The Absorption Spectra of the F.A.C. Color Standards

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INTRODUCTION

COLOR standards for the grading of commercial fats and oils originated in the early 1920's, when in response to a general need, a set of standards was developed in the laboratories of Swift & Company. These standards consisted of solutions of various combinations of organic dyes in a somewhat diluted (80%) water-white glycerine. Shortly after these standards appeared, they were adopted by the Fat Analysis Committee* as the official standards for the color grading of commercial fats and came into general use in the trade in these commodities.

While quite satisfactory, the organic-dye standards exhibited one important fault: they were unstable to light. Special precautions had to be taken to avoid unnecessary exposure to light in their use, and frequent inspection and replacement of standards were found to be essential to insure accuracy. In 1934 Doherty and Ahern reported the development of color standards prepared from inorganic salts dissolved in distilled water. These standards were found to be remarkably light stable, and Doherty and Ahern accordingly proposed that they be used to replace the glycerine-organic-dye standards. After extensive tests the Fat Analysis Committee adopted this suggestion, and early in 1936 began distributing the new inorganic standards. They comprise the standards currently in use.

The set consists of twenty-six solutions sealed in all-glass ampoules. The colors of the individual standards are close approximations of the original organic-dye standards. Standards are numbered with odd numbers only, from 1 to 45; three additional standards are designated 11A, 11B, and 11C. The set is divided into five series:

(1) Very light color fats, No. 1 to No. 9
(2) Yellow fats, No. 11 to No. 11C
(3) Moderately light fats, No. 13 to No. 19
(4) Dark fats (green), No. 21 to No. 29
(5) Dark fats (red), No. 31 to No. 45

While measures have been taken to preserve the accuracy of the standards, there exists no direct record of the actual color of each standard. Undoubtedly one of the best means of recording the color of a solution is its absorption spectrum. The absorption spectrum describes the color in terms of the fraction of light transmitted at each wavelength, and two substances having identical absorption spectra must have identical colors. (The converse is not true.) Consequently, by comparison of the spectral absorption curves of two standards it is possible to state definitely whether those standards possess the same color. It is obvious that the absorption spectrum, once determined, is independent of the physical existence of any particular standard; it is an absolute record of the color of the standard. In view of these facts, the absorption spectra of the F.A.C. color standards have been obtained, and the object of this paper is to report the results found.

EXPERIMENTAL

The absorption spectra were obtained only for the essential visible range (500 to 680 mμ). A polarizing spectrophotometer was employed. The enormous difference in the absorption among the various standards and the need of making the measurements under certain specified conditions, in order properly to operate the spectrophotometer, required the dilution of the standards for many of the readings. One and ten cm. cells were employed in the measurements. All measurements were made at approximately 25° C.

TABLE I.

