COLOR MEASUREMENT AND ITS RELATION TO GRADING OF CANNED AND FROZEN GREEN BEANS

by

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CHAPTER I

INTRODUCTION

The color index is regarded as one of the important factors in most of the standards established for agricultural products. Some agricultural products, like cotton, are valued according to their color. Color is also regarded as one of the factors in grading other agricultural products like rice, honey, meat, grains, bread, mayonnaise and various dairy products. The same is true in grading of fruits and vegetables.

It should be noted that though color has an eye appealing value it also has relationship with various other factors which determine the quality of the product.

1. Maturity as in the case of fruits and vegetables.
2. Cultural practices.
3. Ingredients used in products.
4. Index of baking in bakery products.
5. Spoilage of products.

The color of fruits and vegetables however, is specific for a particular variety. For instance, in case of apples the attainment of a particular color will not be common to all. Some apples attain a characteristic red color when they are fully matured while others remain green in color in their matured state. Determination of change in color with maturity has been found helpful in determining the changes in the constituents of fruits, like dextrose, levulose, sucrose and starch, titrable acidity, and percentage dry matter. Lott (2) of University of Illinois has made studies on changes in reflectance of flesh and skin and in composition of maturing Transparent and Dutchess apples.

(2) Color of fruit is affected by various cultural and environmental factors such as pruning, thinning, cultivation and fertilization. Gourley & Howlett (3) report the work of Dustman and Duncan of their experiment on the effects of sprays on the development of red and yellow pigments in the apple. Magness (9) has reported his observationson relation of leaf area to color. He has also studied the effect of light in relation with color. It is therefore evident that in many cases color determination serves as an index in determining the quality of the fruit as well as vegetable crops, depending however upon the variety and locality where it is grown.

(3) Effect of variation in ingredients on color of different products have been studied. In case of chocolate acidity of milk and quality of soda are important factors. Sweet milk produces a dark cake, while strongly acid milk produces much lighter color (4).

Color is an important factor in the consumer's preference for foods. Unbalanced diets may frequently be laid to foods unattractive in color. Grove reports that Pavlo and other scientists (4) have proved that psychological appeal has a definitely stimulating effect upon digestive processes.

MacGillivray (7) made studies on tomato color as related to quality in the tomato canning industry. He has made studies on the effect of heat, dilution, sugar, iron and copper salts and other ingredients like spices, on the color of tomato juice, tomato catsup, paste, etc.

(4) Even in bakery products the color of the product is considered as one of the essential factors in favor of the consumers. In bread the color of the crust and crumb is of interest to the cereal chemist. A reddish brown crust is associated with high sugar content and this in turn with diastatic activity which may be correlated with flavor, strength and good loaf volume (5).

(5) Methods of processing, packaging and preservation has also an important bearing on processed foods and especially with fruit juices. Fruit and vegetable juices and their products lose their flavor and color more rapidly if processed too long at high temperatures. Similarly, light causes change in color of products stored in glass bottles or jars. The methods of preservation whether in the presence of preservatives or other substances or in

the absence of these will have an effect on retention or loss of color of the product.

From all these points it will be seen that color contributes as one of the grading factors and is an index which determines one of the variable factors mentioned above responsible for its change.

U. S. Department of Agriculture has laid down standards for fresh, canned, and frozen fruits and vegetables; but for some products like beans, no range of color is fixed for quality, but only an uniformity of color is desired in canned and frozen beans at the present time. (12-13).

With this in view the present work of color measurement of canned and frozen green beans was carried out. In the present work, attempts were made to find out:

(1) A suitable method of color determination in overcoming the difficulties afforded by uneven surfaces.

(2) Color and its relation to sieve size, variety and locality.

(3) Color and its relation to quality grades.

CHAPTER II

LITERATURE

What is color?

Color of an object as one observes is simply psychological or optical sensation. Psychologically, color is represented by the three attributes: Hue, value and chroma. Physically, it is represented by a dominant wavelength.

The colorist is interested in reproducing or matching colors. The physicist is interested in the wavelengths and intensities of the light and lighting. The physician is interested in the diagnostic significance of color. The artist is interested in the pictorial effect, the psychologist in the emotional effect of color, and the chemist wants to know the composition and concentration of the pigments or dyes (1).

(A) Psychological methods

1. <u>Qualitative</u>

In qualitative method, a color of a sample can be compared simply by comparison with other samples, and one would say that the one is more lighter or less lighter than the other, but one cannot determine to what degree in color they differ from one another.

(a) Color charts

The system of comparing color with some definite standards qualitatively include the color chart systems in which a large number of colors with different hue, value, and chroma are printed on paper in definite gradation. The Maerz and Paul dictionary of colors include a large number, 7,056 colors. Hue, value and chroma are not stated but each color is given an identifying number (8). In numerous U. S. grading standards of fruits and vegetables these charts are used for grading the color of the products.

(b) Lovibond system

Another system of color measurement commonly used specially for oils is the Lovibond system. An instrument known as the tintometer was devised by J. W. Lovibond for the analysis, synthesis, matching and measurement of color. As described in the advertising circular, it is a system by means of which the depth of color in liquids and solids can be measured in degrees, placed in their position in a permanent color scale and registered for reproduction at any time. It consists of graded series of standards made of colored glasses numbered according to their depth of color and an instrument for holding the glasses and the object to be measured (2).

2. Quantitative

In quantitative method, it is possible to determine the exact degree of color and thus one can compare the colors from each other even though they may differ slightly and the difference may not be perceptible to the observer without the use of the instrument.

Color is specified psychologically by means of the three color attributes namely: Hue, value and chroma (10). In these methods it is important to have the same and uniform conditions of light and surroundings, throughout the color measurement of samples, because any variation in the conditions under measurement will affect hue, value and chroma. This system of color measurement is based on trichromatic specification i.e. where the color is defined in terms of three arbitrary primaries: Red, blue and green.

(a) Munsell color system

Munsell color system consists of various disks of different hue, value and chroma and the neutrals. These disks are selected and the areas are adjusted to match the sample under examination. In this instrument either the disks are rotated or the reflecting rays from the disks are rotated by a prism in order to obtain uniform color. The latter system is more commonly used.

(b) Reflection meter calibrated to I.C.I. system

This instrument consists of a search unit and has three filters: Amber, green and blue. Each filter is calibrated for reflectance against a reflecting surface of magnesium oxide plate, which is arbitrarily assumed to have 100 per cent reflectance. The search unit is placed on the sample with successive filters attached. The degree of sensation produced by these filters is measured in terms of equivalent stimulus produced by the photovolt meter. The readings are read on the scale. The readings thus obtained can be converted to I.C.I. notation and finally in terms of hue, value and chroma.

(B) Physical methods

Spectrophotometers

The methods above define the sensation produced on the eye by a color. A spectrophotometer defines the stimulus which incites that sensation.

Spectrophotometry may be defined as the measurement of relative intensity of radiant energy as a function of wavelength or frequency. This energy may be that emitted by incandescent or other light sources or it may be that transmitted, absorbed, or reflected by transparent or absorbing materials.

The general mechanism of spectrophotometer consists in dispersion of source of light into its spectral components, and then isolating monochromatic beams. These beams are then further divided into two equal parts of the same intensity. One of the beams is allowed to pass or reflected and the second beam is adjusted to get the equal intensity. The intensities at different wavelengths are measured on the scale.

There are certain types of spectrophotometers where photoelectric cells are used. The photoelectric cells under the action of radiant energy of the proper wavelength furnishes another and better means of transmissive or reflective measurements.

Spectrophotometers are of great value in the study of chemical analysis, structure and purity of the chemical compounds of wide variety. Spectrophotometers are of great value in determining the ultra violet and infra red regions where eye is not able to locate the color.

The spectral reflection or transmission data obtained from the results are plotted on the graph which give the percentage brilliance for all the wave-lengths throughout the visible spectrum. Two colors having identical spectrophotometric readings are assumed to be the same under the same conditions of illumination.

