OBJECTIVE COLOR GRADING OF APRICOT NECTAR BY PHOTOELECTRIC TRISTIMULUS REFLECTION METER

by

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INTRODUCTION

Color is one of the most evident and important visual properties of matter. It contributes special characteristics and qualities of its own which are not imparted by other properties alone. Thus, it is indispensable in describing or identifying any object. The importance of color as a major factor in the standardization and grading of agricultural products should not be underestimated. One evidence of this fact is that the specifications of the United States Department of Agriculture and other specifications for grading and standardization of a variety of these products frequently take color into consideration. Such products include many familiar foods like butter, cheese and other dairy items, honey, meat, cereals, rice and other grains, and, most important of them all, the fresh, canned, frozen and dehydrated fruit and vegetable products.

Color is the first thing observed by a consumer when he opens a can or a package of food. It is well known that psychological appeal, due to attractive color and other factors, has a definitely stimulating effect upon digestive processes. Sometimes a wholesome product may look rather unattractive in color and, therefore, may not be acceptable to the consumer. At present, more and more products are packed in transparent containers, which allow the purchasers to see what they are actually buying. Thus, color has an eye-appeal and is one of the deciding factors for the consumer's preference.

Moreover, color has a definite relationship to factors which determine the quality of food products. Color is frequently determined by the variety and maturity of raw products. For example, the Blenheim variety of apricot is commonly used for canning. This fruit has a deep-yellow color, whereas the Royal variety possesses a more intense orange color, and the Tilton is a rather pale yellow. Generally, color changes as the fruit matures. Color, therefore, indicates the degree of maturity, and thus the harvesting period of certain varieties of apricots can be determined using color as an index of maturity.

Factors such as handling, transportation, storage conditions, and manufacturing processes have considerable effect on the color of the final product. It can be said, therefore, that the color gives some idea of the various cultural and environmental conditions to which the product has been subjected.

Reasons for Undertaking This Study:

Fresh or processed fruit puree when diluted and sweetened is known as nectar. It is very similar to fruit juice but cannot be labeled by that name because of the addition of water. The production of nectar holds an important position in the beverage industry. Therefore, the formulation of standards for such beverages is of great commercial significance, and the determination of objective color standards for such products is an essential step for achieving this purpose.

Some grades set by the United States Department of Agriculture for fruit and vegetable products reserve 20 to 25 percent of the total score for color and in some cases as much as 30 to 40 percent, e.g. canned tomatoes and frozen strawberries. As yet no standards have been formulated for nectars. Different fruit nectars, such as apricot, peach, pear, plum, and nectarine, are becoming more and more popular and are available in large quantities. Pulpy fruits with pronounced flavors like mangoes, passion fruit, papayas, guavas and many other tropical fruits make excellent nectars and are produced in some places on a small scale.

<u>Choice of the Instrument:</u>

The modern trend in research is to replace wherever possible subjective methods by objective ones. The same trend is reflected even in the field of color, where the use of photoelectric instruments is becoming widespread. At present, many methods are employed to specify and compare colors. Some of the subjective methods still being used employ simple, inexpensive charts, whereas other methods employ quite complicated and rather expensive but very precise instruments like the spectrophotometer. Within this range lie numerous instruments and methods which are used to achieve somewhat different objectives. There is no one instrument which can be called ideal! The human eye is the best and the most versatile of all known instruments in many respects, yet it has many drawbacks.

Various preliminary investigations have shown that, for the measurement of color of food products and of unclarified beverages such as pulpy fruit juices, the tristimulus photoelectric reflection meter is quite suitable. (1 and 18). Two such instruments are represented by the Photovolt Photoelectric Reflection Meter Model #600 and Model #610. Although these models were originally designed for measuring the diffuse reflection of opaque surfaces like paints, ceramics, plastics, paper, and textiles the manufacturer claims that the instrument can be adapted for such things as powders, pastes and opaque liquids (15).

Although apricot nectar cannot be classified as an opaque liquid, the error due to the container wall is not introduced when it is examined in commercial cans of number 2 or larger size, because even grapefruit juice, which is obviously less opaque, can be measured in number 2 cans without error caused by the container walls. (18). Thus, apricot nectar falls within the scope of these instruments. For this reason, the Photovolt Photoelectric Reflection Meter Model #610 was chosen for this study. Moreover, it has definite advantages over other instruments available for the same purpose, which justify its selection. Some of these advantages are as follows:

1) This instrument can be used both for color specification and for color matching, and the results are claimed to be reproducible.

2) It measures the color as perceived by the human eye. The results can be expressed in the International Commission on Illumination or the Munsell systems by simple calculations.

3) It is very easy to operate and does not involve any preparation of the sample. The samples can be examined directly in the commercial cans in rapid

succession, by merely moving the search unit from one can to the next.

4) It does not involve personal factors which may affect the results and thus can be used by any unskilled or color-blind person.

5) It is quite sturdy, compact and handy. Therefore, it can be used for field work.

6) It can be operated either on A.C. or D.C. currents and therefore can be used on storage batteries of the automobile type wherever electric current is not available or is of unreliable frequency.

7) This instrument is not costly (as compared to spectrophotometers) and therefore can be used universally for routine work in the field as well as in research and plant laboratories.

REVIEW OF LITERATURE

General Aspects of Color:

According to Gardner (5, p.125): "Color, as the term is properly applied, refers to all sensations aroused in the mind of a normal observer by the response of the retina of the eye and its attached nervous mechanisms to radiant energy of certain wavelengths and intensities."

The word 'color' has lost its true meaning due to its indiscriminate use in the common language, with the result that it now means too many different things for precise use. The subject of color is quite complex and involves many different yet related phases. In the past, investigators in this field were handicapped by the absence of a precise color terminology. More recently many attempts have been made to overcome this difficulty, and now all the different types and kinds of color work can be described in the common language of color adopted by the International Commission on Illumination in 1931, which is now known as the I. C. I. system. The commission agreed on what is now referred to as I. C. I. standard observer and standard illuminants A, B, and C, whose energy distribution with wavelength was specified with great precision. The standard observer was taken as an average of the response characteristics of a group of individuals found to possess normal color vision. The standard observer consists of three functions of wavelength showing the relative amounts of three primary stimuli represented by X, Y, and Z which roughly correspond to sensation values for red, green and blue respectively, required to color match a unit amount of energy having the indicated wavelength (8 and 5). Comprehensive reports on this subject have been published by the Committee on Colorimetry of the Optical Society of America, in the hope of removing some of the misunderstandings. (2 and 3)

For real understanding of color, three different aspects should be considered: (1) Physical, (2) Psychological, and (3) Psychophysical.

(1) Physical Aspect of Color: The sensation of color is experienced by virtue of the light or radiant energy of a certain wavelength that enters the eye. The physical aspect deals with the properties and characteristics of this light which can be measured and specified by methods having no connection with the observer. In short, this aspect deals with the quality of light as such without reference to any observer. Physical studies on color include the use of the spectrophotometer, which is an instrument for specifying the color characteristics in terms of

fundamental physical units (4,(p.4), and 13).

(2) Psychological Aspect of Color: This aspect deals with the color actually perceived by the observer under the influences induced by different conditions, such as attitude, attention, mood, physiological and genetic accuity and environment (4, p.5). The same quality of radiant energy does not always produce the same mental perception. In short, the same light is not always interpreted as the same color. Due to the effect of psychological factors the color interpretation becomes quite complicated.

There are three attributes in terms of which color 'sensation' can be described psychologically: hue, saturation and brightness or lightness.

Hue: This is the specific quality which distinguishes one color from another and permits them to be classed as red, yellow, blue, etc.

Saturation: This is the quality of color which distinguishes pure color from a neutral or "grayed" one -- the intensity or "strength" of a particular hue.

Brightness or Lightness: This is that attribute of color which permits it to be classified as equivalent to some member of neutral colors--grays ranging from black to white.

(3) Psychophysical Aspect of Color: Psychophysics, according to Evans (4, p.4) is "the scientific study of the reaction of the visual mechanism under a given, fully specified, set of conditions." The psychophysical evaluation of color is the evaluation of the purely physical light from the source and object in terms of the average observer or the eye considered as a standard mechanism by purely mechanical means. In spite of the progress made on this subject in recent years, the information available is rather limited and much remains to be learned (4, p.5).

Methods of Color Measurements for Food Products:

Color of food products is due to a presence of different pigments, such as chlorophylls--green to blue-green; carotinoids--yellow to orange; anthocyanins--pink to red; etc. The color is affected by many other factors, such as fineness of division of particles, smoothness of surfaces, and nature and opacity of dilutants. Some of the methods for color determination employ the analysis of light transmitted by extracted pigments, and, thereby, both quantitative (concentrations) as well as qualitative results (identities) can be obtained. Some of the other methods do not analyze color but measure color as it is perceived by the human eye. Therefore, practically all means available for color measurement can be grouped into three classes: (1) Psychological, (2) Physical, and (3) Psychophysical methods.