DENSITY VALUES FOR F.A.C. COLOR STANDARDS FOR 1 CM. LENGTH OF LIQUID

Standard	1	3	5	7	9	11	11A	11B	11C	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45
Wavelength (mμ)	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d
500	0.044	0.068	0.16	0.21	0.29	0.21	0.25	2.6	7.3	0.48	0.70	0.72	1.05	54	75	115	78	95	68	57	120	154	123	92	109	122
510	0.044	0.068	0.17	0.22	0.30	0.20	0.24	1.7	4.8	0.48	0.70	0.74	1.07	42	43	71	46	57	42	36	74	91	74	57	63	75
520	0.042	0.066	0.16	0.21	0.29	0.19	0.22	0.94	2.7	0.46	0.69	0.73	1.07	18	22	36	25	31	22	18	41	50	40	31	36	41
530	0.037	0.061	0.144	0.19	0.26	0.17	0.20	0.46	1.26	0.43	0.63	0.66	0.97	8.0	11	19	14	16	11	9	20	23	19	16	18	21
540	0.029	0.047	0.113	0.145	0.21	0.135	0.16	0.18	0.62	0.35	0.50	0.53	0.76	4.1	4.0	10	7	8	5.0	4.5	9	11	9	8	8	10
550	0.022	0.035	0.081	0.107	0.15	0.098	0.117	0.089	0.22	0.25	0.36	0.38	0.57	1.8	2.8	4.0	3.1	3.4	1.9	2.0	3.7	4.7	4.0	3.6	4.3	5.3
560	0.013	0.023	0.056	0.077	0.106	0.068	0.081	0.046	0.123	0.18	0.26	0.26	0.40	0.97	1.3	2.0	1.56	2.3	0.98	1.13	1.6	1.9	2.3	2.1	2.6	3.1
570	0.009	0.015	0.037	0.050	0.079	0.043	0.052	0.025	0.076	0.14	0.18	0.17	0.29	0.63	0.75	1.10	0.84	1.4	0.52	0.63	0.84	1.2	1.18	1.4	1.7	1.8
580	0.005	0.009	0.024	0.036	0.066	0.027	0.034	0.016	0.050	0.12	0.14	0.13	0.21	0.49	0.60	0.88	0.58	0.95	0.32	0.42	0.48	0.79	0.75	0.98	1.18	1.2
590	0.004	0.006	0.018	0.029	0.058	0.020	0.024	0.020	0.061	0.11	0.13	0.13	0.19	0.46	0.55	0.77	0.52	0.80	0.28	0.33	0.35	0.60	0.60	0.78	0.92	0.91
600	0.004	0.004	0.016	0.029	0.061	0.016	0.019	0.023	0.073	0.11	0.15	0.13	0.20	0.52	0.55	0.75	0.52	0.80	0.33	0.34	0.38	0.57	0.55	0.75	0.80	0.90
610	0.003	0.003	0.016	0.030	0.070	0.014	0.016	0.028	0.090	0.13	0.18	0.15	0.24	0.63	0.60	0.78	0.62	0.85	0.40	0.38	0.44	0.62	0.61	0.78	0.90	1.0
620	0.002	0.003	0.017	0.035	0.080	0.013	0.015	0.034	0.112	0.16	0.22	0.18	0.29	0.78	0.75	0.88	0.73	1.00	0.52	0.46	0.55	0.72	0.72	0.90	1.00	1.1
630	0.002	0.003	0.018	0.039	0.096	0.012	0.012	0.042	0.126	0.20	0.27	0.23	0.36	0.92	0.90	1.07	0.92	1.17	0.63	0.56	0.68	0.86	0.88	1.05	1.18	1.3
640	0.002	0.003	0.021	0.044	0.112	0.011	0.011	0.052	0.16	0.26	0.34	0.29	0.46	1.13	1.15	1.32	1.12	1.38	0.75	0.69	0.86	1.00	1.05	1.23	1.45	1.6
650	0.002	0.003	0.023	0.052	0.132	0.010	0.010	0.064	0.20	0.31	0.42	0.36	0.58	1.35	1.40	1.6	1.38	1.7	0.88	0.84	1.06	1.22	1.27	1.5	1.6	1.9
660	0.002	0.003	0.023	0.060	0.15	0.009	0.009	0.076	0.24	0.38	0.51	0.44	0.70	1.6	1.8	1.9	1.7	2.0	1.05	1.01	1.28	1.46	1.5	1.6	1.9	2.3
670	0.002	0.003	0.029	0.069	0.18	0.008	0.008	0.088	0.28	0.46	0.61	0.52	0.83	1.9	2.1	2.2	2.0	2.4	1.26	1.19	1.5	1.7	1.7	1.9	2.2	2.7
680	0.002	0.003	0.030	0.077	0.20	0.006	0.007	0.100	0.34	0.53	0.72	0.62	0.96	2.2	2.5	2.6	2.2	2.9	1.45	1.40	1.8	2.0	2.0	2.3	2.5	3.1

*Common Committee of The American Oil Chemists' Society and the American Chemical Society.

