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Factors Influencing Vegetable Oil Bleaching by Adsorption

LAWRENCE E. STOUT, DONALD F. CHAMBERLAIN, and JAMES M. McKELVEY,
Washington University, St. Louis, Mo.

ABSTRACT

Vegetable oil bleaching by adsorption involves the removal of color particles which are either dissolved or colloidally dispersed in the oil. This type of adsorption follows an exponential relationship and the Freundlich equation was utilized in correlating the data. In utilizing this equation, the color of the oil was assumed proportional to the concentration of the color particles, and a color measurement system based on the Beer-Lambert Law was devised. This system involves a measurement of the transmittance of light of 475 millimicrons wave length through the oil. A Coleman, Model 11, Spectrophotometer was used for the transmittance measurements. Spectral transmittance curves for cottonseed and soybean oil, bleached and unbleached, are given.

The effect of the variables of temperature, time of contact, and particle size on the activity of several adsorbents was determined. It was found that the activity of each adsorbent is at a maximum at some particular temperature. The adsorbents were grouped into three general classes: acid-activated clays, natural earths, and materials high in silica content, and it was found that adsorbents in the same class have a temperature of maximum activity within the same range.

The effectiveness of 16 different adsorbents in bleaching a refined cottonseed oil was determined by utilizing the Freundlich equation and plotting adsorption isotherms for each adsorbent. Similar data are given for 10 different adsorbents in bleaching a refined soybean oil. On the basis of adsorbent activity, acid-activated clays were 1½ to 2 times as effective as natural earths.

THIS paper is the second in a series of studies made by the Chemical Engineering Department of Washington University on the application of adsorbents to industrial processes. The first paper (10) showed the applicability of reclaiming dry cleaning solvents by adsorption. Although adsorption is practically the only method used for bleaching oils which are to be used in edible products, there has been little work reported in the literature on the determination of optimum operating conditions for specific adsorbents and the relative activities of various adsorbent materials. It is recognized that adsorbent activity is only one of several factors that affect the choice of an adsorbent to a specific bleach operation. Other factors involved are cost, oil retention value, filtration characteristics, taste imparted to the oil, and effect of the adsorbent on the free fatty acid concentration in the oil. However, with most of the commercial materials studied in this report, the last three factors were of little consequence: all materials studied had approximately the same filtration characteristics; all oils were deodorized after bleaching, and very low free fatty acid concentrations were not demanded for the product under consideration.

While it is known that the free fatty acid content of an oil will vary with the nature of the adsorbent clay used in its treatment and that a large part of the free fatty acid will be lost during the deodorization, it was felt that economically this factor was small compared to the others listed and hence could be safely ignored. The selection of an adsorbent then resolved itself into an economic balance of: cost of adsorbent, adsorbent activity, and oil retention value (1). Knowing these three factors, nomographs (5) are available for evaluating a series of adsorbents.

Actually adsorbent activity should be determined by tests made on plant size equipment. With the number of adsorbents now available this was considered impractical. It was believed that at least an indication of the relative activities of a number of adsorbents can be obtained from laboratory data. However, the authors would like to state here, that as this work was carried out in small scale laboratory apparatus, the results cannot be properly extrapolated to plant size equipment directly without further work in large scale equipment under plant operating conditions. It should be further emphasized that the ultimate selection of an adsorbent rests on economic balance of three main factors, one of which, oil retention value, was not considered in this work. The object of this work was to determine the effect of the variables of time of contact, temperature, and particle size on adsorbent activity and to evaluate a series of adsorbents as to their activity in bleaching a typical refined soybean and a cottonseed oil. Obviously laboratory data on oil retention values would correlate poorly with actual plant data, and no attempt was made in this work to determine oil retention values.

At the present time much of the bleaching is carried out by contact filtration, using acid activated clays or fuller's earth. In contact filtration (6) the adsorbent is mixed with the oil to be treated, agitated, and the adsorbent removed from the oil by filtration. The temperature is usually held slightly above 100°C. to remove any water that may be in the oil. Much of the fuller's earth comes from Georgia and Florida deposits. Some fuller's earth is processed by high pressure extrusion to increase its activity. Bentonite is activated by an acid treatment to produce an "acid-activated clay."

Davis and Messer (2) showed that the chemical composition of an adsorbent bears no apparent relation to its activity. It is possible for clays, quite similar in composition, to vary greatly in adsorbent properties. For this reason any evaluation of the activity of an adsorbent must be made by tests on the actual material that is to be decolorized.