(1) Psychological Methods: The studies that are concerned only with the color appearance of an object and color standards are set by visual estimates; the methods involved may be termed psychological. This group includes numerous color systems or charts. Different systems have been evolved for specific purposes and definite rules made which have been followed throughout the system. However, all of them have in common a collection of material standards to which names or symbols are given. The complications of color measurement are avoided by the use of color standards which include both qualitative and semi-quantitative methods and which are in wide use in specifying a general approximation to the required color where an approximate match is all that is required. The following is a brief account of some of the well-known systems.

(a) The Ridgway System: This system contains 1,113 names and numbered colors based on 36 fundamental hues which are grouped systematically by regular proportions of white, gray and black. This system is not used for color measurement of food products. (13, p.2)

(b) The Maerz and Paul "Dictionary of Color": As the name signifies, the dictionary is intended as a reference for color names by which the colors are commonly identified. It contains 56 charts with 7,056 colors, ranging from colors approaching white to colors approaching black through practically every gradation of hue, saturation and lightness. In addition it contains a very useful text of 73 pages. Some of the United States Department of Agriculture standards for fruit and vegetable products refer to this dictionary's color system. (13, p.2). To cite one example, canned yellow clingstone peaches, in order to receive a rating of "A" in color, should possess the bright, typical yellow to orange-yellow color of well-ripened fruit which approximates or is better than Plate 9, L-7, as illustrated in Maerz and Paul's Dictionary of Color (16).

(c) The Munsell System: The Munsell Color Book describes the system of arranging colors with reference to three visual attributes: Hue, Value, and Chroma, which roughly correspond with hue, lightness and saturation described previously (refer to p.9). The vertical axis of the three-dimensional color solid represents Value and is divided into ten equal parts--starting with zero at the base representing black and ending at the top with ten representing white. The ten major Hues are arranged in equal angular spacing around the circumference at the equator of the color solid in the order of their appearance in the spectrum and are indicated by the symbols R, YR, Y, GY, G, etc. Each major Hue in its turn is further divided into ten equal parts, thus making space for 100 different Hues around the circumference. Chroma is represented by the distance from the axis to circumference at any particular Value level. This distance is divided into ten parts, starting with zero at the Value axis. Any color can be described with great precision by the simple combination of the three attributes, Hue Value/Chroma, thus: 5R 5/14 represents bright red color.

This method has been used to determine color of agricultural products with the help of the Munsell Disc Colorimeter. This system is referred to in some of the United States Department of Agriculture standards for fruit and vegetable products. For example, 60 per cent of the total score for tomato paste and tomato puree are assigned to color which is determined by comparing the color of the product with that produced by spinning a combination of four Munsell color discs whose notations and percentages are mentioned (17).

Bam (1) has described an accurate and reproducible method for color determination of canned and frozen green beans with the Munsell Disc Colorimeter by suitably arranging the beans. He found some relationship between quality and color. Unfortunately, this method involves personal factors and is rather strenuous on the eye. Moreover, a fatigued eye is not capable of detecting any small differences in color matching.

(2) Physical Methods: A physical method utilizes the spectrophotometer and is often used for analyzing or resolving color into fundamental physical units, by measuring or recording only the intensity factor of the transmitted or reflected light.

A spectrophotometer, regardless of the type, must contain a light source, sample holders and a standard white reflecting surface of known brightness (for reflection work). It must also contain some means of regulating and measuring or recording the light reflected from the standard surface and an arrangement to view the dispersed light at successive and determinable wavelength. The visual type of instrument is mostly replaced by the photoelectric type which measures the amount of reflected or transmitted light of each successive wavelength as a percentage of standard (5, p.130). By means of this instrument slight variations in color can be detected from the differences in the spectrophotometric curves. These curves are permanent records and thus the maintenance of a standard sample is not required. By the help of this instrument both qualitative and ~~the~~ quantitative results may be obtained, by observing the difference and the amount of deviation of the curves representing the sample and the standard. The curves are expressed in units which are understood and accepted universally (6). The spectrophotometer is very useful for work in the region beyond the visible range, like the ultraviolet and the infrared regions.

Another very similar instrument is a filter electrophotometer, in which three to eight spectral filters are used instead of the prism or grating employed in a true spectrophotometer. These filters transmit only wide bands of wavelengths (7).

However, in spite of numerous advantages the spectrophotometer has many drawbacks. It is complicated and rather delicate and is too expensive an instrument for everyday use for the measurement of color. For routine work of measuring color, it is not necessary to resolve color into spectral reflectance or transmittance curves, which are not only difficult to interpret but also somewhat confusing to those who are not well acquainted with them. While spectral reflectance or transmittance curves are of great value in fundamental physico-chemical studies of colorants, in practical industrial work one always prefers a system whereby color can be accurately described by a set of a few figures rather than by a series of curves. Moreover, two colors having identical spectrophotometric curves are always perceived as a match, but two colors which are perceived as a match may possess entirely different curves. This phenomenon is due to the fact that the human eye has its own way of color perception, which is not yet fully understood (15).

Pulpy juices must be clarified because clear solutions are required for the measurement of color by transmission. The appearance of the clarified product is entirely changed and it has hardly any resemblance to the original product (18).

Kramer and Smith (9) have made some preliminary studies in the use of the spectrophotometer for measurement of color in canned foods. They involve the use of suitable solvents for extraction of desired pigments. The next step involves a compensation for turbidity, which interferes with transmittance measurements. Then the results of the pigment solutions are expressed as percent transmittance with the standard as 100 percent and these results are correlated with color as judged by organoleptic methods. Kramer and Smith have described tentative procedures for the examination of tomatoes, snap beans, lima beans, beets, carrots and corn.

The same investigators (10) have presented spectrophotometric and fluorometric methods for measuring quantitatively the extractable green pigment from peaches and apricots, and the results are correlated with ripeness and color as determined organoleptically.

McCollum (11) states that the spectral reflectance curves failed to show marked differences between various grades of tomato juice. His data indicated that factors other than total pigments affect the color value of tomato juice.

Similar quantitative spectrophotometric determinations of some food products, like berries, tomatoes, butter, honey, syrups, oils, and wines, have been studied by different investigators.

(3) Psychophysical Methods: "Instruments designed for the direct measurement of color in psychophysical terms are called colorimeters." (3, p.1). Numerous types of devices including the Munsell Disc Colorimeter and the photoelectric tristimulus colorimeters belong to this class. The latter type of instrument possesses a source-filter-photocell combination which nearly duplicates the

three distribution functions of the standard observer. Three tristimulus filters which transmit bands of wide wavelength range are needed with one source and photocell (7). The Photovolt Photoelectric Reflection Meter Model #610, which was used in this investigation, also belongs to this group and is described in detail in the following pages.

USE OF PHOTOELECTRIC REFLECTION METER

Description of the Instrument

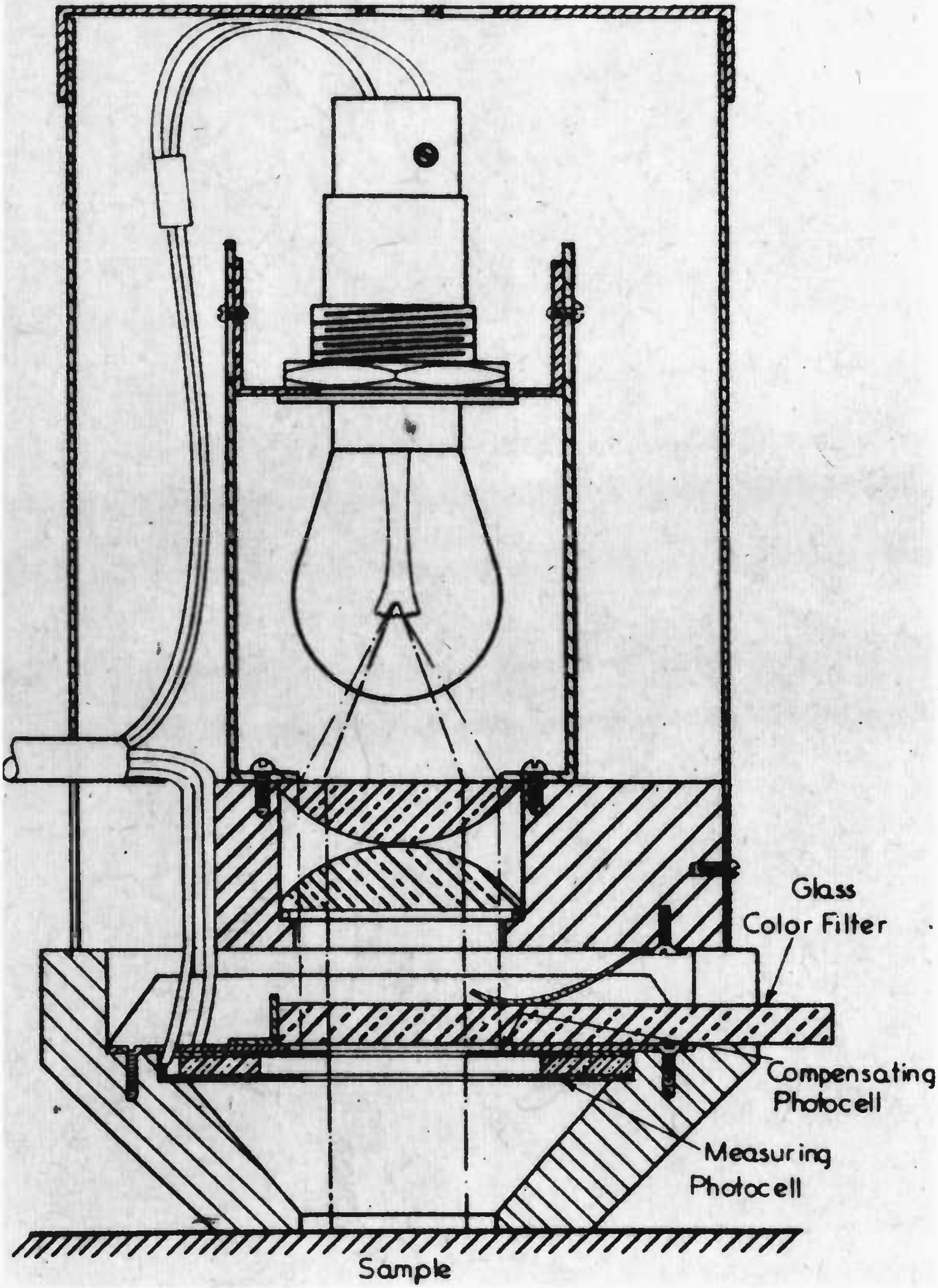
The instrument which was used in this investigation was the Photovolt Photoelectric Reflection Meter Model #610 designed for operation on 105 - 125 volt and 60 cycle AC. It comprises two units, the control unit and the search unit.