The practical difficulties, however, in using this instrument is that its complicated mechanism and interpretation of results are rather difficult for an untrained man to handle, and secondly it involves measurements of all wavelengths for specifying a single color. For routine work of measuring color of products for determining grades where simple interpretation of results and simple mechanism of apparatus is desired, spectrophotometric data will not serve any practical purpose.

(C) Details of the Munsell system of color notation

The present work of color determination was carried on by the Munsell system, and it is therefore necessary to describe this method in more detail.

This system of color notation was developed by A. H. Munsell in the early part of this century. The color is expressed by three attributes: Hue, value and chroma. The Munsell hue is divided in 10 major hues:

R:Red	BG:Blue Green
YR:Yellow Red	B:Blue
Y:Yellow	PB:Purple Blue
GY:Green Yellow	P:Purple
G:Green	RP:Red Purple

Each hue can further be divided into 100 or even 1000 parts at constant value and chroma (10).

Munsell Value is divided into 10 equal parts from 0, black, to 10, white. Thus a particular hue may appear different under different lightness.

Munsell Chroma is that the colors possessing the same hue and value may differ in saturation or concentration. The chroma is divided from 0 to 10 and upwards, in numerical order with 0 at gray extending outward towards 10 or more for the strong colors. Thus for example Munsell color notation of 5 GY 5/9 represents that hue is 5 GY, value 5 and chroma 9.

(D) I.C.I. color specification and the Munsell system

The I.C.I. system of color notation is based on the spectrophotometric color determination in terms of equivalent stimuli. The International Commission of Illuminants adopted a method to bring about an International standardization in 1931. The results were computed for standard observers and standard illuminants. The tristimulus values were adopted by the I.C.I. for various spectrum colors. X, Y, and Z represent the absolute tristimulus values of the three imaginary primaries, red, blue and green; and x, y, and z indicate the amount of each of the I.C.I. primaries that is required to color match a given sample. These quantities are called the trichromatic coefficients. The quality of the color (chromaticity) is represented graphically with x and y coordinates on a graph of a given value. The I.C.I. colorimetric data adopted in 1931 represents dominant wavelength, brightness and purity which correspond to the three Munsell attributes: Hue, value and chroma. The I.C.I. notation for all the Munsell color charts is now available. The graphical representation of loci of constant hue and chroma in I.C.I. x and y coordinates from values 1 to 9 is shown on each chart.

(E) Method of computation

The relation of Munsell hue, value and chroma have thus been studied in I.C.I. terms and data are available for converting from one to the other. The I.C.I. Y equivalents correspond to the Munsell value scale. From the charts of constant loci of constant hue and chroma in I.C.I. x and y coordinates at values 1 to 9, it is possible to convert Munsell notation to I.C.I. specification and vice versa.

For example 5 Y 5/6; 8 GY 7.1/10.4; N 1 and N 5 disks were required to match color of a canned bean sample. The percentage of these disks required were 3.5 per cent of 5 Y 5/6 (X = .0066, Y = .0069, Z = .0019); 16 per cent of 8 GY 7.1/10.4 (X = .0494, Y= .0723, Z = .0232); 78.5 per cent of N 1 (X = .0118, Y = .0121, Z = .0145); and 2 per cent of N 5 (X = .0037, Y = .0069, Z = .0019), under illuminant C resulted in a color specification for the sample of X = .0715, Y = .0951 and Z = .0442. x = .3390 and y = .4510. From tables of I.C.I. Y equivalents the Munsell value for Y = .0951 is V = 3.59. The value lies between 3 and 4. Therefore the Munsell hue and chroma can be found out by interpolation of charts of value 3 and 4. Upon plotting on the chart of value 3 for x .3390 and y .4510, the hue and chroma are found to be 6.7 GY/4.5 and likewise from a chart of value 4 the same obsicca and ordinates yield a hue and chroma of 6.7 GY/5. It is found in this case that the hue remains practically the same i.e. 6.7 GY but the chroma in this case will be chroma at 3 plus .59 of the difference of chroma at value 3 and 4. The interpolated chroma will be:

$$5 - 0.59\ (5 - 4.5) = 4.79$$

The complete notation for the canned bean sample will be:

6.7 GY 3.59/4.79

Similarly the reverse notation from Munsell notation to I.C.I. notation can be calculated.

Some of the U. S. Grade Standards of specifying color of many products is represented by the percentage of disks required to match the color. In this method computation of color into one single notation is not required. The sample is said to be darker or lighter than the disk combination or to be within a certain color range. This method is useful where color is not required to be specified and also for rough determination. But it is more convenient to specify the color in terms of specific single notation. This facilitates one to know without any confusion the degree of difference not only in hue but also in value and chroma, no matter what disks are used to make the color match.

CHAPTER III

EXPERIMENTAL

Methods Adapted in the Measurement of Color of Beans

A. Adjustment of the apparatus

The apparatus used for color measurement is manufactured by Keuffel & Esser Company. This type of colorimeter is now no longer manufactured by the company. The instrument has the following features (11):

1. The use of disc mixture of Munsell papers makes it possible to use the results in terms of psychological attributes: Hue, brilliance and chroma.

2. The instrument may be adjusted to measure either a large or small area.

3. It measures the average color of a highly variegated surface.

4. It has a unique method of illumination by cross lighting.

The photograph of the instrument and diagram of the optical system is shown in Figures 1 and 2.

The illumination is supplied by two lamps which are so placed that they are in a horizontal plane with the center of the sample and in a vertical plane with the center of the discs. The lamps are of 50 volts and are

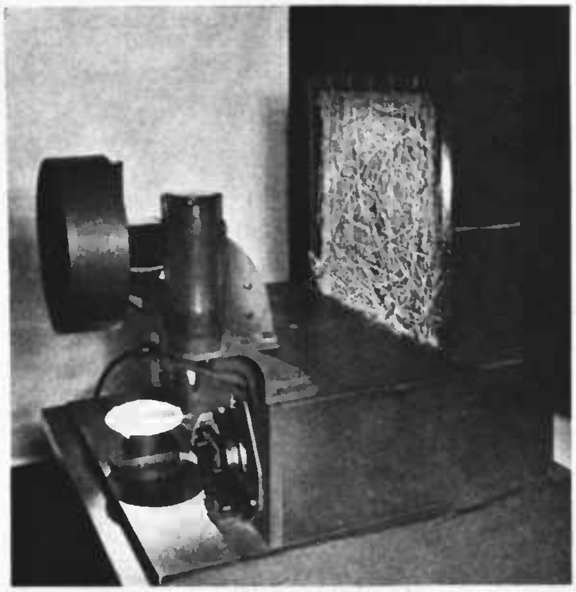

Figure 1 - Munsell Disc
Colorimeter*

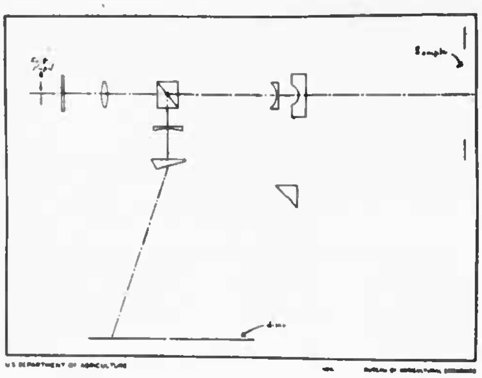

Figure 2 - Optical System
of the Disc
Colorimeter*

*Nickerson, Dorothy. Jour. Opt. Soc. Am.
Vol. 21, No. 10, 1931

of movie projection type with four filaments in the same plane. This has the advantage that the light that is given off at right angles to the plane of the four filaments is greater than that in the same direction when the lamps rotated through 90 degrees. By adjusting the lamps, the bases of which are provided with a slot and screw for this purpose, the light on the sample surface may be made equal to that on the disc surface.