Hassler and Hagberg (4) showed that the bleaching of vegetable oils by adsorption follows the Freundlich exponential equation. This equation can be written as follows:

Where $x/m = K c^n$
x = amount of substance adsorbed
m = amount of adsorbent
c = amount of residual substance after adsorption
K and n are constants.

It is apparent that a plot of x/m against c on a log-log scale paper will produce a straight line with a slope equal to n. With the temperature held constant, this line is called an adsorption isotherm. x/m, the amount of material adsorbed per unit weight of adsorbent, at a specific equilibrium concentration of the adsorbate, is a measure of the adsorbent activity. When the activities of a series of different adsorbents are to be evaluated, the x/m value of each adsorbent, at any desired bleach color, can be obtained from plots of adsorption isotherms. Thus the Freundlich equation offers a practical method of determining the relative activities of a series of adsorbents at any desired bleach color.

Since it is not practical to measure directly the concentrations and weights of the adsorbed substances, an indirect method can be used. Rogers, Grimm, and Lemmon (9) used the Freundlich equation in plotting data for the decolorization of mineral oils (using an Ives Tint Photometer for color measurement). Hassler and Hagberg (4), in plotting isotherms for the bleaching of vegetable oils, used a Lovibond colorimeter and plotted red Lovibond color units in place of concentrations. It is assumed that the color of the oil is directly proportional to the concentration of the impurities, so plotting of color units in place of concentrations offers a practical method of expressing the data for the adsorption of impurities from vegetable oils.

Experimental

The experimental work discussed in this paper can be divided into three general parts. First, it was necessary to develop a suitable method of measuring color of the oils. Part 2 considers the effect of temperature, time of contact, and particle size on the activity of the adsorbents. Part 3 consists of evaluating the adsorbents as to their decolorizing power.

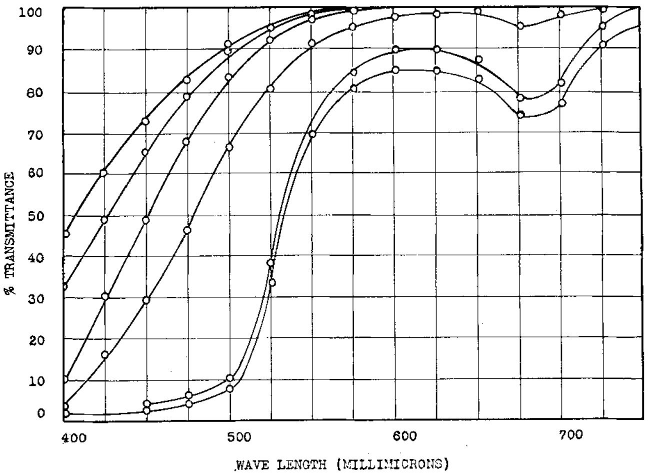

FIG. 1. Spectral transmittance curves for soy bean oil after different bleach treatments.

Two types of vegetable oils were used in the experimental work: refined cottonseed oil and refined soybean oil. Since each batch of a refined vegetable oil is slightly different in composition, a sufficient quantity of each of these oils was obtained from a single batch so that the results of the tests of the different adsorbents could be compared.

PART 1

The color measurement system used in this work is based upon the Beer-Lambert Law (3). Transmittance readings were made with a Coleman, Model 11, Universal Spectrophotometer. This instrument makes it possible to measure intensity of a beam of monochromatic light transmitted through the oil sample, by means of a photoelectric cell and galvanometer. Light of any wave length, from 300 to 800 millimicrons, can be obtained. Light intensity is not measured in absolute units but as a ratio of the intensity of light transmitted by the oil to the intensity of light transmitted by some reference material. This ratio is termed transmittance. The galvanometer scale is divided into 100 equal parts, and the intensity of the light transmitted through the reference material is always made equal to 100 by adjusting the resistance in the photoelectric cell circuit. Then the galvanometer reading, with the oil sample in position, will give the transmittance directly on the galvanometer scale. The reference material used was distilled water.

To utilize this instrument as a colorimeter for oils it was first necessary to determine the most suitable wave length to use. This was done by taking six different samples of soybean oil and determining the transmittance of each (between wave lengths of 400 and 750 millimicrons, in intervals of 25 millimicrons). The data are plotted in Figs. 1 and 2. The resulting curves are known as spectral transmittance curves. The wave length at which the difference in transmittance between the darkest oil and the lightest oil is greatest is the most suitable for use. For both soybean oil and cottonseed oil this wave length is 475 millimicrons.