The control unit, which is the instrument proper, is built into a portable wooden housing with cover and carrying strap. The search unit is stored in a compartment of the housing when the instrument is not in use. The indicating meter is a taut-wire suspension galvanometer of high sensitivity. The instrument panel carries two sets of controls of two knobs each. One of the control knobs of each set is for coarse adjustment and the other for fine adjustment. The set of knobs on the right hand side of the panel serves to set the galvanometer needle on the rated value of the working standard, such as a white enameled plaque. The rated value of any working standard can be obtained by comparing it with a surface of magnesium oxide, which has approximately 100 percent reflectance. The other set of knobs on the left hand side of the panel is provided for setting the needle on zero for a darker standard of less reflectance in measurements with suppressed zero, which offers the advantage of furnishing a wider spread of readings with a given reflectance range.

The search unit, which is a metallic cylinder about three inches in diameter and five inches high, consists of a light source and photoelectric cells for measuring reflected light. The search unit and the instrument proper are connected by a cable with plug connections. The light from a 6-volt 15-c.p. automobile headlight lamp is collimated by an optical system of double condensing lenses and strikes the test surface in a parallel beam after passing through the circular apertures in the photocells. The "test-area" or the circular opening of the search unit in contact with the test surface is approximately 3/4 of an inch in diameter. A cross section of the search unit of the Photovolt Photoelectric Reflection Meter Model #610 is shown in figure 1.

The incident parallel beams of light strike the test surface in the normal direction, so that only the diffusely reflected light of approximately 45 degrees from the normal is registered by the photocell, whereas the specularly reflected light (due to gloss) is not registered as it passes through the aperture of the photocell, which is a ring about one inch broad.

Figure 1
CROSS SECTION OF THE SEARCH UNIT (15)



The search unit is provided with a set of three interchangeable tristimulus glass filters--amber, green and blue, which are so designed as to duplicate the three primary stimuli of the I. C. I. standard observer, represented by X, Y and Z, respectively (7). Thus, through the use of the tristimulus filters, results can be obtained in the I. C. I. notations or the Munsell notations by computations.

Procedure: First, any one of the three tristimulus filters, say tristimulus blue filter, is inserted in the search unit, which is placed on the white enamel plaque which serves as a working standard. The percent reflectance values of the enamel plaque for the three filters are recorded on the back of the plaque--these generally vary from 75 to 80 percent. Then the galvanometer of the reflection meter is set exactly at the particular value mentioned for the blue filter, by the use of a set of control knobs on the right hand side of the panel. Finally, the search unit is placed on the test surface of the sample, or the search unit can be turned over so that the sample opening points upward and the samples are then simply placed on top of it. After the needle has come to rest the reflectance reading is taken. The procedure is repeated for the other two tristimulus filters, green and amber.

__Computation:__ Suppose B, G and A are the percent reflectance values obtained for a sample by measuring with the three tristimulus filters, blue, green and amber, respectively. The I. C. I. notations, X, Y, and Z are calculated by using the following equations: (7)

$$X = 0.8\ A + 0.18\ B$$

$$Y = G$$

$$Z = 1.18\ B$$

These values can be computed, if necessary, in Munsell notation as described by Newhall and others (12). The following computation for canned tomato soup illustrates how the Munsell notations are obtained. The percent A, G and B reflectance values for the canned tomato soup were found to be 20, 11, and 3 respectively.

A = 20.0	X = (0.8 x 20)- (0.18 x 3)	= 16.54
G = 11.0	Y = 11.0	= 11.00
B = 3.0	Z = 1.18 x 3.0	= 3.35
	∴ X + Y + Z	= 30.89

$$x = \frac{X}{X + Y + Z} \times 100 = 53.5$$

$$y = \frac{X}{X + Y + Z} \times 100 = 35.6$$

$$z = \frac{X}{X + Y + Z} \times 100 = 10.8$$

The sum of x, y and z should total 100 (6, p.9 and 10). It is not necessary to calculate the value of z, but the results can better be checked by calculating its value.

The quantity Y corresponds to the Value V in the Munsell system, which can be obtained from a table published in the Journal of the Optical Society of America (12, p.406), giving these equivalents. Therefore, V in this case is equal to 3.84. The Munsell notations of Hue and Chroma are obtained from the Hue and Chroma loci charts at Value 3/ and 4/ for the I. C. I. illuminant C, by using the x and y values (12, p.389 and 390).

0.4 YR 3/7.6

9.5 R 4/9.7

Since V is equal to 3.84/, the Munsell Hue and Chroma are found by interpolation between the values obtained from charts for V 3/ and 4/.

Hue = *10.4 R - (*10.4 R - 9.5 R) x 0.84 = 9.64 R

(*10.4 R is equivalent to 0.4 YR)

Chroma = 7.6 + (9.7 - 7.6) x 0.84 = 9.36

Thus, the complete Munsell color notation for the canned tomato soup is 9.64 R 3.84/9.36.

Error and Reproducibility of Results With the Instrument

Before the instrument is put to work, it is essential to test its validity. In order to achieve this object certain known standards are required. In the present investigation this purpose was accomplished by the use of unglossy Munsell disks of known denominations. More readings were taken for the disks 5 YR 6/12 and 5 YR 6.6/13.9, because they resembled the color of apricot nectar. Readings for three different filters were taken by placing the search unit on the colored surface of the disks. The following table I gives the readings of known Munsell disks and the percentage of errors of Hue, Value and Chroma.

The ten major Hues of Munsell system are ordinarily spaced equally into 100 Hues, designated as whole numbers. The Value system is divided into ten steps (whole numbers). The number of Chroma steps are obtained from the graph of Hue and Chroma loci at different Values (12, p.387-395), which vary considerably from 4 to 28. The percentage error is calculated by taking into consideration these factors, viz., 100 for Hue, 10 for Value and the maximum Chroma steps obtained from the graph pertaining to the Value in question. This step can be illustrated by the following example: The reading obtained for the 5 YR 6.6/13.9 Munsell disk was 4.75 YR 6.82/13.76.

The percentage error in Hue = $\frac{(5 - 4.75)}{100} \times 100$

Therefore, Hue error = -0.25 %.

The percentage error in Value = $\frac{(6.6 - 6.82)}{10} \times 100$

The Value error is equal to ≠ 2.2 percent.

The percentage error in Chroma: The maximum steps obtained from the Hue and Chroma loci graphs of Value 7 are 18, therefore, $\frac{(13.9 - 13.76)}{18} \times 100$

Chroma error is equal to -0.77 percent.

(The percentage error is calculated by subtracting the obtained value from the known one and dividing it by the total. The value so obtained when multiplied by 100 gives the percentage error.)