In order to adjust equal illumination on both the sample and the spinning disks, one disk was placed in the place of the sample and a duplicate was placed in the place of the disks. Both these disks were gray and of the same value. The side lamps were then adjusted at an angle until the color of the two disks appeared the same after spinning the motor at high speed.

B. Arrangement of the sample under Measurement

It is always easy to get a perfectly flat surface in case of liquids and powders. These substances can be evenly spread. In case of other products it is rather difficult to have even surface without properly arranging the product to get almost uniform flat surface. If the surface is not flat there will be a difference in reflecting areas all over the surface of the sample. Secondly the product like beans may offer another difficulty of getting dark and shaded areas if they are not closely arranged or if they overlap.

From the following example (Table I), it will be seen the difference in color measurement due to even, flat surface and uneven surface. From the figures in Table I, it is seen that beans arranged with uneven surface become darker due to shaded areas. The hue shifts more toward green and value becomes less chroma in the first two samples showed an increase, but in case of No. 5 size beans it showed a slight decrease.

Beans were arranged in the petri dish closely without keeping any distance between the beans. Two layers of beans were arranged in such a manner; finally the beans were slightly pressed in order to give a uniform smooth surface.

The arrangement is shown in Figure 3.

In order to have a proper area of bean surface it was found necessary to have a petri dish of 6 inch diameter

Table I

Difference in Color Measurement due to Even and Uneven Surface of Beans

	No. 2-3-4	No. 4 Asparagus Style (whole)	No. 5
Beans with even, flat surface	6.18 Y 4.13/4.87	5.80 Y 4.67/5.14	6.33 Y 4.70/5.62
Beans with uneven surface	6.80 Y 3.93/4.97	6.25 Y 4.61/5.42	6.38 Y 4.63/5.44

Figure 3 Arrangement of the beans for color measurement

In case of a dish of smaller diameter of 4 inch, the area focussed was found larger than the dish.

Avoidance of reflecting surfaces

In order to minimize any reflection from the dish which might otherwise cause difference in matching color, the dish was painted black with black paint. This reduced any rays of light reflecting back. Change of surroundings, colors of background can also cause difference in results. To avoid all these differences the same condition of surroundings and background should be maintained throughout the experiment. The instrument was placed in a dark room and the walls were also darkened.

Choice of disks

A judgment of "match" is not an exact matter. It is made within a tolerance and the reduction of that tolerance to its smallest size should be the aim of every operator (11).

Some colors like green or green yellow require several trials to select proper disks to get a match within tolerance.

Another important point of consideration is training and strain on the eye. After several trials the eye becomes critical to mark sharply the difference in color. Secondly it should be noted that too much strain should not be given to the eye, otherwise due to fatigue of the eye it is not able to mark minute differences which may cause difference in color measurement.

After preliminary trials the selection of disks was made. An attempt was made to have disks from yellow to green yellow to cover the range for all the samples of fresh, canned and frozen beans. But it was found that the same disks which were used for canned beans could not be used for frozen beans. First, the canned beans were more towards yellow side and chroma was less than the frozen beans. The frozen beans were more towards greenish yellow than yellow, and at the same time the chroma was more than canned beans. For this reason a disk of higher greenish yellow hue and higher chroma did not suit the purpose for canned samples. The neutral disks used for both canned and frozen samples were N_1 and N_5. In practice it is not possible to find a disk of exact hue, value and chroma to match a given sample. It is therefore necessary to select two disks of adjacent hues within the range of which the hue of the sample may lie. Similarly for adjusting the value it is necessary to select two disks of proper value range. Thus it is necessary to have four disks which can be adjusted conveniently to give an exact match of the sample. Throughout the whole work an average of three readings was taken for calculation. The selection of disks is shown in Table II.

Table II

Suggested disks for fresh, blanched, canned and frozen beans

1.	Fresh Beans	5Y 5/6,	5 GY 5/8	N 1, N 7
2.	Blanched Beans	5Y 5/6,	8 GY 7.1/10.4,	N 1, N 5
3.	Canned Beans	5Y 5/6,	5 GY 5/8	N 1, N 5
4.	Frozen and thawed	5Y 5/6	8 GY 7.1/10.4,	N 1, N 5

Results

Source of samples

It was thought advisable to collect samples directly from the canning factories which were processed and marketed under the same conditions of blanching, grading according to sieve sizes, etc.

The samples were obtained from Oregon, Washington and Louisiana states. Few of different brands were purchased from the stores. The varieties available were Blue Lake Regular and Stringless strain and Giant Stringless. In requesting these samples, attempts were also made to get the previous history of the samples, as regards variety, date of packing, locality where it was grown, sieve size and method of processing.

Table III

Color determination of fresh green beans according to the sieve sizes

(Variety - Regular Blue Lake)

Serial No.	Sieve No.	Hue	Value	Chroma
1.	1-2-3	4.92 GY	4.91	3.96
2.	4	5.60 GY	5.03	4.60
3.	5	3.30 GY	5.02	3.80
4.	6	3.86 GY	5.28	4.04
5.	Cull	2.50 GY	6.03	4.60

From the above results it is seen that the range of hue lies between 2.5 GY to 5.6 GY, the value lies between 4.91 to 6.03 and chroma lies between 3.80 to 4.60. As regards value it is seen that it increases with the size of the beans. Chroma also shows an increase sometimes.

Table IV

Effect of blanching on hue,
value and chroma

Ser. No.	Sieve No.	Color before blanching			Color after blanching		
		Hue	Value	Chroma	Hue	Value	Chroma
6.	1-2-3	4.92 GY	4.91	3.96	6.25 GY	4.58	5.58
7.	4	5.60GY	5.03	4.60	4.90 GY	4.83	5.07
8.	5	3.30 GY	5.02	3.80	4.90 GY	4.83	5.07
9.	6	3.86 GY	5.28	4.04	5.44 GY	5.14	5.88
10.	Cull	2.50 GY	6.03	4.60	5.44 GY	5.14	5.88

From the above results it is seen that the color is improved by blanching. There is not much change in value but there is a slight increase in chroma.

Table V

Color determination of beans frozen and thawed in the laboratory

Ser. No.	Sieve No.	Color of blanched beans			Color of frozen and thawed beans		
1.	1-2-3	6.25 GY	4.58	5.58	2.5 GY	4.04	4.20
2.	4	4.90 GY	4.83	5.07	2.50 GY	4.61	5.30
3.	5	4.90 GY	4.83	5.07	2.50 GY	4.62	5.30
4.	6	5.44 GY	5.14	5.88	5.00 GY	4.33	5.26
5.	Cull	5.44 GY	5.14	5.88	5.00 GY	4.33	5.26

Blanched beans were frozen and examined after 14 days after complete thawing at room temperature.

From the above figures it is seen that blanching on the whole improves the color of the beans, but on thawing the color on the contrary seems slightly faded. There is practically no change in value and chroma in blanched and frozen and thawed samples.

Table VI

The range of color of commercially quick frozen beans after thawing at room temperature
(Date of packing: August 1947)
Variety: Regular Blue Lake

Ser. No.	Sieve No.	Hue	Value	Chroma
1.	1-2-3	6.04 GY	3.54	4.63
2.	1-2-3	6.63 GY	3.65	4.79
3.	1-2-3	6.00 GY	3.63	4.78
4.	1-2-3	6.70 GY	3.59	4.79
5.	1-2-3	5.87 GY	3.18	3.47
6.	1-2-3	7.10 GY	3.97	5.00
7.	1-2-3	6.80 GY	3.77	5.26
8.	1-2-3	6.94 GY	3.80	5.20
9.	1-2-3	6.73 GY	3.76	5.21
10.	1-2-3	6.70 GY	3.59	4.79
11.	1-2-3	6.45 GY	3.57	5.91
12.	1-2-3-4	6.80 GY	3.64	4.59

From the above results it is seen that the hue lies between 5.87 GY to 7.10 GY value lies between 3.18 to 3.97 and chroma lies between 3.47 to 5.91.

