PROCEDURES FOR SNAP BEANS (FREEZING AND CANNING)



Pod width and thickness and seed length and thickness was measured in millimeters (mm) with a Vernier Calipher. A summary of these data for the fresh, frozen and canned products is recorded and presented in the Appendix Tables I, II, III. Correlation coefficients were made on subjective and objective measurements of quality for the fresh, frozen and canned samples with the "t" test used to show the significance of these data (Table 1).

TABLE 1. Correlations ('r' values) and Statistical Significance ('t' values) of Objective and Subjective Measures Quality for Frozen and Canned Snap Beans

Measures of quality	Frozen product		Canned product	
	'r'	't'	'r'	't'
Percent by weight seeds vs seed length	+.89	16.42	+.67	6.16
Percent by weight seeds vs seed width	+.80	11.15	+.63	5.92
Percent by weight seeds vs flavor	—.53	5.34	—.65	6.27
Percent by weight seeds vs tenderness	—.70	6.90	—.58	5.22
Percent by weight seeds vs fiber	+.58	6.08	+.29	2.20*
Percent by weight seeds vs clearness of liquor			—.63	6.03
Fiber vs tenderness	—.67	7.61	—.77	8.58

*This value is significant at the 5 percent level, all other values are significant at the 1 percent level.

A sample of each variety at each stage of maturity for the fresh, frozen and canned samples was prepared for chemical analyses. The samples were extracted with 80% alcohol. Soluble solids were determined on the extract and the alcohol insoluble solids on the residues. Total solids were determined by the summation of the soluble solids and the insoluble solids. The residues were subsequently analyzed for total reserve polysaccharides, nitrogen, cellulose, ash and pectin content (Flow Sheet II). The means of these varieties at the three stages of maturity for each chemical constituent are given in Table 2, and Charts I through VIII. The "F" test was used in the chemical analyses using maturity as one factor and the particular chemical constituent as the other. The significance of these data were determined by using the "F" tables as calculated by Snedecor (13a). Table 3 gives the difference between the means with the statistical significance indicated at the 5% and 1% level and the calculated corresponding Least Significance Difference of the chemical analyses at the different stages of maturity for the fresh and frozen, frozen and canned and for the canned and fresh snap bean samples. Table 4 gives the test of significance of difference between the means of the chemical analyses of the fresh, frozen and canned snap beans at the different stages of maturity.

Flow Sheet No. II

SCHEMATIC DIAGRAM OF CHEMICAL ANALYSES

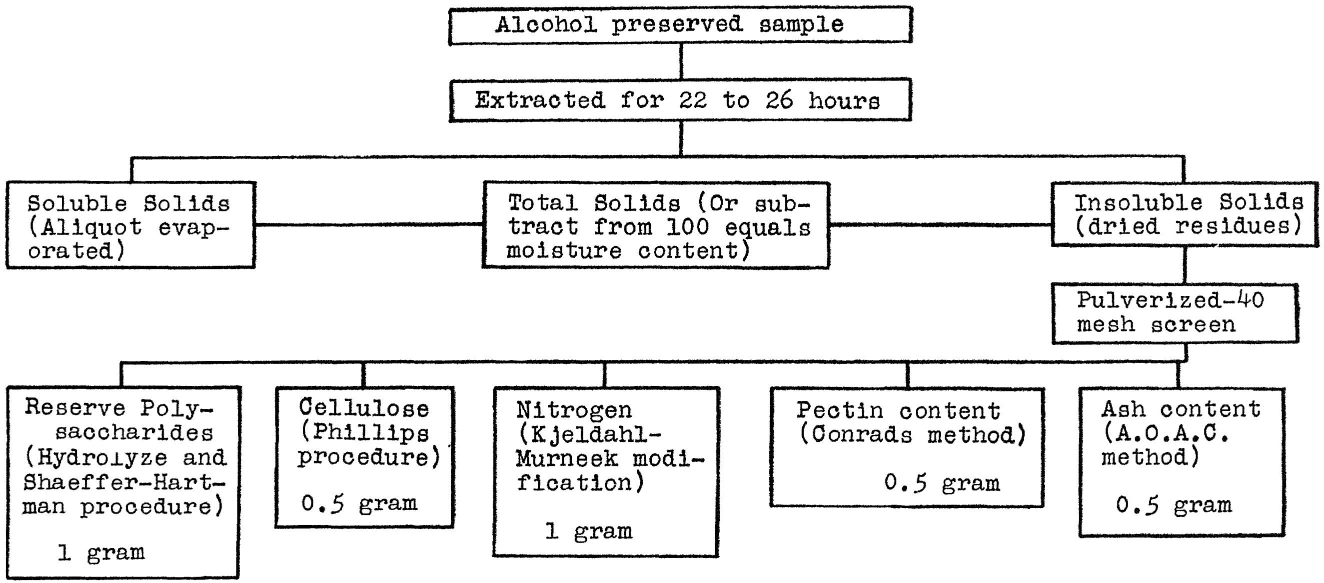


TABLE 2. Approximate Chemical Composition of Fresh, Frozen and Canned Snap Beans at Three Stages of Maturity (fresh weight basis)

Chemical constituent in percent	Stage of maturity (Percent by weight seeds)								
	Immature (Under 8.1%)			Optimum (8.1 to 16.0%)			Mature (16.1 to 25.0%)		
	Fresh	Frozen	Canned	Fresh	Frozen	Canned	Fresh	Frozen	Canned
Total solids	8.19	7.98	6.29	9.65	8.92	7.83	11.76	11.27	10.08
Alcohol soluble solids	3.42	3.18	2.18	3.48	3.30	2.14	3.79	3.55	2.26
Alcohol insoluble solids	4.80	4.89	4.10	6.10	5.71	5.69	8.01	7.73	7.78
Reserve polysaccharides	1.43	1.45	0.90	2.12	1.71	1.37	3.12	2.64	2.08
Nitrogen	0.15	0.16	0.14	0.20	0.18	0.17	0.25	0.26	0.23
Cellulose	1.02	0.92	0.91	1.26	1.00	1.18	1.41	1.15	1.48
Pectin	0.40	0.42	0.43	0.58	0.57	0.34	0.67	0.57	0.50
Ash		0.22	0.18		0.23	0.22		0.29	0.26
Undetermined insoluble fraction	1.80	1.78	1.54	1.94	2.02	2.41	3.56	2.82	3.23

DISCUSSION OF RESULTS

EFFECT OF PROCESSING (Freezing and Canning) ON THE QUALITY AND THE CHEMICAL COMPOSITION IN SNAP BEANS

Alcohol soluble solids

Table 2 and Chart I shows that the alcohol soluble solids content is a factor of great importance to determine the difference between frozen and canned and between fresh and canned snap beans. However, it does not appear to be a useful factor to determine differences between the fresh and frozen products as the differences in soluble solids content are not statistically significant. In the former cases, the "F" values are highly significant (1% level) at all stages of maturity. This means that during the canning operations considerable change takes place in the soluble solids content of snap beans. Since the soluble solids contents were determined from the pericarps and seeds and not from the brine or liquor surrounding the product, this may in part, explain the great differences that exist. To state this in another way, the canning operations leach out considerable quantities of water soluble solids when compared to the frozen or the fresh products. Another inference that could be drawn from these data is that a large proportion of the soluble solids in snap beans are water soluble, at least, water soluble at elevated temperatures as are used in canning (240° F.). Considering the soluble solids fraction then as a factor of quality in itself, the frozen product has a retention that is not significantly different from that of the fresh product. The canned product, on the other hand, has only 40% of the alcohol soluble solids of the original fresh product left in the pericarps. Kramer (12) has shown that the soluble solids of the liquor in canned snap beans make up 36.2% of solids content, so these results are in agreement with his data.