TABLE I

ERROR OF METHOD ON KNOWN MUNSELL DISKS

Disk	By Refectometer	Percentage Error		
		Hue	Value	Chroma
5 YR 6/12	4.73 YR 6.38/11.59	-0.27	+3.8	-2.27
"	4.88 YR 6.40/11.78	-0.12	+4.0	-1.22
"	4.87 YR 6.43/11.47	-0.13	+4.3	-2.94
"	5.07 YR 6.40/11.33	+0.07	+4.0	-3.72
"	4.98 YR 6.4/11.42	-0.02	+4.0	-3.22
"	5.03 YR 6.41/11.25	+0.03	+4.1	-4.16
"	5.46 YR 6.4/10.98	+0.46	+4.0	-5.66
"	4.97 YR 6.38/11.17	-0.03	+3.8	-4.61
*5 YR 6/12	5.02 YR 6.40/11.25	+0.02	+4.0	-4.16
5 YR 6.6/13.9	4.75 YR 6.82/13.76	-0.25	+2.2	-0.77
"	5.00 YR 6.85/13.98	0	+2.5	+0.44
"	4.85 YR 6.82/13.93	-0.15	+2.2	+0.16
"	4.77 YR 6.82/14.04	-0.23	+2.2	+0.77
"	4.62 YR 6.81/14.3	-0.38	+2.1	+2.22
"	4.50 YR 6.79/13.52	-0.50	+1.9	-2.11
10 Y 7/6	10 Y 6.96/6.97	0	-0.4	+6.06
3 GY 7.5/11.2	4.07 GY 7.55/11.6	+1.07	+0.5	+2.22
10 GY 5/8	9.39 GY 4.8/7.26	-0.61	-2.0	-4.11
5 GY 6/8	4.45 GY 6.12/7.07	-0.55	+1.2	-5.81

* Average of 23 readings

5 YR 6/12 disk was slightly soiled.

Table I indicates that the percentage of error distribution of Hue was least compared to those of Value and Chroma, and varied from -0.16 to ≠ 1.07. The percent Value error in many cases was found to be fairly constant, and the error was greatest in the case of "soiled" or used disks, whereas the percentage Value error was considerably less when newer or less used disks were examined. The percentage of error distribution in Table I is from -2.0 to ≠4.3 for Value and -5.81 to ≠6.06 for Chroma, for different disks. This variation cannot be accounted for, but it may, perhaps, be due to the aging, fading, soiling, etc. of the disks.

Use of Dark Standard

It has been suggested by the manufacturer of the Photovolt reflection meter that when the percent reflectance is close to zero, the use of a "dark standard" is advantageous. When this procedure is followed, a dark standard, usually unglossy gray or neutral color, such as a Munsell Value disk, is used in addition to the white plaque. First the galvanometer is set at the proper percent reflectance on the white plaque for a given filter as calibrated before, then the percent reflectance from the dark standard is determined. The galvanometer can be adjusted to any desirable multiple of the percent reflectance of the dark standard, so that the final reading when taken on the product is large enough to minimize the error of the "accuracy" of the reading. Finally, in order to obtain the true reflectance of the product for that particular filter, the final reading is divided by the multiple (used in the last step).

Therefore, in the investigation being conducted, a dark standard, N 5/ or N 6/ unglossy Munsell disk, was used both in the measurement of color of a known Munsell disk and also of apricot nectars. These results were compared with the results obtained for the same samples when the dark standard was not used. The following table II shows that in most cases the use of a dark standard introduces more error than it eliminates. Perhaps the same may be true where the dark standard was used for evaluating the color of apricot nectar (See table X in Appendix).

TABLE II

ERROR OF THE METHOD WITH AND WITHOUT THE USE OF DARK STANDARD ON KNOWN MUNSELL DISKS

Disk	Direct Reading	Percentage Error H	Percentage Error V	Percentage Error C	Use of Dark Standards	Percentage Error H	Percentage Error V	Percentage Error C
					N 5/-			
* 5.0 YR 6.0/12.0	5.07 YR 6.4/11.33	+0.07	+4.0	-3.7	5.59 YR 6.4/10.84	+0.59	+4.0	-6.4
					N 6/-			
5.0 YR 6.6/13.9	2.90 YR 6.64/14.96	-2.10	+0.4	+5.9	2.24 YR 6.55/14.86	-2.76	-0.5	+5.33
5.0 YR 6.0/12.0	3.04 YR 6.23/11.92	-1.96	+2.3	-0.44	2.76 YR 6.20/12.02	-2.24	+2.0	+0.11
5.0 RP 3.0/10.0	6.45 RP 3.31/11.60	+1.45	+3.1	+8.0	7.03 RP 3.32/11.42	+2.03	+3.2	+7.1
10.0 Y 7.0/6.0	10.0 Y 6.96/6.97	0	-0.4	+6.06	9.02 Y 6.87/6.84	-0.98	-1.3	+5.25
5.0 P 5.0/10.0	6.10 P 5.30/10.24	+1.10	+1.3	+0.85	6.1 P 5.08/10.69	+1.10	+0.8	+2.46
5.0 YR 6.6/13.9	4.97 YR 6.85/13.93	+0.03	+2.5	+0.16	5.26 YR 6.86/13.72	+0.26	+2.6	-1.00
5.0 YR 6.0/12.0	5.22 YR 6.375/10.94	+0.22	+3.75	-5.90	5.52 YR 6.44/11.17	+0.52	+4.4	-4.61
10.0 GY 6.0/10.0	9.83 GY 6.0/8.57	-0.07	0	-7.15	10.15 YR 6.10/9.21	+0.51	+1.0	-4.0

* Average of 23 readings.

Effect of ±0.5% Error in Percent Reflectance of A, G and B Filters.

The galvanometer of the reflection meter is calibrated from 0 to 100 in one hundred equal divisions. Therefore, one division of the scale represents one percent of reflectance, and less than one percent reflection cannot be indicated accurately by the galvanometer. For this reason it was decided to calculate the error introduced by a deviation of ± 0.5 percent in the reading of the galvanometer. The following table III gives the error so introduced. The color of 5 YR 6/12 disk calculated from twenty-three readings was obtained to be 5.02 YR 6.4/11.25.

Judging from the results in table III, it can be said that a certain percentage of error is introduced in the final results due to the inaccurate reading of the galvanometer. This error may be reduced or eliminated by having an enlarged scale for the galvanometer, so that even 1/4 percent reflection can be read on it. This is absolutely essential for more accurate determination of color.

TABLE III

ERROR DUE TO + 0.5 PERCENT REFLECTANCE FOR DIFFERENT FILTERS

Readings	Munsell Notation	Percentage Error, on Basis of the Average			Percentage Error on Basis of Stated Munsell Notation		
		H	V	C	H	V	C
Calculated from 23 readings	5.02 YR 6.4/11.25	-	-	-	+0.02	+4.0	-4.16
+ 1/2% A	4.88 YR 6.4/11.44	-0.14	0	+1.05	-0.12	+4.0	-3.11
- 1/2% A	5.22 YR 6.4/11.12	+0.20	0	-0.72	+0.22	+4.0	-4.88
+ 1/2% G	5.31 YR 6.44/11.18	+0.29	+0.4	-0.39	+0.31	+4.4	-4.55
+ 1/2% B	4.83 YR 6.40/11.07	-0.19	0	-1.0	-0.17	+4.0	-5.16
+ 1/2% A, G & B	4.94 YR 6.44/11.10	-0.08	+0.4	-0.82	-0.06	+4.4	-5.0
- 1/2% A, G & B	5.03 YR 6.36/11.48	+0.01	-0.4	+1.28	+0.03	+3.6	-2.88

Precision of Measurements in a Series of Percent A, G and B Reflectances for a Known Munsell Disk.

Lack of precision may be due, among other causes, to the error in readings obtained from the instrument or may be introduced during the computations of the results of these readings. For this reason the statistical variance in a series of percent A, G and B (amber, green and blue tristimulus filters) reflectances of 23 readings for a known Munsell disk 5 YR 6/12 was calculated. The direct use of percent reflectance instead of Munsell notations eliminates errors due to computation.

	A	G	B
s = Standard deviation	0.685	0.316	0.133
*Coefficient of Variation	1.310	0.907	2.070

(*Formula for coefficient of variation is $(s/\bar{x}) \times 100$)

These statistical data show that the coefficient of variation calculated from twenty-three readings is not high and, therefore, the precision of these results are reliable. As expected, the coefficient of variation for the tristimulus blue filter is highest because of the low galvanometer value of these readings.

APPLICATION OF THE INSTRUMENT TO APRICOT NECTARS

Experimental Procedure

The validity of the results obtained by the reflection meter having been already discussed in the preceding pages, the instrument's application to measurement of color of "colloidal suspension-type" liquids, such as pulpy or unclarified juices, purees, nectars, etc., is described in this section. In this investigation only apricot nectars were studied.

Worthington et al (18) have made a preliminary study of this instrument for a similar purpose and have described a technique for determination of color of unclarified juices. In order to prevent any incident light being reflected from the walls of the container, a condition which may introduce an error, they found that for canned or fresh grapefruit juice the minimum size of the container should be three inches in diameter and three inches in height. They also made use of a wooden, collar-like support for the search unit, which is placed on the container so that the distance between the liquid surface of the sample and the search unit is always the same. The liquid level in the container is kept constant by keeping the container filled--if necessary glass plates or some other substance can be dropped into the container to raise the level to the top.

The same procedure was adopted for the present investigation of apricot nectars.

Figure 2

THE INSTRUMENT IN USE

(Showing the Use of Positioning Collar)

It was observed that cans smaller than #2 could be used in the case of apricot nectar as it is more pulpy and, therefore, transmits less light than grapefruit juice. But this difficulty was not encountered in practice because all the samples of the nectar examined were canned in sizes #303, #2 and #1-tall, and all these sizes are larger in dimension than the minimum dimensions mentioned before by Worthington and others. Therefore, it was not necessary to transfer the sample into another container, and the collar with the search unit was placed on the original container.

It was also observed that when the distance between the search unit and the liquid was not kept constant the results varied to some extent. The presence of air bubbles and foam definitely interfered and gave erroneous results. Stirring was found to have a slight effect, and as expected it gave higher reflectance values for each filter when compared to similar readings taken of the unstirred sample. This difference can be explained by the fact that when the nectar is stirred the suspended particles are distributed throughout the mass and, therefore, more light is reflected back from the test surface than when the nectar is not stirred and the suspended particles settle at the bottom of the container. The results in Munsell notation of two of the unstirred samples and results of the same after stirring are given in the following table.

TABLE IV

EFFECT OF STIRRING APRICOT NECTAR ON COLOR DETERMINATION IN MUNSELL NOTATIONS

	Unstirred	Stirred
(1)	0.93 Y 3.76/6.69	8.125 YR 3.75/6.83
(2)	0.46 Y 3.50/5.47	9.82 YR 3.66/6.17

The necessity of stirring before taking each reading is evident from the above results.

Effect of Gloss

The effect of specular reflectance on color determination is not quantitatively understood at present, but it is of considerable importance in the study of color.

According to the manufacturer of the Photovolt reflection meter, the readings obtained on the instrument are a true measure of diffuse reflectance without any error due to gloss. This is due to the fact that light from the search unit strikes the test surface in a parallel beam with practically all the specularly reflected light returning through the aperture of the photocell (See Figure 1). However, this is true, only if the lamp is properly focused. Under this condition, it is claimed by the manufacturer that the effect of gloss should be less than one division on the galvanometer.

In order to study the effect of gloss on color determination, it is necessary to measure the color of known glossy versus matte Munsell disks of the same denomination. The gloss effect can be evaluated as the difference between the results of the matte and the glossy disks.

Unfortunately, due to the unavailability of the necessary disks, detailed study was not made. Therefore, no quantitative conclusions can be drawn on the effect of gloss on color determination by the reflection meter. However, with the apricot nectar, there was no apparent difficulty due to gloss.

Identification of Samples

Samples #1 to #8 in Table V were supplied by "K", one large manufacturer of apricot nectar, and originated from different sources. Each of these samples was visually graded for color by a panel of experts of manufacturer "K". The second group of 6 samples of like origin--samples #15 to #20--were also visually graded in the same manner as mentioned above and were supplied by the same manufacturer. The first four of this second group, i.e., #15, #16, #17, and #18, were selected from the same production lot as the #1, #2, #7 and #8 respectively of the first group.

Twelve more samples which belonged to the same production lot as #7 and #17 but not necessarily true replicates were also obtained from the same source. The other samples, #41 to #50, which were not visually graded but known to be replicates, were also supplied by the same source, "K".

Samples #9, #10, #13, #14 and #36 to #40 were obtained from the local market and belonged to a popular brand, say "H". These samples had good color, flavor and 14.5 to 15.5 percent total soluble solids (determined by a hand refractometer). Similarly, samples #11, #12, and #33 to #35 were also obtained from the market but belonged to another brand, "J". These fourteen samples were not visually graded, but it was observed that the latter five samples were superior in color to most of the samples examined.

Moreover, it was also observed that the samples with superior color had more aroma but were rather flat in taste. These samples had 15 to 16 percent total soluble solids. The ungraded samples obtained from manufacturer "K" were good in color, very good in flavor and had minimum amounts of total soluble solids, 13.5 to 14.5 percent. The pH of all samples examined varied from 3.4 to 4.5.

TABLE V

COLOR MEASUREMENT OF APRICOT NECTAR IN MUNSELL NOTATION

Sample	By Reflectometer	Calculated to an Average Value
1	2.74 Y 3.46/4.4	2.75 Y 3.42/4.29
2	2.8 Y 3.25/3.67	2.70 Y 3.42/4.15
3	1.90 Y 3.69/6.70	1.87 Y 3.42/6.32
4	3.02 Y 3.32/5.22	2.87 Y 3.42/5.29
5	0.25 Y 3.49/5.68	0.29 Y 3.42/5.60
6	0.21 Y 3.47/5.12	0.23 Y 3.42/5.08
7	2.42 Y 3.40/5.15	2.42 Y 3.42/5.16
8	4.39 Y 3.27/4.79	4.26 Y 3.42/4.89
9	2.54 Y 3.63/5.60	2.60 Y 3.42/5.17
10	1.40 Y 3.50/5.32	1.41 Y 3.42/5.15
11	0.17 Y 3.85/6.56	0.32 Y 3.40/6.16
12	0.12 Y 3.75/6.38	0.30 Y 3.40/6.06
13	1.20 Y 3.57/6.15	1.38 Y 3.40/5.90
14	1.06 Y 3.67/6.03	1.36 Y 3.40/5.66
15	4.20 Y 3.67/5.77	4.28 Y 3.40/5.57
16	2.3 Y 3.09/5.38	2.20 Y 3.40/5.67
17	3.50 Y 3.34/5.07	3.51 Y 3.40/5.11
18	3.21 Y 3.17/4.58	3.13 Y 3.40/4.72
19	2.34 Y 3.84/6.30	0.97 Y 3.40/5.55
20	0.70 Y 3.49/6.01	0.06 Y 3.40/5.46
21	2.15 Y 3.29/4.39	2.13 Y 3.40/5.02
22	2.15 Y 3.29/4.93	2.13 Y 3.40/5.02
23	1.03 Y 3.21/5.29	2.42 Y 3.40/5.82
24	0.16 Y 3.21/5.29	0.76 Y 3.40/5.83
25	2.59 Y 3.22/5.86	2.53 Y 3.40/6.08
26	2.40 Y 3.22/6.04	2.33 Y 3.4/6.26
27	1.68 Y 3.28/5.15	1.64 Y 3.40/5.26
28	3.08 Y 3.33/5.12	3.06 Y 3.40/5.18
29	2.92 Y 3.33/4.91	2.90 Y 3.40/4.97
30	1.78 Y 3.31/5.05	1.75 Y 3.40/5.13
31	2.44 Y 3.34/4.89	2.43 Y 3.40/4.90
32	4.18 Y 3.38/5.17	4.17 Y 3.40/5.19
33	0.35 Y 3.78/6.81	0.52 Y 3.40/6.33
34	9.49 YR 3.75/7.05	9.61 YR 3.40/6.56
35	9.91 YR 3.84/6.92	0.09 Y 3.40/6.37
36	1.74 Y 3.54/5.78	1.78 Y 3.40/5.65
37	1.12 Y 3.50/5.85	1.18 Y 3.40/5.74
38	0.72 Y 3.50/5.77	0.76 Y 3.40/5.67
39	0.67 Y 3.52/5.99	0.70 Y 3.40/5.86
40	0.14 Y 3.53/5.73	1.42 Y 3.40/5.60

TABLE V (Continued)

COLOR MEASUREMENT OF APRICOT NECTAR IN MUNSELL NOTATION

Sample	By Reflectometer	Calculated to an Average Value
41	3.45 Y 3.30/5.04	3.42 Y 3.40/5.12
42	4.10 Y 3.24/4.94	4.04 Y 3.40/5.07
43	4.30 Y 3.37/5.24	4.29 Y 3.40/5.24
44	9.97 YR 3.28/5.25	9.91 YR 3.40/5.36
45	1.90 Y 3.27/5.69	1.86 Y 3.40/5.83
46	2.09 Y 3.27/5.62	2.04 Y 3.40/5.75
47	2.51 Y 3.35/5.16	2.49 Y 3.40/5.20
48	1.17 Y 3.34/5.30	1.08 Y 3.40/5.36
49	0.50 Y 3.31/5.37	0.40 Y 3.40/5.48
50	0.96 Y 3.31/5.33	0.92 Y 3.40/5.42

Visual Grading

As mentioned before, the samples of groups I and II were visually graded in descriptive terms by a panel of experts of manufacturer "K", who supplied them. It is convenient and more appropriate to specify the visual grades by numerical or alphabetical values rather than by descriptive terms. Therefore, the visual grades in descriptive terms were arbitrarily given numerical and alphabetical values, which are listed in table VI.

TABLE VI

VISUAL GRADES AND CORRESPONDING NUMERICAL AND ALPHABETICAL VALUES

Visual Grades	Corresponding Numerical Values	Corresponding Alphabetical Values
Excellent - - - - - - - -	10	A+
	9	A
Very good to excellent - - -	8.5	
	8	A-
Very good - - - - - - - -	7	B+
	6	B
Good - - - - - - - -	5	B-
	4	C+
Fair - - - - - - - -	3	C
	2	C-
Poor - - - - - - - -	1	D

DISCUSSION AND RECOMMENDATIONS

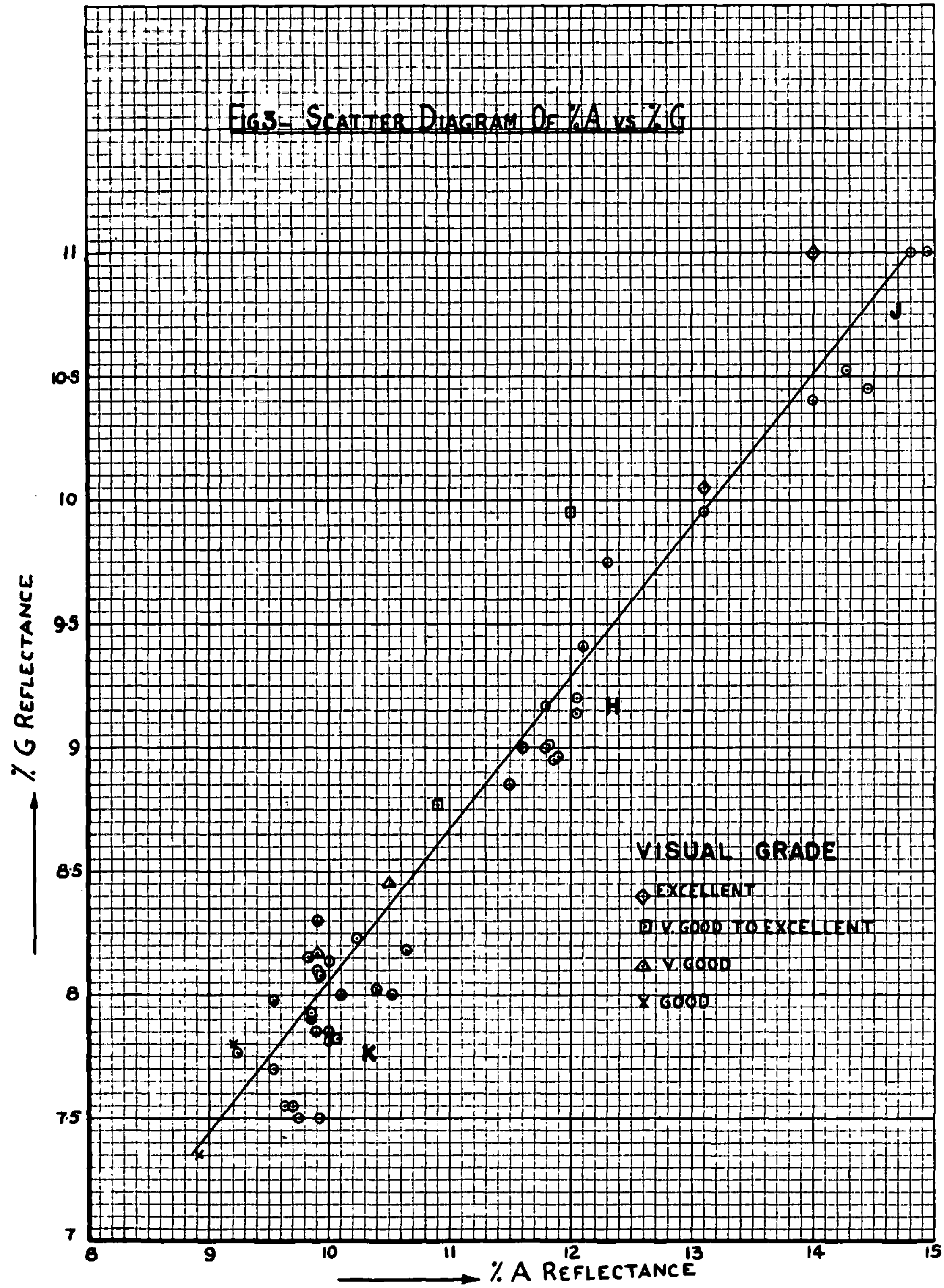
Relationships Between the Objective Measurements

Linear regression was applied to find out statistically the relation between percent A versus percent G, percent A versus percent B, percent G versus percent B, and Chroma versus Hue. The most definite relationship as shown by statistical measures was obtained between percent A and percent G, and hence only this relationship is described.

A distribution of the samples is obtained by the help of a scatter diagram, and the following Figure 3 indicates a linear relationship between percent A and percent G reflectance for fifty apricot nectar samples. The percent A on the horizontal axis represents the percent reflectance of the sample with the tristimulus amber filter and the percent G on the vertical axis represents the percent of reflectance with the tristimulus green filter.

The linear correlationship between percent A and percent G is also confirmed by the calculation of correlation coefficient, r. When all the points fall on a line, the value of r equals one. In this case the value of r is equal to 0.909, which shows a high degree of linear correlationship.

Figure 3



SCATTER DIAGRAM OF PER CENT A VERSUS

PER CENT G REFLECTANCE

The regression coefficient, b, is equal to 0.6092 and the estimated line of regression is:

$$\bar{y}_x = (b)\cdot(x) + (a)$$

$$= (0.6092)\cdot(\%A) + (1.97)$$

where $\bar{y}_x$ is the sample estimate of the population mean of the array of y.

The regression coefficient, b, is the number of units of y per unit of x, or it is the slope of the line of regression and consequently measures the rate of change of the mean of the array of y with respect to x. The intercept or origin on the vertical axis is represented by "a". The line of regression is drawn between the x values of 8.5 and 15.

The standard error of the estimate is $s_{y.x}$. For ideal conditions the standard deviation from the mean should be minimum. In other words, when all the points fall on the line of regression, the $s_{y.x}$ is equal to zero. In this case the $s_{y.x}$ is 0.463, which shows that the points are close to the line of regression.

The most important feature of this scatter diagram is that the different visual grades are symetrically distributed along the regression line. That is, those which were graded excellent fall on the upper part of the line, whereas the next grade falls below the first group, with a slight overlapping. In short, the visual quality decreases systematically from the upper to the lower part of the regression line, with a slight over-lapping of each grade over the other. This indicates that there may be some relationship between visual grading and percent A and/or percent G reflectance.

Another feature of this scatter diagram (Figure 3) is that it shows how samples of different manufacturers fall into different well-defined groups. The samples belonging to the source "J" are grouped together along with those graded "excellent". This confirms the visual observation that these samples had color superior to that of most of the other samples. The samples from the source "H" are next in order, grouped together with those graded "very good to excellent" in color. Those ungraded samples obtained from the manufacturer "K" are grouped with those graded "very good and good" and had reasonably good color.

In order to show the relationship between percent A or percent G reflectance and visual color grade and to show how reliably visual color grading can be predicted by different objective measurements (such as %A, %G, Hue and Chroma) linear regression was made. The following table gives the different statistical values of fourteen graded samples.

TABLE VII

STATISTICAL RELATIONSHIP BETWEEN VISUAL COLOR GRADE AND VARIOUS OBJECTIVE MEASUREMENTS

Measurement	$s_{y.x}$	r
%A	2.86	0.405
%G	2.92	0.330
Hue	3.04	-0.190
Chroma	2.96	0.294

N = 14

Table VII indicates that the best linear correlationship exists between percent A and visual color grades. This is because the relationship shows the highest value for r and lowest for $s_{y.x}$. The comparatively low value of r may here be due to the unreliability of the visual grading. A slightly lower correlationship exists using percent G than percent A versus visual color grade.

Table VII also indicates the undesirability of using Hue, Chroma or other Munsell factors, which are calculated from the readings of the reflection meter, for predicting the visual color grades of the samples.

The scatter diagram, Figure 4, shows the relationship between percent A reflectance and the visual color