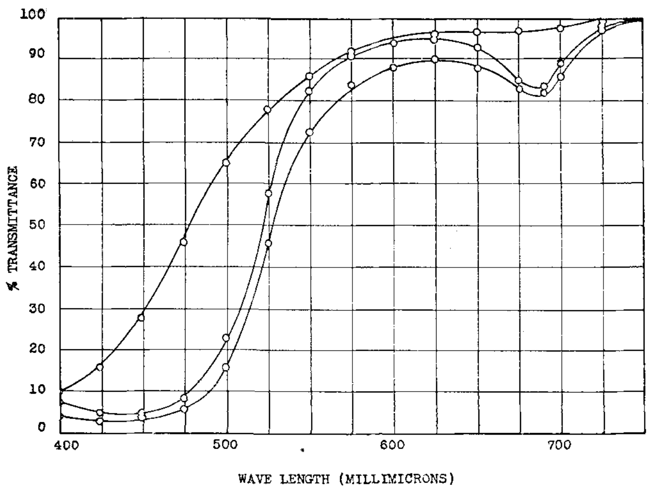

FIG. 2. Spectral transmittance curves for cottonseed oil after different bleach treatments.

An equation relating oil color to transmittance was derived in the following manner: from the Beer-Lambert Law (3),

$$\ln I/I_0 = -K\,l\,c$$

where

I = intensity of light transmitted through the absorbing medium

I_0 = intensity of light before passing through the absorbing medium

K = constant

l = thickness of the absorbing medium

c = concentration of the absorbing medium

Since the ratio of I/I_0 is equal to the transmitance, and the thickness of the cell is constant, equation (1) can be written,

$$\ln T = -K'c \tag{2}$$

Assuming that the color of the oil is directly proportional to the concentration of the light absorbing substances in it,

$$\ln T = -K''N \tag{3}$$

where N = oil color

Equation (3) can also be written,

$$N = K''' \ln 1/T \tag{4}$$

It is desirable that N values correspond as closely as possible to the red Lovibond units commonly used by vegetable oil refiners. Therefore values of K‴ must be selected that will give a calculated value for N (equation 4) which is in reasonable agreement with red Lovibond reading. To determine this constant 12 samples of refined cottonseed oil were given different bleach treatments and the color of the resulting product read on both instruments. Trial and error shows that a K‴ value of 5 gives results which have a fair correlation with the Lovibond red scale. These relative values are shown in columns 2 and 4 in Table I.

TABLE I

Comparison of Lovibond Red Colors With N Color Units (K‴ = 5)

Oil Sample	Lovibond Red Color	Transmittance	Color (N units)
1	1.4	.840	.9
2	1.4	.815	1.0
3	1.9	.785	1.2
4	1.9	.780	1.3
5	2.0	.750	1.4
6	2.3	.720	1.6
7	2.0	.710	1.7
8	2.2	.700	1.8
9	3.1	.655	2.4
10	3.0	.600	2.7
11	6.0	.310	5.9
12	10.0	.035	16.7

PART 2

The following test was made to show the effect of time of contact on adsorbent activity: 200 grams of the cottonseed oil were heated to 70°C. on a hot plate and 8 grams of Special Filtrol added to it with stirring. After a measured interval of time the oil was filtered and its color determined. Five sets of data were obtained at time intervals of 1, 2, 5, 10, and 40 minutes. These data are plotted in Figure 3. An inspection of Figure 3 reveals that little change occurs after approximately 15 minutes, and subsequent runs (Part 3) to determine relative adsorbent activities were all made for this period. Inasmuch as the plant processes, for which these laboratory controls were being set up, were batch processes, which provide long periods of exposure, it was decided that time was not a critical factor, and therefore similar tests of other adsorbents were not made.

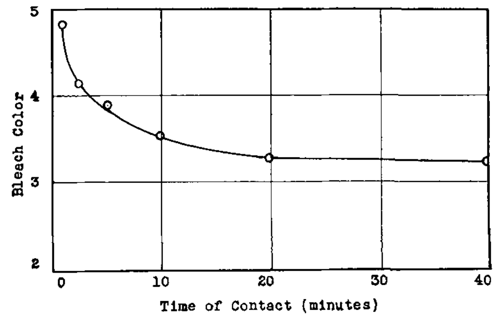

FIG. 3. Effect of time of contact on bleach color.

One criticism which might be offered concerns the sequence of operation of the above tests. Odeen and Slosson (7) and later Robertson, Munsberg, and Gudheim (8) published data showing that clays are more effective in color removal if added to the oil before heating. This recommended sequence was actually followed in the Part 3 tests, but in the time series it was felt that it would be more accurate to measure the time at a constant temperature rather than to include a variable heating-up period.