Alcohol insoluble solids

Insoluble solids are significantly affected by processing when the snap beans are in the immature state, that is, under 8% by weight of seeds. At this stage of maturity the "F" values are 14.5 between the frozen and the canned samples and 12.86 between the canned and the fresh samples. Both values are highly significant (1% level). The differences are not significant with either method of processing at the optimum and the mature stage of maturity. A possible explanation of this might be that the immature snap beans contain materials that are in the transition stage, that is, between the soluble solids and the insoluble

TABLE 3. Test of Significance of Difference Between Means of Chemical Analysis of Different Stages of Maturity of Fresh and Frozen, of Frozen and Canned and of Canned and Fresh Snap Beans

Chemical constituent determined as percent fresh weight composition	Stage of maturity (by weight of seeds)	Fresh-Frozen Mean diff.[1]	Fresh-Frozen LSD[2]	Frozen-Canned Mean diff.[1]	Frozen-Canned LSD[2]	Canned-Fresh Mean diff.[1]	Canned-Fresh LSD[2]
	Under 8%	0.24*	.21	1.00**	.41	1.24**	.30
Alcohol soluble solids	8 to 16%	0.18		1.16**	.43	1.34**	.31
	16 to 25%	0.24	. .	1.29**	.52	1.53**	.58
	Under 8%	0.09		0.79**	.57	0.70**	.53
Alcohol insoluble solids	8 to 16%	0.39		0.02		0.41	
	16 to 25%	0.28	. .	0.05		0.13	
	Under 8%	0.21		1.69**	.62	1.90**	.50
Total solids	8 to 16%	0.73		1.09**	.80	1.82**	.98
	16 to 25%	0.49		1.19		1.68*	1.48
Easily hydrolyzable	Under 8%	0.02		0.55**	.50	0.53**	.25
reserve polysaccharides	8 to 16%	0.41*	.32	0.34*	.26	0.75**	.38
	16 to 25%	0.48		0.56		1.04**	1.01
	Under 8%	0.01		0.02		0.01	
Alcohol insoluble nitrogen	8 to 16%	0.02		0.01		0.03**	.025
	16 to 25%	0.01		0.03		0.02	
	Under 8%	0.10		0.01		0.11	
Cellulose	8 to 16%	0.26**	.20	0.18**	.14	0.08	
	16 to 25%	0.26		0.33*	.28	0.07	
	Under 8%	0.02		0.01		0.03	
Alcohol insoluble pectin	8 to 16%	0.01		0.23*	.22	0.24**	.22
	16 to 25%	0.10		0.07		0.17	
	Under 8%			0.04**	.035		
Alcohol insoluble ash	8 to 16%			0.01			
	16 to 25%			0.03			

[1]Difference between the two means given in Table 2 with the statistical significant difference indicated at the 5 percent level (indicated as *) and statistical significant difference indicated at the 1 percent level (indicated as **).

[2]Calculated least significant difference at the 1 and 5 percent level as indicated in the corresponding mean difference column.

solids. They could be too complex to be extractable with 80% alcohol, but still be extractable by water with the elevated temperature as is used in the canning operation. Since alcohol insoluble solids are not appreciably affected at the optimum and the mature stages of maturity by canning, this fraction could be an important measure of quality to show the changes taking place during processing.

TABLE 4. Test of the Significance of Difference Between Means of Chemical Analyses of Fresh, Frozen and Canned Snap Beans at Different Stages of Maturity

Chemical constituent determined as percent fresh weight composition	'F' values		
	Fresh	Frozen	Canned
Total solids	35.92 †	32.43 †	47.42 †
Alcohol soluble solids	3.709	1.78	0.31
Alcohol insoluble solids	26.89 †	20.68 †	14.72 †
Easily hydrolyzable reserve polysaccharides	37.12 †	33.66 †	10.26 †
Cellulose	93.97 †	56.68 †	14.46 †
Nitrogen	16.92 †	26.01 †	40.89 †
Pectin	4.95 †	1.05	7.64 †
Ash	———	0.125	0.172

Significant at the 5% level.
†Significant at the 1% level.

Pectin

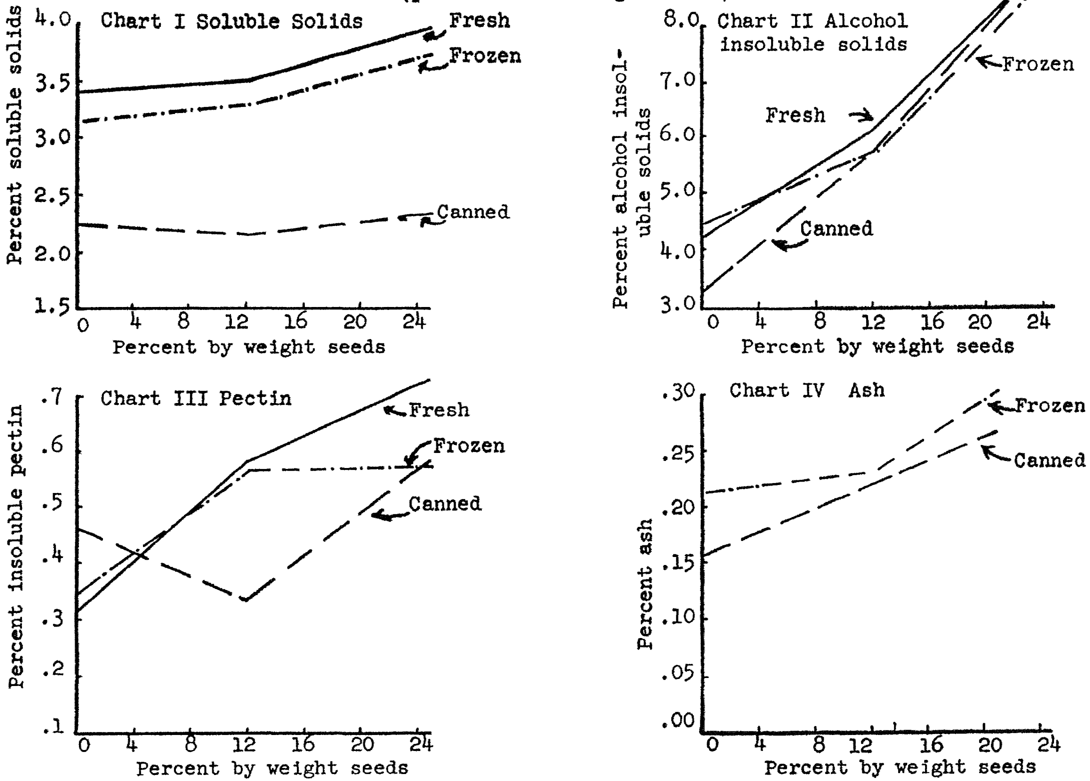
The pectin content of the alcohol insoluble solids is appreciably affected at the optimum stage of maturity between the canned and fresh samples and the frozen and canned samples. In the former case, the difference is highly significant (1% level) and in the latter it is significant (5% level). However, the means from the data show that the pectin content at the immature range is 0.425, optimum 0.336 and at the mature stage 0.498% for the canned product while the raw product has the following pectin values respectively, 0.403, 0.583 and 0.672%. Thus the "F" values would tend to be high in the optimum range and this factor of measuring quality retention in processing could not be considered important. This means that by determining the pectin content of the alcohol insoluble solids alone on the canned product, without knowing the stage of maturity, one would not know whether he had a mature or an immature sample. A possible explanation of this difference could be attributed to the fact that a change in the chemical composition of pectin within the pod from the insoluble to the soluble form might take place at this stage of maturity at these elevated temperatures. The soluble forms of pectin were not determined and this statement cannot be further substantiated from these data.

