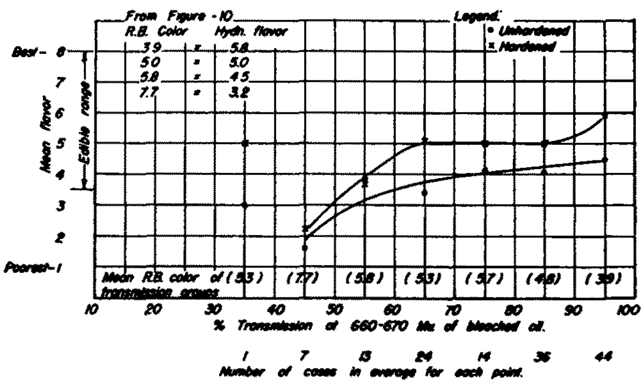
urements a 10 cm. cell of oil was used, so that small variations of chlorophyl give large variations in the transmission. The general slope of the curve indicates that chlorophyl might be damaging to flavor. Some qualifications are needed, however. Low bleach colors usually accompany low chlorophyl contents, and could account for the slope of the line. The average bleach color of each transmission group is listed beneath the curves. Tabulated also is the expected flavor for the listed bleach color. Notice that the flavor level could have been predicted reasonably well by the bleach, except for the lowest transmission values, where quality seems to be a little poorer. It appears therefore that small variations in chlorophyl do not seriously affect flavor.

FIGURE-11
LABORATORY EDIBILITIES ON CRUDE SOYBEAN OIL
AGED FLAVOR VS. CHLORPHYL IN BLEACHED OIL
AS MEASURED BY SPECTROPHOTOMETRIC TRANSMISSION.




The best evidence on the effect of chlorophyl in crude bean oil was obtained in the fall of 1942. An unusually early frost arrested the growth of the beans before they matured; and these frost-damaged beans produced very green crude oils. Many of these beans were harvested late in the season after considerable exposure to bad weather conditions. These field damaged beans produced dark crude oils, that could not be processed to light colored oils.

Several test lots of these damaged beans were obtained from various processors and crushed in pilot plant equipment. The crude oils were then tested for edibility. Table I shows typical results.

The samples are listed in the order of their flavor quality. The No. 2 yellow beans produce easily bleachable oil, of good quality. Beans that are frost

TABLE I

| | RB Color 6% Natural Earth | Activated Earth Bleach | | | |
|---|---|---|---|---|---|
| | | %* Used | Lovibond Red Color | Flavor Quality | |
| No. 2 yellow beans | 25/2.3 | 2 | 2.1 | 8 | Best grade |
| 60% frost damaged | ............ | 4 | 3.0 | 7 | Intermediate grade |
| 30% field damaged | 120/7.2 | 5 | 6.4 | 4 | Barely edible |
| 85% field damaged | 240/14.8 | 12 | 8.2 | 2 | Inedible |

* To bleach oil substantially free of chlorophyl.

damaged only, will also produce fairly good oil. More bleaching earth is of course required to adsorb the large amounts of chlorophyl, but if the chlorophyl-free oil is of light color, its quality will be reasonably good. It ought to be said that green samples on which natural clay would not produce readable Lovibond colors were rarely encountered.

The third and fourth samples are from field damaged beans. The bleach colors are high with either type of earth bleach, and flavor quality is poor.

These samples are actual results typical of about 65 edibilities on the 1942-43 crop. They are in reasonably good agreement with several hundred results from previous seasons. They suggest that flavor quality will be related to bleach color of normally refined oils about as follows:

TABLE II

| Flavor Quality | Approximate Lovibond Red Bleach Color | |
|---|---|---|
| | 6% English Earth | 4% Domestic Activated Earth |
| High quality | 3.0 max. | 1.5 max. |
| Intermediate quality | 3.1 to 5.5 red | 1.6-3.5 |
| Low quality | 5.6 to 8.5 | 3.6-6.5 |
| Inedible | Above 8.5 | Above 6.5 |

For the green crude oils the activated earth bleach is preferable.

Perfect segregation into quality classes will not result from use of the foregoing grading scale. Two-thirds of the oils can be accurately classified, and the others will fall close to the arbitrary dividing line between the grades.