To determine the effect of particle size on adsorbent activity the following test was made: Five samples of "Tamms Silica" were obtained. The samples were composed of the same material and differed only in that they were ground to different particle sizes. In making the test, 200 grams of refined cottonseed oil were heated to 70°C. and 8 grams of the adsorbent added. The oil was then filtered and its color determined. The per cent of total color removed was calculated. The results of this test are shown in Table II.

TABLE II

Effect of Particle Size on Activity

Mesh Analysis of Clay	Bleach Color	% Total Color Removed
4-10	12.9	16.8
10-30	12.4	20.0
30-60	11.3	27.1
100	5.4	65.2
200	4.5	71.0

To determine the effect of temperature upon decolorizing power of adsorbents the following procedure was used: 100 grams of the refined oil and 2% by weight of the particular adsorbent being tested were heated with agitation on a hot plate to the desired temperature, the oil filtered, and the bleach color determined. This was done for each of the adsorbents on both cottonseed and soybean oil, and the resulting temperature-bleach color curves are shown in Figures 4 and 5.

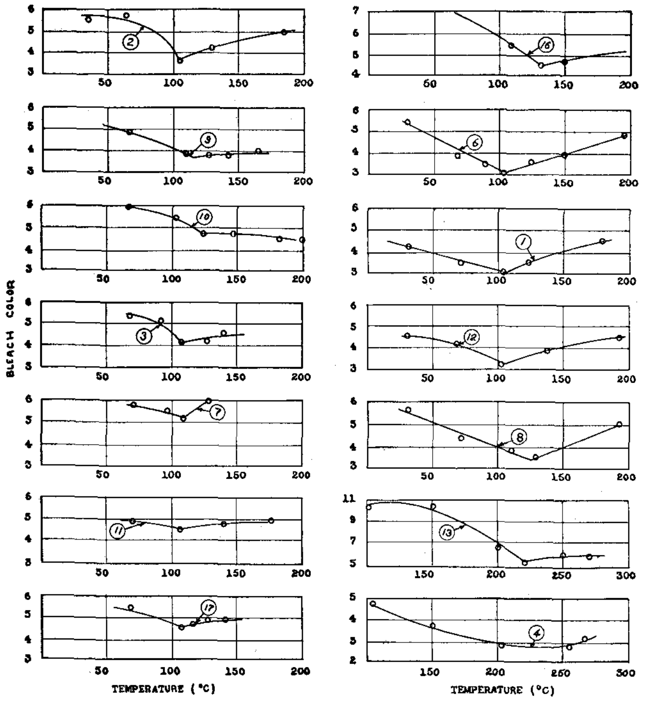

FIG. 4. Effect of temperature on bleach color of cottonseed oil for different adsorbents. (Numbers on curves refer to Tables III and IV.)

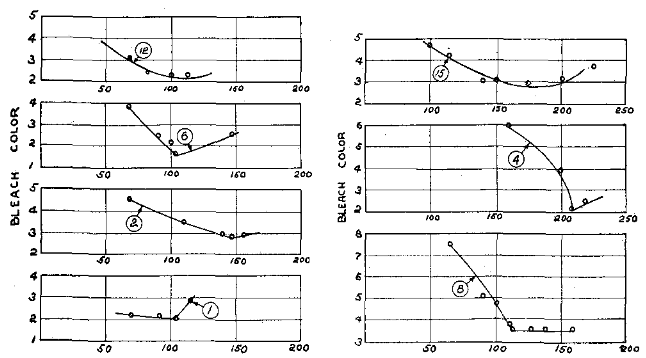

FIG. 5. Effect of temperature on bleach color of soy bean oil for different adsorbents. (Numbers on curves refer to Tables III and IV.)

PART 3

The procedure used in determining the relative activities of the adsorbents was to plot isotherms for each adsorbent on the same oil and then compare the x/m value at the same bleach color. The procedure used in determining the isotherms is as follows: 200 grams of the oil were weighed into each of four beakers and varying amounts of the adsorbent were weighed into the beakers with the oil. The beakers were then placed on a hot plate and heated to the desired temperature with agitation. The oil was then filtered and the color of the bleached oil determined. From these data the value of x/m for each run was calculated and on a log-log scale paper, x/m was plotted against c. The relative activities of the adsorbents on cottonseed oil were calculated at a bleach color of 3. A bleach color of 2 was selected for soybean oil. These values were selected to conform with plant demands. Figures 6 and 7 show adsorption isotherms for cottonseed oil. In these first runs the temperature was 70°C. for all adsorbents. Figures 8, 9, and 10 show adsorption isotherms for cottonseed and soybean oil in which the adsorbents were all tested at the temperature that was indicated by the temperature-bleach color curves as being the temperature of maximum activity for the particular adsorbent. The adsorbent activity data are summarized in Tables III and IV.