Ash

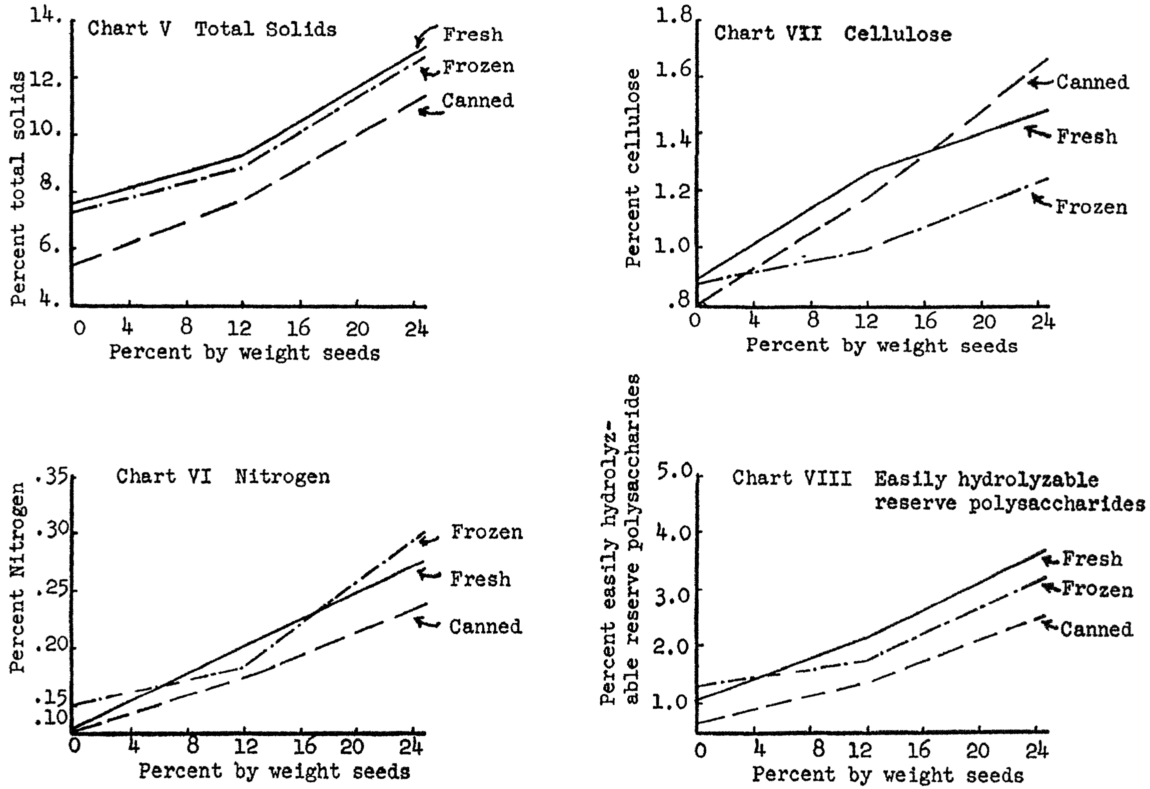
The fresh analyses are not given with these data for the reasons presented below. Statistical analysis of the frozen and canned samples show differences that are highly significant (1% level) for the immature stage only. This should emphasize the importance of using the liquor from the canned product since 19% of the ash constituents were lost to the liquor by canning snap beans at the immature stage when compared to similar frozen samples.

At the time the fresh samples were preserved for extraction, the interest in this problem was in determining fractions of both alcohol soluble and insoluble portions. However, as the work progressed, time did not permit the determination of the soluble fractions and the efforts were concentrated on the insoluble fractions. Therefore, calcium carbonate should not have been added to these samples as the calcium carbonate affects the ash values greatly. The ash was determined by the usual procedure on the fresh sample with the intention of deducting the added calcium carbonate and correcting for this value in the ash samples. After all the determinations were made, the calculations were carried out by assuming that none of the calcium carbonate became soluble during the extraction, or none of it became lost in the cleaning of the thimbles, and/or none of it became lost on the hardened filter paper used in transferring the extract to the volumetric flask. In this case the full amount of the original 0.5 gram should be deducted. A simple experiment was conducted to show the amount of calcium carbonate remaining in the ash after ashing the plant material. It was found that only 12% was lost, thus 88% of the original 0.5 gram of calcium carbonate in the total sample should be deducted from the sub-sample used for ashing. A 0.5 gram of the alcohol insoluble solid fraction was used for the ash determination. In one specific case, 0.04 gram of the material was left after the sample was ashed and in calculating the amount of calcium carbonate that should be present in this sample, it was found to be 0.06 gram. Thus it is seen that the theoretical value of the calcium carbonate gives erroneous values and these data on the fresh sample are not reported here since the ash values after correcting for the calcium carbonate gives negative values in some cases. This is in agreement to work reported by Denny (6).

RELATIONSHIP OF CHEMICAL ANALYSES TO MATURITY OF FRESH, FROZEN AND CANNED SNAP BEANS
(percent fresh weight basis)



RELATIONSHIP OF CHEMICAL ANALYSES TO MATURITY OF FRESH, FROZEN AND CANNED SNAP BEANS
(percent fresh weight basis)



Theoretically, little of the ash should be lost in the frozen sample, and the frozen values probably could be used with some assurance that they represent the difference between the fresh and canned samples. However, this was not done, but the assays for the frozen and canned samples for ash were made and these values do not show any significant difference except at the immature stage as mentioned above.

Total solids

The effect of processing on the total solids content of snap beans is highly significant (1% level) at the immature and mature stages between the canned and fresh product and between the frozen and canned product. In the mature range for maturity it is significant at the 5% level for canned and fresh samples, but no significant difference appears between the frozen and canned products. The difference between the frozen and the fresh sample is not significant at any stage of maturity. The soluble solids fraction makes up approximately ½ of the total solids content in the immature stage and approximately ⅓ of the total solids in the mature stage. Therefore, significant differences should be expected in the immature stages, but not in the mature range as total solids content was determined from the summation of the soluble solids content and the insoluble solids content.

Nitrogen

The alcohol insoluble nitrogen content is not affected by processing except in the optimum range between canned and fresh samples. Here the values are highly significant at the 1% level. Actually the difference is 3% between the immature and optimum range of the fresh and canned samples. Since there is no significant difference between the fresh and the frozen and the frozen and the canned samples and only this one "F" value is significant between the fresh and canned beans, nitrogen content could be an important measure of quality. The difference between the three stages of maturity is approximately 0.5% on the fresh weight basis and the values increase consistently for the fresh, frozen and canned products. This would seem to be one of the best measures of quality determined and one of the best indices of maturity for either the fresh, frozen or canned products.

Cellulose

There are no significant differences in the cellulose contents between canned and fresh samples of snap beans at any stage of maturity and only at the optimum stage of maturity for the fresh and frozen samples. However, the cellulose contents of the frozen samples show highly significant differences (1% level) from the canned product at the optimum stage of maturity and a significant difference (5% level) at the mature stage. The mean values for cellulose are lower for the frozen product than for the canned product and for the fresh product. The writer is not able to explain this directly, however, an examination of the fiber values (Appendix Tables II and III) for the same samples shows the canned samples to have lower fiber contents than the frozen products. These differences are not great, but they do represent a difference and seem to indicate that during the freezing operation chemical changes must affect the cellulose and fiber contents. The writer did not determine the fiber content of the raw product, so that it is impossible to state whether or not the raw products values would be higher or lower in fiber content than the frozen or canned samples. Since the cellulose content makes up from 1.0 to 1.4 percent of the fresh weight composition in the raw and canned product and only up to 1.15% in the frozen product it is an important factor to be considered in evaluating quality of the canned product, at least. The cellulose content of the frozen products are significantly lower than the fresh and canned and it is possible that some other chemical constituent, such as, pentosans are more important than the cellulose content. The fiber values bear out this statement to some extent and will be further discussed under objective evaluation methods.

Easily hydrolyzable reserve polysaccharides

The differences in "F" values for the easily hydrolyzable reserve polysaccharides are highly significant (1% level) at all stages of maturity between the canned and the fresh product. This indicates that in canning a considerable amount of the easily hydrolyzable reserve polysaccharides are leached from the product. This, again, is probably due to the elevated temperatures converting some of the less stable reserve polysaccharides to soluble fractions that are lost to the surrounding liquor during the canning operation. Thus, easily hydrolyzable reserve polysaccharides are an important indice of quality between the fresh and canned snap beans with the effect of processing by canning found to reduce the easily hydrolyzable reserve polysaccharides by approximately 30% at all stages of maturity.