Table VII

The range of color of canned beans from identical raw material (Variety: Regular Blue Lake)

Ser. No.	Sieve No.	Hue	Value	Chroma
1.	2 (Fancy)	6.19 Y	3.15	3.46
2.	2	6.72 Y	4.40	3.84
3.	3 (Fancy)	3.90 Y	3.61	3.60
4.	2-3-4 (Cuts)	5.80 Y	4.00	3.80
5.	2-3-4 (Short cuts)	6.90 Y	3.82	3.16
6.	4	6.64 Y	5.29	4.83
7.	4	5.94 Y	5.66	5.66
8.	4	5.80 Y	4.42	4.14
9.	5 (Extra standard)	6.60 Y	5.15	3.89
10.	5 (Extra standard)	6.25 Y	4.50	3.85
11.	6 (Standard)	5.62 Y	4.92	5.52

From the above results it is seen that hue lies between 3.90 Y to 6.60 Y, value lies between 3.61 to 5.29 or say between 4 to 6 and chroma lies between 3.60 to 5.52 or say between 3.5 to 6.

Table VIII

The range of color of canned beans of the same variety and different sieve sizes

(Date of packing: 1947)
Variety: Blue Lake Stringless

Ser. No.	Sieve No.	Hue	Value	Chroma
12.	1 (Whole)	5.18 Y	3.77	3.90
13.	1 (Whole)	6.12 Y	4.13	4.70
14.	1 (Whole)	6.08 Y	4.03	4.64
	Average	5.79 Y	3.97	4.41
15.	4 (Fancy)	6.05 Y	4.39	4.91
16.	4 (Fancy)	6.20 Y	4.47	4.47
17.	4 (Fancy)	6.60 Y	4.31	4.85
	Average	6.28 Y	4.39	4.73
18.	5(Ext.standard)	5.92 Y	4.61	4.64
19.	5(Ext.standard)	6.48 Y	4.33	4.57
20.	5(Ext.standard)	6.51 Y	4.27	4.62
	Average	6.30 Y	4.40	4.57
21.	6 (Standard)	6.60 Y	4.42	4.94
22.	6 (Standard)	6.05 Y	4.45	4.76
23.	6 (Standard)	6.02 Y	4.52	4.82
	Average	6.22 Y	4.46	4.84

From the above results it is seen that the average hue, value and chroma for sieve No. 1 is less than that of sieve No. 4-5 and 6. Beans of sieve No. 6 are on average lighter in color.

Table IX

The range of color of canned beans of the same variety packed by different companies

(Date of packing: August 1946)
Variety: Blue Lake Regular

Ser. No.	Sieve No.	Hue	Value	Chroma
24.	1-2-3(Fancy)	6.50 Y	4.16	4.53
25.	1-2-3-4	6.14 Y	4.20	4.84
26.	2 (Fancy)	6.46 Y	4.35	5.21
27.	2 (Fancy)	6.12 Y	4.37	4.96
28.	4 (Fancy)	6.05 Y	4.45	5.26
29.	4-5	6.10 Y	4.35	4.95
30.	5 (Extra standard)	6.03 Y	4.48	5.19
31.	5 (Extra standard)	6.05 Y	4.52	5.02
32.	5 (Extra standard)	6.14 Y	4.33	5.03
33.	5-6	6.10 Y	4.39	3.64
34.	5-6	6.17 Y	3.93	4.55
35.	5-6	6.25 Y	3.94	4.38
36.	6 (Standard)	6.25 Y	4.39	5.11
37.	6 (Standard)	6.36 Y	4.54	5.23

From the above results it is seen that in general the color of the canned beans does not change considerably but remains practically the same after two years storage. The value also remains practically the same, but it is noticed that chroma is increased slightly as seen from Table VII.

Table X

The color of canned green beans of two different varieties grown and packed in the state of Washington

Ser. No.	Variety	Sieve No.	Hue	Value	Chroma
38.	Regular Blue Lake	5 Standard	6.20 Y	4.54	5.20
39.	Do	5 Standard	6.60 Y	4.52	5.36
40.	Do	5 Standard	6.02 Y	4.73	5.18
	Average		6.28 Y	4.62	5.34
41.	Blue Lake Stringless	5 Standard	6.60 Y	4.58	5.26
42.	Do	5 Standard	6.60 Y	4.58	5.26
43.	Do	5 Standard	6.60 Y	4.52	5.22
	Average		6.60 Y	4.56	5.24

From the above results it is seen that there is a slight difference between two different varieties of green beans. The hue of Blue Lake Stringless is on an average more than the Regular Blue Lake variety. As regards value and chroma there is practically not much difference.

Table XI

The color of canned green beans grown and packed in the state of Louisiana

Ser. No.	Variety	Sieve No.	Hue	Value	Chroma
44.	Giant stringless	5 (Extra standard)	6.25 Y	4.49	5.00
45.	Do	5 Do	6.08 Y	4.38	4.70
46.	Do	5 Do	6.41 Y	4.55	4.95
47.	Do	5 Do	5.80 Y	4.24	4.67
48.	Do	5 Do	6.16 Y	4.55	5.04
49.	Do	5 Do.	6.60 Y	4.38	4.70
	Average		6.21 Y	4.43	4.84

From the above results it is seen that hue, value and chroma does not show any marked difference from beans of the Blue Lake variety in the preceding table.

Table XII

Comparative results of the color of canned green beans of sieve size No. 5 of different varieties and localities

Variety	Locality	Hue	Value	Chroma
1) Regular BlueLake	Washington	6.20 Y	4.54	5.20
Do	Do	6.60 Y	4.52	5.36
Do	Do	6.02 Y	4.73	5.18
	Average	6.28 Y	4.62	5.34
2) Regular BlueLake	Oregon	6.60 Y	5.15	3.89
Do	Do	5.66 Y	4.68	4.00
	Average	6.13 Y	4.91	3.94
3) Blue Lake Stringless	Washington	6.60 Y	4.58	5.26
Do	Do	6.60 Y	4.58	5.26
Do	Do	6.60 Y	4.52	5.22
	Average	6.60 Y	4.56	5.24
4) Blue Lake Stringless	Oregon	5.92 Y	4.61	4.64
Do	Do	6.48 Y	4.33	4.46
Do	Do	6.51 Y	4.27	4.62
	Average	6.30 Y	4.40	4.57
5) Giant Stringless	Louisiana	6.25 Y	4.49	5.00
Do	Do	6.08 Y	4.38	4.70
Do	Do	6.41 Y	4.55	4.95
Do	Do	5.80 Y	4.24	4.67
Do	Do	6.16 Y	4.55	5.04
Do	Do	6.60 Y	4.38	4.70
	Average	6.21 Y	4.43	4.84

Comparison of color measurement between Reflection meter and Munsell disc colorimetry

Reflection meter which is based on trichromatic specification was tried to measure color on some bean samples. The instrument consists of a search unit having an opening of 5/8 inch diameter. It has three filters: Amber, green, and blue. Each filter is caliberated for reflectance against a reflecting surface of magnesium oxide plate, which is arbitrarily assumed to have 100 per cent reflectance.

The opening of the search unit being small it is rather doubtful to have one or two readings for a sample like beans which has not a uniform surface. Secondly, a sample having different shades and variation in color in an area under examination, will give different readings at different places when the search unit is placed on the sample. An attempt was made to see whether the reflection meter could be used with advantage for samples having uneven surface like beans. In order to have a good representative color data of the sample it was found necessary to have an average of 8 to 10 readings taken at different places over the entire area of the sample, taking care not to position the unit over a space between beans. The following are few results of color values of few samples of beans for reflection meter and Munsell disc colorimeter. It was found that the value and chroma remain practically the same but hue in general is found to be 0.8-0.9 less than the Munsell disc colorimeter. This may be due to the fact that some rays of light might not be completely reflected back due to uneven surface.