RESULTS:

The data were obtained in terms of "density" readings. Density, d, may be defined as

$$d = \log \frac{I_0}{I}$$

where I_0 is the initial light intensity and I the intensity after passing through the absorbing liquid. $\frac{I}{I_0}$, the fraction of light transmitted, may be calculated from this quantity.

The data are recorded for each standard in terms of the density reading of a column of liquid one cm. in length for every ten mμ in the range 500 to 680 mμ inclusive. These are shown in Table I. Each figure listed represents the smoothed value of independent observations by two individuals. Such pairs of observations usually agreed within three per cent. In calculating all data to one cm. lengths it was assumed that Beer's law held for these solutions. The validity of this assumption was proved experimentally in several instances.

The data are also shown graphically; in seven of these figures the standards are grouped according to the series described above. In order to plot series 4 and 5 satisfactorily, it was necessary to divide them each into two groups. Fig. 8 shows all the data on one plot, and indicates the relation of the various groups with each other. It is to be noted that the enormous difference in the absorption among the various standards required the plotting of log d instead of d. The value of I/I_0 corresponding to log d is shown on the right side of all the plots. Noting that d is a logarithmic function and that unit change in d results in tenfold change in I/I_0, we see that unit change in log d results in one hundred fold change in I/I_0. With this in mind, it is apparent from the figures that there are enormous differences in the absorption among the various standards.

DISCUSSION

It is observed that there is an increase in the amount of absorption as one goes progressively up the series and that, in addition, the character of the absorption changes. Thus the series 21 to 29 falls in the same range of intensity of absorption as does the series 31 to 45. However, it is of a different character; hence, these standards

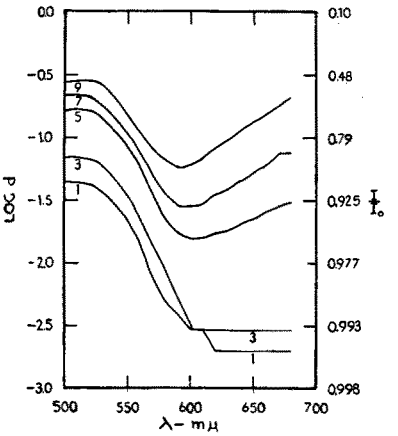

Fig. 1

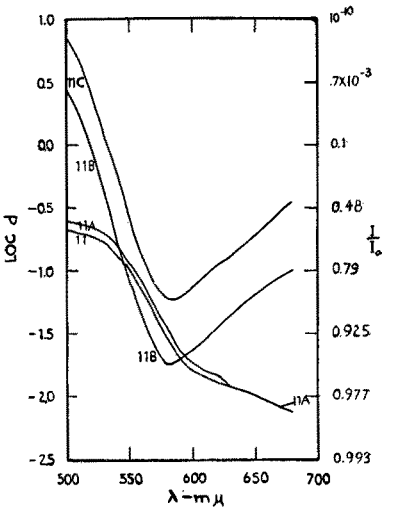

Fig. 2

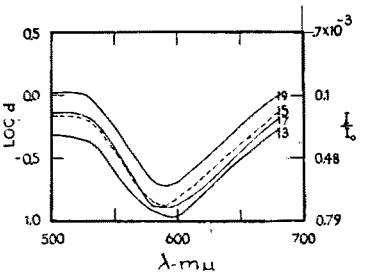

Fig. 3

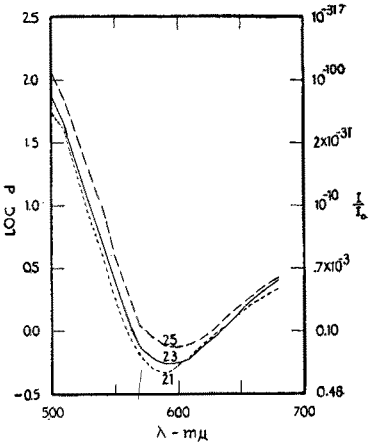

Fig. 4

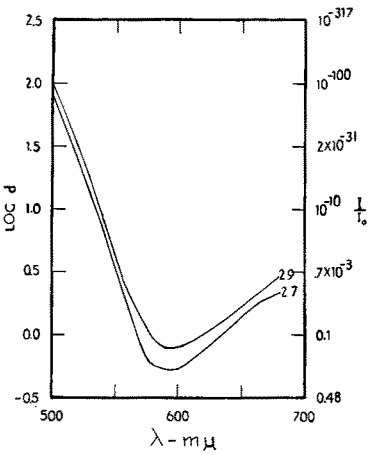

Fig. 5

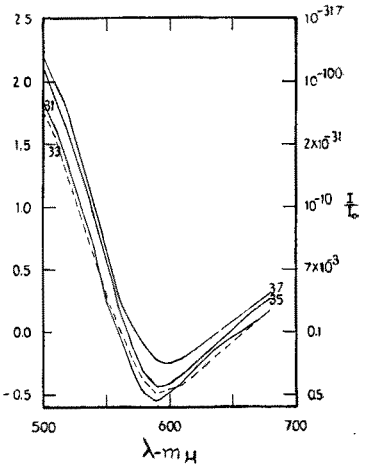

Fig. 6

may be used on fats of about equal darkness, but with different colors. As is known, the series 21 to 29 is to be used on dark fats which have a green cast, while the series 31 to 45 is for dark fats with a reddish-brown hue.

Attention is called to standards 31 and 33. It is noted that the spectrophotometric curve of 33 lies below that of 31. This would indicate a lighter color and, in fact, the formula indicates that less coloring matter is present. However, due to the peculiarities of the human eye, standard 33 actually appears darker than 31.

Those who care to may find other points of interest in these absorption data, and no doubt proper interpretation of them in the light of the theory of color may be of assistance in the more intelligent use of the F.A.C. standards.

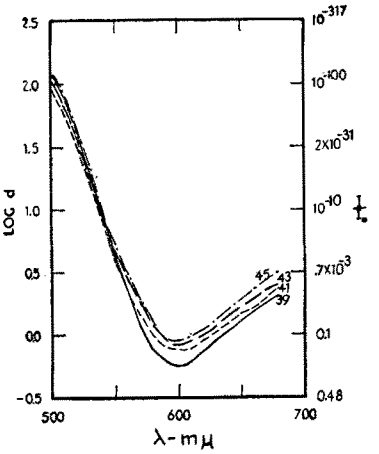

Fig. 7

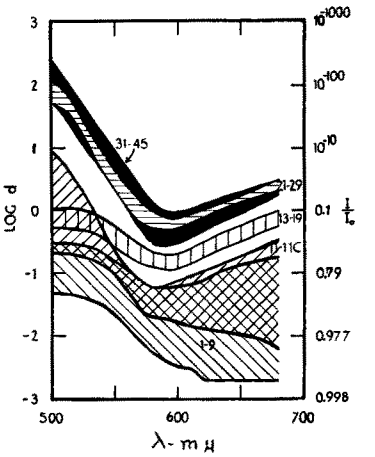

Fig. 8

SUMMARY

The absorption spectra of the Fat Analysis Committee color standards for commercial trade in fats and oils have been determined as a means of recording the color of each standard for future reference.

REFERENCE

Doherty and Ahern; This Journal, **11**, 46 (1934).

Aerial view of plants of Central Sugar Company, Inc., Central Soya Company, Inc., and McMillen Feed Mills, Inc., Decatur, Indiana.

Since this photo was taken, a corn mill has been installed in the McMillen Feed Mills, Inc. plant, additions have been made to the expeller plant of Central Soya to house 8 more expellers, 4 of which have been installed, and this summer 1,000 bu. more storage for soybeans, requiring 20 more storage bins, like those seen at the left, will be added, besides complete change of trackage layout and the addition of a large ingredients warehouse. Total acreage of floor space at present time in these plants is about 8-12.