The difference between the frozen and canned products are highly significant (1% level) at the immature stage of maturity and significantly different (5% level) at the optimum stage of maturity with no difference at the mature stage. This difference is about 30% at the immature stage and 20% at the optimum stage. Another interesting observation on the data is that at the mature stage the difference is 13%, but this value is not significantly different. This means that the difference between varieties is greater than the effect of processing at this stage of maturity. In the statistical calculations this gives a high standard deviation which compensates for the high difference between the means for these values. The difference between the fresh product and the frozen product is not significant at any stage of maturity.

EFFECT OF MATURITY ON THE QUALITY AND CHEMICAL CHANGES IN SNAP BEANS

The same mean values of the chemical constituents were used (Table 2).

These data show that alcohol insoluble solids, total solids, easily hydrolyzable reserve polysaccharides, cellulose and nitrogen are all factors affected by maturity. Since they increase with an increase in percent by weight of seeds, the "F" values were determined and for these factors they were all found to be highly significant (1% level). Thus, any one of these factors could be determined with a high degree of assurance for measuring the stage of maturity of the snap beans whether in fresh, frozen or canned condition.

In the fresh sample the cellulose values are most affected by maturity, showing an increase of 30% ("F" - 93.97) with maturity. This is followed by easily hydrolyzable reserve polysaccharides with an increase of 55% ("F" - 37.12) with maturity and then by total solids with an increase of 24% ("F" - 35.92) with maturity. These data are given in Table 2. In every case the "F" values are highly significant, although, of course, no attempt has been made to compare "F" values as their fluctuations depend upon the degrees of freedom and the random effects within the samples. However, this should emphasize the importance of using statistics in evaluating these types of data as otherwise inferences could be drawn from the means that might be misleading.

In the frozen product, cellulose content gives the highest "F" value followed by easily hydrolyzable reserve polysaccharides and total solids with an increase in the mean values of 21% ("F" - 56.88), 37% ("F" - 33.66), and 30% ("F" - 32.43) respectively, with maturity. The same statements should apply here as to the use of mean values, percentage increase and the statistical evaluation of the data.

In the canned product, total solids gives the highest "F" value, followed by nitrogen content, alcohol insoluble solids and then cellulose. The percentage increase with maturity is 39, ("F" - 47.42), 30 ("F" - 40.89), 48 ("F" - 14.72), and 38 ("F" - 14.46), respectively. All of the values have a very high "F" value and the percentages are great enough so that any one of these values should make good indices of quality.

With these above statements in mind, the mean values for all the varieties for the three stages of maturity as shown in Charts I through VIII could be used as quality levels for these different factors. Table 5 is proposed as a chemical standard for each of the grades for the different chemical constituents that give significantly high "F" values.

TABLE 5. Proposed Chemical Standards of Quality
(Maximum values for maximum percent by weight seeds)

Process	Stage of maturity percent by weight seeds	Chemical constituent percent				
		Alcohol in-soluble solid	Total solid	Nitro-gen	Cellu-lose	Reserve polysac-charides
	8.0	5.3	8.4	.17	.96	1.5
Frozen	16.0	6.6	10.0	.22	1.08	2.2
	25.0	8.7	12.3	.30	1.22	3.2
	8.0	5.4	9.0	.175	1.14	1.8
Fresh	16.0	7.0	10.8	.225	1.34	2.7
	25.0	9.2	13.0	.275	1.54	3.7
	8.0	4.9	7.0	.155	1.05	1.1
Canned	16.0	6.7	9.0	.20	1.32	1.7
	25.0	9.2	11.4	.26	1.66	2.5

EFFECT OF VARIETY ON FIBER CONTENT

One of the major problems confronting the snap bean processors today is the maximum tolerances set by the Food and Drug Administration for fiber on the canned product. This value was originally (1947) set at 0.12%, however, in June 1948 the tolerance was raised to 0.15% since many processors could not meet this lower level. Therefore, one of the major portions of this problem was to determine the fiber content and show its relationship to the individual varieties. Difficulty was encountered at the time of harvest in obtaining the monel screen and the double scallop stirrer; consequently, the fiber values were not determined on the fresh product. It was thought that the cellulose values would be approximately the same for the fresh product and for the two processed products and that the values for fiber of the frozen or the canned product would be identical. However, as will be pointed out, this was not the case. In addition to this chemical procedure, a taste panel was established and tenderness was evaluated by this panel. The statistical correlation values (Table 1) for the percent by weight seeds and fiber, (frozen product + 0.582, canned product + 0.292); percent by weight seeds and tenderness (frozen product — 0.700 and canned product —

0.570) and fiber and tenderness (frozen product — 0.670 and canned product —0.769). All of these values are highly significant at the 1% level except for the percent by weight seeds and fiber of the canned product. Here the (r) value is significant at the 5% level.

The frozen samples, as a whole, have slightly higher fiber content than the comparable canned samples (Appendix Tables II and III). This suggests one of two factors contributing to this difference in fiber content: (1) the procedure of determining fiber may not be as accurate on the frozen sample as on the canned samples since more fiber is usually found. The method that was used in this study was reported for use on canned samples only and consequently, may not be an acceptable procedure for the frozen product since the frozen product had not been heat processed for 20 minutes at a temperature of 240° F. However, the values for the different varieties show an increase in fiber content with maturity and these values are proportionate to that of the canned product although slightly higher values were found. (2) The fiber content may be broken down somewhat on canning due to the high temperature and pressure used in the processing of canned snap beans. This has never been reported in the literature reviewed by the writer, nor has the percent fiber content on the raw product been compared with that of the frozen or canned. An additional fact, as previously mentioned, was the effects of freezing on the cellulose content. Here the values were found to be somewhat less than the values for the canned or the fresh sample. Thus, with an increase in fiber content on the frozen sample over the canned, and a decrease in cellulose content on the frozen sample over the canned or the fresh, these data are difficult to explain as to exactly what is taking place within these tissues during the freezing process.

Some varieties of snap beans were found with low fiber content in the frozen product, that is, fiber content below 0.15% at all stages of maturity under investigation. These varieties are: Burpee Stringless Green Pod, Tendergreen, Pencil Pod Black Wax, Giant Stringless Green Pod and Landreths' Stringless Green Pod. None of these varieties were over 20% by weight seeds, which in the frozen product is not exceeding the commercial samples examined on the market, previous to this work, by the writer. As mentioned previously no standard for percent by weight seeds has been established on the frozen product. Varieties that definitely should not be recommended for freezing due to high fiber content are Bountiful, Idaho Refugee, Logan, Tennessee Green Pod, Improved Golden Wax, Sure Crop Wax, Hopkins Earliest Red Valentine, Stringless Black Valentine, Plentiful, Stringless Keystonian, Improved Commodore, U. S. Refugee No. 5, and Florida Belle.

In the canned product, varieties found to meet the fiber standards of 0.15% and percent by weight seeds under 16% or in the grade A and B range are: Idaho Refugee, Giant Stringless Green Pod, Asgrow Stringless Green Pod, and Landreths' Stringless Green Pod. Varieties that are definitely unsuitable for canning are Bountiful, Tennessee Green Pod, Hopkins Earliest Red Valentine, Sure Crop Wax, Stringless Black Valentine, Florida Belle, Stringless Refugee, U. S. Refugee No. 5, Improved Commodore, Pencil Pod Black Wax and Keystonian. Had more samples been available for processing a better evaluation of all the varieties could have been made. However, this should suffice to show that fiber is an index of quality for each variety at the different stages of maturity and thus it should be evaluated accordingly. Some varieties develop more fiber than others and some develop fiber at an earlier stage of maturity than others. In addition, it has been reported that temperature does have an effect on the development of fiber (14). However, these varieties were all grown at the same time, although some matured later than others, and they were grown in the same plots so within reasonable limits it should be safe to conclude that fiber development is primarily due to variety and not to other factors. Another observation is noted. In the literature, mention is made of the variety Rival and its relative freedom from developing fiber content. The work reported here on the frozen product shows that this variety has a fiber content of .34% at the maximum percent by weight seeds (25%). This fact suggests that processors must have varieties evaluated within their own production areas, if climatic conditions do effect fiber development; or processors cannot rely wholly on seedsmen's statements as to the amount of fiber in the particular varieties at the different stages of maturity.

