DETERMINATION OF YIELD, MATURITY, AND VITAMIN C IN SINGLE-HARVEST BUSH SNAP BEANS

by

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I. INTRODUCTION

Most of the snap beans grown in the Pacific Northwest are of the pole types and since these have little possibility for mechanical harvesting, interest has been centered on the bush types. Should the bush varieties lend themselves to mechanical harvesting it would mean a huge saving in labor costs to the processors. However, the introduction of a single harvest in place of the present three and even as high as six pickings, creates new problems. One important problem is the yield — will the mechanical harvest equal the harvests by hand, or how much extra acreage is needed? Another vital consideration is that of maturity, if all the beans on a vine are picked at one time, what percentage will be suitable for processing and what will be the percentage distribution by grades? The effect of a single harvest on the various quality factors must be known. Such factors are vitamin content, fiber, ratio of hull to seed, etc. It will be the responsibility of the field men to decide when the majority of beans in any variety are ready for harvest and they must be right the first time.

In an attempt to find the answers to some of these problems, this research was undertaken.

II. LITERATURE REVIEW

A survey of the literature on green beans reveals that much emphasis has been given to the vitamin content of beans at various stages of maturity as well as vitamin loss during storage and cooking.

At the United States Vegetable Breeding Laboratory in Charleston, South Carolina, Hayden and his associates (11) have taken an increase in vitamin content as one of the objectives in the program of breeding snap beans adapted to that region. In a recent article (11) these workers have stressed the value of snap beans by stating that the commercially canned pack ranks next to those for tomatoes, peas, and corn.

There appears to be some conflicting reports in the literature as to the effect of maturity on the vitamin content of snap beans. The results of work by Mack, Tapley and King, (17) indicate that the variation in ascorbic acid content is greatest with the large seeded varieties. They suggest that the effect may be due to the distribution of vitamin C between the seed and the seed pod. These workers found that on a fresh-weight basis the seeds contained from 3 to 4 times as much ascorbic acid as the seed pod. Hence, they show, ascorbic acid content due to the seeds increases with growth, while that due to the shelled pods decreases rapidly at first and then remains about

constant, resulting in a net effect of minimum ascorbic acid content at the usual stage of maturity at which snap beans are harvested. Kramer (16) has also shown that the seeds contain more ascorbic acid than the pods and his results show increase in ascorbic acid with increasing maturity. Hayden, Heinze and Wade (11) agree with the results of Kramer stating that on a fresh weight basis significantly more thiamin and slightly more ascorbic acid were found in the green-overmature beans. Phillips and Fenton (22) found that Vitamin C concentration was higher in the immature stage than in the mature or over-mature. They have this timely comment to add, "Mack, Tapley and King reported no change in ascorbic acid content of Tendergreen beans with maturity but distribution of the vitamin varying within the vegetable according to the proportion of seed to pod. In interpreting the values found in the literature one should realize that standards of maturity are difficult to define and recognize." Phillips and Fenton also found that the seeds in the over-mature beans on the moist basis, had nearly twice as much ascorbic acid as the pod. From their results it would appear that either there is a loss of vitamin C as the beans mature, or there is a transfer of the vitamin from the pod to the seeds. Wade and Kanapaux (28) found no significant differences between large, medium and small

pods within a strain. Like Mack and co-workers (17) they found that maturity was not associated with large differences in ascorbic acid content of the pods and the beans of mature marketable stage contained the least ascorbic acid. Hibbard and Flynn (13) report that ascorbic acid content gradually increased with maturity and that the summer crop contained approximately 25 percent more than the fall crop. These workers state that for commercial purposes only the immature pods are desired, and a premium is paid for the smaller sizes, which may not be the most nutritious when the vitamin content is considered. Wade and Kamapaux (28) found that varieties with large pods ranked highest in ascorbic acid but some of the smaller podded varieties also ranked high. Caldwell et al (3) concluded, as a result of forty series of determinations upon as many varieties and strains, that ascorbic acid is lowest in youngest beans and increases progressively with increase in weight of pod and in proportion of seed weight to total pod weight. They noted that vitamin C is low in pods in which the seeds constitute only 3 to 4 percent of the total weight and increases rapidly up to a point at which the seeds constitute 11 to 15 percent of the pod weight, after which the increase becomes slow and relatively small in amount. These workers emphasize the fact that if the ascorbic acid content in varieties of

beans varies with the stage of development of the pods, comparison between varieties can be made only with material of a like stage of development. Flynn (9) and her associates are among those who believe that vitamin C gradually increases with maturity. They also found the vitamin C content of the seed to be higher than that in the pod. Troscler, Mack and King (26) studied factors affecting the vitamin C content of vegetables and concluded that vitamin C is approximately the same in all stages of maturity of snap beans. However, they do stress the importance of variety as a factor in variation of ascorbic acid results. Fincke, Perkins and Davey (7) have found that some varieties of snap beans would contribute a relatively small amount of thiamin to the day's dietary while other varieties were quite high in thiamin. Mayfield and Richardson (15) report that raw green string beans are a good source of vitamin A; a good source of vitamin B_1; and an excellent source of vitamin C.

The storage loss in ascorbic acid as shown by Fitzgerald and Fellers (8) amounted to 25 percent when held at 21.1°C (70°F). They report that no loss would have occurred at 2.2°C (36°F). Mack, Tapley and King (17) found a loss of 29 to 60 percent in four varieties held at 21 to 23°C (69.8 to 73.4°F) for one day. Those workers

state that in comparison with other vegetables snap beans lose their vitamin C very rapidly. Wade and Kanapaux (28) find a loss of approximately 2 percent in the vitamin C content when stored at 2.2°C (36°F) for 24 to 48 hours and a loss of approximately 5 percent when held at 21.1°C (70°F). If held for 72 hours at 21.1°C the loss was sharp and significant. A very important factor affecting loss of vitamins in storage has been stressed by the work of Harris et al (10) whose research proves that humidity has a bearing on the retention of ascorbic acid. Their work indicated that the rate of destruction of the vitamin in six vegetables, including snap beans, stored at an average relative humidity slightly less than 65 percent averaged about 64 percent greater than in corresponding samples stored at an average relative humidity of 93 percent.