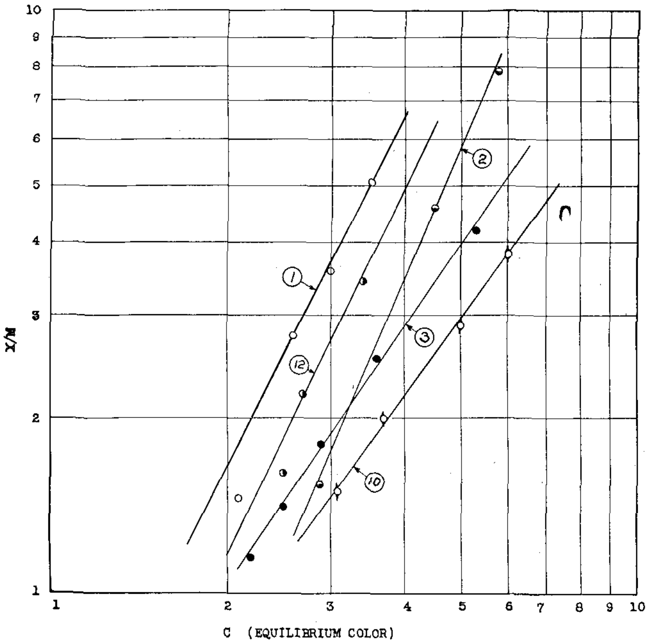

FIG. 6. Adsorption isotherms.
Refined cottonseed oil—70°C.
(Numbers on curves refer to Table III.)

Discussion

Figures 1 and 2 show spectral transmittance curves for soybean and cottonseed oil. The transmittance is lowest at the blue-violet end of the spectrum and is high at the yellow-red end of the spectrum. However, as more color was removed, the blue violet transmittance increased greatly while the yellow-red transmittance, already being high, did not show as great an increase. This indicates that the main impurities present absorb light mainly in the blue-

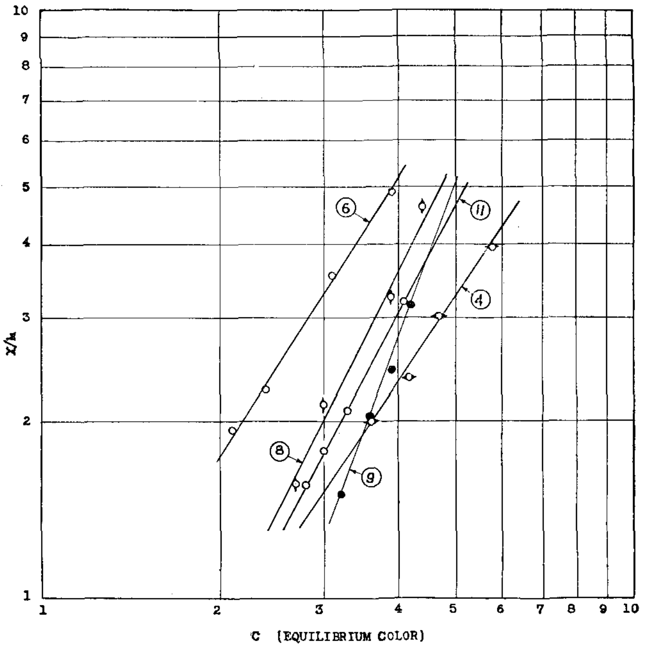

FIG. 7. Adsorption isotherms.
Refined cottonseed oil—70°C.
(Numbers on curves refer to Table III.)

violet range. Since the wave length selected for the transmittance readings (475 millimicrons) is a blue-violet colored light, the N color units should be roughly a measure of the total impurities present. Thus using this wave length, the course of the adsorption or color particle removal can be followed fairly well as the same oil was used for all tests, and the adsorption isotherms are straight lines.

From Figure 3 it can be seen that the rate of removal of the color particles is very rapid during the first few minutes that the adsorbent is in contact with the oil, and then decreased to a point where equilibrium is reached and no more color is removed. This equilibrium time for Special Filtrol on cottonseed oil is approximately 15 minutes at 70°C. The purpose of making this test was to determine a minimum time of contact necessary for the other test data that was obtained. Actually this figure means nothing as far as plant operation is concerned as the quantities involved in plant operation mean a contact time running into hours. In fact, it is possible that these longer contact times may cause partial oxidation and subsequent darkening of the oil.

Table II shows the effect of particle size of the adsorbent on the per cent of total color removed. The data show that as the particle size decreases and consequently the surface area becomes larger, the per cent of total color removed increases. Although the effect of particle size was determined for only one adsorbent, it is to be expected that for any adsorbent the adsorptive power will increase with the increase in surface area as all adsorption theory considers adsorption as a surface phenomenon. Consequently in the contact filtration process the adsorbent used will be as small a particle size as can be handled by the filter presses. For this reason only one adsorbent was tested as to the effect of particle size.

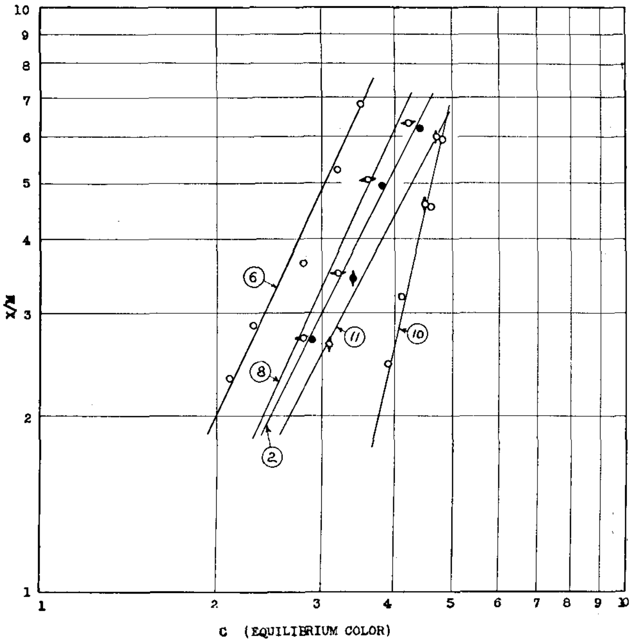

FIG. 8. Adsorption isotherms.
Refined cottonseed oil.
Adsorbents tested at temperatures of maximum activity.
(Numbers on curves refer to Table III.)

TABLE III
Summary of Adsorbent Activity Data
(Tests Made on Refined Cottonseed Oil)

No.	Type of Material	Manufacturer and Trade Name	T_a (°C.)	$\left(\frac{x}{m}\right)_{c=3}^{T=70°}$	T=70°C.		$\left(\frac{x}{m}\right)_{c=3}^{T=T_a}$	$T=T_a$	
					K	N		K	N
1	Acid activated clay	Industrial Minerals and Chemical Co. (M-Special No. 4)	105	3.73	.42	2.00	4.20	.15	3.03
2	Acid activated clay	Bennette-Clark Co. (Activite	105	1.80	.14	2.34	3.05	.34	1.99
3	Acid activated clay	Bennette-Clark Co. (Chloro-flo)	106	1.88	.38	1.45	2.85	.53	1.53
4	Magnesium silicate	Westvaco Chlorine Products Co. (Magnesol)	250	1.80	.36	1.48	8.15	.10	4.00
5	Activated magnesia	Westvaco Chlorine Products Co.	......	......*	......*	......*	......*	......*	......*
6	Acid activated clay	Filtrol Corp. (Special Filtrol)	100	3.24	.59	1.55	4.80	.45	2.16
7	Activated carbon	Darco Corporation	106	......*	......*	......*	......*	......*	......*
8	Fuller's earth	Floridin Co. (Florex XXX)	132	1.97	.22	1.99	3.31	.29	2.21
9	Natural clay	Attapulgus Clay Co.	118	1.25	.063	2.72	2.35	.052	3.46
10	Natural material high in silica	Tamms Silica Co.	180	1.42	.31	1.38	.89	.0064	4.50
11	Natural clay	General Reduction Co.	105	1.80	.20	2.00	2.64	.32	1.91
12	Acid activated clay	L. A. Salomon Co. (Kleenflo M-4)	103	2.66	.27	2.00	3.58	.13	3.00
13	Silica gel	Fisher Scientific Co.	212	......*	......*	......*	......*	......*	......*
14	Activated alumina	Aluminum Ore Co. (8120 F-1)	......	......*	......*	......*	......*	......*	......*
1[illegible]	Natural clay	Bennette-Clark Co. (B-C Clay)	180	......*	......*	......*	......*	......*	......*
17	Acid activated clay	Industrial Minerals and Chemical Co. (No. 260)	100	......*	......*	......*	......*	......*	......*

* Poor results.

TABLE IV
Summary of Adsorbent Activity Data
(Tests Made on Refined Soy Bean Oil)

No.	Type of material	Manufacturer and Trade Name	T_a (°C.)	$\left(\frac{x}{m}\right)$ $T=T_a$ $c=2$	$T=T_a$ K	$T=T_a$ N
6	Acid activated clay	Filtrol Corp. (Special Filtrol)	105	8.70	3.12	1.48
1	Acid activated clay	Industrial Minerals and Chemical Co. (M.-Special No. 4)	105	5.75	1.51	1.93
8	Fuller's earth	Floridin Co. (Florex XXX)	130	2.31	1.00	1.21
2	Acid activated clay	Bennette-Clark Co. (Activite)	146	3.56	2.22	.68
4	Magnesium	Westvaco Chlorine Products Co.	210	4.10	1.26	1.70
	Silicate	(Magnesol)	100	5.12	2.60	.98
12	Acid activated clay	L. A. Salomon Co. (Kleenflo M-4)	......*	......*	......*	......*
14	Activated alumina	Aluminum Ore Co. (8120 F-1)	......*	......*	......*	......*
5	Activated magnesia					
15	(2:1 mixture of No. 6 and No. 4	Westvaco Chlorine Products Co.	185	5.40	1.70	1.00

* Poor results.

Figure 4 shows temperature-bleach color curves for the various adsorbents on cottonseed oil. Since the same amount of adsorbent was used for each run, the temperature at which the low point in the curve occurs is the temperature at which the adsorbent activity is at a maximum. If the adsorbents are classified in three groups: natural earths, acid activated clays, and compounds containing a high proportion of silica, it can be seen that the natural earths are at a maximum activity in the range of 118 to 132°C., that the silica compounds are at a maximum activity in the range of 180 to 250°C., and the acid-activated clays are at a maximum activity in the range of 100 to 106°C. Figure 5 shows that the same generalization can be made for the adsorbents acting on soybean oil. The fact that the adsorbents containing a high proportion of silica must be heated to a temperature near 200°C. limits their use as a vegetable oil bleaching agent as high temperatures cause more rapid oxidation of the oils.

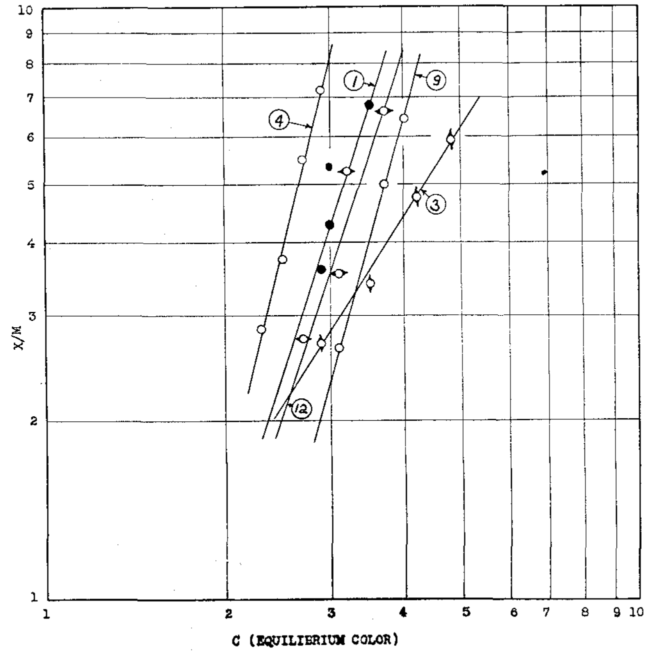

FIG. 9. Adsorption isotherms.
Refined cottonseed oil.
Adsorbents tested at temperatures of maximum activity.
(Numbers on curves refer to Table III.)

Although the adsorption isotherms are straight, they are not parallel. Therefore it is entirely possible for one adsorbent to be more efficient than another in bleaching an oil to one specific color and also be less efficient in bleaching the same oil to another color. For this reason adsorption isotherms offer the only correct method of evaluating adsorbents.

Table III is a summary of the adsorbent activity data for the adsorbents acting on cottonseed oil, x/m being a measure of the adsorbent activity. The values of x/m were determined at a bleach color of 3. In the first case the temperature was 70°C., and in the second case the temperature at which the activity of the adsrobent is at a maximum was used. These two sets of data change in activity as the temperature changes and illustrate the importance of using an adsorbent at the proper temperature.