OBJECTIVE MEASUREMENTS OF QUALITY

Table 1 summarizes some of the correlations of objective and subjective measurements of quality. The data show the ascorbic acid content for the wax varieties to be very high even at the immature stage, thus explaining the reason for ascorbic acid value not correlating with maturity. Thus instead of obtaining a straight line for the correlation curve, it is a parabolic curve.

The value found with the highest positive correlation was seed length. This would seem to be an excellent objective measurement of maturity in contrast to deseeding of the pericarps and weighing the seeds. The length of the seeds could be measured directly in the field since weighing equipment would not be needed and a very reliable indication of maturity could be had. The values proposed as maximums to correspond with the immature, optimum and mature stages of maturity are: 9, 13 and 17 millimeters, respectively.

Seed width was also found to give a high positive correlation with maturity. This could be used as an indication of maturity, although the measurement is more precise than the values for seed length since they are less than ½ the seed length values. Maximum suggested values for seed width are 4 mm. for immature, 7 mm. for optimum and 10 mm. for the mature snap beans. These recommended values are for all varieties, however, they are the mean values and naturally some varieties would be found at the extremes of the range for the different stages of maturity.

Flavor, although a subjective method, was found to give a high significant correlation with maturity, that is, percent by weight seeds. Tenderness and fiber as previously discussed were also found to give a high correlation with maturity on both the canned and frozen samples.

In addition to these factors, clearness of liquor on the canned product gave a negative correlation of —0.63 which was found to be highly significant (1% level). Thus, by subjectively evaluating the clearness of the liquor or brine the stage of maturity could be indicated. There are some that would not agree with this statement, but it is made on the basis of preparing samples as they were in this study. On the other hand, it is possible that cloudy liquors can be made by using pieces of snap beans, extra long cook, excessive agitation and/or cloudy waters or brines. None of these factors were evaluated as such, but it is possible that they could give the same effect as maturity.

An instrument called the Texture Meter was used to evaluate tenderness. The values on the raw product were found to give a significant correlation value with maturity (—0.55). This should indicate the value of using this instrument on the raw product as a quality control measurement for tenderness. This is further substantiated by the evaluation of tenderness on the processed product which showed that tenderness decreased with maturity.

Tough strings were also determined on the canned product. Varieties that should be eliminated on account of this factor are Tennessee Green Pod, Red Valentine, Sure Crop Wax, Florida Belle, Stringless Refugee, Bountiful and U. S. Refugee No. 5. Most varieties have had the strings eliminated from them through the improvements by breeding. Nevertheless, some varieties still have tough strings and for canners specifically to meet the minimum standard of quality, they should use varieties that are free of tough strings.

SUMMARY

There is no significant difference in the chemical composition between the fresh product and the frozen product except at the immature stage of maturity for the alcohol soluble solids content and at the optimum stage of maturity for the cellulose content. Differences for both values are significant. However, at the optimum and mature stage of maturity for the alcohol soluble solids content and at the immature and mature stage for the cellulose content the differences are not significant, thus indicating that the fresh and the frozen snap beans are nearly identical in chemical composition.

The canned product differs significantly in chemical composition from the fresh product at all stages of maturity in soluble solids, total solids and easily hydrolyzable reserve polysaccharides content. A significant difference exists at the immature stage in alcohol insoluble solids content and at the optimum stage of maturity for alcohol insoluble nitrogen content and pectin content. These values are all lower in the canned product when compared to the fresh product, thus indicating that the canning process leaches out a significant portion of these chemical constituents to the liquor surrounding the beans.

The canned product differs significantly in chemical composition from the frozen product at all stages of maturity in alcohol soluble solids content. A significant difference exists at the immature stage of maturity for alcohol insoluble solids, total solids, easily hydrolyzable reserve polysaccharides and ash content. At the optimum stage of maturity a significant difference was found in the total solids, easily hydrolyzable reserve polysaccharides, cellulose and alcohol insoluble pectin contents. Finally a significant difference was found at the mature stage of maturity for cellulose content. These values are all lower for the canned product when compared to the frozen product except for cellulose content. This indicates that the canning process leaches out a significant portion of these chemical constituents to the liquor surrounding the beans.

In the fresh product, cellulose, easily hydrolyzable reserve polysaccharides, total solids, alcohol insoluble solids, alcohol insoluble nitrogen and alcohol insoluble pectin contents were found to increase with maturity. These constituents gave highy significant differences between stages of maturity suggesting their use as quality indices.

In the frozen product, cellulose, easily hydrolyzable reserve polysaccharides, total solids, alcohol insoluble nitrogen and alcohol insoluble solids were found to increase with maturity. These constituents gave significant differences between stages of maturity suggesting their use as quality indices.

In the canned product, total solids, alcohol insoluble nitrogen, alcohol insoluble solids, cellulose, and easily hydrolyzable reserve polysaccharides were found to increase with maturity. These constituents give highly significant differences between stages of maturity suggesting their use as quality indices.

Seed length was found to give a highly significant correlation with maturity (+ .89). Proposed maximum seed length at the immature stage — 9 mm., optimum stage — 13 mm., and mature stage — 17 mm.

Seed width was found to give a highly significant correlation with maturity (+ .80). Proposed maximum seed width at the immature stage — 4 mm., optimum stage — 7 mm., and the mature stage — 10 mm.

Both seed length and seed width measurements are quicker methods for determining maturity than deseeding the pods and weighing the seeds and thus are suggested as the best quick objective methods for maturity determinations.

In the frozen product the varieties with low fiber content at all stages of maturity under investigation were: Burpee Stringless Green Pod, Tendergreen, Pencil Pod Black Wax, Giant Stringless Green Pod, and Landreths' Stringless Green Pod.

Varieties that should not be recommended for freezing due to high fiber content were: Bountiful, Idaho Refugee, Logan, Tennessee, Green Pod, Improved Golden Wax, Sure Crop Wax, Hopkins Earliest Red Valentine, Stringless Black Valentine, Plentiful, Stringless Keystonian, Improved Commodore, U. S. Refugee No. 5, and Florida Belle.

Varieties found with low fiber content in the canned product (under 16.0% by weight seeds) were: Idaho Refugee, Giant Stringless Green Pod, Asgrow Stringless Green Pod, and Landreths' Stringless Green Pod.

Varieties found to be unsuitable for canning due to excess fiber content were: Bountiful, Tennessee Green Pod, Hopkins' Earliest Red Valentine, Sure Crop Wax, Stringless Black Valentine, Florida Belle, Stringless Refugee, U. S. Refugee No. 5, Improved Commodore, Pencil Pod Black Wax and Keystonian.

Varieties that should not be recommended for processing due to tough strings are: Tennessee Green Pod, Red Valentine, Sure Crop Wax, Florida Belle, Stringless Refugee, Bountiful and U. S. Refugee No. 5.

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APPENDIX

TABLE I. Relationship of Stage of Maturity to Quality Factor for 47 Varieties of Snap Beans (Fresh Product Analysis)

