THE REHYDRATION OF BLUE LAKE BEANS AS INFLUENCED BY TREATMENTS PRECEDING DEHYDRATION

by

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CHAPTER I

INTRODUCTION

Green beans, also known as snap beans, have for many years been a significant item on the roster of American processed foods. Canning and freezing are the favored methods of preservation, and general public acceptance of this vegetable is indicated by the relatively large commercial packs reported for recent years. In 1951, commercially canned green beans were reported as 9.45 per cent of the total commercial pack of canned vegetables in the United States (11, p.208), while frozen green beans constituted 10.6 per cent of the total commercial frozen vegetable pack (11, p.215). Of these amounts, approximately one-fourth of the total of green beans is attributed to the states of the northwest, consisting of Oregon, Washington, Idaho, and Montana. Oregon's prominence as a producer of snap beans, particularly pole beans of the Blue Lake variety, is well known.

Although dehydration is one of the oldest forms of food preservation, its commercial application to vegetables, particularly to green beans, has been limited. In recent years, vegetable dehydration has received considerable stimulation by the demands of the armed forces for acceptable food products of reduced weight and volume. Dehydrated potatoes, onions, and soup mixes have reached a present point of relatively good public acceptance. Green beans have not as yet been accepted as worthy of commercial dehydration. This appears to be primarily due to their general inability, following dehydration, to reconstitute into a product closely resembling their original form. Wrinkling and loss of full-body have generally characterized their reconstituted condition, discouraging acceptability by the consumer.

A new method for dehydrating green beans was developed at Oregon State College in 1951-52. By combining principles of freezing and dehydration, it was found that an acceptable dehydrated bean could be prepared. The prime factor in this method was the inclusion of freezing in the treatment of cut beans prior to dehydration. The cut and blanched product, sulfited and non-sulfited, was first frozen solid before being submitted to normal heated-air dehydration. Freezing as an adjunct to dehydration was not a new principle, but as far as can be ascertained, this appears to be its first reported application to the dehydration of green beans.

Dehydrated green beans, which in their natural state are approximately 89 per cent water (23, p.12), could produce economic benefits in savings of transportation and handling costs to food distributors and consumers. Acceptable dehydrated green beans would be of value to processors and consumers alike, especially should there be a wartime or other emergency need. Further study of the rehydration implications of the prefreeze, heated-air dehydration process was prompted by a desire to clarify the practical use of pre-treatments in the dehydration of Blue Lake green beans.

Blue Lake beans, a pole variety, are an important Oregon crop that has provided the foundation for a large commercial industry. Particularly suitable to Oregon climatic and growing conditions, this variety is adaptable by reason of its freedom from curling to rapid machine handling within a processing plant. It also possesses natural tenderness of texture and a characteristic flavor. Consequently, the Blue Lake bean has obtained considerable acceptance by consumer and processor alike.

The purpose of the investigation undertaken by this study was to ascertain whether certain variations in the blanching, sulfiting, and freezing treatments, which were applied before drying, influenced the ability of the dehydrated beans to take up water upon reconstitution—to be rehydrated. The information obtained, it was believed, could provide a useful basis for making specific recommendations as to the application of the prefreeze, heated-air process to the dehydration of Blue Lake beans.

CHAPTER II

REVIEW OF LITERATURE

Dehydration of Green Beans

Developments and improvements in the dehydration of vegetables in general have arisen largely as the result of wartime emergency demands. Green beans have received somewhat less attention than many others. Reported investigations of the dehydration of this vegetable are not abundant. Some intensive development work was sponsored by the United States government at the time of the second World War, but dehydrated green beans did not become a part of armed forces' rations. It is notable that in the United States War Department Cooking Manual for Dehydrated Foods (22), issued in 1943, dehydrated green beans are not mentioned.

Andrea (1, p.71) in 1920 stated that green beans could be dehydrated satisfactorily if cut lengthwise. The method recommended consisted of steam blanching for three to five minutes, followed by three to four hours dehydration in heated air at a starting temperature of 110 F and a finishing temperature of 145 F. So-called "conditioning" by holding for three days in a cool place was recommended after drying.

Nichols, et al (18) in a United States Department of Agriculture bulletin of 1925, mentions briefly that cut green beans may be successfully dehydrated by usual procedures for vegetables if first blanched by immersion in hot water or dilute solution of soda to intensify and preserve green color.

Caldwell and Culpepper (4), in a preliminary study in 1942 of the dehydration of thirteen varieties of green beans, including Blue Lake, found that differences in dehydrated quality and appearance were apparently due to inherent varietal characteristics or maturity variations. They stated then that Blue Lake beans, along with seven other varieties, were unsuitable for dehydration. Additional investigation by them in 1943, in cooperation with Hutchings, Ezell, and Wilcox (5), extended their work to forty varieties of green beans. A two-stage, laboratory dehydrator was used, furnishing an initial drying temperature of 155 F to 160 F and finishing temperatures of 140 F to 145 F. Moisture levels of approximately six per cent were attained by a total drying time of five to seven and one-half hours. Results were evaluated by subjective judgments of cooked material as to color, general appearance, flavor and texture. Comparative ascorbic acid retention was also measured. The final results classified the forty varieties into four groups on the basis of desirability. Blue Lakes were placed in the second class, described as good to very good.

Moyer, et al (16), investigated the adaptability of certain New York vegetables to dehydration in 1943. Of nine varieties of bush beans tested, they concluded that none were satisfactory when reconstituted. Mrak (17, p.6) suggests in a general discussion of dehydration developments up to 1943 that dehydrated vegetables were unattractive and not well received by the armed forces during both Civil War and World War I because of poor methods of dehydration and storage.