Considerable research has been conducted on losses of vitamins as a result of blanching and cooking. Phillips and Fenton (22) concluded that blanching in boiling water preparatory to freezing, caused a loss of 13 percent ascorbic acid, 11 percent thiamin and 14 percent riboflavin. Fincke and her group (7) found a loss of 14 to 21 percent thiamin in cooking fresh snap beans. Batchelder, Stein and Sater (2) state that the amount of ascorbic acid is higher with a 2 minute than with a 3 minute scald in boiling water and the percent retention during 9 months

storage at 0°F., is higher in samples scalded 2 minutes than in those scalded for 3 minutes. Bedford and his group (3) found no significant difference between steam blanching and water blanching, although initially there was a slightly less loss of ascorbic acid by steam blanch which, however, showed a greater loss during storage. Mayfield and Richardson (18) maintain that freshly cooked green string beans have lost none of their vitamin A or B_1 potency and are still a good source of vitamin C, even though a 30 to 40 percent loss of this vitamin occurred during cooking. They comment further that canned green string beans, taken from storage and re-heated, appear to be nearly as rich in vitamin A as the freshly cooked beans; but seem to have lost about 40 percent of their vitamin B content. They report the loss in vitamin C is very marked, being 80 to 85 percent of that present in raw beans.

The work carried on by Janes (14) showed an insignificant difference between varieties of snap beans grown in seven different areas of Florida and their dry weight, ascorbic acid and carotene content.

The following table reproduced from the publication of Mayfield and Richardson (18) is of interest from the nutritional aspect. One average serving of 70 grams of cooked green string beans would supply the following:

	Freshly Cooked Beans		Canned Beans Stored and Re-Heated	
	I.U. per serving	Percentage of daily requirement	I. U. per serving	Percentage of daily requirement
Vit. A	840	14 - 28	700	11 - 23
Vit. B_1	23	4 - 8	14	2 - 4
Vit. C	7 - 12mg	10 - 30	3mg.	3 - 10

The review of the literature indicates that there is a need for standardization of the methods used in ascertaining the quality of green beans as well as a need for correlation of quality and nutritive factors. Kramer (15) tells us that the three important factors of quality for green beans are maturity, size and fibrousness. He states that maturity may be measured by the proportion of the weight of seeds to the pods; size by determining the mean diameter from suture to suture and fibrousness by alkali digestion. Maturity is apparently judged in various ways, such as ratio of hull to seed, size of pod, and length of seed. Fiber determinations seem to have been omitted by too many workers while results of starch analyses are seldom seen.

III. EXPERIMENTAL METHODS

1. Planting

There were four varieties of bush snap beans selected for this study, namely U.S.D.A. Rival, Burpee Tender Pod, Burpee Tendergreen and Burpee Stringless Green Pod. These varieties were grown in Hillsboro, Oregon, in the experimental plots of a large commercial frozen food company. Each variety was planted on June 3, 1948, in 3 one-hundred foot rows with 3 foot spacing for 3 rows. The seeding rate for Tender Pod, Tendergreen and Stringless Green Pod was about 25 pounds per acre since this was all of the seed available. Rival was actually planted much thicker (60 pounds per acre) but was thinned down to a comparable stand. Guard rows were also planted on each side of the experimental plot. The experimental plot was fertilized with 100 pounds nitrates, 200 pounds phosphates, 100 pounds potash, and was irrigated three times during the growing season.

2. Harvest

The beans were harvested, upon the advice of an experienced fieldman, when the majority of pods in a variety had reached the optimum stage of maturity for commercial processing. In this work the "optimum stage of

maturity" aimed for, was that which would result in most beans of commercial grades 1 and 2, to be explained later. The harvest was carried out, as near as could be arranged, at 8 o'clock each morning. There was only one harvest of each variety and all bushes, yielding or not, of the variety were harvested by hand and counted into bean bags. Four men participated in the harvest which required 15 to 20 minutes. The bags were immediately hauled by truck to the processing plant. It would be safe to say that the time required from commencement of harvest to arrival at the processing plant was not over one-half hour.

3. Processing

(a) Upon arrival at the processing plant the bushes were weighed and the pods quickly removed by hand, from the vines.

(b) The pods alone were weighed.

(c) The pods were put through a mechanical grader which distributed them according to diameter as follows:

Grade 0 or less than 21/64 inches

Grade 1 or 21/64 inches to, but not including 24/64 inches

Grade 2 or 24/64 inches to, but not including 27/64 inches

Grade 3 or 27/64 inches and over

(d) Each size group was weighed to give percentage distribution.

(e) Each size group was divided equally into two lots, one lot being held for 24 hours at room temperature, the other handled immediately.

(f) 100 pods were selected at random from each size group of the lot handled immediately, and weighed.

(g) The percent crooked pods in each size group was determined using the pods of part (f).

(h) The ratio of hull to seed in each size group was determined using the beans in part (f).

(i) A sample of each group of the fresh beans was used immediately for a vitamin C determination and another sample was sealed in glass jars and frozen immediately, for use in analysis at a later date.

(j) The remainder of the fresh beans were snipped mechanically if possible, by hand if not, weighed, blanched in steam in a small retort for 2 minutes, cooled in running tap water for 1 to 2 minutes and placed in Peters-style consumer cartons. The cartons were labeled, sealed in a wax paper over-wrap and quick frozen. The beans were tested after blanching and cooling for catalase activity by means of the Thompson catalase test (25). The period from harvest to blanch was approximately two

hours.

(k) The delayed samples which had been held for 24 hours at room temperature were re-weighed, snipped and weighed again. A sample was taken for vitamin C determination and another sample taken and held by freezing for further analysis. The remaining pods were processed in similar fashion to the fresh material.

4. Analysis

Each size group of the fresh and 24-hour delay beans were analyzed for the following:

A. Total solids

B. Starch content

C. Crude fiber

D. Ascorbic acid

The methods of analysis were:

A. Total Solids

(1) The jar containing the frozen sample was allowed to thaw at room temperature, whereupon the outside of the jar was dried thoroughly, and the jar plus contents weighed accurately on a triple-beam balance to the nearest 0.1 gm. and estimated to 0.05 gm.

(2) The beans were transferred to a clean, dry Waring Blendor, care being exercised to see that as much moisture as possible was transferred from the jar to

the blendor.

(3) Using a volumetric pipet, exactly 25 ml. of water were added to the Blendor to facilitate blending. A satisfactory blend could not be accomplished unless this technique was employed.

(4) The beans were thoroughly blended (3 to 4 minutes), then a large portion of the blended sample was poured into the sample jar, the lid screwed on and the jar shaken. The sample was then returned to the blendor and given another short blend. The last step was done to incorporate any water droplets remaining in the sample jar, thus yielding a homogeneous sample.