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1. W. J. Morse and J. L. Cartter, Improvement in Soybeans. U. S. Dept. Agr. Year Book, 1937; 1154-1189, illus.
2. Piper and Morse, The Soybean. McGraw-Hill (1923).
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# Color Committee Report

THE Lovibond system of color readings has been of incalculable use to the oil industry for many years. However, the difficulty of obtaining color glasses and the increasing use of oils of widely varying hues led to a desire on the part of the Color Committee to institute better methods of reading oil colors. Simultaneously, the increased use of photoelectric equipment for purposes of color measurement has stimulated a desire to investigate the possibility of substituting a suitable photoelectric colorimeter for the Lovibond colorimeter now in use. It is not the purpose of this report to consider as yet a final system for grading oils but to:

1. Evaluate the Lovibond System.
2. Evaluate a series of oils by
   a. Visual observation
   b. Lovibond color
   c. Spectrophotometric methods.
3. Arrive at some conclusion as to the physical characteristics of an oil that determine *color* as one judges it by visual observation.

This report is divided into two parts, the first a Report of the Sub-Committee on *Methods of Color*

*Reading* and the second a Report of the Sub-Committee for the *Development of a Colorimeter*. An evaluation of the Lovibond system will be dealt with in the first report while the second report will deal with the evaluation of a series of oils by various methods and an analysis of these findings.

## PART I

### Report of the Sub-Committee on Methods of Reading Colors

*Evaluation of the Lovibond System.* The Lovibond system of reading the color of an oil is dependent upon:

1. A standard colorimeter.
2. An observer.
3. The ability to match the color of the oil with a combination of red and yellow glasses.

Although a very serious attempt has been made to standardize the Lovibond colorimeter, variations occur in the light intensity (as much as 100% in a single colorimeter depending upon the 100 w. bulb used), in the glasses used, and in the color tubes.

Equally as important are the variations to be found in the observer. Here two factors are of decided importance, (1) the ability of the observer to grade colors, i.e., his standard of color perception and (2) the end point he attempts to obtain. This latter has been shown to exist and is dependent upon whether he strives to attain an exact match of the color hue or a match of the lightness or darkness of the oil.

The third factor, that of matching an oil with red and yellow glasses becomes increasingly important as new oils such as soybean, etc., are used in increasing amounts. Many oils cannot be matched with red and yellow and in these cases a Lovibond reading is practically of no value.

A detailed consideration of these factors makes it readily apparent that the Lovibond system suffers from too many serious defects. It is with these considerations in mind that the Color Committee has embarked on an effort to study the physical characteristic of oils that may in the end contribute to a suitable system for quickly evaluating the color of an oil for commercial purposes.

To evaluate one factor of the Lovibond system of reading oil colors, Dr. Milner sent to each member of the Color Committee a Corning No. 5900 blue color filter to be used in reading a series of oil.

1. In the regular Colorimeter—
   a. With the official yellow
   b. With matched yellow.
2. With a clear 100 w. Mazda lamp and the blue filter in the color tube. (This gives illumination approximately that of illuminant C.)
   a. With the official yellow
   b. With matched yellow.

A total of 750 readings were made on 55 oils, nine different operators participating. From these data it can be concluded that in general the use of a clear Mazda bulb and blue filter No. 5900 giving approximately illuminant C would result in Lovibond reading of 0.5 red higher than the now official colorimeter.

At a somewhat later date, Dr. Freyer sent two oils to each member of the Color Committee to be evaluated in a like manner. These data are shown in Tables 1 and 2.

The results can be summarized thus:

1. Oil No. 1 having a mean red of 5.2 has an average deviation of 0.46, while Oil No. 2 having a mean red of 8.8 has an average deviation of 0.43. This would indicate that variations of as much as 1.0 red occur with regularity and that wider variations can be expected all too frequently.
2. The use of the clear bulb and blue filter resulted in reading of approximately 0.5 red higher than the official readings. The variation was from about 0.2 red to 1.0 red.

TABLE 2

Cooperative Sample No. 2
(E. B. Freyer)

| Laboratory | Observer* | Regular Conditions | | Special Conditions | |
|---|---|---|---|---|---|
| | | Official Yellow | Matched Yellow | Official Yellow | Matched Yellow |
| S. K. & Sons | Brandt | 70–8.4 | 115–9.5 | 70– 9.8 | 80– 9.6 |
| S. K. & Sons | Freyer | 70–8.7 | 105–9 2 | 70– 9.8 | 105– 9.6<br>105– 9.8 |
| Northern | Milner | 70–9.4 | 70–9.4 | 70–10.1 | 70–10.1 |
| Lever | Bass | 70–8.4 | 85–8.5 | 70– 9.6 | 95– 9.5 |
| P & G | Stillman | 80–8.3 | 95–8.4 | 90– 9.0 | 80– 9.7 |
| P & G | Thomson | 80–8.2 | 100–8.3 | 95– 9.5 | 100– 9.4 |
| Staley | Durkee | 70–9.0 | 90–9.0 | 70–10.7 | 90–10.5 |
| Humko | Seabold | 70–9.5 | 70–9.5 | 70– 9.5 | 70– 9.5 |
| N. Y. Prod. Exc. | Trevithick | 70–9.2 | 100–9.0 | 5–12.0° | ........ |
| B-A Labs | Agee | 70–8.5 | 75–8.5 | 70– 9.2 | 75– 9.4 |
| S. W. Labs | Hamner | 70–8.9 | 80–8.7 | 70–11.0 | 80–10.2 |
| Average | | –/8.8 | –/9.0 | –/9.8 | –/9.7 |
| Av. Dev | | 0.48 | 0.40 | 0.46 | 0.30 |
| Std. Dev | | 0.44 | 0.44 | 0.59 | 0.35 |