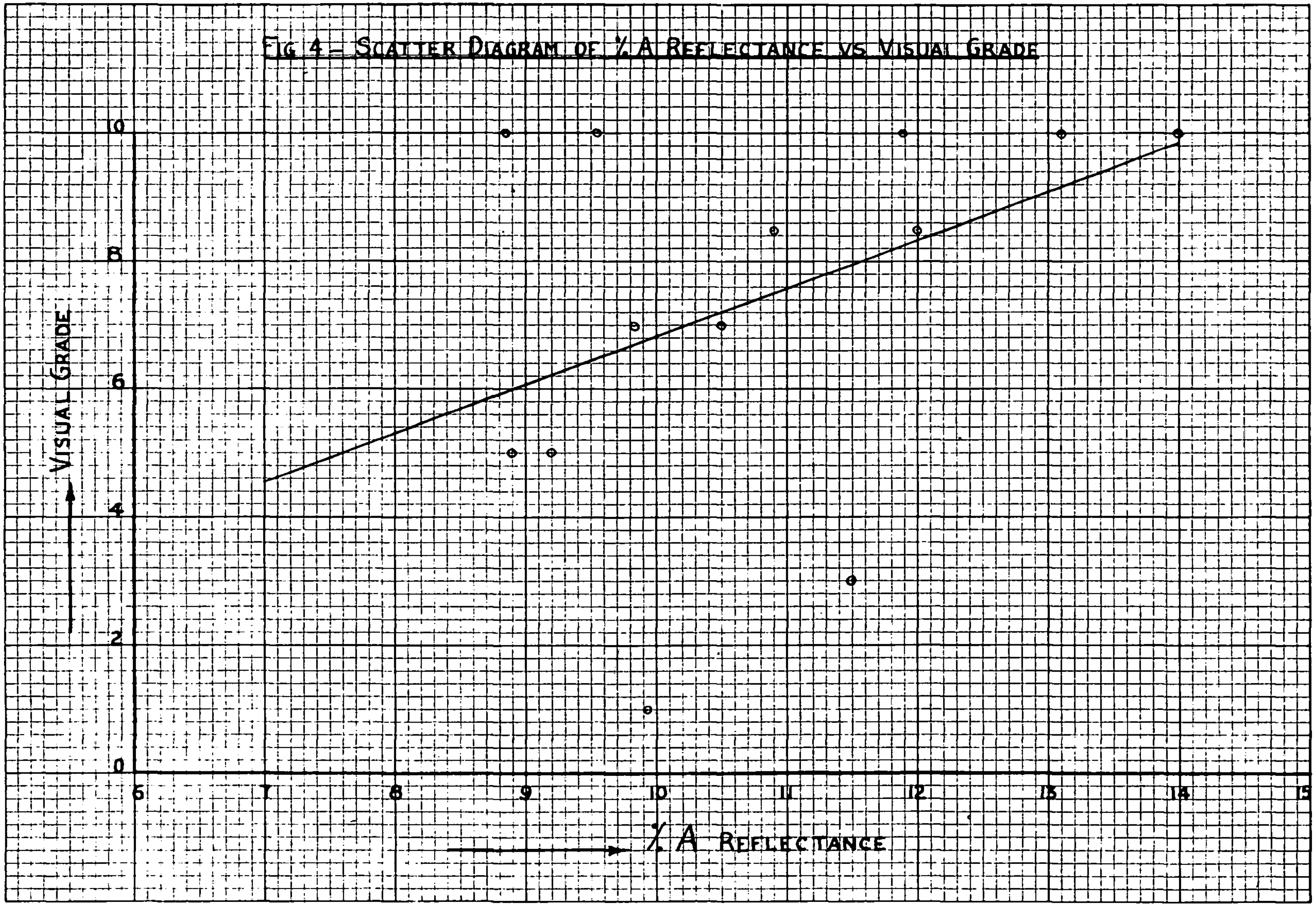


Figure 4

SCATTER DIAGRAM OF PER CENT A REFLECTANCE VERSUS VISUAL GRADING grade of the fourteen samples. The regression line in this diagram is the locus of points representing the percent reflectance of the samples with the tristimulus amber filter (%A) on the horizontal axis, x, and the visual color grading of those samples in numerical values on the vertical axis, y. The regression coefficient, b, in this case is equal to 0.756 and the estimated line of regression is:

$$\bar{y}_x = (b).(x) + (a)$$
$$= (0.756).(\%A) + (-0.71)$$

The line of regression is drawn between the values of x equal to 7 and 14.

<u>Recommendations for a Rapid Objective Method for Determination of Visual Color Grades of Apricot Nectar</u>

According to Osborn and Kenyon (14) a three-number or three-variable system (i.e., the I. C. I. tristimulus system of color specification) is universally recognized and can classify virtually all types of products. But such specifications are rather inconvenient to obtain and difficult to interpret. On the other hand, a single-number or single-letter system is the basis for the denotation of many products. Although all types of products cannot be specified by this system, it is obviously the most desirable method for expressing color standards.

The scatter diagram, Figure 4, is based on the single-number type of specification, and therefore provides a model of an easy and rapid method of color grading of apricot nectars. Suppose an unknown sample is to be graded. The only thing that is required is to take a reading with the tristimulus amber filter; say it is equal to 10.5. Then with the aid of Figure 4, the corresponding visual grade can be obtained--in this case it comes to 7.2. Reference to Table VI (which gives the visual grades and the corresponding numerical and alphabetical values) indicates that the approximate corresponding grade is "very good" or "B+".

Figure 4, being a model based upon fourteen samples, gives only approximate results as now constructed. In order to obtain precise, reliable results of more universal applicability, a large number of representative samples of different grades must be visually graded in single-numerical values by a panel of experts. Then these should be plotted against the percent reflectance with the tristimulus amber filter. In short, it can be said that percent A reflectance is the most reliable objective tristimulus measurement for prediction of visual color of apricot nectar so that a rapid objective method can be set up for quality control work where a large number of samples is available.

For even greater perfection of the method, a filter or a filter-combination may be chosen as suggested by Osborn and Kenyon (14) so that a more distinct and sensitive response is obtained with the reflection meter when different grades of samples are examined. Such desirable qualities for a filter can be selected from the spectrophotometric reflectance curves of the samples of the product. The region of the spectrum where greatest change occurs for different grades of the sample is selected. The readings obtained with such a filter naturally will be expected to be more valid.

An Improved Viewing Technique

As mentioned before, the search unit of the reflection meter is placed directly on the container with the help of a wooden collar. The level of the apricot nectar in the container is kept constant, and it is taken for granted that, when the search unit is placed on the container, the distance between the liquid level and search unit is always constant.

This method is rather messy and clumsy. The liquid under examination always contacts the search unit and if proper care is not taken the liquid may splash and dampen the photoelectric cell. Moreover, every time the substance is stirred, the search unit has to be lifted from the container, and before each replacement of a filter the search unit has to be cleaned. The presence of air bubbles or foam which is generally on the top of the liquid leads to erroneous results.

All these disadvantages are overcome by using an improved viewing technique, in which a special container with a removable glass bottom is placed on the search unit. This container should be practically the same size as the commercial container.

In this study a brass cylinder four inches in height by 2 3/4 inches in diameter was used. A technical glass plate 2/16 of an inch in thickness (with good optical quality and essentially free from disturbing color in the glass) was fixed at the bottom end of the cylinder with the help of a removable base. Instead of glass, a plastic disk-like lucite can also be used.

The nectar was poured into the cylinder, which was then placed on the search unit. In this way, the search unit was always separated from the liquid by the glass plate; thereby the distance between the two was always constant. The liquid in the cylinder did not come in contact with the search unit, and therefore there was little chance for the search unit to be unclean. Stirring was done without the inconvenience of removing the search unit before taking every reading. The error due to air bubbles and foam on the top of the liquid level was eliminated by this method. In short, the improved viewing technique was comparatively more neat, convenient and perhaps more precise.

The following tables VIII and IX show the results of eight samples, claimed to be commercial replicates, tested both by the direct measurement and by the improved viewing technique.

TABLE VIII

% A, % G AND % B BY DIRECT MEASUREMENT AND BY THE IMPROVED VIEWING TECHNIQUE

Sample Number	Direct Measurement % A	% G	% B	Improved Viewing Technique % A	% G	% B
43	9.90	8.30	1.90	11.40	9.00	2.20
44	9.90	7.85	1.93	11.40	9.00	2.20
45	10.07	7.83	1.47	10.63	8.53	1.97
46	10.00	7.83	1.50	10.73	8.70	2.00
47	10.23	8.23	1.90	11.00	8.88	2.07
48	10.67	8.17	1.93	11.23	9.00	2.13
49	10.53	8.00	1.83	10.93	8.77	2.00
50	10.40	8.03	1.83	11.00	9.00	2.10
Mean ($\bar{x}$)	10.21	8.03	1.80	11.04	8.86	2.08
s	0.2943	0.5928	-	0.2865	0.5624	-
Coeff. of variation	2.88	7.382	-	2.595	6.347	-

Table VIII shows that the readings with the improved viewing technique, in which the sample is viewed through the glass, are slightly higher than those obtained directly. This may be due to the fact that the use of glass introduces two reflecting surfaces--each plane of the glass. The statistical calculations indicate that the standard deviation (s) of both the methods are approximately equal, thus showing that both the methods are equally good as far as the variations in readings are concerned. But the mean of all readings ($\bar{x}$) of the two methods is significantly different because of a high F value (F_A = 37.8) obtained by analysis of variance. This high value indicates that the new method gives entirely different results from the direct method. Although it is not possible to predict from these data which method gives more accurate results, further experiments with known samples such as standard Munsell disks, may determine comparative accuracy.

TABLE IX

COLOR IN MUNSELL NOTATION DETERMINED BY DIRECT MEASUREMENT AND BY THE IMPROVED VIEWING TECHNIQUE

Sample Number	Direct Reading*	Reading with the New Viewing Technique*
43	4.29 Y 3.4/5.25	1.73 Y 3.4/5.16
44	9.91 YR 3.4/5.36	1.58 Y 3.4/5.16
45	1.86 Y 3.4/5.83	2.36 Y 3.4/5.20
46	2.04 Y 3.4/5.75	2.88 Y 3.4/5.59
47	2.49 Y 3.4/5.20	1.88 Y 3.4/5.48
48	1.08 Y 3.4/5.48	2.37 Y 3.4/5.13
49	0.40 Y 3.4/5.48	2.46 Y 3.4/5.34
50	0.92 Y 3.4/5.42	3.16 Y 3.4/5.07

*All results computed to a Value of 3.4

The above results in Munsell notation indicate that most of the readings with the improved viewing technique are slightly different from those obtained by direct measurement--in most cases Hue is greater and Chroma lower than those obtained directly.

Since this is merely a preliminary study of a particular viewing technique and was conducted on only a few samples, no definite conclusions can be drawn. The newer method, however, seems to have some definite advantages over the other method, and therefore further work should be conducted to investigate the possible superiority of this technique.

SUMMARY AND CONCLUSIONS

Although apricot nectar is available in large quantities, the standards for this product are not established. Formulation of standards is important both from the point of view of the consumer and the manufacturer. Color is one of the major factors in determining grades of such products (as can be judged by the fact that the United States Department of Agriculture standards for tomato puree allot 60 percent of the total score to color). Therefore, the determination of objective color standards for nectars is an essential step for establishing their quality grades.