(5) Duplicate samples from the blended mixture which would approximate the specifications called for in the Methods of Analysis of the Association of Official Agricultural Chemists were weighed accurately to 0.1 gram on a triple-beam balance. The samples were weighed in previously heated, cooled and tared aluminum weighing dishes. These dishes were 36.30 sq. cm. in area necessitating a blended sample weighing approximately 10 grams to meet with the aforementioned specifications.

(6) The sample jars and lids were rinsed clean, thoroughly dried inside and out and weighed giving the weight of the fresh sample.

(7) The weighing dishes were placed in the

vacuum oven and dried according to the official methods (20), repeated herein:

Weigh into flat-bottomed dish a portion of sample of such size that dry residue will not be less than 9 mg. nor more than 12 mg/sq. cm. of drying surface. Distribute thinly in even layer over bottom of dish, diluting with H_2O if necessary to facilitate distribution. Place in vacuum oven at 70°C with release cock left partly open so that degree of vacuum does not exceed 450 mm of Hg and moisture evolved is carried off rapidly. Dry air admitted through release cock by bubbling through H_2SO_4. After one hour examine dishes and remove from oven any in which material has reached apparent dryness. Continue this removal of dishes with dried material at subsequent half-hour intervals. After material in all dishes has reached apparent dryness return dishes to oven, nearly close release cock so that about two bubbles of air each second are admitted through the H_2SO_4 and dry at 70°C for four hours at pressure not exceeding 100 mm.

(8) The dried samples were accurately weighed on the triple beam balance to 0.1 gram and estimated to 0.05 gram.

B. Starch Content

The method adopted for starch analysis was essentially that of Nielsen. (19)

(1) Blending

The jar containing the frozen sample was allowed to thaw at room temperature whereupon the outside of the jar was dried thoroughly and the jar plus contents weighed accurately to 0.1 gram on a triple-beam balance. The beans were transferred to a clean dry Waring Blendor, care being exercised to see that as much moisture as possible was transferred from jar to blendor. The jar and lid were rinsed, thoroughly dried and weighed. Using a graduated cylinder, and a graduated pipet when necessary, a quantity of water equivalent to the weight of the beans was added to the blendor. The blendor was allowed to run for 3 to 4 minutes.

(2) Weighing

Duplicate samples of the blended mixture of approximately 2 grams were weighed accurately on an analytical balance into tared 50 ml. beakers.

(3) Analysis

One ml. of water was added to the sample in the 50 ml. beaker by means of a 1 ml. pipet and 3.7 ml. of dilute perchloric acid (43.8 ml. of 60 percent perchloric + 6.2 ml. distilled water) was added by pipet. The acid was stirred in slowly. The sample was allowed to stand in contact with the acid for 15 minutes with occasional stirring and then made up to 25 ml. with water.

The sample was now filtered through a Whatman No. 1 filter paper in preference to settling which required too much time. A 1 ml. aliquot of the clear filtrate was transferred by means of a 1 ml. volumetric pipet, to a 25 ml. graduate cylinder and 6 ml. of water added. A drop of phenolphthalein was added and the solution brought to a pink color with a few drops of 6 N sodium hydroxide. Next 2 N acetic acid was added by buret until the pink color disappeared, 2.5 ml. in excess were added, 0.5 ml. of 10 percent potassium iodide by pipet and 5 ml. of 0.01 N potassium iodate added accurately by pipet. The solution was allowed to stand at least 5 minutes and then was made up to exactly 25 ml. with water. The solution was shaken, transferred to a Fisher electrophotometer tube and read in the Fisher electrophotometer using a red filter No. 650 and reading on the A scale. The percentage starch was calculated from a curve prepared from the colorimeter readings of a known range of potato starch concentration. The colorimeter readings were corrected with a blank containing all of the reagents.

C. Crude Fiber

(1) Blending

The jar containing the frozen sample was allowed to thaw at room temperature. The beans were then transferred to a clean dry Waring Blendor, care being

exercised to see that as much moisture as possible was transferred from jar to blendor. The sample was blended with intermittent shaking in an effort to distribute the loose moisture evenly.

(2) Weighing

Fifty grams of the blended sample were weighed on a triple-beam balance and dried by the vacuum oven method as previously described. Duplicate dried samples weighing in proximity to 2 grams were weighed out accurately on the analytical balance and each was transferred to a 1000 ml. beaker.

(3) Analyzing

The method adopted for crude fiber determination was taken from the Official and Tentative Methods of Analysis (20). However, the ether extraction was deemed unnecessary.

One-thousand ml. beakers were used as digestion flasks and large kjeldahl flasks were employed as condensers to maintain a constant volume of digesting solution. The kjeldahl flasks rested on the rim of the beakers, presenting a large cool surface to vapors and foam from the digestion. Approximately 0.5 gram of digested asbestos was added to the dried beans in the beaker and 200 ml. of boiling sulfuric acid (1.25 gm. H_2SO_4/100ml) was added. The digestion flask was immediately connected

to the condenser and heat was applied by Bunsen burner. A battery of four digestion flasks was operated at one time. The contents of the flask were brought to boiling as close as possible to the one minute called for by the Official Methods. Boiling was then continued for exactly 30 minutes. The flasks were rotated occasionally to wash down any material clinging to the walls. At the expiration of 30 minutes the flasks were removed, filtered through dress linen in a fluted funnel, and washed with boiling water until the washings were no longer acid. Litmus paper was used to test the acidity of the wash water. A quantity of sodium hydroxide (1.25g/100 ml.) had been kept boiling under reflux condenser and now 200 ml. of this base was used to wash the charge and asbestos into a clean dry 1000 ml. beaker. A wash bottle marked to deliver 200 ml. facilitated the washing of charge into the beaker. The beaker was brought into contact with the kjeldahl flask and the sample digested as before for 30 minutes. At the end of that time the contents of each flask were filtered through a Gooch cruicible prepared with a thin asbestos mat. The filtered material was thoroughly washed with boiling water and then washed with approximately 15 ml. of alcohol. The crucibles and contents were dried at 100°C to constant weight, cooled in a desiccator and weighed, on an analytical balance.

The contents of the crucibles were incinerated in an electric muffle oven for approximately 20 minutes, cooled in a desiccator and weighed. The difference in weighings were reported as crude fiber.

D. Ascorbic Acid

The method employed was a modification of Bessey's (4) analysis for vitamin C.

(1) Determination of Calibration Constant (k) For Ascorbic Acid Using the Fisher Electrophotometer and Filter 525 B.