Code	Variety, seed house and lot number	Percent by weight seeds	Maerz and Paul's color	Texture meter value (av. 3-50 gm.)	Ascorbic acid content (Mg/100 gm.)	Number pods/ 100 grams	Length (cm.) range	Length (cm.) ave.	Shape
101	Bountiful	5.2	20L 7	207		15	9 -15	12	Sl. curved
	(Woodruff 29926)	12.5	21J 6	213	9.3	12	6 -14	12	Flat
		13.5	21J 6	222	17.1	13	9 -14	12	
102	Burpees St.` Gr.† Pod	3.5	21 I 8	260		19	8½-14	13½	Sl. curved
	(Woodruff 29578)	8.0	21 I 6	260	19.0	17	8 -13	10	Round
		34.0	21 I 6	300	14.0	12	9 -13	11½	
103	Tendergreen	7.8	21K6	278	6.6	17	9 -11	10	Sl. curved
	(Woodruff 29922)	13.5	21J 6	269	14.08	14	8 -13	10½	Round
		21.4	21J 7	288	16.85	14	10 -13	11	
104	Improved Kidney Wax	6.8	19 I 7-19J 1	210	24.6	17	6 -12	10	Straight
	(Asgrow 56422)								Flat
105	Bountiful	4.6	21K7	215		21	7½-15	13½	Sl. curved
	(Asgrow 16646)	14.7	21J 5	221	19.8	13	7 -14	13½	Flat
		27.8	21K7	298	16.24	10	11 -15	14	
106	Idaho Refugee			225					Sl. curved
	(Asgrow 56412)	13.0	21J 5	250	14.8	20	7 -11	9	Round
		25.0	20B5	252	16.24	23	8 -11	10½	
107	Asgrow St. Gr. Pod	4.6	21K8	263		24	5½-13	10	Curved
	(Asgrow 56316)	15.6	21 I 7	265	11.8	13	9 -12	11½	Round
		17.5	21J 6	293	16.3	13	8 -13	11	
108	Low's Champion	9.0	21G5	233	27.7	20	6 - 9	8	Fairly str.
	(Asgrow 56278)								Round
109	Logan	7.4	21 I 7	220	6.8	18	9 -13	11	Sl. curved
	(Asgrow 56448)	3.8	21 I 6	243	5.8	16	9 -12	10½	Round
		14.0	21 I 6	251	7.9	13	10 -13	11	

TABLE I. Relationship of Stage of Maturity to Quality Factor for 47 Varieties of Snap Beans (Fresh Product Analysis)—Continued

Code	Variety, seed house and lot number	Percent by weight seeds	Maerz and Paul's color	Texture meter value (av. 3-50 gm.)	Ascorbic acid content (Mg/100 gm.)	Number pods/ 100 grams	Length (cm.) range	Length (cm.) ave.	Shape
110	Brittle Wax (Asgrow 56375)	10.6	19 I5-19 I1	273	22.8	19	5 -11	10	Curved Round
111	Tiny Green (University of N. H.)	21.0	21E6	272		27	6 - 9	7½	St. curved Round
112	Logan	6.2	19H7	220	9.8	19	7 -11	10	Straight Round
113	Unrivaled Wax (Livingston 2950)	7.4	19H4-19H1	198	22.9	21	9 -12	11	St. curved Round
114	Streamliner	3.3	21K7	235	14.7	20	10 -14	12½	Straight
	(Livingston 3603)	7.3	21K7	242	18.6	15	10 -15	12½	Flat
115	Tenn. Gr. Pod	6.0	21 I6	215	14.1	24	8 -15	11	Nearly
	(Livingston 3449)	10.2	21J 7	198	18.0	16	9 -14	11	straight
		11.4	21K7	205	10.54	14	9 -13	11	Very flat
116	Improved Golden Wax (Livingston 3688)	10.2	21 I5-21 I1	210	25.9	20	7 -12	9½	Straight Flat
117	Sure Crop Wax (Livingston 3687)	7.4	19J 6-19J 2	190	24.6	20	9 -13	11	Curved Flat
118	Pencil Pod Black Wax	3.71	20K6-20 I1	280	6.5	22	8 -12	9	Curved
	(Livingston 3686	9.7	19K6-19 I1	265	8.7	15	9 -13	11	Round
		18.0	19J 5-19J 1	272	9.3	15	8 -13	11	
119	Hopkins Earliest Red Valentine	7.3	22J 7	233	5.8	23	7 -11	10	Sl. curved
	(Livingston 3447)	9.5	21K7	239	5.4	17	9 -13	11	Medium
		18.0	21K7	258	2.1	15	8 -10	10	Flat

TABLE I. Relationship of Stage of Maturity to Quality Factor for 47 Varieties of Snap Beans (Fresh Product Analysis)—Continued

Code	Variety, seed house and lot number	Percent by weight seeds	Maerz and Paul's color	Texture meter value (av. 3-50 gm.)	Ascorbic acid content (Mg/100 gm.)	Number pods/ 100 grams	Length (cm.) range	Length (cm.) ave.	Shape
120	Asgrow Valentine (Livingston 3359)	7.9	21J 6	210	12.2	14	10 -13	12	Curved ends Med. round
121	Giant St. Gr. Pod (Livingston 3020)	5.9	21K7	270	9.0	21	9 -13	11	Sl. curved tips Med. round
123	St. Keystonian (Livingston 3423)	14.6	21J 6	242	14.3	15	8 -13	11½	Fairly Str. Round
124	Tenderpod (Livingston 3790)	3.0	21H8	164	14.0	22	7 -13	9	Str. round
125	St. Gr. Pod (Livingston 3683)	6.7	21 I 6	260		16	7 -13	11	Curved tips Med. round
126	Tendergreen (Livingston 3363)	7.04	21J 6	268	13.4	16	6 -12	10	Curved tips Round
127	Bountiful (Livingston 3113)	9.52	21J 6	193	13.8	14	10 -15	13	Sl. curved Round
129	Sure Crop Wax	6.5	20K4-20J 1	228	13.7	17	10 -13	11	Sl. curved
	(Ferry-Morse 55440)	11.2	19K3-19J 1	230	24.6	13	10 -13	11	Flat
		8.7	19K2-19J 1	247	25.1	11	10 -13	12	
130	Plentiful (Ferry-Morse 19006)	3.92	21H7	218		24	8 -14	11	Sl. curved Flat
131	St. Black Valentine	4-¾	21J 6	216	10.9	19	7 -13	11	Sl. curved
	(Ferry-Morse 58435)	8	21J 6	211	21.1	17	9 -13	12	Med. flat
		17	21J 7	246	14.0	15	9 -15	13	

TABLE I. Relationship of Stage of Maturity to Quality Factor for 47 Varieties of Snap Beans (Fresh Product Analysis)—Continued

Code	Variety, seed house and lot number	Percent by weight seeds	Maerz and Paul's color	Texture meter value (av. 3-50 gm.)	Ascorbic acid content (Mg/100 gm.)	Number pods/ 100 grams	Length (cm.) range	Length (cm.) ave.	Shape
132	Round Pod Kidney Wax (Ferry-Morse 58542)	8.4	19 I5-19 I1	254	25.7	19	7 - 9	8	Curved Round
133	Florida Belle	4.3	21J 6	193	18.8	16	12 -16	14	Straight
	(Ferry-Morse H 5024)	25.0	21J 6	300	11.6	14	10 -15	14	Flat
134	Tendergreen	2.3	21J 8	271			6½-13	9½	Sl. curved
	(Ferry-Morse 58585)	11.4	21H6	271	12.2	17	9 -12	10	Round
		7.6	21 I6	253	9.7	15	8 -12	10	
		20.0	21 I6	275	17.3	14	9 -14	13	
135	Black Seeded Wax Pod	3.24	19J 5-19J 2	206	20.1	16	10 -14	13	Sl. curved
	(Ferry-Morse H6028)	5.04	21J 7-21J 1	210	27.4	11	10 -14	13	Flat
136	Giant St. Gr. Pod		21K7	272		23	6 -12	8½	Sl. curved
	(Ferry-Morse C5724)	10.0	21 I6	262	10.5	22	8 -12	10	Round
			21K7	288	11.5	16	10 -13	11	
		20.0	21J 6	292	12.5	13	10 -14	12	
137	Idaho Refugee	6.86	21J 5	253	14.9	24	7 -11	9	Sl. curved
	(Ferry-Morse 58560)	22.4	21B5	247		21	8 -11	10	Round
138	Landreths St. Gr. Pod	3.0	21 I6	264		22	8 -13	11	Sl. curved
	(Ferry-Morse 58425)	8.8	21 I6	236	16.6	17	7 -12	11	Round
		14.3	21J 7	293	10.5	14	9 -12	11	
139	St. Kidney Wax (Ferry-Morse 58575)	11.0	19H1-19 I6	210	26.8	18	8 -13	10	Straight Flat
140	St. Refugee (Ferry-Morse 59663)	24.6	21K7	246		15	9 -12	11	Curved Round

TABLE I. Relationship of Stage of Maturity to Quality Factor for 47 Varieties of Snap Beans (Fresh Product Analysis)—Concluded