He recommended the relatively high temperatures of 180 F to 185 F for the initial stage of vegetable dehydration.

The United States Department of Agriculture, Bureau of Agricultural and Industrial Chemistry, in its plant operators' manual on dehydration in 1944 (20, p.189), listed the essential steps in the dehydration of snap beans as grading, sorting, snipping, washing, blanching, and dehydration in a two-stage, heated-air cabinet at a starting temperature of 180 F and a finishing temperature of 150 F. Drying ratios for snap beans were expected to average 8.5 to 1. A moisture content of not more than five per cent for dehydrated snap beans was believed essential.

Cruess (6, p.565) states that dehydration intensifies any toughness that green beans may originally possess and, consequently, only very tender beans should be dehydrated. He recommends blanching of cut and snipped beans in live steam for three to six minutes, followed by dehydration to a moisture content of less than five per cent. Drying ratios are expected to be within the range of 7-10 to 1.

Treatments Preceding Dehydration

Blanching as a treatment to most vegetables prior to dehydration is widely recommended. Both steam and water blanching have been used. The effects of steam blanching on green beans for dehydration were examined by Caldwell and Culpepper (5) in their work on forty varieties. They concluded that a blanching time of ten to fifteen minutes in flowing steam was desirable on the grounds of improving texture and rehydration. Although this period was considerably in excess of that required to destroy enzyme activity, they recommended its use as a "pre-cook." It was their premise that preservation of "fresh" characteristics was not a consideration in dehydration.

Moyer, et al (16, p.16) in studying the adaptability of certain New York vegetables to dehydration, examined nine varieties of cut green beans, not including Blue Lake. Their preparation process included a comparison of three-minute steam blanch with fifteen-minute steam blanch. They concluded the fifteen-minute blanch did not improve their product.

Cruess, Friar, and Balog (7, p.19) investigated vitamin losses during dehydration of blanched and unblanched snap beans. They found that carotene and the B-vitamins were better retained in blanched beans. Balls (3, p.38) reports that in the dehydration of vegetables, inactivation of enzymes is attained in two ways, that is, by blanching and by reducing the moisture content. The reduction of water by dehydration greatly reduces the activity of the enzymes.

Wiegand, Madsen, and Price (24, p.17) mention that blanching is a requisite to the success of dehydrated vegetables. They attribute much of the dissatisfaction with World War I dehydrated foods to the results of action of enzymes which had not been inactivated prior to dehydration. Many factors influence the time required for adequate blanch, such as the size of the food particles, amount and depth of material on the drying trays, uniformity of heat distribution, constancy of temperature, and varietal and maturity characteristics.

Moyer (15, p.16) proposes that blanching of dehydrated vegetables is essential inasmuch as the ultimate loss of ascorbic acid is greater if blanching is omitted. Overblanching, on the other hand, results in greater loss of water soluble substances.

Sulfur dioxide has been used quite extensively in the dehydration of fruit, but its use with vegetables has been more limited. MacKinney, Friar, and Balog (14, p.294) ran experiments with dehydrated asparagus, broccoli, carrots, cauliflower, and cabbage, in which they demonstrated that sulfur dioxide treatments preserved flavor, odors, and vitamin content in air storage at 90 F for three months. Their method of treatment consisted of dipping the product for a brief period, following steam blanching, in water solutions of sedium bisulfite or potassium metabisulfite. They called attention to the fact that dried potatoes were treated with sulfur dioxide for shipment to the Yukon during the gold rush and that Great Britain utilized such treatment for dehydrated cabbage.

Caldwell, Culpepper, et al (5) tried various methods of treating green beans with various compounds prior to dehydration. The treatments were designed to preserve color or to prevent destruction of vitamins and flavors. They experimented with dipping in solutions of sodium chloride, sodium bicarbonate, sulfur dioxide, sodium bisulfite, potassium metabisulfite, and sodium thiosulfate. They also tried exposure of the prepared product to sulfur dioxide gas. Their conclusion was that color and appearance were particularly benefited by such treatments, although proper concentrations in the product were difficult to control.

Freezing as a preliminary treatment to the dehydration of vegetables is uncommon. It is reported by Cruess (6, p.561) to be desirable with certain forms of dehydrated potatoes. He indicates that freezing of blanched potatoes before grinding and drying results in an improved reconstituted mashed product.

John L. Kellogg and Company (12) obtained a United States patent in 1949 for a method of dehydrating food products, including fruits, vegetables, meats and their extracts, which includes freezing of the products before dehydration. This method describes an alternate procedure of either freezing the product and reducing it to small particles, or first reducing the product to pulp or liquid, then freezing it solid. Following this, it is introduced into a hot airstream held at a temperature of approximately 350 F. This high temperature vaporizes the water content of the material without decomposing it, on the proposed grounds that the ice particles within the material prevent overheating.

Lee, Gortner, and Withycombe (13) investigated the effects of rapid, intermediate, and slow freezing on peas and snap beans, although this work was not related to dehydration. They found that significant differences in vitamin content, taste and texture could not be detected in samples which had been frozen at either of these temperatures. Photomicrographs showed large ice crystals in the slow-frozen products, but when thawed, damage was not apparent. These findings may suggest some of the effects connected with the prefreeze, heated-air dehydration procedure.