Table XIII

Comparative color measurement results between Reflection meter and Munsell disc colorimeter

Sample	Readings with Reflection Meter	Readings with Munsell Disc Colorimeter
Canned beans	5.84 Y 3.92/4.45	6.6 Y 3.92/4.36
Frozen beans	5.30 GY 3.70/4.75	6.18 GY 3.72/4.55
Frozen beans	6.96 GY 3.90/5.92	6.50 GY 3.87/4.72
Frozen beans	5.85 GY 3.85/4.82	6.75 GY 3.84/5.08

The advantages of using this instrument are as follows:

1. Ease of operation
2. Low cost of the instrument
3. No color-matching skill required - objective determination not dependent upon the human eye.

In order to have maximum reflection and no interference of surrounding light, a wooden disc having a tapering hole exactly fitting into the neck of the search unit was used.

The lower part of the disc was painted black and was kept over the sample. This prevented any rays of side light falling on the sample. The search unit was placed on the sample, through the wooden disc and was slightly pressed on the sample to have a more uniform surface.

CHAPTER IV

DISCUSSION OF RESULTS

From all the data in the preceding chapter collected so far, it is seen that there is a noticeable difference in hue, value and chroma of fresh, canned and frozen green beans. Attempts were made to find out whether there would be any marked difference in color as regards sieve size, variety and locality in canned and frozen beans.

Fresh Beans

In the case of fresh beans, different varieties which are used specially for canning were not available in the state of Oregon. The color determination in the fresh condition was therefore restricted to one variety, namely, Blue Lake. The color of different sieve size beans in fresh condition, effect of blanching, freezing and thawing in the laboratory was studied. The hue of the beans in fresh condition was found to be maximum in beans of sieve size No. 4 and there was a decrease in hue as the beans were more matured. Similarly there was an increase in the lightness of the beans as the maturity progressed. The chroma was found to be variable with this small number of samples. (Table III).

Effect of blanching

Blanching of the beans improves the color on the whole as is seen from Table IV. This improvement in greenness is of course a common observation. These beans were water-blanched in the laboratory at 193 degrees F. for 1½ minutes. It was noticed that hue shifts by 1.33 to 1.60 towards Green. In case of No. 4 size beans the hue was seen to have dropped down by 0.70 towards yellow. The reason for this is not known. In the case of beans of sieve size No. 5 it was found that the hue is much improved. The beans become slightly darker and the change in lightness decreases with the size of the beans. Chroma, however, showed an increase from 28 to 46 per cent.

Canned beans

In order to get an idea of the range of canned beans as packed by the canneries, a number of samples of various sieve sized beans, of different varieties and grown in different localities were examined.

From Table VII it is seen that different sieve sized beans of one variety, namely, Regular Blue Lake was examined to find out the range of color with respect to sieve size. It was found that all canned samples were very similar yet considerably different from fresh samples. The range of hue varied from 3.90 Y to 6.60 Y. The only marked difference noticed was in value. Beans of sieve size No. 2, 3, and 2-3-4 combined were darker than those of sieve sizes No. 4 and above. The range of value varied between 3.61 to 5.66 and chroma from 3.60 to 5.66. It was however noticed that No. 2 and 3 Fancy were much darker.

Effect of different varieties on color

Another strain of Blue Lake, namely, Stringless, was examined for color and its final effect on color by canning is shown in Table VIII. Beans of sieve sizes No. 1, 4, 5 and 6 available. On examination it was found that on an average the hue for sieve size No. 1 was 5.79 Y, but the value was 3.97, which was darker than other sieve sizes. The hue was maximum for sieve size No. 5, and then again dropped for sieve size No. 6. Lightness however, increased progressively, but not much difference was noticed in hue, value and chroma for sieve size No. 4 and 5. From this it seems that there is no appreciable change in hue, value and chroma for sieve sizes for No. 4 and above. It is therefore seen that there is a dividing line between color of sieve sizes from No. 1 to 3 and from 4 and above.

As regards the difference in color between Regular Blue Lake and Stringless strain there was not much difference noticed in hue and value in all sieve sizes but chroma for No. 1 whole, for stringless variety was slightly more as compared with No. 2 Fancy of Regular Blue Lake. This may be due to the fact that whole beans tend to retain more intensity in color in canning than cut beans.

Another point which was studied was to find out whether canning procedures adopted differently by different canneries had any effect on the final color. A few samples of different brands were examined and which were approximately two years old (Table IX). It was noticed that there was not noticeable difference in hue, value and chroma between different brands. It was however seen that on the whole there was a slight increase in chroma in all th samples as compared with chroma of beans in Table V. From this it is seen that the intensity increases with the storage time, or the difference was due to the season.

Effect of locality and different varieties

Few samples of beans were obtained from the states of Washington and Louisiana to study the effect of locality on color of canned beans. Two varieties of beans grown in the state of Washimgton and packed by one packer, and one variety from Louisiana, were examined for color. Hue on an average for stringless beans was more than regular Blue Lake (Table X, and Fig. 7), but there was not any appreciable difference in value and chroma between these two varieties. The Giant Stringless beans grown and packed in Louisiana had on an average less hue than that of Blue Lake Stringless variety from the state of Washington. Value on the whole did not differ much though beans from Washington did show slight more lightness but chroma was slightly more in beans from Washington. On the whole it is seen that locality had not much effect on hue but it did have some effect on value and chroma. From Table XII and from graph (Figure 7) it will be seen that Regular Blue Lake and Stringless from Washington are on the whole darker in color.

Range of color of canned beans

In the present work, attempts were made to determine the range of color for canned beans irrespective of size and period of storage and variety. All the results obtained so far are plotted on graph of hue, value and chroma with value corrected to 5 for all the samples (Figure 4). This value was thought better to fix, as most of the samples had a value range between 4 and 5. Very few samples had value less than 4 or above 5. From the graph of the points plotted for canned beans it is seen that all these samples lie close together. The range of color for canned beans was found to be, for the most part, from 5.50 Y to 6.60 Y for all the samples irrespective of size, and value 4 $\pm$ .2 for beans from Sieve No. 1 to 3, and 4.50 $\pm$ .20 for sieve sizes No. 4 and above; chroma 4.75 $\pm$ .50 for all the samples irrespective of size. From the graph (Figure 6) plotted for value and chroma, it is seen that No. 1, or 1-2-3 combined sieve sized beans lie within a range of 3.2 to 4.4 value, and 3.2 to 5 chroma, but there

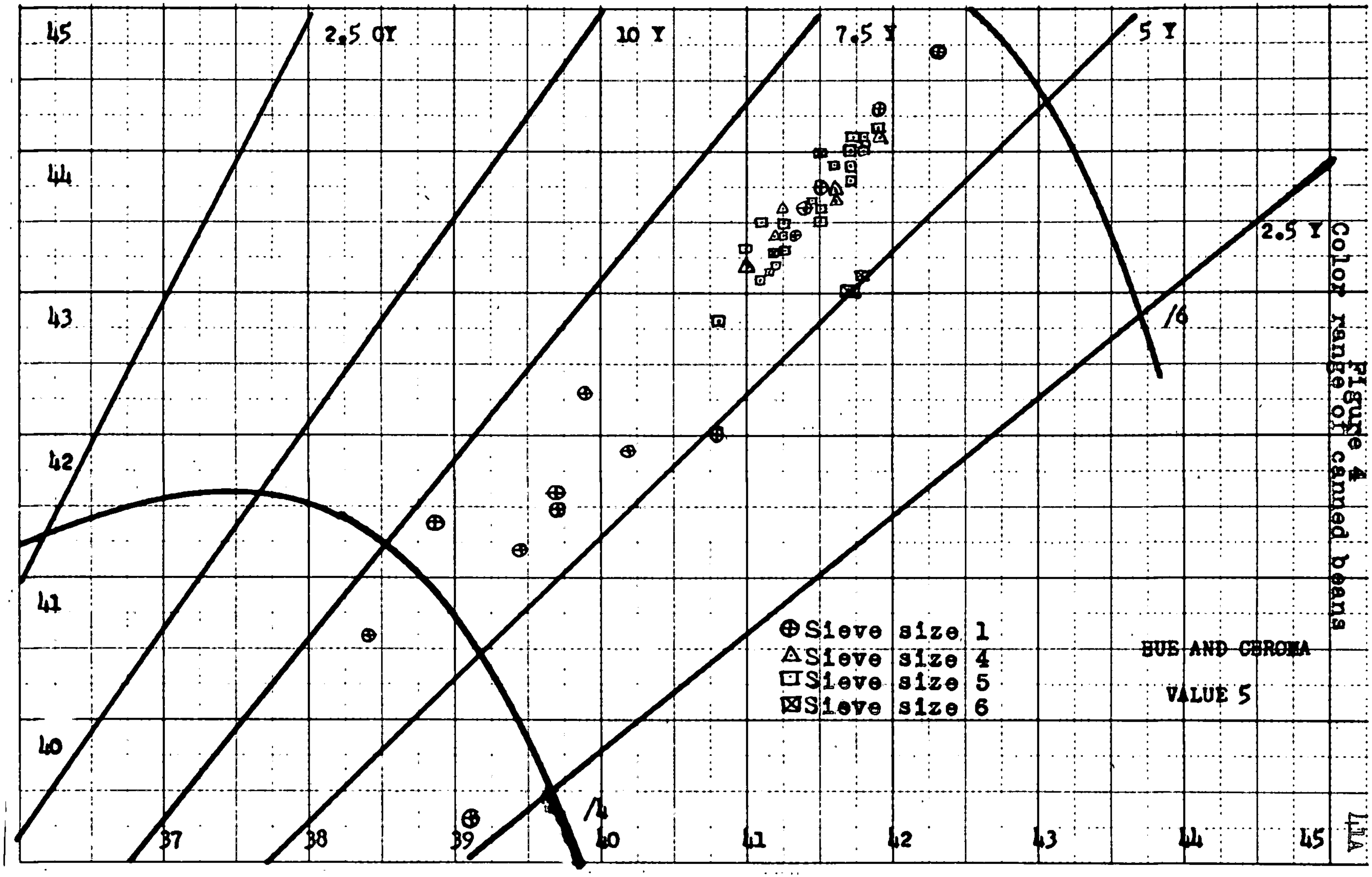

Figure 4
Color range of canned beans

is not much difference in grouping between sieve sizes 4 and above, however No. 5 are found much grouped together.

Frozen beans

Frozen beans obtained for color determination were Regular Blue Lake variety packed in Oregon. The frozen beans are generally of sieve sizes 1-2-3, or at times 4 are packed. The color determination was therefore restricted to one variety. It was found that the color of fresh beans greatly improves after blanching. The beans after thawing appear to have more hue shifted towards green and appear more dark.

A few samples of fresh beans were obtained from Stayton, Oregon. These were blanched at 193 degrees F. for $1\frac{1}{2}$ minutes and were frozen in cartons in cellophane bags. These samples after thawing did not show the hue as it was with commercial samples after thawing. This may be due to the fact that the beans frozen in the canneries are quick frozen and are individually frozen and packed; while the beans which were frozen in the laboratory were slow frozen. From Table V and VI it appears that quick freezing prevents deterioration of the color. The color for beans of sieve size No. 1-2-3 frozen and thawed in the laboratory as seen from Table V, was 2.5 GY 4.04/4.20, while the commercial samples for the same size ranged from 5.87 GY 3.18/3.47 to 7.10 GY 3.97/5.00. From the graph of hue, value and chroma for frozen beans (Figure 5), it may be observed that all the samples lie very close together. The range of hue of frozen beans is 6.50 GY $\pm$ 0.25, value is 3.60 $\pm$ 0.20, and chroma is 5.00 $\pm$ 0.25 (Figure 5).

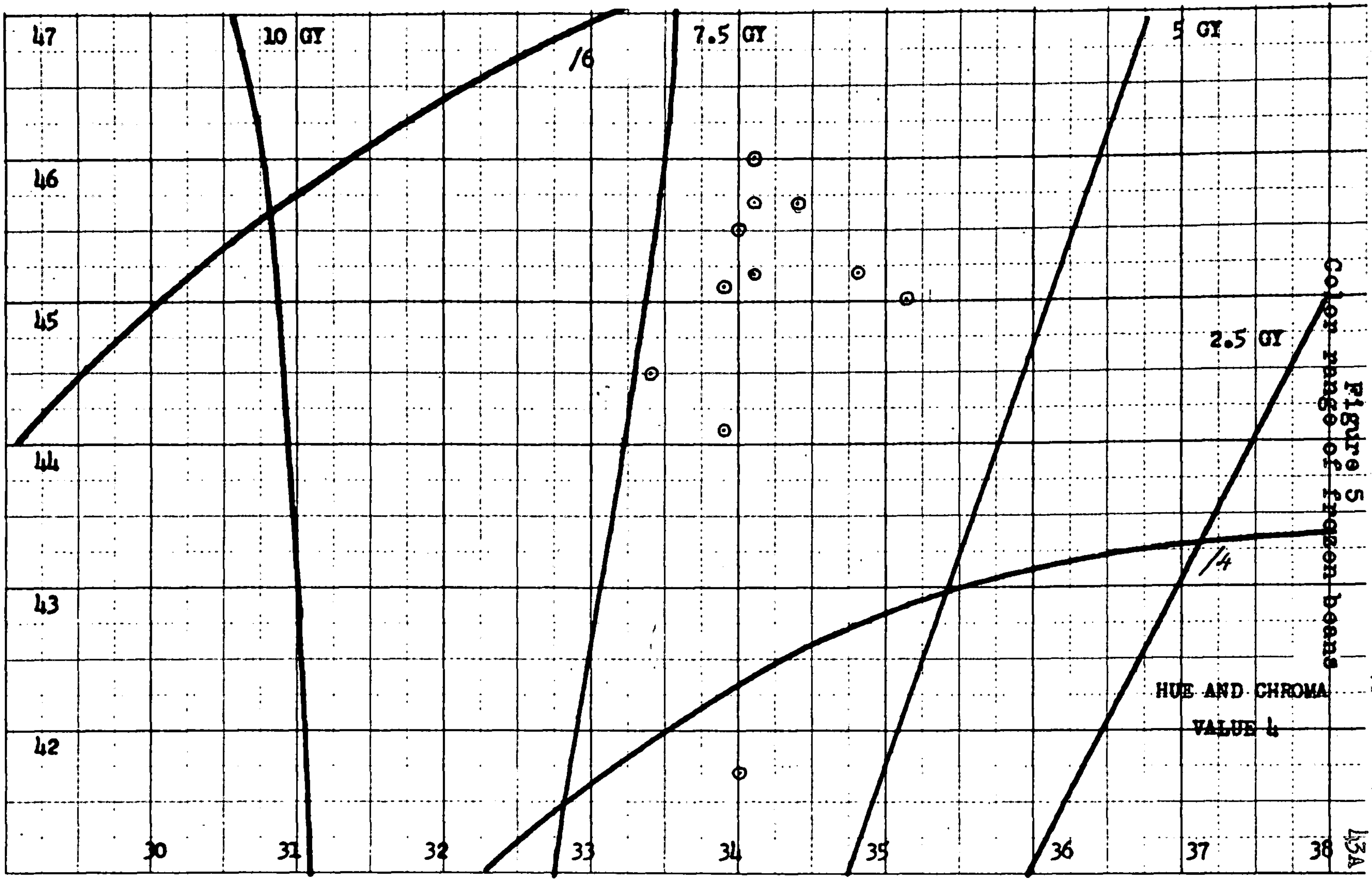

Figure 5
Color range of frozen beans

CHAPTER V

SUMMARY AND CONCLUSION

The U.S.D.A. grading standards have not yet set the range of color either for canned or frozen beans, except that a uniformity of color is desired, at the present time. It was therefore thought worthwhile to study the range of color in canned and frozen beans and determine if possible the range of color for both of these products. In order to do this it was thought necessary to examine the samples from various canneries and to make a preliminary survey to find out the probable range of color of canned and frozen beans with respect to sieve size, variety and quality. In this preliminary survey three or four samples were examined in classifications of (a) sieve size, (b) labelled quality grade, (c) locality, (d) variety, (e) fresh, canned and frozen, and (f) rapidity of freezing. This made approximately 70 different samples after the method was worked out.