In this study a photoelectric reflection-meter was used for the determination and specification of color of apricot nectar, because 1) it measures the color as seen by the eye without involving any personal factors; 2) the results can be expressed in the I. C. I. or the Munsell notations; 3) it is not very expensive and is easy to operate and therefore can be used universally, and 4) samples can be examined directly in commercial cans without any preparation.

A study was made of the error and reproducibility of the results obtained with this instrument by using Munsell disks as standards. It was found that a slight percentage error is caused in Hue, Value, and Chroma, with Hue having the minimum (usually less than $\pm$ 0.5%) and Chroma the maximum percentage error (usually less than $\pm$ 5.0%)

The use of a dark standard with Munsell neutral disks N 5/- and N 6/- was investigated by using Munsell disks of known denominations as standards. It was found that the use of a dark standard introduces more error than it eliminates, and therefore it is not advisable.

The effect of $\pm$ 0.5 percent error in reading of percent reflectances of A, G and B filters was calculated. The results indicate that slight error (usually less than one percent) may be introduced in the final results due to this inaccurate reading of the galvanometer.

Statistical calculations, such as variance and standard error of percent A, G and B reflectances, showed that the results obtained by the photoelectric tristimulus reflection-meter are reliable. The application of this instrument for color measurement is described, complete with manipulative details.

Altogether fifty apricot nectar samples were examined. By the application of linear regression, the statistical relationship between the various objective measurements was studied. The highest correlation coefficient, 0.909, was shown between percent A and percent G reflectances. A scatter diagram (Figure 3) of percent A and percent G reflectances showed that the visual grade decreased systematically from the upper to the lower part of the regression line, with a slight over-lapping of the grades. The samples from different sources were found to be distributed in different well-defined groups along the regression line.

A preliminary study was conducted for an improved viewing technique in which a special container with a removable glass bottom was used. This method seems to have certain advantages over the other method, and therefore further work should be conducted to investigate the possibility of using this technique. If it is found successful it would facilitate color measurement of pulpy juices and similar products.

It is concluded that:

1) This objective method for grading color of apricot nectar by the photoelectric tristimulus reflection meter is simple, rapid and reliable. It is especially suitable for quality control work where a large number of samples is available.

2) Statistical relationship between visual color grades on fourteen samples and various objective

measurements indicates the best linear relationship between percent A reflectance and visual grading. It also indicates the undesirability of using Munsell factors.

3) With a limited number of visually graded samples, for which a regression line is computed relating visual grades with percent A (tristimulus amber filter) reflectance, it is possible to obtain objective color grades of apricot nectar directly from the regression diagram.

4) The above method serves as a model, since only fourteen commercially graded samples were available; thus, for a practical application of this method, a regression line of visual grades on percent A based upon a large number of samples must be constructed.

5) For greater perfection of the method, a filter should be selected from the spectrophotometric reflectance curves of the product so that more sensitive results may be obtained.

LITERATURE CITED

1. Bam, S. G. Color measurement and its relation to grading of canned and frozen green beans. Master's Thesis, Oregon State College, 1948.

2. Committee on colorimetry of the optical society of America. The concept of color. Journal of optical society of America 33: 544-554. 1943.

3. Committee on colorimetry. Colorimeters and color standards. Journal of optical society of America 35:1-25, 1945.

4. Evans, R. M. An introduction to color. New York, John Wiley and Sons, Inc., 1948.

5. Gardner, H. A. Physical and chemical examination of paints, varnishes, lacquers and colors. Eighth edition. Distributed by the institute of paint and varnish research, Washington, D.C. 1937. 1523p.

6. Hardy, A. C. Handbook of colorimetry. Cambridge, Mass. Technology press, 1936. 87p.

7. Hunter, R. S. Photoelectric tristimulus colorimetry with three filters. National bureau of standards, Circular C-429, 1942.

8. Judd, D. B. The 1931 I. C. I. standard observer and coordinate system for colorimetry. Journal of optical society of America 23:359-374. 1933.

9. Kramer, A. G. and Smith, H. R. Preliminary investigation on measurement of color in canned foods. Food research 11:14-31. 1946.

10. Kramer, A. G. and Smith, H. R. Electrometric methods for measuring color of canned peaches and apricots. Food technology 1:527-539. 1947.

11. McCollum, J. P. Color and pigment studies with different grades of tomato juice. Proceedings of the American society of horticultural science 44:398-402. 1944.

12. Newhall, S. M., Nickerson, D., and Judd, D. B. Final report of the O.S.A. subcommittee on the spacing of the Munsell colors. Journal of the optical society of America 33:385-418 1943.

13. Nickerson, Dorothy. Color measurement and its application to the grading of agricultural products. U. S. D. A. misc. pub. 580, 1946.

14. Osborn, R. H. and Kenyon, W. C. A general method of color grading. Industrial and engineering chemistry, analytical edition 18:523-530. 1946.

15. Photovolt photoelectric reflection meter model 610. New York, Photovolt Corp.

16. United States standards for grades of canned yellow clingstone peaches (effective July 1, 1942). U. S. D. A. agricultural and marketing administration, Washington 25, D. C.

17. United States standards for grades of canned tomato puree (tomato pulp) (effective January 1, 1946). War food administration office of distribution, Washington 25, D. C.

18. Worthington, O. J., Cain, R. F. and Wiegand, E. H. Determination of color of unclarified juices by reflectometer. Food technology 3:274-277. 1949.

APPENDIX

APPENDIX

TABLE X

COLOR OF APRICOT NECTAR IN MUNSELL NOTATION BY USING A N 5/- MUNSELL DISK AS A DARK STANDARD

Sample Number	Munsell Notations
1	4.75 Y 3.54/4.58
2	2.61 Y 3.23/3.68
3	3.40 Y 3.68/6.00
4	3.23 Y 3.27/5.27
5	0.59 Y 3.42/5.50
6	0.81 Y 3.38/5.10
7	1.12 Y 3.29/5.34
8	2.76 Y 3.30/4.60
9	1.32 Y 3.58/6.00
10	1.14 Y 3.46/5.30
11	2.10 Y 3.70/6.66
12	1.45 Y 3.69/6.62
13	2.53 Y 3.46/6.00
14	2.40 Y 3.67/6.50
15	2.02 Y 3.59/5.89
16	4.02 Y 3.23/5.65
17	2.58 Y 3.37/5.43
18	2.72 Y 3.22/4.98
19	1.72 Y 3.88/6.52
20	1.88 Y 3.50/6.02
21	1.22 Y 3.21/5.22
22	1.22 Y 3.21/5.22
23	5.00 Y 3.31/4.98
24	4.84 Y 3.32/5.02
25	3.37 Y 3.31/5.55
26	2.50 Y 3.31/5.76
27	2.82 Y 3.33/5.45
28	2.61 Y 3.32/5.38
29	0.34 Y 3.21/5.19
30	1.60 Y 3.27/5.24
31	0.59 Y 3.17/5.27
32	9.68 YR 3.16/5.42

TABLE XI

% A, % G AND % B REFLECTANCE OF FIFTY SAMPLES

Sample Number	% A	% G	% B
1	10.9	8.77	1.90
2	9.55	7.70	1.70
3	13.10	10.07	1.55
4	9.93	8.08	1.71
5	11.87	8.95	2.00
6	11.50	8.85	2.37
7	10.50	8.45	2.00
8	9.20	7.80	2.00
9	12.30	9.75	1.85
10	11.6	9.00	1.80
11	14.8	11.0	1.87
12	14.00	10.40	1.82
13	12.1	9.41	1.87
14	13.1	9.95	1.95
15	12.00	9.96	1.90
16	8.85	6.96	1.37
17	9.82	8.15	1.19
18	8.91	7.35	2.00
19	14.00	11.00	2.00
20	11.9	8.95	1.83
21	9.85	7.90	1.95
22	9.85	7.93	1.95
23	9.75	7.5	1.62
24	9.92	7.50	1.80
25	9.61	7.55	1.20
26	9.70	7.55	1.12
27	10.00	7.86	1.85
28	10.00	8.13	1.85
29	9.95	8.10	1.90
30	10.10	8.00	1.95
31	9.90	8.17	1.86
32	10.05	10.83	1.83
33	14.28	10.63	1.76
34	14.43	10.45	1.71
35	14.95	11.00	1.86
36	12.06	9.20	1.88
37	11.81	9.01	1.86
38	11.80	9.00	1.90
39	12.03	9.13	1.81
40	11.80	9.00	1.90

TABLE XI (Continued)

% A, % G AND % B REFLECTANCE OF FIFTY SAMPLES

Sample Number	% A	% G	% B
41	9.57	7.97	1.83
42	9.21	7.66	1.76
43	9.90	8.30	1.90
44	9.90	7.85	1.93
45	10.07	7.83	1.47
46	10.00	7.83	1.50
47	10.23	8.23	1.90
48	10.67	8.17	1.93
49	10.53	8.00	1.83
50	10.40	8.03	1.83