Code	Variety, seed house and lot number	Percent by weight seeds	Maerz and Paul's color	Texture meter value (av. 3-50 gm.)	Ascorbic acid content (Mg/100 gm.)	Number pods/100 grams	Length (cm.) range	Length (cm.) ave.	Shape
141	Pencil Pod Wax		21L6-21L1	253		23	6 -10	9	Curved
	(Ferry-Morse 58490)	9.92	19L5-19J 1	273	9.2	18	7 -12	10	Round
			19 I5-19J 1	288	20.0	16	8 -10	9	
142	Bountiful	3.4	21 I6	210		22	7 -14	11	Curved
	(Ferry-Morse 18964)	11.2	21 I6	200	21.5	14	8 -12	11	Flat
		24.3	21K7	283	14.6	12	10 -14	12	
145	Tendergreen		21 I6	264		24	7 -10	5	Curved
	(Corneli 6118)	8.6	21J 6	287	7.3	22	7 -13	10	Round
		8.8	21H6	278	14.8	14	9 -12	10	
		19.8	21J 6	300	18.8	13	10 -12	10½	
146	Keystonian		21 I6	252		22	8 -12	10	Curved
	(Corneli 4085)	13.8	21 I6	252	16.2	17	7 -11	10	Round
		10.4	21K7	295	9.85	12	9 -13	12	
147	Improved Commodore	8.32	21 I7	235		14	11 -18	15	Fairly str.
	(Corneli 6026)	12.0	21G6	232	14.0	14	12 -16	14½	Round
148	Tenderpod	3.56	22J 7	180	10.9	24	8 -10	9	Straight
	(Corneli 6150)								Round
149	U. S. Refugee #5	14.0	21J 5	277	15.8	20	7 -11	10	Nearly str.
	(Corneli 6106)	33.6	20B5	287		21	9 -12	11	Round
150	Rival	3.56	21H5	207	14.0	17	8 -13	12	Straight
	(U. S. D. A.-B. P. I.)			236					Round
		25.0	21H6	295		10	12 -13	12½	

*St.—Stringless. †Gr.—Green.

TABLE II. Relationship of Stage of Maturity to Quality Factor for 38 Varieties of Snap Beans (Frozen Product Analysis)

Code	Variety	Percent by weight seeds	Pod width (mm)	Pod thickness (mm)	Seed length (mm)	Seed width (mm)	Flavor (1 to 10 pts.)	Tenderness (1 to 10)	Percent fiber content	Seed color
101B	Bountiful	13.0	14	7‡	10	7	9.0	7.3	.126	Green
101C	Bountiful	18.5	14	8‡	14	8	9.0	7.0	.320	Purple
102A	Burpees St.* Gr.† Pod	3.5	9	7		2	8.6	9.0	.087	Green
102B	Burpees St. Gr. Pod	11.5	10	10	13	7	8.5	8.5	.052	Gray
102C	Burpees St. Gr. Pod	10.5	10	10	13	7	8.5	8.0	.086	Gray
103A	Tendergreen	7.5	9	9	10	6	8.75	8.25	.040	Light green
103B	Tendergreen	12.5	11	9	11	6	8.5	6.75	.118	Gray
105A	Bountiful	3.0	11	5‡	7	3	8.25	8.5	.191	Green
105B	Bountiful	14.0	13	7‡	11	6	7.5	5.25	.197	Light gray
105C	Bountiful	26.0	15	8‡	16	9	4.5	4.5	.634	Gray
106A	Idaho Refugee	4.0	9	8	7	3	8.75	8.5	.195	Green
106B	Idaho Refugee	10.5	9	9	11	6	8.0	7.5	.205	Light green
106C	Idaho Refugee	25.5	14	11	14	7	7.5	6.0	.311	Purple
107A	Asgrow St. Gr. Pod	4.0	9	9	9	4	7.75	7.5	.073	Green
107B	Asgrow St. Gr. Pod	8.5	11	10	11	6	7.5	7.0	.071	Light purple
107C	Asgrow St. Gr. Pod	15.5	12	11	15	9	8.75	7.75	.557	Light gray
108B	Lows' Champion	9.0	14	7	9	7	8.25	7.75	.194	Green
109A	Logan	6.0	9	9	9	5	9.25	8.75	.109	Light green
109B	Logan	10.0	10	9	10	6	9.0	7.75	.058	Gray
109C	Logan	13.5	10	10	12	6	8.75	7.75	.199	Gray
111C	Tiny Green	20.0	10	8	14	7	8.25	7.75	.176	Light gray
112A	Logan	7.0	9	9	9	5	8.5	8.5	.399	Green
113A	Unrivaled Wax	6.5	10	5‡	8	4	8.75	9.0	.167	Light gray
114A	Streamliner	3.0	10	5‡	8	5	8.5	8.0	.134	Green
114B	Streamliner	5.0	10	7‡	8	5	7.5	6.25	.322	Green
115B	Tennessee Gr. Pod	10.0	15	5‡	10	7	7.0	3.5	.194	Gray
115C	Tennessee Gr. Pod	20.0	15	7‡	12	8	6.75	3.25	.361	Gray

TABLE II. Relationship of Stage of Maturity to Quality Factor for 38 Varieties of Snap Beans (Frozen Product Analysis)—Continued

Code	Variety	Percent by weight seeds	Pod width (mm)	Pod thickness (mm)	Seed length (mm)	Seed width (mm)	Flavor (1 to 10 pts.)	Tenderness (1 to 10)	Percent fiber content	Seed color
116A	Improved Golden Wax	7.0	14	5‡	9	7	8.6	8.0	.346	Gray
117B	Sure Crop Wax	9.0	13	8‡	11	6	8.6	7.6	.270	Gray
118A	Pencil Pod Black Wax	7.0	9	9	9	5	8.6	9.0	.093	Grayish green
118B	Pencil Pod Black Wax	10.0	10	10	11	6	8.6	8.0	.066	Gray
118C	Pencil Pod Black Wax	16.0	10	10	14	7	8.6	8.3	.112	Gray
119A	Hopkins Earliest Red Valentine	9.5	9	8	10	5	8.0	6.0	.342	Light green
119B	Hopkins Earliest Red Valentine	14.0	10	10	13	7	7.6	4.0	.328	Gray
119C	Hopkins Earliest Red Valentine	18.0	10	10	16	8	5.0	1.0	.441	Gray
120B	Asgrow Valentine	8.0	10	7	9	5	7.6	6.3	.130	Green
121B	Giant St. Gr. Pod	7.5	11	8	7	5	9.0	9.0	.076	Green
123B	Stringless Keystonian	8.5	10	7	11	6	9.0	8.6	.056	Grayish green
125B	Stringless Green Pod	10.5	12	10	11	6	9.0	8.0	.156	Grayish green
127B	Bountiful	10.0	14	7‡	11	7	8.75	7.0	.155	Light gray
128B	Plentiful	9.0	12	7‡	9	6	9.25	8.75	.225	Lt. gray-green
129B	Sure Crop Wax	8.5	13	9‡	8	5	8.75	8.0	.174	Lt. gray-green
129D	Sure Crop Wax	17.0	14	9‡	15	9	7.5	5.75	.401	Gray
130B	Plentiful	6.0	12	8‡	7	4	9.0	9.0	.108	Green
131A	St. Black Valentine	6.0	9	6‡	9	4	8.5	7.25	.146	Green
131B	St. Black Valentine	13.0	11	8‡	12	7	8.5	7.0	.382	Gray to green
131C	St. Black Valentine	10.0	14	9‡	12	7	8.0	6.5	.312	Gray to green
133A	Florida Belle	5.5	12	6‡	9	6	8.5	7.75	.292	Gray to green
133B	Florida Belle	23.0	13	7‡	15	8	5.5	2.25	1.140	Gray

TABLE II. Relationship of Stage of Maturity to Quality Factor for 38 Varieties of Snap Beans (Frozen Product Analysis)—Concluded