The calibration constant was secured by employing the following equation on a known range of ascorbic acid concentrations.

$$K = \frac{(C)}{G_1 - G_2} \times 100$$

When: C = the concentration of ascorbic acid in mgm/ml

G_1 = average readings of test solution minus sample ie; 1 ml. 3% metaphosphoric acid + 25 ml. dye - buffer mixture

G_2 = average reading of ascorbic acid test solution

K = calibration constant in mgm. per 100 gms. per degree on galvonometer.

Ten samples of ascorbic acid were run in matched

tubes, the concentrations beginning at 0.01 mg. per ml. and increasing by 0.01 mgm. per ml. until a concentration of 0.10 mg. per ml. had been reached.

(2) Preparation of the Dye-Buffer Mixture

(a) 32 gms. of sodium acetate (buffer) were weighed and transferred to a 2000 ml. volumetric flask. Distilled water was used to wash the buffer into the flask.

(b) 17 mgms. of 2, 6 dichlorophenolindophenol were weighed and hot distilled water was used to wash the dye through a filter paper into the flask containing the buffer solution.

(c) The flask was then made up to the 2000 ml. mark with distilled water.

(d) 25 ml. of this dye-buffer mixture would usually read 50 ± 5 on the galvonometer of the Fisher Electrophotometer, and was adjusted to this range by dilution or concentration if necessary. The dye-buffer mixture was prepared each day for the samples run.

(3) Procedure Followed in Running a Fresh Bean Sample

(a) The galvonometer was adjusted to 0 whereupon sample tubes of distilled water were inserted and the galvonometer once more adjusted to 0.

(b) The G_1 reading was obtained by

pipetting 1 ml. of the 3% metaphosphoric acid (extractant) into the colorimeter tube, adding 25 ml. of dye-buffer mixture by means of a pipet calibrated to deliver in 20 seconds and reading the galvanometer within 30 seconds after the dye is started into the test tube. The G_1 reading was obtained by making duplicate or triplicate readings and was checked periodically.

(c) 30 gms. of fresh beans (ends snipped off) were deposited in the bowl of the Waring Blendor and 250 ml. of 3% metaphosphoric acid was added. The sample was blended for 3 minutes then filtered through a No. 193 (Eaton-Dikeman Co.) filter paper. The first 10 to 20 mls. of the filtrate was discarded and then a volumetric pipet was employed to transfer 1 ml. of the filtrate into a sample tube. Next 25 ml. of the dye-buffer mixture was added by means of a volumetric pipet to the sample in the tube. The solution was now decolorized with C.P. ascorbic acid crystals and the galvonometer readjusted to 0. This readjustment is accomplished by moving the initial null control knob. This action nullifies the effect of the turbidity of the 1 ml. sample. A second ml. of the filtered extract was pipetted into a colorimeter tube, 25 ml. of dye-buffer mixture added and the galvonometer reading taken. Duplicate readings were obtained.

d. Calculations

Ascorbic acid in mgms. per 100 gms. fresh beans $= K (G_1 - G_2) \frac{(250 \text{ ml. acid} + \text{gms. moisture of sample})}{\text{weight in gms. of sample}}$

IV. RESULTS

1. Yield

The following table presents the harvest data for the varieties studied:

Table I

Harvest Results

Variety	Rival	Tenderpod	Tendergreen	Str. Greenpod
Date planted	6-3-48	6-3-48	6-3-48	6-3-48
Date harvested	8-4-48	8-5-48	8-6-48	8-6-48
Growth period	62 days	63 days	64 days	64 days
No. bushes emerged	420	446	456	467
Wt. vines & pods	185 lbs. 6 oz.	154 lbs. 3 oz.	163 lbs. 3 oz.	164 lbs. 3 oz.
Wt. of pods	75 lbs. 14 oz.	54 lbs. 7 oz.	54 lbs. 3 oz.	64 lbs. 10 oz.
% Yield	40.9	35.3	33.2	39.1

The following tables give the process yields by variety:

TABLE II

Yield Results for Rival Variety

Grade Sizes	#0 <21/64"	#1 21/64" TBNI* 24/64"	#2 24/64" TBNI* 27/64"	#3 27/64" and over
Wt. distribution	11 lb. 1 oz.	13 lb. 14 oz.	23 lb. 15 oz.	27 lb. 0 oz.
% distribution	14.5	18.3	31.5	35.6
% crooked pods by count	13.0	23.0	18.0	39.0
Wt. per 100 pods	0.64	1.12 lbs.	1.58 lbs.	1.87 lbs.
% seed to hull	2.8	2.0	3.0	3.5
Wt. unshipped pods processed immed.	5 lb. 8 oz.	6 lb. 15 oz.	12 lb. 0 oz.	13 lb. 8 oz.
Shipped wt. pods processed immed.	4 lb. 0 oz.	4 lb. 9 oz.	11 lb. 9 oz.	12 lb. 4 oz.
% shippage pods processed immed.	27.3	20.3	3.6	9.6
No. cartons code R8-4-48#	7	8	24	24
Fresh wt. pods of 24 hr delay sample	5 lb. 8 oz.	6 lb. 15 oz.	12 lb. 0 oz.	13 lb. 8 oz.
Wt. after holding 24 hr at 60-70°F	5 lb. 8 oz.	6 lb. 14 oz.	11 lb. 9 oz.	13 lb. 4 oz.
% wt. loss after holding 24 hr.	0	0	3.6	1.9
Shipped wt. of 24 hr delay sample	3 lb. 9 oz.	5 lb. 13 oz.	10 lb. 4 oz.	11 lb. 9 oz.
% ship. pods hld 24 hr No crtns code R8-4-48#	34.5 9	14.5 12	11.2 20	12.8 23

*To But Not Including

Table III

Yield Results for Variety Tenderpod

Grade sizes	#0 <21/64"	#1 21/64"* TBNI 24/64"	#2 24/64"* TBNI 27/64"	#3 27/64" and over
Wt. distribution	7 lb. 2 oz.	6 lb. 13 oz.	19 lb. 3 oz.	21 lb. 5 oz.
% distribution	13.0	12.5	35.3	39.2
% crooked pods by count	6	12	11	17
Wt. per 100 pods	0.43 lbs.	1.00 lbs.	1.42 lbs.	1.77 lbs.
% seed to hull	0.5	1.5	2.0	2.5
Wt. unsnipped pods processed immed.	3 lb. 9 oz.	3 lb. 6 oz.	9 lb. 9 oz.	10 lb. 10 oz.
Snipped wt. pods processed immed.	2 lb. 10 oz.	2 lb. 11 oz.	9 lb. 0 oz.	9 lb. 9 oz.
% snippage pods processed immed.	27.3	21.2	6.2	9.4
No. cartons code T P8-5-48 #	6	5	17	19
Fresh wt. pods of 24 hr delay sample	3 lb. 1 oz.	2 lb. 13 oz.	8 lb. 15 oz.	10 lb. 7 oz.
Wt. after holding 24 hr at 60-70°F	2 lb. 14 oz.	- - -	8 lb. 12 oz.	10 lb. 4 oz.
% wt. loss after holding 24 hr	6.1	- - -	2.1	1.8
Snipped wt. of 24 hr delay sample	2 lb. 3 oz.	2 lb. 6 oz.	7 lb. 4 oz.	8 lb. 6 oz.
% snippage pods held 24 hr.	24.1	- - -	17.0	18.4
No. cartons code TP de 8-6-48 #	4	4	13	15

* To But Not Including

Table IV

Yield Results for Variety Tendergreen

Grade sizes	#0 <21/64"	#1 21/64" TBNI 24/64"	#2 24/64" TBNI 27/64"	#3 27/64" and over
Wt. distribution	7 lb. 3 oz.	4 lb. 9 oz.	16 lb. 9 oz.	25 lb. 6 oz.
% distribution	13.3	8.5	30.6	46.7
% crooked pods by count	3	5	2	6
Wt. per 100 pods	0.38 lbs.	1.05 lbs.	1.36 lbs.	1.63 lbs.
% seed to hull	1.0	2.0	4.0	6.0
Wt. unsnipped pods processed immed.	3 lb. 8 oz.	2 lb. 4 oz.	8 lb. 4 oz.	12 lb. 3 oz.
Snipped wt. pods processed immed.	2 lb. 6 oz.	1 lb. 7 oz.	6 lb. 6 oz.	10 lb. 3 oz.
% snippage pods processed immed.	31.4	34.8	22.9	16.4
No. cartons TG 8-6-48 #	5	3	11	20
Fresh wt. pods of 24 hr delay sample	3 lb. 4 Oz.	2 lb. 0 oz.	8 lb. 0 oz.	11 lb. 14 oz.
Wt. after holding 24 hr at 60-70°F	2 lb. 12 oz.	1 lb. 7 oz.	7 lb. 4 oz.	11 lb. 4 oz.
% wt. loss after holding 24 hr.	15.4	28.1	9.4	5.3
Snipped wt. of 24 hr delay sample	2 lb. 1 oz.	1 lb. 5 oz.	6 lb. 8 oz.	10 lb. 3 oz.
% snippage pods held 24 hr	25.0	7.1	10.9	8.8
No. cartons code TG de 8-7-48 #	4	3	12	20

* To But Not Including

Table V

Yield Results for Variety Stringless Greenpod

Grade sizes	#0 <21/64"	#1 21/64" TBNI *24/64"	#2 24/64" TBNI * 27/64"	#3 27/64" and over
Wt. distribution	11 lb. 15 oz.	16 lb. 1 oz.	24 lb. 11 oz.	11 lb. 15 oz.
% distribution	18.4	24.8	38.4	18.4
% crooked pods by count	11	7	18	28
Wt. per 100 pods	0.45 lbs.	1.32 lbs.	1.37 lbs.	1.60 lbs.
% seed to hull	1.0	3.0	6.0	8.0
Wt. unsnipped pods processed immed.	6 lb. 0 oz.	8 lb. 0 oz.	12 lb. 6 oz.	6 lb. 0 oz.
Snipped wt. pods processed immed.	4 lb. 13 oz.	7 lb. 0 oz.	10 lb. 14 oz.	5 lb. 8 oz.
% snippage pods processed immed.	20.0	12.5	12.2	8.3
No. cartons CP 8-6-48 #	10	13	21	11
Fresh wt. pods of 24 hr delay sample	5 lb. 12 oz.	7 lb. 12 oz.	12 lb. 2 oz.	5 lb. 12 oz.
Wt. after holding 24 hr at 60-70°F	5 lb. 1 oz.	7 lb. 2 oz.	11 lb. 2 oz.	4 lb. 12 oz.
% wt. loss after holding 24 hr.	12.0	8.1	8.2	17.4
Snipped wt. of 24 hr. delay sample	4 lb. 4 oz.	6 lb. 2 oz.	9 lb. 14 oz.	4 lb. 3 oz.
% snippage pods held 24 hr.	16.0	14.1	11.7	12.5
No. cartons code GP 8-6-48 #	10	12	19	9

*To But not Including

2. Analyses

The following table gives the results of duplicate determinations of total solids, starch, crude fiber and vitamin C.

Table VI

Analyses of Different Varieties of Bush Snap Beans

Variety	Grade	Total Solids Percent		Starch Dry Basis Percent		Crude Fiber Percent		Vitamin C mgms/100 gms.	
		Fresh	24 hr.	Fresh	24 hr.	Fresh	24 hr.	Fresh	24 hr.
Rival	0	9.2	5.1	1.16	0.59	0.95	—	23.19	14.78
	1	11.2	5.2	2.61	2.51	0.84	—	20.84	13.14
	2	10.6	6.0	4.62	3.86	0.80	—	19.94	16.68
	3	8.5	5.0	5.29	5.34	0.83	—	17.94	13.14
Tenderpod	0	6.9	6.6	1.74	0.51	0.44	—	15.28	11.86
	1	6.4	7.4	3.71	1.11	0.58	—	15.76	10.00
	2	7.4	7.1	6.41	7.37	0.52	—	11.11	12.96
	3	7.4	8.3	7.49	7.82	0.62	—	13.70	9.99
Tendergreen	0	10.2	9.2	0.73	0.49	—	—	30.00	15.25
	1	8.7	7.8	2.13	2.55	—	—	28.68	15.46
	2	10.2	11.1	4.45	3.21	0.86	0.74	27.69	15.86
	3	11.9	11.2	6.36	6.83	1.40	0.93	30.76	19.08
Stringless Green Pod	0	11.2	11.7	2.34	1.66	—	0.78	24.89	20.38
	1	11.7	11.5	8.32	6.20	0.80	—	26.74	24.89
	2	12.9	12.1	11.2	10.20	0.88	—	27.14	27.81
	3	11.1	14.3	14.7	10.20	0.92	—	26.74	22.61

V. DISCUSSION OF RESULTS

1. Experimental Methods

The procedure followed in transferring the frozen samples to the blendor may have incurred a slight error in the final results. Similarly, the use of water to facilitate blending increases the difficulty in obtaining a representative sample. Experimentation on this technique would probably show that there is an optimum concentration of sample and water to give most accurate results.

Use of potato starch as a standard in the starch analysis provides only relative results which are, however, quite satisfactory in a series of analyses which include only one product. Nielsen (19) has shown that in his method of starch analysis the error due to dextrins is much less than in a hydrolysis procedure for starch where the dextrins are not removed.

2. Yield

The following table summarizes the data on yield characteristics of the varieties studied:

Table VII

Variety	Growth period in days	Bushes Emerged	% Yield	% Distribution			
				#0	#1	#2	#3
Rival	62	420	40.0	14.5	18.3	31.5	35.6
Tender Pod	63	446	35.3	13.0	12.5	35.3	39.2
Stringless Green Pod	64	467	39.1	18.4	4.8	38.4	18.4
Tendergreen	64	456	33.2	13.3	8.5	30.6	46.7

In the light of this data it would appear that Rival is a much better yielding variety and an earlier maturing variety than the others. This may be an erroneous conclusion in that the actual number of bushes yielding beans were not counted, but rather the total number of bushes emerged for each variety. This, however, does not seem likely since there is such a significant difference in the total bushes emerged for Rival and the other varieties. Had Rival been allowed to mature the extra one to two days like the other varieties it is probable that the yield of this particular variety would have been even greater.

The largest percentage of beans, with the exception of Stringless Green Pod, are distributed in grades 2 and 3. Stringless Green Pod was the most evenly distributed variety.

Rival showed the highest percentage of crooked pods.

Tendergreen and Stringless Green Pod showed the highest weight loss from holding 24 hours at room temperature. The weight loss in holding showed no correlation to grade size.

Table VIII shows the total snippage loss for each variety:

Table VIII

Total Snippage Loss by Variety

	Rival	Tenderpod	Tendergreen	St.Grn Pod
Unsnipped wt. of all grades processed immed.	37 lbs. 9 oz.	27 lbs. 2 oz.	26 lbs. 3 oz.	32 lbs. 6 oz.
Snipped wt. of all grades processed immed.	32 lbs. 6 oz.	23 lbs. 14 oz.	20 lbs. 6 oz.	28 lbs. 3 oz.
% Snippage	13.8	13.6	22.1	12.9

With the exception of Tendergreen, the total loss due to snippage was close to 13 percent for each of the other varieties.

In general the snippage tended to lessen with increasing grade size.

The seed content was in all cases well below the 15% allowable for U. S. Grade C standards for maturity of canned green beans, and only in one grade of one variety did the seed content exceed the 6% allowable for a standard grade according to Rowe and Bonney (23).

The following table is of interest in comparing the yield results of the four varieties studied with similar research conducted in Michigan in 1947 by Wittwer and Harrison (29).

Table IX

Comparison of Snap Bean Trials in Michigan and Oregon

Variety	Michigan Source	Oregon Source	Total Yield Bushels/acre Mich.	Total Yield Bushels/acre Ore. one picking	Yield lbs/100 plants Mich.	Yield lbs/100 plants Ore. one picking	Total plants Emerged Mich. 3-20ft rows	Total plants Emerged Ore. 3-100ft rows	Wt. gms per 100 pods Mich.	Wt. gms per 100 pods Ore.*
RIVAL	Zaumeyer U.S.D.A.	Zaumeyer U.S.D.A.	386	101.2	25.0	18.0	162	420	831	672
TENDERPOD	Burpee	Burpee	191	72.6	29.8	12.2	68	446	617	622
TENDER-GREEN	Assoc.	Burpee	266	72.3	16.1	11.9	149	456	668	604
STR. GREEN POD	Assoc-iated	Burpee	253	86.2	21.1	13.8	128	467	540	558

* Weighted average of grades
** Michigan variety Giant Stringless Green Pod

The results indicate that the yields of these varieties grown in Michigan are higher than the Oregon yields, but here again the stages of maturity at harvest and the number of pickings should be known before true comparisons can be made.

Wittwer and Harrison (29) point out that Rival was outstanding in yield and make this interesting comment, "There is an indication from these tests that Rival belongs to the same hardy class, may be more productive, and has the quality of Tendergreen." This statement is corroborated by the present work just completed in Oregon, for Rival proved superior in yield to Tendergreen and lower in starch and crude fiber. However, Rival did not contain as much vitamin C as Tendergreen.

Tenderpod when grown in Michigan showed the highest yield on a plant basis, yet, because the plants failed to develop in cold wet weather it was the least productive variety. The Oregon results show Rival to be superior in yield to Tenderpod or any of the other varieties on a plant basis.

3. Analyses

A. Total Solids

The results of the statistical analysis (24) on total solids are presented below. The F value of 17.4 indicates that there is a highly significant difference

between varieties insofar as total solids are concerned. No significant difference was found in comparing grade sizes and no significant difference was found in comparing fresh with 24 hour delay samples.

	S S	D F	M S	F
Varieties	124.03	3	41.34	17.89**
Grades	7.13	3	2.38	1.03
Delay	7.90	1	7.90	3.42
Error	55.51	24	2.31	
Total	194.57	31		

** Highly significant

Stringless Green Pod contained the highest percentage of total solids on the average, while Tendergreen was next and Tenderpod and Rival were about even.

Parker and Stuart (21) found that small beans contained a higher percentage of moisture than large beans and that the percent of loss in weight on storage was practically the same in both sizes.

B. Starch

The figures for the statistical analysis of starch on the dry basis as shown, reveal that there is a highly significant difference in starch between varieties and among grades, but no significant difference between the fresh and 24 hour delayed samples.

	S S	D F	M S	F
Varieties	124.13	3	41.38	21.9**
Grades	220.13	3	73.38	38.9**
Delay	5.13	1	5.13	2.7
Error	45.29	24	1.89	
Total	394.68	31		

** Highly significant

Stringless Green Pod contained by far the highest percentage of starch on the weighted average, Tendergreen was next highest, then Tenderpod, and finally Rival.

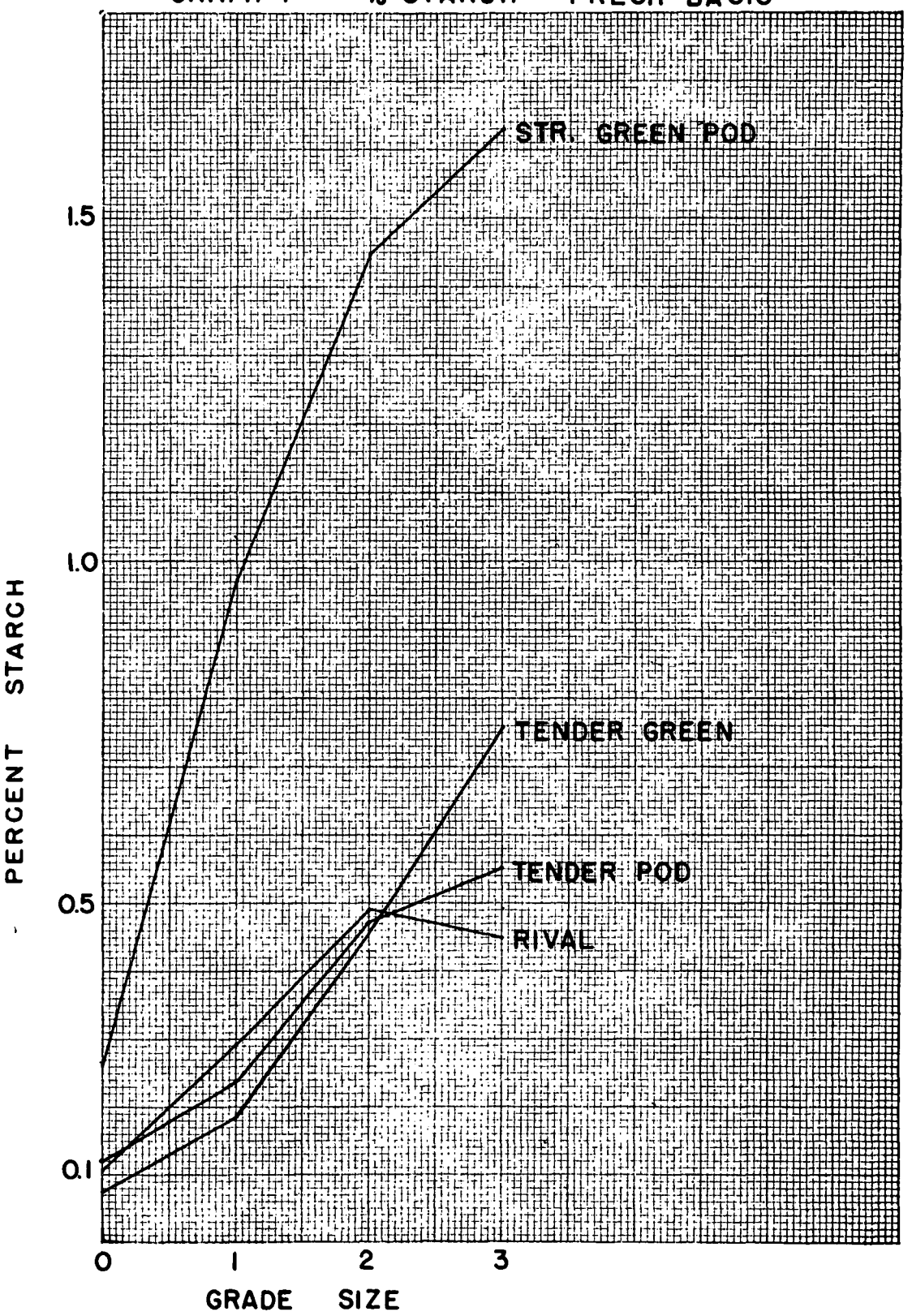
The starch content increased rapidly with increasing grade size, which agrees with the results of Parker and Stuart (21). The rise in starch content is illustrated in graphs 1 and 2.

C. Crude Fiber

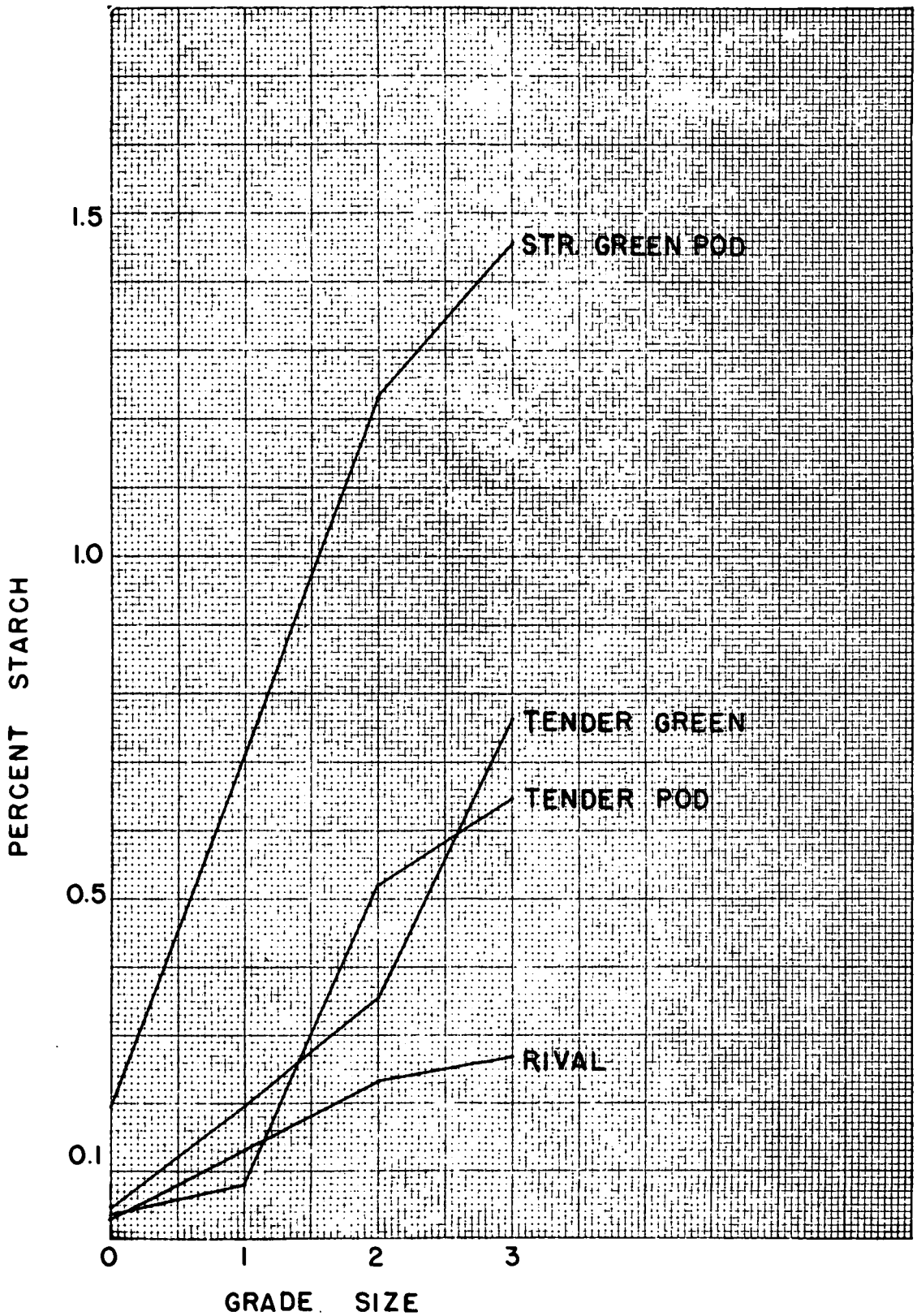
Only in one instance did the fiber exceed 1 percent on the fresh basis.