* Or individual reporting.
° Not used in evaluating.

TABLE 1

Cooperative Sample No. 1
(E. B. Freyer)

| Laboratory | Observer* | Regular Conditions | | Special Conditions | | Booth? Yes No | Voltage | |
|---|---|---|---|---|---|---|---|---|
| | | Official Yellow | Matched Yellow | Official Yellow | Matched Yellow | | Line | Lamp Rating |
| S. K. & Sons | Brandt | 70–5.8 | 40–5.0 | 70–5.4 | 35–5.9 | Yes | 113 | 120 |
| S. K. & Sons | Freyer | 70–5.4 | 35–5.3 | 70–5.5 | 35–5.6 | Yes | 113 | 120 |
| Northern | Milner | 70/5.7 | 70/5.7 | 70/5.8 | 70/5.8 | Yes | 119 | Clear 120<br>Daylight 115 |
| Lever | Bass | 70/4.9 | 50/5.0 | 70/5.3 | 55/5.7 | No | ...... | 130 |
| P & G | Stillman | 42/4.2 | 35/4.5 | 52/5.2 | 30/6.1 | Yes | ...... | ...... |
| P & G | Thomson | 44/4.4 | 35/4.5 | 53/5.3 | 50/5.4 | Yes | ...... | ...... |
| A. E. Staley | Durkee | ........ | 28/4.8 | 70/6.0 | 30/6.0 | No | 110 | 120 |
| Humko | Seabold | 70/5.4 | 35/5.5 | 70/5.3 | 35/5.3 | No | ...... | ...... |
| N. Y. Prod. Exc | Trevithick | 70/5.9 | 35/6.0 | 15/8.3° | ........ | ...... | ...... | ...... |
| B-A Labs | Agee | 70/4.9 | 50/5.0 | 70/5.5 | 50/5.7 | Yes | 118 | Clear 120<br>Special 115 |
| Southwestern | Hamner | 70/5.2 | 45/4.9 | 70/5.2 | 70/5.2 | ...... | ...... | ...... |
| Average | | –/5.2 | –/5.1 | –/5.4 | –/5.7 | ...... | ...... | ...... |
| Av. Dev | | 0.46 | 0.37 | 0.19 | 0.23 | ...... | ...... | ...... |

* Or individual reporting.
° Not used in evaluating.

3. There is some indication that the use of the clear bulb and blue filter results in slightly more uniform color readings but this is by no means certain and the higher readings obtained virtually eliminate any possibility of making the change.

From these results it is believed that the Lovibond system of measuring oil colors, while it has been extremely valuable in the past (and still is), has serious defects that warrant work on newer methods of measuring oil colors. Changing the Lovibond illumination to roughly that of illuminant C would shift the Lovibond scale but would not markedly improve color reading reproducibility and would therefore be unjustified.

## PART II

### Report of the Sub-Committee for the Development of a Colorimeter

The primary problem for this sub-committee was to decide what it is that is to be measured by the new colorimeter. To throw some light on this, 19 samples of oil, as described in Table 3, were prepared.