Code	Variety	Percent by weight seeds	Pod width (mm)	Pod thick-ness (mm)	Seed length (mm)	Seed width (mm)	Flavor (1 to 10 pts.)	Ten-der-ness (1 to 10)	Percent fiber content	Seed color
134B	Tendergreen	7.0	10	10	10	5	8.0	7.75	.089	Green
134C	Tendergreen	13.0	11	10	13	7	6.5	4.5	.124	Light gray
134D	Tendergreen	19.5	10	10	16	8	8.75	8.0	.132	Gray
136B	Giant St. Gr. Pod	7.5	9	7	9	6	8.75	8.25	.050	Light green
136C	Giant St. Gr. Pod	13.5	10	8	14	8	8.75	7.75	.074	Gray
136D	Giant St. Gr. Pod	22.0	10	12	16	8	8.75	7.5	.216	Gray
137A	Idaho Refugee	11.0	8	7	11	6	9.0	8.25	.289	Light gray
137B	Idaho Refugee	21.0	8	10	14	6	8.75	7.0	.267	Gray
138B	Landreths' St. Gr. Pod	9.5	11	9	10	6	8.6	8.3	.097	Gray to green
138C	Landreths' St. Gr. Pod	18.5	13	11	13	9	8.3	7.0	.164	Gray to green
141B	Pencil Pod Wax	9.0	10	10	10	6	8.0	7.6	.081	Light gray
142A	Bountiful	4.0	12	5‡	7	4	8.6	7.6	.219	Green
142B	Bountiful	18.0	15	7‡	12	7	8.0	5.3	.337	Green
142C	Bountiful	30.0	15	10	17	10	3.3	1.3	.733	Light gray
145B	Tendergreen	10.0	10	10½	10	6	8.25	7.75	.080	Light green
145C	Tendergreen	13.5	10	11	13	7	8.0	7.75	.091	Light gray
145D	Tendergreen	18.0	10	11	15	8	8.0	7.75	.218	Gray
146B	Keystonian	14.0	11	9	11	7	8.5	8.25	.118	Gray
146C	Keystonian	15.0	12	11	14	7	8.25	7.25	.199	Light gray
147A	Improved Commodore	10.0	10	8	12	7	8.75	8.25	.158	Light green
147B	Improved Commodore	8.0	11	9	11	6	8.25	7.5	.097	Light green
149A	U. S. Refugee No. 5	16.0	9	9	11	7	8.0	6.25	.487	Gray
149B	U. S. Refugee No. 5	25.0	9	9	15	7	8.25	7.75	.318	Gray to green
150A	Rival	4.0	8	10	6	4	8.75	8.5	.115	Green
150B	Rival	25.5	8	12	15	8	7.75	6.25	.342	Gray

*St.—Stringless. †Gr.—Green. ‡Flat podded varieties.

TABLE III. Relationship of Stage of Maturity to Quality Factor for 28 Varieties of Snap Beans (Canned Product Analysis)

Code	Variety	Percent by weight seeds	Clear-ness liquor (1 to 5)	Sedi-ment in liquor (cc/can)	Flavor (1 to 10)	Tender-ness (1 to 10)	Percent fiber content	Tough strings
101A	Bountiful	2.8	5	0	7.75	9.75		None
101B	Bountiful	11.2	4	1	5.75	7.25		None
101C	Bountiful	15.4	2	10	6.75	6.25		None
102B	Burpees St.* Gr.† Pod	10.3	3	2	7.25	7.50	.016	None
102C	Burpees St. Gr. Pod	19.5	3	2	6.50	7.0	.159	None
103A	Tendergreen	10.0	5	0	7.0	9.0	.055	None
103B	Tendergreen	13.0	2	6	7.0	7.0	.075	None
103C	Tendergreen	19.0	1	15	7.75	8.0	.161	None
105B	Bountiful	13.0	3	1	8.0	8.25	.080	None
105C	Bountiful	30.0	3	2	6.0	6.0	.256	None
106A	Idaho Refugee	4.3	4	0	9.0	9.50	.060	None
106B	Idaho Refugee	11.5	3	2	9.50	9.25	.066	None
106C	Idaho Refugee	22.0	0	65	8.25	5.0	.129	None
107B	Asgrow Stringless	8.3	4	2	8.75	8.50	.041	None
107C	Asgrow Valentine	17.0	2	10	6.75	5.25	.101	None
109A	Logan	6.0	5	0	9.0	9.0	.046	None
109B	Logan	6.5	5	0	9.0	9.0	.050	None
109C	Logan	12.1	4	1	8.0	6.5	.140	None
112C	Logan	6.0	5	0	8.5	8.0	.072	None
115B	Tennessee Gr. Pod	10.0	3	2	8.25	7.0	.172	Excessive
115C	Tennessee Gr. Pod	17.0	3	3	7.0	3.5	.461	Excessive
118B	Pencil Pod Black Wax	10.0	3	3	8.25	8.0	.048	None
118C	Pencil Pod Black Wax	13.0	4	10	8.75	8.25	.226	None
119A	Hopkins Earliest Red Valentine	5.7	5	0	8.25	4.0	.451	Excessive
119B	Hopkins Earliest Red Valentine	14.0	4	1	6.60	2.3	.489	Excessive
119C	Hopkins Earliest Red Valentine	17.5	4	1	6.60	1.6	.544	Excessive
120B	Asgrow Valentine	7.5	5	0	8.60	8.3	.142	None
129B	Sure Crop Wax	10.0	3	1	6.00	5.0	.341	Excessive

TABLE III. Relationship of Stage of Maturity to Quality Factor for 28 Varieties of Snap Beans (Canned Product Analysis)—Continued

Code	Variety	Percent by weight seeds	Clearness liquor (1 to 5)	Sediment in liquor (cc/can)	Flavor (1 to 10)	Tenderness (1 to 10)	Percent fiber content	Tough strings
129D	Sure Crop Wax	10.5	3	7	6.30	3.3	.268	Excessive
131A	St. Black Valentine	5.5	5	0	8.30	8.6	.177	None
131B	St. Black Valentine	10.0	4	2	8.0	4.3	.307	None
132A	Round Pod Kidney Wax	6.0	5	0	7.6	8.6	.131	None
133A	Florida Belle	11.0	5	0	7.6	4.6	.492	Slight
133B	Florida Belle	26.0	3	1	4.6	1.0	1.171	Excessive
134C	Tendergreen	10.0	3	2	8.0	8.0	.073	Slight
134D	Tendergreen	13.0	3	7	7.6	7.6	.142	Slight
136C	Giant St. Gr. Pod	13.5	5	1	8.25	8.25	.039	None
136D	Giant St. Gr. Pod	19.5	4	10	8.25	6.0	.098	None
137A	Idaho Refugee	8.5	4	0	8.0	7.5	.104	None
137B	Idaho Refugee	20.0	1	0	6.0	4.25	.109	None
138B	Landreths' St. Gr. Pod	10.0	5	0	8.75	9.0	.045	None
138C	Landreths' St. Gr. Pod	13.0	5	5	7.25	5.75	.066	None
140C	St. Refugee	18.0	3	2	7.5	7.25	.309	Excessive
141B	Pencil Pod Wax	10.0	5	0	8.0	8.0	.022	None
142A	Bountiful	3.0	5	0	9.25	9.25	.227	None
142B	Bountiful	15.0	4	0	8.75	7.75	.349	Slight
142C	Bountiful	25.0	3	3	5.25	3.75	.544	Slight
145B	Tendergreen	8.5	4	0	8.75	8.25	.042	None
145C	Tendergreen	10.0	3	8	8.0	7.6	.285	None
145D	Tendergreen	13.0	4	8	7.6	8.3	.129	None
146B	Keystonian	10.0	5	0	8.6	8.6	.069	None
146C	Keystonian	10.0	5	1	9.0	8.6	.200	None
147B	Improved Commodore	5.0	5	1	9.6	9.0	.176	None
149A	U. S. Refugee No. 5	12.0	3	2	8.6	8.6		None
149B	U. S. Refugee No. 5	23.0	0	50	7.6	5.6	.426	Slight
150A	Rival	2.0	4	2	9.0	8.6	.042	None
150B	Rival	6.5	5	0	7.6	8.6	.072	None

*St.—Stringless. †Gr.—Green.