As regards sieve size of canned beans it was found that there is a demarkation of line of color up to sieve size No. 1-2-3. The hue in some cases may be the same as that of beans of higher sieve sizes, but value and chroma is found generally less. But for sieve sizes 4 and above, the canning procedures do not make any difference on the final color as regards hue, value or chroma.

As regards varietal and locality difference it was found that it did not have any marked difference on the final color of canned beans. The stringless strain of Blue Lake variety canned in Washington had slight darker appearance than that packed in Oregon in the same season. Similarly was the case for regular Blue Lake variety. A sample of Giant Stringless beans packed in one of the canneries in Louisiana was found to be intermediate in lightness and chroma with that packed in Oregon and Washington, but hue was less than both of the latter.

As regards quality of beans it was found that most of the fancy beans of sieve size No. 1-2-3 fell within a value range of 3.2 to 4.4 and chroma range of 3.2 to 5. Fancy beans of sieve size No. 4 fell within a value range of 4.3 to 4.7 and chroma range from 4.2 to 5.2. Extra standard beans mostly of sieve size No. 5 fell for most of the part within a value range of 4.3 to 4.6 and chroma range from 4.5 to 5.1. Standard beans had for most of the part a value range from 4.4 to 4.7 and chroma range from 4.8 to 5.3. As regards hue there was no definite relation either for sieve size or for quality. (Figure 8).

The range of color for frozen beans was determined and it was found that the hue range was 6.50 GY $\pm$ 0.25, value 3.60 $\pm$ 0.20, and chroma 5.00 $\pm$ 0.25. It was noticed that the color of quick frozen beans was retained much more than those of slow frozen ones as determined from laboratory samples.

The discs for measuring the fresh, canned and frozen beans was determined as shown in Table II.

The possibility of using a reflection meter was explored and it was found that under the same conditions of bean arrangement and container the hue showed a difference of 0.8 to 0.9, while the value and chroma remained practically the same.