TABLE 3

Composition of Samples Prepared for R. T. Milner

| | Lovibond Colors | Brightness TW |
|---|---|---|
| 1. Refined, filtered cottonseed oil | 120y/10.4r | .3383 |
| 2. Refined, filtered peanut oil | 28y/ 2.1r | .782 |
| 3. Refined, filtered cottonseed oil | 37/ 5.0 | .616 |
| 4. Refined, bleached cottonseed oil | 40/ 5.5 | .576 |
| 5. Refined, bleached soybean oil | 34/ 4.4 | .623 |
| 6. Refined, bleached soybean oil | 8/ .9 | .937 |
| 7. Refined, bleached cottonseed oil | 53/ 9 3 | .4922 |
| 8. Refined, bleached cottonseed oil | 10/ 1.1 | .918 |
| 9. Refined, filtered cottonseed oil | 33/ 3.2 | .717 |
| 10. Refined, bleached cottonseed oil | 37/ 2.2 | .812 |
| 11. Refined, bleached soybean oil | 30/ 3.0 | .809 |
| 12 Refined, bleached cottonseed oil | 39/ 3.2 | .760 |
| 13. Refined, bleached coconut oil | 2.0/ 0.1 | .959. |
| 14. Refined, bleached soybean oil | 23/ 2.8 | .838 |
| 15. Refined, bleached soybean oil | 330/10.9 | .1156 |
| 16. Refined, filtered soybean oil | 310/ 8 6 | .1472 |
| 17. Refined, filtered soybean oil (green) | 175/ 6.7 | .2977 |
| 18. Refined, filtered soybean oil | 45/ 4.1 | .4928 |
| 19. Refined, bleached peanut oil | 11/ 1.1 | .905 |

Three separate methods of evaluating these oils were carried out. First, four experts were asked to rank the oils in the same manner as they would if they were reading them with Lovibond glasses. The oils were placed in stubby 4-oz. bottles so that judgments of the color could be made rather easily. One of the experts was a Referee Chemist of the A.O.C.S. with a great many years of experience; two were experienced color readers in the Procter & Gamble Company, one was a chemist of long experience connected with the Lever Bros. Co.

The second method was to make portions of the oils into plastic shortening. Twenty parts of a soybean oil hard stock under 1 red color, was mixed with 80 parts of each oil. The mixture was stirred down with cooling and a fairly acceptable standard shortening produced. These were judged for attractiveness by 16 observers at the Northern Regional Laboratories about one-third of whom were men and two-thirds women.

The third method was the "attractiveness" of the oils as judged by the same 16 observers. The term "attractiveness" was used in order to avoid prejudicing the observers toward judgments of lightness or darkness or towards judgments of chromaticity. This resulted in a set of judgments that was at first hard to untangle. Upon study, however, it became apparent that a number of the judges found an oil the more attractive the darker it was up to a certain point. When these were placed in the proper order and averaged in with the observers who found the oil the more attractive the lighter it was, the adjusted attractiveness scale was derived. These various choices are shown in Table 4, together with the position given by the Lovibond color and by the luminous transmission (Tw).

Using the Spearman rank order correlation formula

$$1-6\frac{d^2}{n(n^2-1)}$$

the luminous transmission correlates somewhat better than the Lovibond with choice, the values being 96 for TW and .92 for Lovibond. However, the Lovibond correlates better for the light oils. An inspection of the spectrophotometric curves for the oil furnished by R. T. Milner of the Northern Regional Research Laboratory throws some light on these facts. Apparently the average observer is influenced in this judgment of the "color" of an oil by the light absorbed in the 450 and 670 millimicron regions to a greater extent than could be predicted from the visibility curve of the standard observer. While we can say that a simple photocell instrument, reading luminous transmission, would grade oils at least as well as the Lovibond system, there is a strong probability that a proper choice of filter would enable a photocell filter system to do as well as the Lovibond on the light oils and very much better on the dark oils. The committee is working on this phase of the problem.

This report was prepared by a sub-committee consisting of Procter Thomson, R. C. Stillman, and R. T. Milner.

—G. WORTHEN AGEE, chairman.

TABLE 4

| Oil No. | 13 | 6 | 8 | 19 | 14 | 10 | 11 | 2 | 12 | 9 | 5 | 3 | 4 | 18 | 7 | 1 | 17 | 16 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Experts "Color Rating" | 1 | 2 | 3 | 4 | 6 | 5 | 8 | 7 | 9 | 10 | 12 | 11 | 13 | 15 | 14 | 17 | 16 | 19 | 18 |
| Shortening | 1 | 4 | 2 | 3 | 8 | 5 | 7 | 6 | 13 | 10 | 15 | 9 | 12 | 16 | 11 | 14 | 17 | 18 | 19 |
| Adjusted "Attractiveness" | 1 | 3 | 2 | 4 | 7½ | 5 | 7½ | 6 | 11 | 9½ | 14 | 9½ | 12 | 15½ | 13 | 14½ | 17 | 18 | 19 |
| Final Position by Choice— Average of the three above | 1 | 3 | 2 | 4 | 7 | 5 | 8 | 6 | 11 | 9½ | 14 | 9½ | 12 | 16 | 13 | 15 | 17 | 19 | 18 |
| Lovibond Position | 1 | 2 | 3 | 4 | 7 | 6 | 8 | 5 | 10 | 9 | 12 | 13 | 14 | 11 | 17 | 18 | 15 | 16 | 19 |
| Luminous Transmission Position | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |