THE PHOTELOMETER AND COLOR MEASUREMENTS

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A Paper Delivered Before the 1934 Fall Meeting A.O.C.S.

A discussion of the principles involved in the construction and operation of the Photometer and a preliminary report on possible application of this instrument in the color problems of the oil industry.

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The Photelometer, designed and constructed in accordance with principles suggested by Drs. Sheard and Sanford[1,2,3,4] of the Mayo Clinic, functions according to the Lambert-Beer law. This law may be summarized by the equation

$$x = -K \log (E/Eo) \qquad (1)$$

where x, the concentration of material in solution, is proportional to the logarithm of the fraction of unabsorbed light, E/Eo, passing through the solution. Since perfect matches between absorption bands of the filters and liquid solutions are not obtainable, deviations from the Lambert-Beer relation occur. Unless this discrepancy is very great the usefulness of the instrument is not impaired.

After the Photelometer had been successfully used for the determination of haemoglobin and in other color problems of the clinical laboratory, as well as in the measurement of small quantities of molybdenum, manganese and carbon in steel, it seemed advisable to study its possible application to color problems of the oil industry. To date the results have been decidedly encouraging so that a further study of the problem gives hope of success.

It is recognized that the evaluation of the color of oils is quite a different problem from the measurements referred to above. In haemoglobin measurements, for example, the factor which produces the degree of color saturation may be determined by other means. Consequently, Photelometer indications are correlated with the number of grams of haemoglobin per 100 cc of blood and not with a specific color value. In other words, the change in color saturation is a means to an end. The fundamental factors which produce the color or colors in oils are not known, or, at least, they are not easy to determine quantitatively. This makes a different treatment of the problem necessary. Although Lovibond color readings may leave much to be desired in the standardization of oils, their use, as well as their limitations, are well-known to those who deal with the color of oils. Hence, an attempt was made to correlate red Lovibond color readings with Photelometer indications. Certain interesting results have been obtained, notwithstanding that the problem is further complicated by the unrelated variation of other color values.

Dr. A. S. Richardson and Mr. J. T. R. Andrews of the Procter & Gamble Company kindly furnished a number of oil samples—19 in all—for a series of measurements. Mr. Andrews retained a similar number of check samples for reference. Careful color readings were taken on all of these and the color readings of the first 13 were sent with the samples. Samples 14 to 19 were unknown, both as to their color readings and to the nature of the oil. Furthermore, the exact nature of the oil making up the 19 samples was unknown during the course of the experiments. The problem was one of determining the red Lovibond readings of the unknown samples.

Photelometer readings were made on all of the samples and the readings of the known samples were plotted against red Lovibond numbers as shown in the curves of Figs. 1 to 3. It will be noticed that the readings fell into three groups and a fairly consistent correlation obtained. Likewise, the Photelometer readings of the unknown samples were similarly grouped so that it became a simple matter to determine the color readings for these by reference to the three calibration curves.

To settle the question as to whether the Photelometer indicated correct Lovibond numbers, comparison of the data was made at Cincinnati. The results are

TABLE I—LOVIBOND RED COLOR READINGS

Sample	—Procter & Gamble Co.— June 27	June 29	——Photelometer—— June 27	June 29
14	.90	.95	1.0	1.0
15	1.75	1.80	1.8	1.95
16	1.6	1.70	1.6	1.60
17	4.8	4.9	4.6	5.1
18	5.2	5.1	4.0	4.0
19	6.7	6.6	6.7	6.7

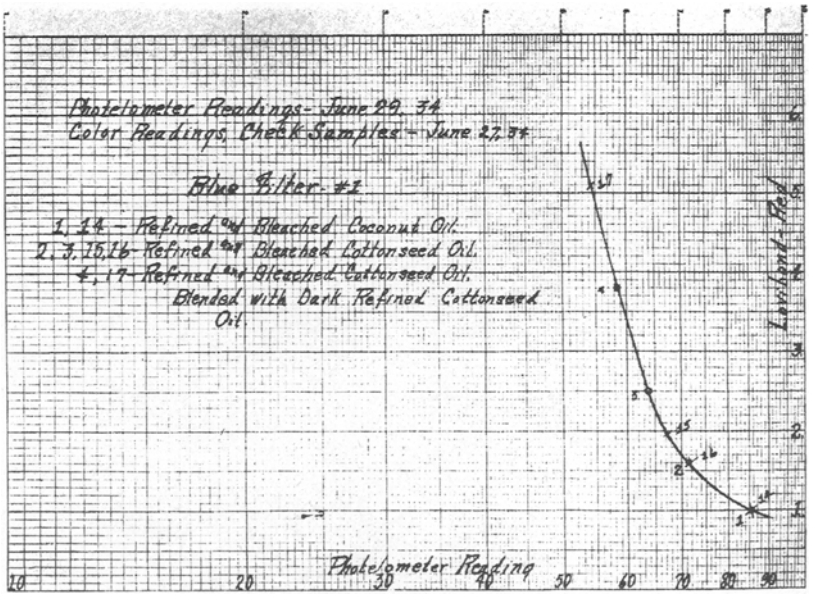

FIGURE ONE

[1]Sanford & Sheard: Jour. Lab. & Clin. Med., 15:483-489, 1930.
[2]Sheard & Sanford: Jour. Lab. & Clin. Med., 14:558-573, 1929.
[3]Sheard & Sanford: Jour. Am. Med. Assn., 93:1951-1956, 1929.
[4]Sanford, Sheard & Osterberg: Am. Jour. Clin. Path., 3:405-420, 1933.

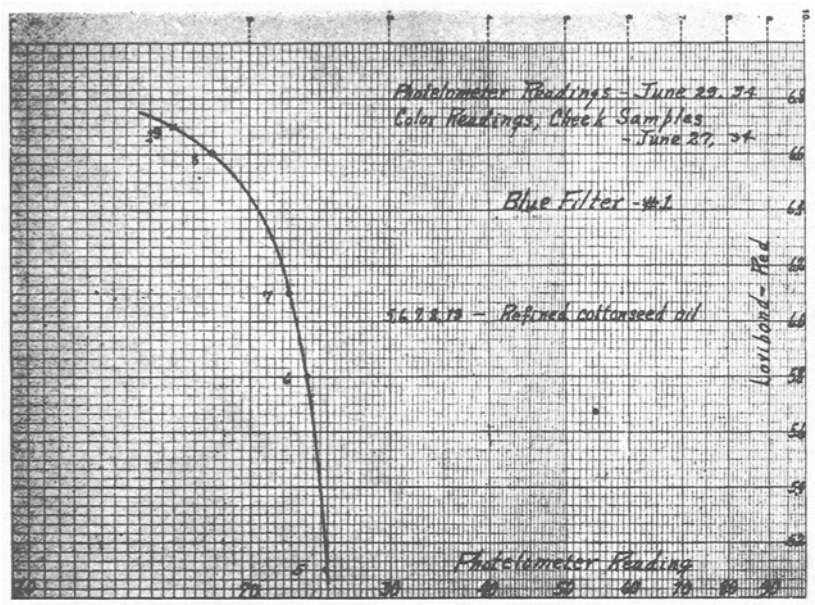

FIGURE TWO

shown in Table I. Good agreement was obtained in five of the samples and the discrepancy in sample No. 18 was to be expected since the curve in Fig. 2 had to be extrapolated before the reading for this sample could be obtained. The dotted portion of the curve shows the correct extrapolation based on the color reading for the sample.

In Table II are shown Photelometer readings on samples 1 to 4. The readings in the first three columns were made on successive days and the readings in column 4 were made on the check samples at Cincinnati. The increase in these readings indicates that the samples faded slightly during this interval. The consistency among the readings of the samples and the check samples is worthy of note.

TABLE II—PHOTELOMETER READINGS

Sample	June 27	June 28	June 29	July 2
1	84.0	85.8	85.7	85.3
2	70.6	70.3	71.4	71.0
3	62.3	63.0	63.9	64.5
4	56.9	57.7	58.7	58.2

Mr. W. H. Irwin of Swift & Co. kindly supplied additional samples of cottonseed oil, cocoanut oil, peanut oil and lard for study together with their respective color readings and sources of the oils. Photelometer readings have been made on the samples, using various light filters and combinations of filters, but to date a satisfactory correlation between Lovibond readings and Photelometer indications has not been found. Certain interesting relationships have been obtained but the significance of these is not apparent at present.

It is worthy of note that preliminary tests on a few of these samples show that the change in Photelometer reading per degree centigrade change in temperature is of the order of .1 to .05 of a division.

A schematic diagram of the Photelometer is shown in Fig. 4 and the instrument itself in Fig. 5. The light source, a, is energized by a constant wattage transformer, t. The light from the source passes through an iris diaphragm, b, lens, l, light absorption cell, c, light filter, d, and finally reaches the Photronic cell, e. The electrical current, produced by the light which ultimately reaches the Photronic cell, is indicated by the galvanometer, f.

In operating the Photelometer the iris diaphragm is first adjusted until the light, which passes through the absorption cell containing distilled water or other solvent and the light filter, has sufficient intensity at the Photronic cell to produce full scale deflection of the galvanometer—100 divisions. Subsequently, the liquid under examination is interposed in the light path in place of the standard solution and a lower reading of the galvanometer obtains. The Photelometer readings, corresponding to a variable component of the solution, are then plotted against known properties of the absorbing material to form a calibration curve. Subsequently, unknown solutions are checked by comparing Photelometer readings with the calibration curve.

To obtain the best results and to produce maximum sensitivity in the Photelometer a light filter is required as shown in Fig. 4. The filter is selected so that its light transmission band corresponds as nearly as possible to an absorption band of the material or solution under investigation. The filter excludes much of the light—ideally all of the light—which experiences very little change in intensity as the concentration of the solution changes. The light received by the Photronic cell, therefore, is of the hue whose degree of saturation changes appreciably as the concentration of the solution varies. Consequently, small differences in concentration produce noticeably different Photelometer readings, because the light which is changing in intensity is not diluted by light of unvarying intensity. Without the use of the filter marked changes in the Photelometer indications would not occur.

As applied to the Photelometer the Lambert-Beer law may be written

$$E = Eo\ e^{-(c_1 x + c_2 t)y} \qquad (2)$$

where Eo and E are light intensities before and after passing through the absorption cell, c_1 and c_2 are proportionality factors, x is the concentration of the solution, y is the thickness of the cell. and t is the turbidity of the solution. If the current response of the Photronic cell is proportional to the intensity of light falling on it; i. e., E is proportional to I,

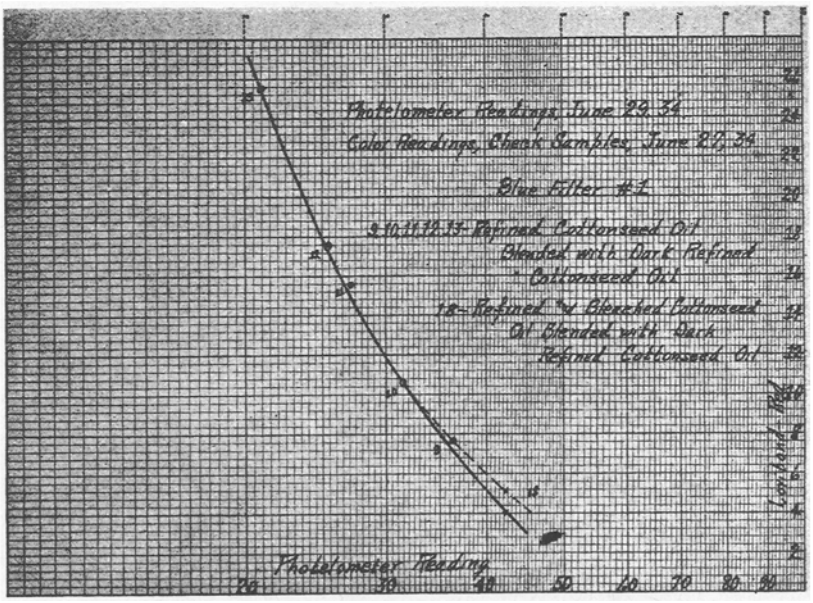

FIGURE THREE

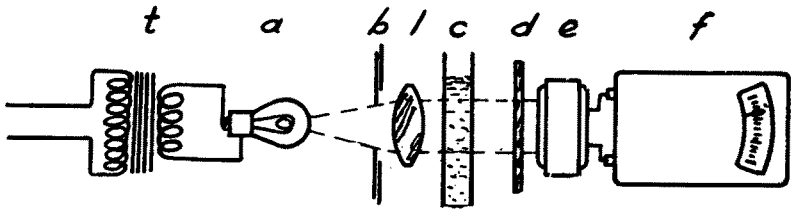

FIGURE FOUR

Eq. 2 reduces to

$$I = Io\ e^{-(c_1 x + c_2 t)y} \qquad (3)$$

where Io is the full scale deflection of the galvanometer when the distilled water or standard solvent is interposed in the light path, and I is the reading of the galvanometer when the sample is placed in the light path. Taking the logarithm of both sides of Eq. 3

$$\log_e I - \log_e Io = \log_e (I/Io = -(c_1 x + c_2 t)y \qquad (4)$$

Solving Eq. 4 for x and introducing a constant c in converting to logarithms of base 10

$$x = -\frac{c}{c_1 y} \log \left(I/Io - \frac{c_2 t}{c_1}\right) \qquad (5)$$

If the turbidity of the solution, t, is negligible, and the absorption cell thickness, y, is constant, Eq. 5 reduces to the simple form of Eq. 1 in which galvanometer readings replace light intensities. That is,

$$x = -K \log (I/Io) \qquad (6)$$

In the experiments here reported red Lovibond numbers replace the values of solution concentration, x, and changes in other hues of the oil are comparable to the turbidity term, t. That a factor corresponding to the turbidity term, t, is present in the oil samples seems clear in view of the fact that straight line relations are not obtained when Photelometer readings are plotted on a logarithmic scale against red Lovibond numbers.

In conclusion, it may be pointed out that these preliminary experiments show that the standard absorption cell has the proper thickness and the general design of the Photelometer is suitable for obtaining a fairly wide spread of readings on oil samples. In one set of experiments it appears that the Photelometer indicated correctly the Lovibond numbers of certain samples of oil. Although the ultimate success of the Photelometer in specifying colors of oil cannot at this time be predicted, the promising results thus far obtained give reason to believe that the principles embodied in the instrument are fundamentally sound and adaptable to color measurement. The fact that different observers can agree on the Photelometer reading for a given oil sample to a fraction of a division, and the simple technique required to operate the device is worthy of note. The writer ventures the opinion that it might be possible to calibrate the Photelometer to specify colors satisfactorily, but in doing so it might be necessary, and, perhaps, desirable to completely eliminate from consideration the Lovibond standards. Whether this procedure would be desirable from the standpoint of the oil industry the writer is not in position to render an opinion.

The writer expresses appreciation for the cooperation and for the assistance of Dr. Richardson and Mr. Andrews of the Procter & Gamble Co., Mr. Irwin of Swift & Co. and members of his committee, and for the privilege of bringing these experiments to your attention.

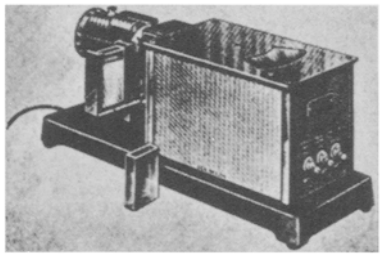

FIGURE FIVE

THE DIETARY VALUE OF FATS

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A Paper Delivered Before the 1934 Fall Meeting, A.O.C.S.

The practical problems of dietetics are not concerned so much with food values as with the preparation and service of food, in a manner to make it acceptable. Nutritive values of foods are the background upon which meals are planned. The intrinsic nutritional value of food receives less attention on the part of the average ultimate consumer than its palatability. In a competitive market with two foods of equal value that one which succeeds in creating interest will be more generally used. It is true that certain individuals need to be concerned with the nutritive value of foods, particularly the housewife or the dietetian who plans meals and the physician who prescribes specific diets. Undoubtedly some individuals do consciously consume certain foods for their specific nutritional value but the number is probably comparatively small.

Fats and oils have a unique place in the dietary because of their ability to impart flavor, especially richness of flavor, to change texture, and to add attractiveness. For example take the shortening value of fats in such baked products as pastries, cakes, crackers and breads. The richness of meat is due largely to the fat that is laid down in and around the muscles. In frying, whether it be pan frying or deep fat frying, fats and oils aid in the browning of foods and impart flavor and improved appearance, for instance the improved flavor of fried mush and french fried potatoes over ordinary mush and boiled potatoes. Fats and oils are added directly to foods to impart richness or smoothness and attractiveness. Examples of this phase of the use of fats are mayonnaise dressing, salad dressings, cream, butter and oleomargarine and in cooking in general. It is apparent, therefore, that fats play a very important role in improving the attractiveness of foods and in assisting to stimulate the consumption of foods that have little flavor or lack richness.

The intrinsic nutritive value of fats and oils is chiefly as a source of energy. Some fats carry sufficient quantities of vitamins to be useful in increasing the vitamin content of the diet. Certain of the fish oils are important as sources of vitamins D and A. Recent evidence indicates that there are essential unsaturated fatty acids which the body is unable to synthesize, and must, therefore, be supplied in the diet. The vitamin content of oils of fish as well as that of butter and body fats depends upon the nature of the diet ingested by the animal from which they are derived. When sold as an avowed source of vitamins A or D the potency of the product should be determined and declared. Vitamin-rich fats and oils are not the only sources of these vitamins, since they may also be obtained from vegetables or indirectly from the sunlight but they constitute a convenient source, especially for medicinal purposes. Any addition to the diet, however, that will contribute to an increase in the vitamin content of the diet is important in attaining the "abundant health," characterized by Sherman.

Experiments on rats using highly purified diets of casein and sucrose with the addition of vitamins and salts have established the fact that certain fatty acids,