Rehydration of Green Beans

Rehydration, which is also referred to as reconstitution, signifies the restoration of water to the dehydrated product. This is ordinarily accomplished in connection with cooking. Standardized rehydration procedures have not been developed for dehydrated green beans. Investigators have differed considerably in their methods and recommendations. Stillman, Watts, and Morgan (19), in working with home dehydration and home use of snap beans, experimented with various soaking times and concluded that an hour of soaking was necessary for a good rehydrated product. The rehydrated beans were characteristically flabby in texture and of shrunken appearance. It was their recommendation that successful rehydration of snap beans could be accomplished only if the beans were split lengthwise before dehydration.

Caldwell, Culpepper, et al (5) reconstituted dehydrated green beans, including the Blue Lake variety, by soaking overnight (about fifteen hours) followed by cooking in flowing steam for forty minutes. Water absorption was measured as the per cent of increase of the weight of the dry sample and was found to be generally about four times the dry weight. There were considerable variations between varieties. Blue Lakes, classified on the basis of appearance, were poorly rehydrated but were scored on other factors of comparative desirability as very good.

Moyer, et al (16, p.17) rehydrated green beans by soaking for three hours followed by boiling thirty to fifty minutes. The nine varieties of bush beans which were studied were found to be unpalatable after cooking, even though all were fancy grade when fresh.

Recommendations by the United States Department of Agriculture for dehydration plant operators in 1944 (20, p.190) suggested a four-hour soak for rehydration of green beans followed by slow boiling for thirty minutes. It was estimated that cooked weight should be about two to three times the weight of the dried vegetable.

Ashe (2), in studies at Oregon State College with home dehydration of two varieties of green beans, reconstituted them by pre-soaking in water at room temperature for one hour followed by boiling for eight minutes. Average rehydrated weight attained was 35.7 per cent of the fresh weight. Blue Lake beans, steam blanched before dehydration, yielded 31.3 per cent of fresh weight without a pre-soak, 34.2 per cent with one-hour pre-soak, and 37.3 per cent with four-hour pre-soak. The rehydrated product was judged to be poor in form but good in flavor. Sliced dehydrated green beans were suggested as the most acceptable.

Holmes (10), in investigating the reconstitution characteristics of twenty-five varieties and strains of bush and pole beans at Oregon State College, found rehydration percentages to have very wide variations. The method of reconstitution consisted of soaking small samples for one-half hour in water at room temperature, followed by one-half hour boiling. The two strains of Blue Lake beans tested attained 53.1 per cent and 59.9 per cent of fresh weight, respectively. Wide differences in appearances were noted resulting from the degree of wrinkling.

Moyer (15, p.16) speaking of dehydrated vegetables in general suggests that they should be added directly to boiling water. He states that vegetables not soaked at all were found the most palatable, and rated those soaked for the longest times as soggy.

Davis and Howard (8), in discussing reconstitution methods for dehydrated vegetables, believe that a slow rate of boiling is preferred to rapid or vigorous boiling regardless of the amount of soaking. They indicate that the rate of rehydration is directly proportional to the surface area and weight ratios of the individual pieces of vegetable.

CHAPTER III

EXPERIMENTAL PROCEDURE

Preparation of Samples

Blue Lake beans (strain No. 231 of Associated Seed Growers, Inc, Oakland, California) were grown on college plots under supervision of the Oregon State College horticulture department. At the proper stage of maturity, they were harvested by hand and delivered to the food technology department pilot plant. Here they were immediately size-graded by a standard Chisholm-Ryder grader and the sizes four and five segregated.

Grade sizes four and five were chosen on the basis of previous findings that indicated the larger sizes of green beans were well suited to this method of dehydration. United States Department of Agriculture standards for canned green beans are used in determining size. These standards provide six grades based on the diameter of the bean at the time of picking. Sizes are designated by consecutive numbers one to six, with number "one" representing the smallest. Fours and fives are classified by word designation as "medium" and "large," (21, p.3).

These segregated, graded beans were placed in a Chisholm-Ryder, screen size two, snipper where the ends were snipped off. Hand sorting on a moving belt followed to remove any unsnipped or damaged beans. The snipped and graded beans were placed in an Urschel cutter, where they were cut into one-half inch lengths.

These cut beans were weighed into lots of three thousand grams each. Each lot was thoroughly rinsed in cold water and spread evenly to a depth of about three-fourths of an inch on 23" x 23", five-mesh, stainless steel wire trays. This was a spread of approximately one and one-half pounds per square foot of tray area.

These loaded trays were placed in a cabinet-type steam blancher. In specifically designated lots, they were blanched by exposure to steam for four or six minutes.

Following the blanch, and while still warm, the loaded trays of beans were immersed for five minutes in a water solution of sulfur dioxide which had been prepared by dissolving sodium metabisulfite ($Na_2S_2O_5$) in cold water. Two concentrations of the dipping solution were set up. One lot of beans was immersed in a solution containing, by calculation, one thousand parts per million sulfur dioxide, while a second lot was immersed in three thousand parts per million sulfur dioxide solution. These calculated concentrations were based upon a weighed quantity of sodium metabisulfite for a given volume of water.

A third lot of blanched beans was not sulfite dipped.

These dipped or undipped, cut and blanched beans, still on their respective wire trays, were handled without delay in the following manner:

(a) One group was taken immediately to the dehydrator and dehydrated without prefreezing;

(b) A second group was placed on racks in the -20 F circulated-air freezing room and frozen solid by remaining overnight;

(c) A third group was placed on racks in the 0 F circulated-air freezing room where it also was frozen solid by remaining overnight.

The groups were so arranged that all combinations of size, blanching time, and sulfite dipping or non-dipping, were submitted to these two freezing temperature conditions and to one non-freezing condition, prior to dehydration.

Dehydration

The samples prepared as described above, frozen or non-frozen on the wire trays, were placed in a cabinet-type, recirculating air dehydrator in the Food Technology Department laboratories. This dehydrator, developed by investigations of the Oregon State College Food Technology and Agricultural Engineering Departments (24), consists of a self-enclosed cabinet, approximately six feet high and seventeen feet long, which is equipped with steam heating coils, a circulating air fan, adjustable air vents, a steam jet humidifier, wet and dry temperature bulbs, electric and compressed-air automatic controls, and racks for a full-load capacity of fifteen trays of the type on which the beans were prepared. A maximum dehydrator load for this experiment, due to lot sizes, consisted of fourteen trayloads of prepared green beans, or forty-two thousand grams fresh weight. This load permitted the dehydration of every specific lot of treated beans as a unit, during one dehydration cycle.

The dehydrator, similar in operating principle to the two-stage tunnel dehydrators of commercial use and functioning by automatic controls, established an initial dry-bulb air temperature inside the cabinet, or "tunnel," of 195 F. After forty-five minutes of dehydration, the air temperature was gradually reduced, over the period of one hour, until it reached 145 F (dry-bulb). It was held at this second level for the balance of the dehydration. The wet-bulb temperature during this latter stage reached, after four hours, a minimum of 90 F where it remained until the beans were removed. The dry-bulb temperature of 145 F and wet-bulb temperature of 90 F indicated a relative humidity at the final dehydration stage of twelve per cent (24, p.10-11).

The frozen and unfrozen beans were placed in the tunnel at its initial temperature of 195 F. Although recordings were not made of the internal temperatures of the product itself during dehydration, it seems probable that at no time did the product reach this elevated temperature, due to the cooling effect of the evaporating moisture within the product. A trial record of dry and wet bulb temperatures at fifteen minute intervals during the dehydration cycle of frozen beans revealed that the dry-bulb air temperature of the tunnel was reduced at the outset, by a load of fourteen trays of product, to 170 F, that it increased to a maximum of 191 F after thirty minutes, and finally reduced to a stabilized minimum point after one hour and forty-five minutes of 145 F.

A uniform total dehydration time of six and one-half hours was used for all samples. At the end of this time, the trayloads of dry beans were removed, carefully weighed, and placed by specific lots in accumulating trays in a bin drier constructed for this work.

The function of this bin drier was not to reduce further the moisture content of the beans. Its aim was to equalize as nearly as possible, by mixing different trayloads of the same lot in a single container, the moisture content of individual trayloads coming out of the dehydrator. It also served as a practical holding device for accumulating samples preparatory to further handling. It was made up of a self-enclosed, plywood cabinet, equipped with a circulating fan, an electric heating element, product holding trays, and a screen tray containing silica gel as a desiccating agent in the airflow. The air temperature was maintained at 115 F.

The dehydrated beans were held in this bin drier for forty-eight hours, following which they were again weighed, filled into five, gallon, airtight cans and immediately placed in cool storage at 34 F. Here they remained until all dehydration of various samples was completed, a period of one to four weeks.

There was no appreciable change in the total weight of a particular lot during bin drying. The recorded weights for specific lots from the bin drier were used as the basis for drying ratios on which rehydration percentages were later calculated.

Storage

At the conclusion of all dehydration, each lot of dry beans was removed from cold storage and filled, in measured quantities (fifty grams for frozen, twenty-five grams for unfrozen) into size "307 by 306" (canners' designation) inside-enameled, code-marked tin cans. These were hermetically sealed in air then placed in two groups in controlled temperature storage rooms of 72 F and 100 F. A uniform starting date of controlled temperature storage was thus established for all samples.

A total weight of 1269.7 pounds of Blue Lake beans was dehydrated to a weight of 113.3 pounds, with an average drying ratio of 11.20:1. Drying ratios ranged from 9.06-12.53 to 1.

Moisture Determinations

At this time, coincident with the start of controlled storage, moisture determinations were made on all samples. Accurately weighed, triplicated portions of dehydrated beans, which had been ground in an abrasive grinder and sifted through a twenty-mesh screen, were placed in an electrically heated vacuum oven, held at a temperature of 140 F, and dried to a constant weight. The moisture content was ascertained by the loss of weight.

Rehydration

At two-month, four-month, and six-month periods from the commencement of storage at 72 F and 100 F, samples representing each treatment variation were removed from the storage rooms and tested for rehydration.

The method adopted for the rehydration test was determined by a series of preliminary cooking trials from which an optimum uniform procedure was selected. These preliminary trials considered the factors of open- and closed-vessel cooking, amount of cooking water with respect to the size of sample, and average length of boiling time at which maximum rehydration was attained. The results provided a uniform rehydration procedure, which was used for all samples as follows:

Twenty grams of dehydrated beans were added to twelve hundred milliliters of hot tap water in an open pyrex pan. This pan, without cover, was placed immediately on a gas burner and brought to a boil as rapidly as possible. The elapsed time from the immersion of the beans in water to the start of boiling was six and one-half to seven minutes. The beans were boiled rapidly for ten minutes. The flame was then reduced to produce a moderate boiling action and the cooking continued for an additional twenty-five minutes. After thirty-five minutes of total boiling time, the beans were poured from the pan onto an eight-mesh to the inch screen and allowed to drain for one minute. Immediately thereafter, they were weighed.

The amount of rehydration was ascertained in terms of the percentage of original fresh weight represented by the rehydrated weight of the sample. The original fresh weight was computed from the drying ratios. The rehydrated weight divided by the fresh weight, with the result multiplied by one hundred, constitutes the percentage of rehydration. These rehydration percentages then formed the basis for determining the influence of the treatments preceding dehydration on the rehydration of the samples.

CHAPTER IV

STATISTICAL ANALYSIS AND RESULTS

The treatments used in this investigation consisted of (a) three conditions of freezing or non-freezing, (b) three sulfite dipping levels, (c) two blanching times, (d) two grade sizes, and (e) two storage temperatures, resulting in a total of seventy-two combinations. This plan constituted a 3 x 3 x 2 x 2 x 2 factorial design with single replication. The percentage of rehydration was obtained for each treatment combination at the end of each of three storage periods. The three sets of data were treated separately by the method of the analysis of variance. Higher order interactions whenever insignificant were pooled. The five per cent significance level was used for all statistical tests.

A. Two-Month Storage Period

The analysis of variance of percentage of rehydration for the two-month storage period is shown in Table I, page 22.

The interaction, Freezing x Sulfiting, is significant. The means of percentage rehydration for the nine treatment combinations of these two factors are shown in Table II, page 22.

Table II indicates that sulfiting (either 3000 ppm or 1000 ppm dip), as compared to non-sulfiting, yields higher percentage rehydration with the frozen beans but makes no difference with the unfrozen

TABLE I

ANALYSIS OF VARIANCE

Percentage Rehydration of Dehydrated Blue Lake Beans at Two Months Storage

Variation Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Freezing Temperature	12,033.2119	2	6,016.6060	52.41*
Size of Beans	291.2089	1	291.2089	19.30*
Blanching Time	0.1422	1	0.1422	0.01
Sulfite Dipping Level	676.7269	2	338.3635	2.95
Storage Temperature	409.9339	1	409.9339	27.17*
Freezing x Size	6.4286	2	3.2143	0.21
Freezing x Blanching	39.7153	2	19.8577	1.32
Freezing x Sulfiting	459.1865	4	114.7966	7.61*
Freezing x Storage	39.9603	2	19.9802	1.32
Size x Blanching	42.0139	1	42.0139	2.78
Size x Sulfiting	86.7220	2	43.3610	2.87
Size x Storage	50.0000	1	50.0000	3.31
Blanching x Sulfiting	7.4653	2	3.7327	0.25
Blanching x Storage	29.3889	1	29.3889	1.95
Sulfiting x Storage	43.6103	2	21.8052	1.44
Higher Order Int'act	679.0579	45	15.0902	----
Total	14,894.7728	71	----	----

*Significant

TABLE II

Mean Percentage of Rehydration for Sulfite Dipping Level and Freezing Temperature (At Two Months Storage)

	3000 ppm	1000 ppm	No sulfite
0 F	90.45	89.49	84.49
-20 F	78.94	78.71	65.51
Unfrozen	57.98	55.45	56.26

L.S.D. (5%): 3.93%

beans. There is no difference in the effect of 3000 ppm and 1000 ppm dipping levels.

It is seen from Table I that differences due to storage temperature are significant. The means of percentage rehydration for 72 F storage and 100 F storage are 75.4 per cent and 70.64 per cent respectively. After two months, 72 F storage yields higher percentage rehydration than 100 F storage.

Difference due to the effect of size is also significant. The means for size four and size five are 75.04 per cent and 71.02 per cent respectively. The effect of freezing temperature is shown to be significant. The means of percentage rehydration for freezing temperatures are 88.14 per cent for 0 F, 74.39 per cent for -20 F, and 56.56 per cent for unfrozen. The least significant difference (5 per cent level) is 8.59 per cent. It is clear, at this storage period, that 0 F freezing temperature results in significantly higher rehydration than -20 F freezing, which in turn is significantly higher than unfrozen beans.

The effect of blanching time is not significant, indicating that four- or six-minute blanches have the same effect on percentage rehydration at this time.

B. Four-Month Storage Period

The analysis of variance of percentage of rehydration for the four-month storage period is given in Table III.

TABLE III

ANALYSIS OF VARIANCE

Percentage Rehydration of Dehydrated Blue Lake Beans
at Four Months Storage

Variation Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Freezing Temperature	9,368.5908	2	4,684.2954	18.75
Size of Beans	262.9688	1	262.9688	1.90
Blanching Time	16.0555	1	16.0555	0.12
Sulfite Dipping Level	436.8133	2	218.4067	2.62
Storage Temperature	1,265.0450	1	1,265.0450	5.06
Freezing x Size	21.7754	2	10.8877	1.04
Freezing x Blanching	90.3120	2	45.1560	4.30*
Freezing x Sulfiting	333.0534	4	83.2634	7.93*
Freezing x Storage	499.6308	2	249.8154	23.80*
Size x Blanching	138.3340	1	133.3340	13.18*
Size x Sulfiting	15.8045	2	7.9023	0.75
Size x Storage	17.6023	1	17.6023	1.68
Blanching x Sulfiting	1.2212	2	0.6106	0.06
Blanching x Storage	1.8689	1	1.8689	0.18
Sulfiting x Storage	54.0300	2	27.0150	2.57
Higher Order Int'act	472.3891	45	10.4975	----
Total	12,995.4950	71	----	----

*Significant

The interaction, Size x Blanching, is significant. The means of percentage rehydration for the four treatment combinations of these two factors are given in Table IV, page 25.

Table IV indicates that size four rehydrates higher for a six-minute blanch than it does for a four-minute blanch, and also that it rehydrates higher than size five for a six-minute blanch, although the two sizes rehydrate the same for the four-minute blanch. The six-minute blanch increased the rehydration of size four but not of size five.

TABLE IV

Mean Percentage of Rehydration for
Size and Blanching Time
(At Four Months Storage)

Time	Size 4	Size 5
Four Minutes	70.38	69.33
Six Minutes	74.09	67.50

L.S.D. (5%):2.18%

The interaction, Freezing x Storage, is significant. The means of percentage rehydration for the six treatment combinations of these two factors are shown in Table V.

TABLE V

Mean Percentage of Rehydration for
Freezing Temperature and Storage Temperature
(At Four Months Storage)

	72 F	100 F
0 F	86.44	81.33
-20 F	79.02	63.20
Unfrozen	58.09	53.87

L.S.D. (5%):2.67%

Table V reveals that freezing at 0 F and -20 F make a difference at either storage temperature, and that storage temperature makes a difference for each freezing temperature condition. A freezing temperature of 0 F produces higher rehydration than freezing at -20 F.

A storage temperature of 100 F for 0 F frozen beans is equivalent to 72 F storage for -20 F frozen beans in this case.

The interaction, Freezing x Sulfiting, is significant. The means of percentage rehydration for the nine treatment combinations of these two factors are shown in Table VI.

TABLE VI

Mean Percentage of Rehydration for Sulfite Dipping Level and Freezing Temperature (At Four Months Storage)

	3000 ppm	1000 ppm	No sulfite
0 F	87.26	83.38	81.03
-20 F	75.03	73.89	64.41
Unfrozen	57.74	53.71	56.49

L.S.D. (5%): 3.27%

Table VI indicates that 3000 ppm sulfite dip increases the rehydration of 0 F frozen beans and of unfrozen beans, and that 1000 ppm dip and non-sulfiting have the same effect in these two cases. The rehydration of -20 F frozen beans, on the other hand, is increased by both 3000 ppm and 1000 ppm sulfite dipping, with both levels having the same effect.

The interaction, Freezing x Blanching, is significant. The means of percentage rehydration for the six treatment combinations of these two factors are given in Table VII, page 27. It is shown by this table that four or six-minute blanches make no difference on beans frozen at either 0 F or -20 F, but that a six-minute blanch increases the rehydration of unfrozen beans at this time.

TABLE VII

Mean Percentage of Rehydration for
Blanching Time and Freezing Temperature
(At Four Months Storage)

0 F	84.76	83.02
-20 F	70.69	71.52
Unfrozen	54.11	57.85

L.S.D. (5%):2.67%

C. Six-Month Storage Period

The analysis of variance of percentage of rehydration for the six-month storage period is shown in Table VIII, page 28. This table indicates that the difference due to storage temperatures is significant. The means of percentage rehydration for 72 F and 100 F storage are 74.45 per cent and 64.01 per cent respectively. A storage temperature of 72 F yields higher rehydration than 100 F after six months of storage.

The effect of sulfite dipping levels is significant. The means of percentage rehydration for sulfite dipping levels are 72.34 per cent for 3000 ppm level, 69.58 per cent for 1000 ppm level, and 65.77 per cent for non-sulfiting. The least significant difference (5 per cent level) is 3.45 per cent. This indicates that sulfite dipping at either of the two levels increases rehydration of the beans over non-sulfiting, but that there is no significant difference after six months storage in

TABLE VIII

ANALYSIS OF VARIANCE

Percentage Rehydration of Dehydrated Blue Lake Beans at Six Months Storage

Variation Source	Sum of Squares	Degrees of Freedom	Mean Square	F
Freezing Temperature	10,497.6436	2	5,248.8218	175.97*
Size of Beans	409.9339	1	409.9339	13.74
Blanching Time	1.1250	1	1.1250	0.04
Sulfite Dipping Level	522.5553	2	261.2777	14.08*
Storage Temperature	1,963.5556	1	1,963.5556	85.31*
Freezing x Size	8.7020	2	4.3510	0.15
Freezing x Blanching	52.2525	2	26.1263	0.88
Freezing x Sulfiting	230.4206	4	57.6052	3.10
Freezing x Storage	594.4836	2	297.2418	12.91
Size x Blanching	86.2422	1	86.2422	2.89
Size x Sulfiting	19.9203	2	9.9602	0.39
Size x Storage	0.8450	1	0.8450	0.04
Blanching x Sulfiting	39.0925	2	19.5463	0.77
Blanching x Storage	17.0139	1	17.0139	0.67
Sulfiting x Storage	41.7336	2	20.8668	1.12
Fr x Size x Bl	59.6553	2	29.8277	11.24
Fr x Size x Sul	20.0688	4	5.0172	1.89
Fr x Size x Stor	46.0308	2	23.0154	8.67
Fr x Bl x Sul	59.4700	4	14.8675	5.60
Fr x Bl x Stor	26.5603	2	13.2802	5.00
Fr x Sul x Stor	74.2122	4	18.5531	6.99
Size x Bl x Sul	17.1519	2	8.5760	0.34
Size x Bl x Stor	25.4422	1	25.4422	1.01
Size x Sul x Stor	19.0074	2	9.5037	0.38
Bl x Sul x Stor	15.0752	2	7.5376	0.30
Fr x Size x Bl x Sul	13.3206	4	3.3302	1.25
Fr x Size x Bl x Stor	11.5519	2	5.7760	2.18
Fr x Size x Sul x Stor	18.9018	4	4.7255	1.78
Fr x Bl x Sul x Stor	33.2006	4	8.3002	3.13
Size x Bl x Sul x Stor	50.5771	2	25.2886	9.53
Fr x Size x Bl x Sul x Stor	10.6188	4	2.6547	----
Total	14,986.3645	71	----	----

*Significant

the influence of the two levels on percentage rehydration.

The effect of blanching time or size is not significant. This indicates that four-minute and six-minute blanches and sizes four and five make no difference on percentage rehydration after six months storage.

The effect of freezing temperature is significant. The means of percentage rehydration for freezing temperatures are 83.64 per cent for 0 F freezing, 69.96 per cent for -20 F freezing, and 54.09 per cent for unfrozen. The least significant difference (5 per cent level) is 6.78 per cent. Thus, it is seen that 0 F frozen beans yield distinctly higher percentages of rehydration than -20 F frozen beans, and that -20 F frozen beans, in turn, yield higher percentages of rehydration than unfrozen beans after six months of storage.

The mathematical computations of the foregoing statistical analyses were performed with the assistance of the Oregon State College mathematics department.

CHAPTER V

DISCUSSION

1. Effect of Freezing Temperature

Freezing temperature had a clear-cut influence on the percentage of rehydration of these dehydrated beans. At the end of two months storage, beans which had been prefrozen at a temperature of 0 F yielded rehydration percentages, on a weight to weight basis, which were approximately 13 per cent higher than percentages for beans which had been frozen at -20 F. These -20 F frozen beans, on the other hand, produced rehydration percentages approximately 17 per cent higher than beans which were unfrozen. It was clear that unfrozen beans rehydrated less than either of the two groups of frozen beans.

This same relationship persisted at the end of four months storage and again at the end of six months. The analyses of variance demonstrated that these differences were significant at each storage period.

The relative magnitude of the differences did not change appreciably during the storage time. At four months storage, 0 F frozen samples were approximately 12 per cent higher in average percentage rehydration than -20 F frozen samples, which were in turn approximately 15 per cent higher than unfrozen samples. At six months storage, the differences were approximately the same as at four months.

The reasons for these differences were not investigated in this experiment, but it is believed that the nature of ice crystals formed within the product at the time of freezing may have some physical effect on the internal structure of the bean, enabling more ready absorption of water upon reconstitution.

2. Effect of Sulfite-Dipping Level

At the end of two months storage, sulfiting showed a different effect on the percentage rehydration of beans which had been frozen than on beans which had not been frozen. In the case of frozen samples, the sulfited beans, at either dipping level, were significantly higher in percentage rehydration than non-sulfited beans, but unfrozen samples showed no significant differences whether sulfited or non-sulfited. At four months, this effect was modified in that three thousand parts per million dipped samples showed higher rehydration for both unfrozen and frozen samples. At the end of six months, the effect of sulfiting as compared to non-sulfiting was the same for both frozen and non-frozen beans, irrespective of the dipping level. One thousand parts per million and three thousand parts per million dipped samples indicated no significant difference between them in percentage rehydration, but both levels yielded significantly higher rehydration than non-sulfited samples, whether frozen or non-frozen.

3. Effect of Blanching Time

After two months storage, steam blanching times of four or six minutes indicate no difference in effect on percentage rehydration of the dehydrated beans. At four months storage, the six-minute blanch had increased the rehydration of unfrozen beans, but there was no difference in effect on frozen beans. The amount of difference in the unfrozen beans was not large. After six months, blanching times again showed no difference in effect on percentage of rehydration, irrespective of other treatments. These results would indicate that, in terms of percentage of rehydration, there is nothing to be gained for the pre-freeze dehydration process by steam blanching for six minutes rather than for four minutes.

4. Effect of Size of Beans

Grade size four was found at the two months storage period to rehydrate slightly higher than size five. At four months, size four was higher in rehydration only in the case of the six-minute blanch. The two sizes were otherwise the same in effect. At six months, no difference in the effect of these two sizes on percentage rehydration appeared. The results suggest the view that the small difference in the effects of size present at the beginning was gradually lost during the storage period.

5. Effect of Storage Temperature

Samples stored at 100 F had consistently lower rehydration values than 72 F stored samples. After two months storage, the 100 F samples were approximately five per cent lower in average rehydration than samples stored at 72 F. This difference between the general averages increased to eight per cent at four months and ten per cent at six months. In each case the difference was significant. It is evident that there was a gradual lowering of rehydration capacity at 100 F storage temperature with increasing storage time. Normal storage temperature, represented by 72 F, resulted in essentially no difference in average rehydration percentages at two, four, and six months storage.

6. Moisture Levels

After dehydration the moisture content of the dehydrated beans which had been frozen was found to range from 2.05 per cent to 2.95 per cent on a weight to weight basis. The unfrozen dehydrated beans had moisture contents from 4.14 per cent to 5.63 per cent, weight to weight basis. The average for samples of the twenty-four different treatment combinations (before storage) of pre-frozen beans was 2.52 per cent while that of samples of the twelve different unfrozen combinations (before storage) was 4.57 per cent. This average difference of approximately two per cent in the removal of moisture from the bean by the dehydration process suggests the possibility that, for equal dehydration time, the prefreeze method of dehydration is effective in attaining lower moisture levels in dehydrated Blue Lake beans. (Table X, Appendix)

CHAPTER VI

SUMMARY AND CONCLUSIONS

The reconstitution, at three storage periods, of two grade sizes of cut and dehydrated Blue Lake green beans (Associated strain No. 231), which had been subjected to variations in treatments by steam blanching, sulfite dipping, and freezing or non-freezing preceding heated-air dehydration, resulted in percentages of rehydration which were analyzed by statistical methods for determination of the effects of the pre-treatments on the extent of rehydration. It is concluded that:

1. Freezing of cut and blanched Blue Lake beans prior to dehydration increases the percentage of rehydration of the dehydrated product upon reconstitution. Freezing at a temperature of 0 F yields higher rehydration percentages than freezing at a temperature of -20 F;
2. Sulfiting of cut and blanched Blue Lake beans prior to dehydration, by dipping for five minutes in a water solution of one thousand parts per million or three thousand parts per million sulfur dioxide, increases the percentage of rehydration of the dehydrated product upon reconstitution. These two dipping levels are equivalent in their effect on percentage rehydration;
3. Steam blanching for either four or six minutes of cut Blue

Lake beans, which are then frozen prior to dehydration, produces the same results in terms of percentage of rehydration of the reconstituted bean;

4. After six months of storage, grade sizes four and five of Blue Lake beans, dehydrated by the method of this experiment, yield the same results in percentage of rehydration;

5. Storage temperature of 100 F causes some reduction of the percentage of rehydration attained by Blue Lake beans dehydrated by the method used in this investigation.

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APPENDIX

TABLE IX

Dehydration of Blue Lake Beans
Wet and Dry Bulb Temperature Readings
(Test Run)

One dehydration cycle of 14 trayloads (42,000 grams) cut, blanched, and frozen beans

Time (minutes)	Dry-Bulb Temperature (F)	Wet-Bulb Temperature (F)
At start (dehydrator empty)	195	——
At start (dehydrator with load)	170	106
15 minutes	189	128
30 "	191	129
45 "	185	125
60 " (one hour)	171	118
75 "	153	109
90 "	147	105
105 "	145	103
120 " (two hours)	145	101
135 "	146	99
150 "	147	97
165 "	145	95
180 " (three hours)	145	94
195 "	147	93
210 "	145	92
225 "	145	91
240 " (four hours)	145	90
. . . .		
390 " ($6\frac{1}{2}$ hours)	145	90

TABLE X

Dehydration of Blue Lake Beans*
Drying Ratios and Moisture Levels

Code	Fresh Weight (grams)	Dehydrated Weight (grams)	Drying Ratio	% (Wt/Wt) of Moisture (Dehydrated)
4-FO	21,000	2,026	10.37:1	2.35
4-F1/SO	"	1,943	10.81:1	2.57
4-F3/SO	"	1,826	11.50:1	2.07
4-XO	"	2,039	10.30:1	2.12
4-X1/SO	"	1,896	11.08:1	2.52
4-X3/SO	"	1,762	11.92:1	2.44
5-FO	"	2,133	9.85:1	2.75
5-F1/SO	"	2,042	10.28:1	2.73
5-F3/SO	"	1,823	11.52:1	2.23
5-XO	"	1,999	10.51:1	2.59
5-X1/SO	"	1,839	11.42:1	2.69
5-X3/SO	"	1,840	11.41:1	2.59
4-F20	"	1,945	10.80:1	2.54
4-F1/S20	"	1,939	10.83:1	2.77
4-F3/S20	"	1,819	11.54:1	2.53
4-X20	"	1,909	11.00:1	2.71
4-X1/S20	"	1,833	11.46:1	2.51
4-X3/S20	"	1,777	11.82:1	2.42
5-F20	"	2,057	10.21:1	2.95
5-F1/S20	"	2,015	10.42:1	2.90
5-F3/S20	"	1,868	11.24:1	2.78
5-X20	"	1,908	11.01:1	2.12
5-S1/S20	"	1,826	11.50:1	2.05
5-X3/S20	"	1,820	11.54:1	2.37
4-FU	6,000	604	9.93:1	4.53
4-F1/SU	"	551	10.89:1	4.14
4-F3/SU	"	516	11.63:1	4.35
4-XU	"	584	10.27:1	4.31
4-X1/SU	"	586	10.24:1	4.93
4-X3/SU	"	662	9.06:1	5.63
5-FU	"	582	10.31:1	4.96
5-F1/SU	"	483	12.42:1	4.23
5-F3/SU	"	491	12.22:1	4.45
5-XU	"	500	12.00:1	4.21
5-X1/SU	"	479	12.53:1	4.27
5-X3/SU	"	492	12.20:1	4.86

*Size: 4 or 5; Blanch time: F or X (F is 4 min; X is 6 min)
Sulfite dip: 1/S or 3/S (1000 ppm SO_2; 3000 ppm SO_2)
Freezing temperature: 0 or 20 or U (0 F, -20F, unfrozen)

TABLE XI

REHYDRATION OF BLUE LAKE BEANS

General Averages of Percentage Rehydration
with respect to
Temperature of Freezing Before Dehydration and Storage Temperature

Freeze temperature:	0 F		-20 F		Unfrozen	
Storage temperature:	72 F	100 F	72 F	100 F	72 F	100 F
	%	%	%	%	%	%
Combined Sulfited Variations: (12 samples each item)						
2-Month	90.79	85.49	77.53	71.25	57.93	55.19
4-Month	86.44	81.34	79.02	63.20	58.09	53.87
6-Month	89.13	78.49	78.74	61.19	55.83	52.35
Sulfite Components: (4 samples each item)						
3000 ppm						
2-Month	92.25	88.65	81.20	76.68	59.20	56.75
4-Month	88.12	86.40	82.98	67.08	59.70	55.78
6-Month	92.60	83.38	84.73	63.28	58.58	52.48
1000 ppm						
2-Month	93.23	85.75	83.70	73.73	57.18	53.73
4-Month	88.13	78.63	83.58	64.20	55.53	51.90
6-Month	89.93	76.95	81.38	63.23	54.03	51.98
No sulfite						
2-Month	86.90	82.08	67.68	63.35	57.43	55.10
4-Month	83.08	78.98	70.50	58.33	59.05	53.93
6-Month	84.85	75.13	70.10	57.05	54.88	52.60

Note: Blanching time of four and six minutes and sizes four and five are combined in these averages.