It is difficult, from the results of the analysis, to predict whether or not the fiber increases with increasing grade size. However, there appears to be some difference in varieties, since Rival, Tendergreen and Stringless Green Pod contain approximately the same amount of fiber while Tenderpod appears to have considerably less than the aforementioned varieties.

GRAPH 1 % STARCH — FRESH BASIS



GRAPH 2 % STARCH — FRESH BASIS, 24 HR. DELAY



The Canned Food Reference Manual (1) gives an average of 0.5 percent crude fiber in green beans, Kramer (16) reports an average of 0.65 percent and Chatfield and Adams (6) 1.40 percent. The average of all grade sizes reported herein was found to be 0.9 percent for Rival, 0.5 percent for Tenderpod, 1.1 percent for Tendergreen and 0.9 percent for Stringless Green Pod.

D. Vitamin C

The results of the statistical analysis on ascorbic acid figures appear below:

	S S	D F	M S	F
Varieties	761.54	3	253.84	26.47**
Grades	1.92	3	0.64	0.07
Delay	287.40	1	287.40	29.97**
Error	230.10	24	9.59	
Total	1280.95	31		

** Highly significant

In this experiment the F values indicate that there is a highly significant difference in vitamin C content between the varieties of beans and also a highly significant difference between the fresh and twenty-four hour delay samples. That no significant difference was found in vitamin C determinations by grades confirms the work by Mack et al (17), Wade and Kanapaux (27) and Tressler et al (26). However, Flynn and associates (9), Caldwell et al (5) Kramer

(15) and Phillips and Fenton (22) found that vitamin C varied with the grade size or stage of maturity.

Mack, Tapley and King (17) report that in comparison with other vegetables snap beans lose their vitamin C rapidly in storage, especially at low temperature, which is quite evident from the tables showing vitamin C content.

Wade and Kanapaux (28) noted that the more fibrous strains or varieties had a higher ascorbic acid content. This observation can be made in the present work for Tenderpod having a decidedly lower fiber content has also a decidedly lower ascorbic acid content while Tendergreen with highest fiber content has highest ascorbic acid content.

The following table presents a comparison of the results of several investigations of ascorbic acid content in milligrams per 100 grams fresh beans, of the varieties studied.

Table X

Vitamin C Content of the Different Varieties of Snap Beans

Investigators	Rival	Tenderpod	Tendergreen	Str.Green Pod
Mack et al (17)			24.0	
Heinze et al (12)			25.0	19.9
Hayden et al (11)		16.7	24.2	
Phillips & Fenton (22)			27.1	
Hibbard & Flynn (13)			25.5	
Janes (14)			15.8	
Flynn et al (9)			26.7	
Van Duyne et al (26)				21.0
Mayfield & Richardson (18)				27.0
Bedford et al (3)			29.0	30.9
Present Work (Weighted av. of grades)	20.1	13.2	29.5	26.6

It is a difficult task to rank the varieties studied on the results presented here and indeed, such was not the object of this research. However, if the values for starch, crude fiber and vitamin C be considered approximately equal in a practical sense, then an attempt may be made to rank the varieties on harvest yield and processing characteristics.

Rival was best as it gave the highest yield in the shortest growing period. Stringless Green Pod having a growing period one day longer than Tenderpod produced a slightly higher yield than that variety. Had the growth periods been equal the yield of Tenderpod would probably

have been higher than it was. Tendergreen gave the lowest yield.

As far as snippage loss was concerned, Tendergreen lost most while the other varieties were about even in snippage loss.

The grade sizes 1 and 2 are most desirable if the beans are to be frozen for commercial use. Stringless Green Pod had the highest percentage of beans in these grade sizes, followed by Rival, Tenderpod and Tendergreen.

Since Rival is so outstanding in yield it may be ranked first. Stringless Green Pod having most beans in the preferred grade sizes may be ranked second, followed by Tenderpod. On the basis of the factors just discussed, Tendergreen deserves to be placed fourth.

VI. CONCLUSIONS

If snap beans are to be harvested mechanically it is evident that increased planting must be made in order to equal the yield by hand picking. The date of harvest must be carefully considered if a majority of a specific grade size is desired.

Rival appears to give a higher yield and to mature earlier than the other varieties.

The snippage loss is sufficiently high in some grades to warrant further investigation.

The seed content increases with increasing grade size which should obviate the necessity of determining percent seed as an indication of stage of maturity.

There is a tendency for the beans to lose weight slightly during storage for 24 hours at room temperature, while starch on the dry basis shows no significant change and vitamin C loss is highly significant.

Starch content increases rapidly with maturation and the relatively simple and rapid starch analysis of Nielsen (19) could easily be used as a quality control measure. The starch content on the fresh basis was below 1 percent in most results and in no case exceeded 2 percent. These results compare favorably with those of Chatfield and Adams (6) who give an average of 2.2 percent starch for green beans.

No significant difference in vitamin C of beans from the various grades was observed.

The varieties studied were not excessively high in starch or crude fiber and the ascorbic acid content compared favorably with the findings of other workers.

VII. SUMMARY

A review of the literature on green beans has been presented.

Figures for harvest yield, yield by grades and processing losses for four varieties of single-harvest bush snap beans are shown in tabular form.

Analyses are given for total solids, starch, crude fiber, and ascorbic acid on both fresh and a 24 hour delayed basis.

Some conclusions from the work are made.

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