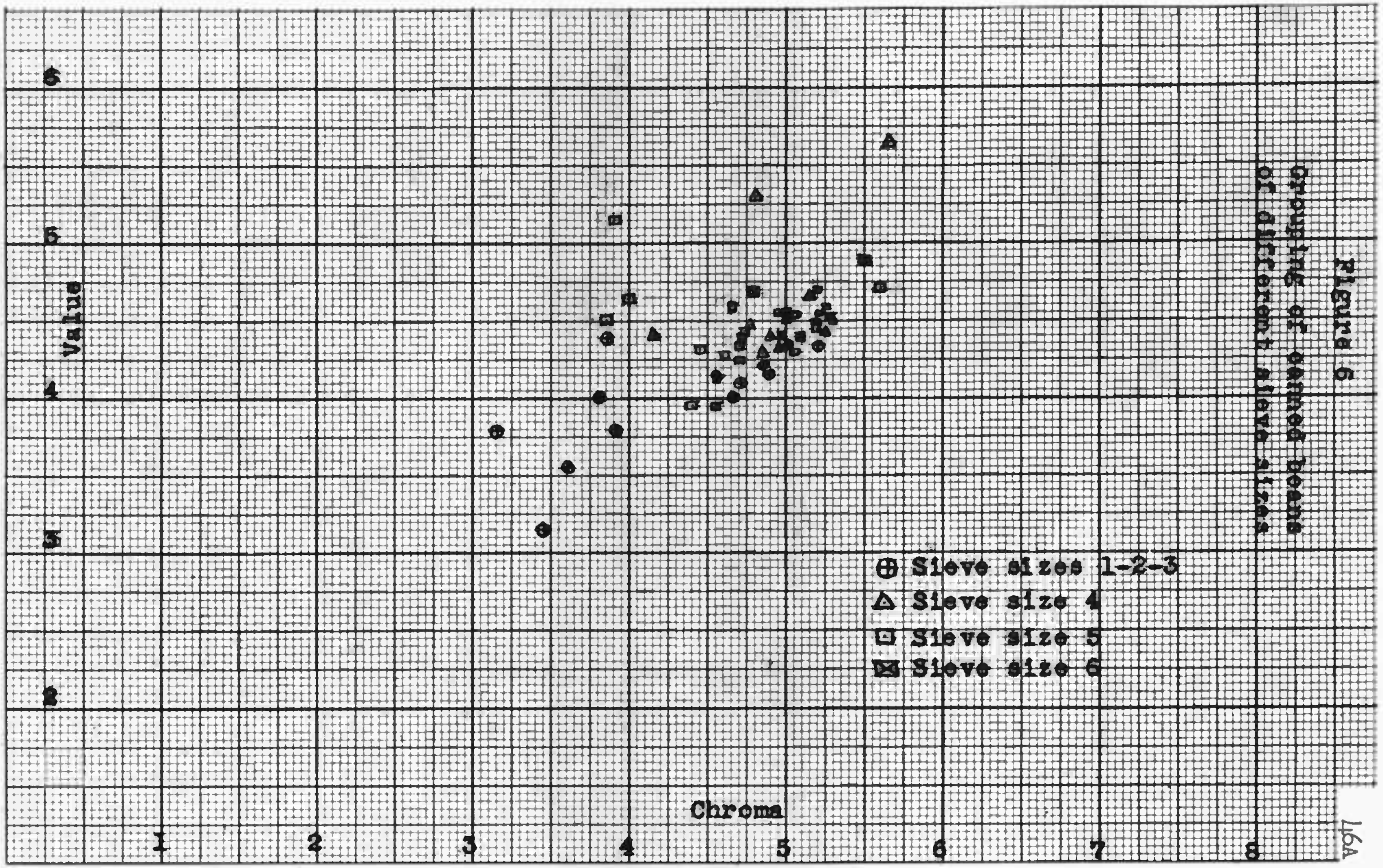

Figure 6
Grouping of canned beans
of different sieve sizes

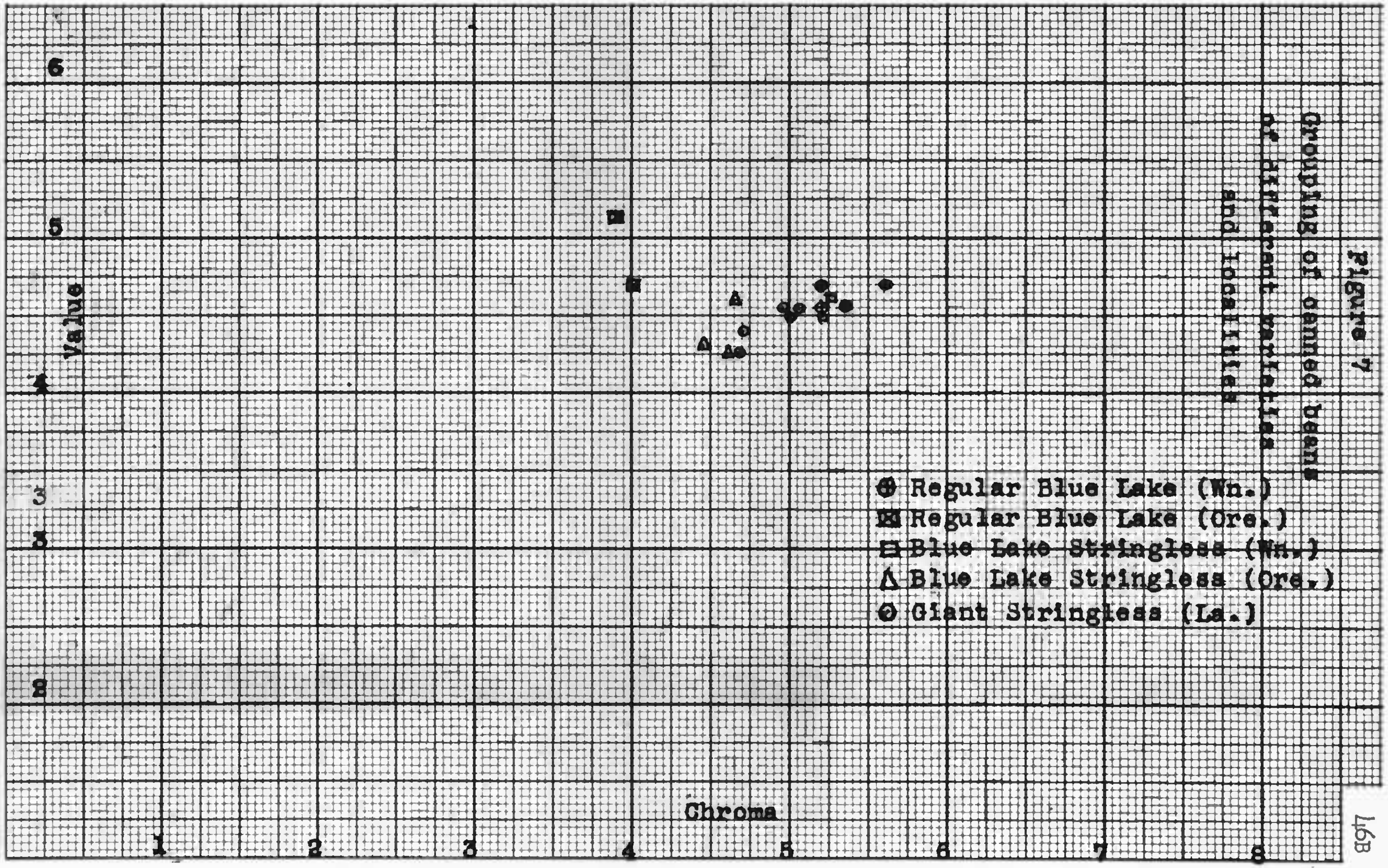

Figure 7
Grouping of canned beans of different varieties and localities

CONCLUSION

(1) A satisfactory method for color determination with disc colorimeter by suitably arranging the beans has been determined.

(2) The possibility of using a reflection meter was explored and it was found that under the same conditions of bean arrangement and container the hue showed a little difference but value and chroma remained practically the same. The use of this method if made successful by further investigation would facilitate color measurement and make it entirely devoid of the personal factor in color matching. The disc method gives much strain on the eye by constant leaning over the eyepiece and further to a fatigued eye it is not possible to detect any small difference in color match.

(3) Range of color for canned beans according to sieve size is determined and it is found that there is a demarkation line between beans of 1-2-3 sieve sizes and 4-5-6 sieve sizes.

(4) Locality and variety did not have much effect on the final color of canned beans in these samples.

(5) Color with respect to quality has been determined and is found to have some relation as seen from grouping of beans by quality as seen in Figure 8. But to have more

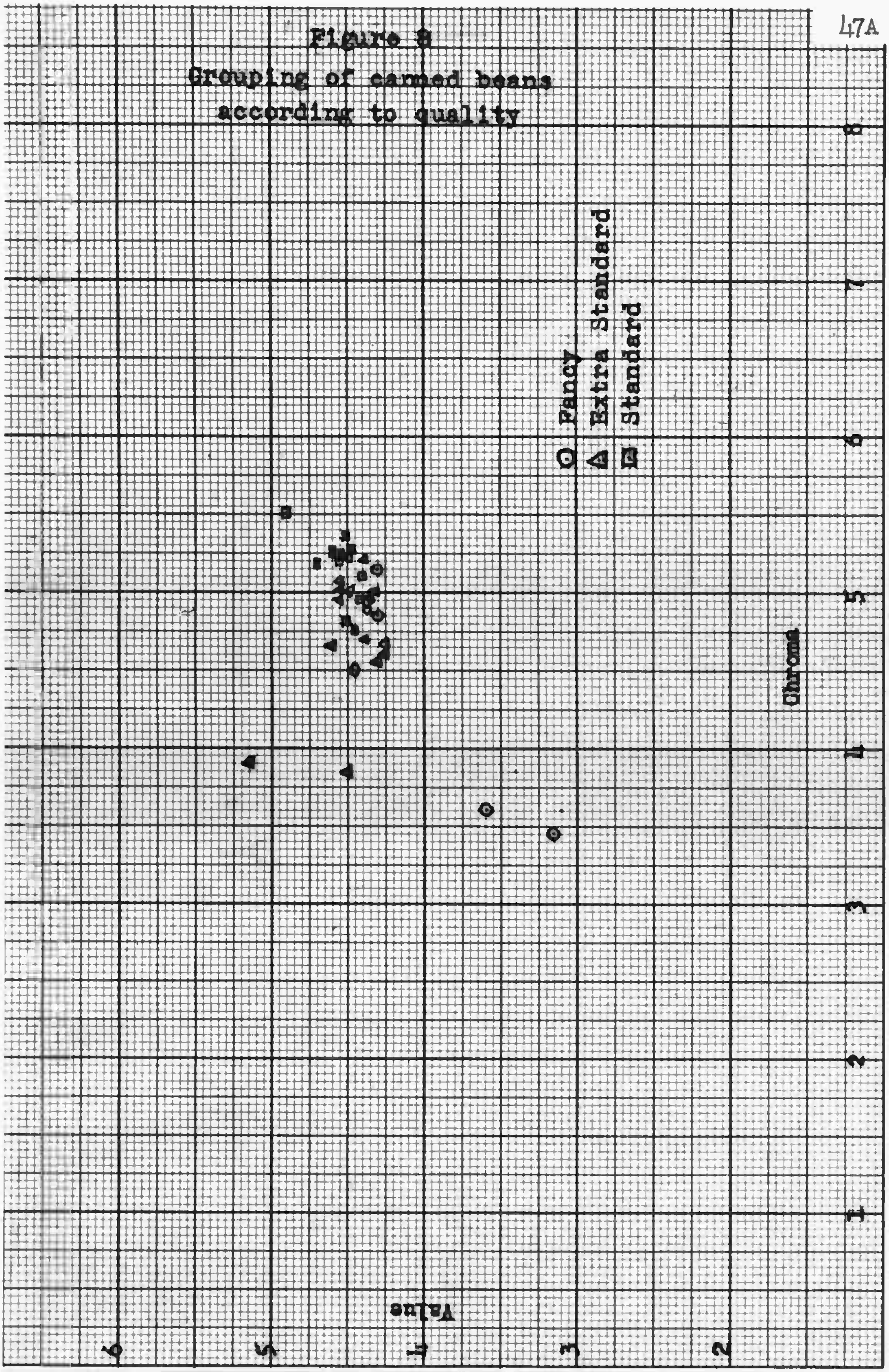

Figure 8
Grouping of canned beans
according to quality

definite results it is recommended that this work should be carried out in three or four canneries where a number of cans are opened every day for quality and color grading and in addition numerous samples from different states may be examined.

(6) The range of color of frozen beans is determined and it is found that quick freezing tends to retain color more than slow frozen ones.

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