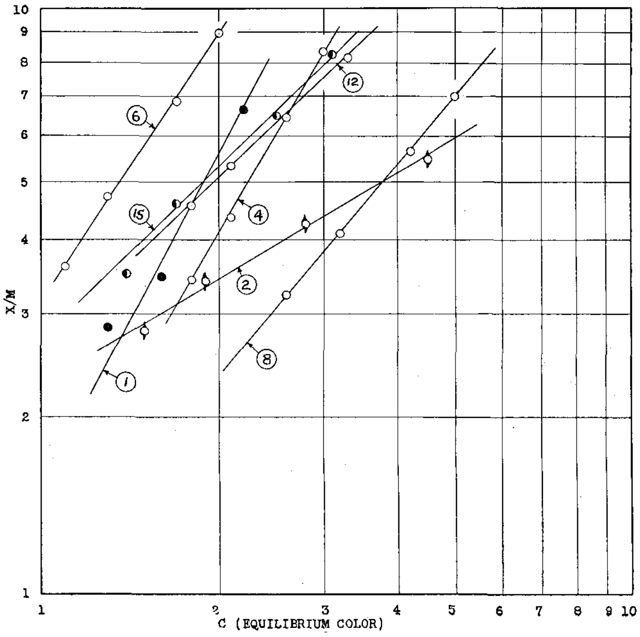

FIG. 10. Adsorption isotherms.
Refined soy bean oil.
Adsorbents tested at temperatures of maximum activity.
(Numbers on curves refer to Table III.)

Table IV is a summary of the adsorbent activity data for the adsorbents acting on soybean oil. These runs were all made at the temperatures at which the activity of the adsorbent is at a maximum.

Conclusions

1. On the basis of adsorbent activity the acid activated clays are generally 1½ to 2 times more effective as bleaching agents than the natural earths.
2. The activity of an adsorbent in bleaching a vegetable oil is at a maximum at some particular temperature.
3. The acid-activated clays that were tested had a temperature of maximum activity in the range of 100 to 106°C.
4. The natural earths that were tested had a temperature of maximum activity in the range of 118 to 132°C.
5. The three materials tested that were high in silica content had a temperature of maximum activity in the range of 180 to 250°C., which is high for effective use in the edible oil industry.

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The Study of 20 Varieties of Soybeans With Respect to Quantity and Quality of Oil, Isolated Protein, and Nutritional Value of the Meal

O. H. ALDERKS, Soybean Research Council, Technical Division, The Buckeye Cotton Oil Company,*
M. A. & R. Building, Ivorydale 17, Ohio

Summary

TWENTY samples of soybeans, representing the most promising strains now being grown at several stations were selected and prepared by J. L. Cartter and colleagues of the U. S. Regional Soybean Laboratory. Ten samples represented strains grown in the north central states and ten in the southern states. They were composited samples of the uniform soybean variety tests and therefore location and soil differences cancelled out, giving a good comparison of germ plasm.

Studies of these soybeans included the following:

1. Yield and quality of the oil with respect to flavor reversion.
2. Yield and quality of isolated protein for industrial usage.
3. Quantity and quality of protein for nutritional purposes as indicated by: a) Amino acid composition of solvent extracted raw and toasted flakes; b) availability of amino acids based on in-vitro enzyme digestion tests.

The following is a summary of the results:

1. Samples analyzed for oil varied from 17.41% to 22.9% dry basis, equivalent to a difference of 98.8 lb. per ton of 10% moisture beans. Roanoke contained the highest per cent.
2. Samples analyzed for protein varied from 39% to 44%, dry basis, equivalent to a difference of 91.8 lb. per ton of 10% moisture beans.
3. Three strains grown at Lafayette, Ind., Ames, Ia., Urbana, Ill., and Columbus, O., varied as much as 1.79% oil and 3.1% protein, dry basis.
4. The fatty acid composition varied considerably. The triple unsaturated acids varied as follows:
   Per cent linolenic acid from 6.16% to 8.45%
   Per cent arachidonic acid from .01% to .09%.
   If these are important in the development of "flavor reversion," one would expect no differences in the oils in this respect.
5. The quality and flavor stability of each solvent extracted oil from the 20 strains was top No. 1 grade. The oils were equal in flavor stability to the best quality commercial oils. All oils showed "flavor reversion" after aging in open new tin cans at 140°F. for several days.
6. The average yield of all 20 strains of alkali extracted, purified, isolated protein was 36.1% (DB). The yields varied widely from 33.1% to 42.7% (DB). Roanoke and Arksoy 2913 gave the highest yields of industrial protein.
7. No significant differences were found between the amounts of any one of the "essential" amino acids contained in the 20 soybean strains. There is no indication in this work that a strain might be selected and grown for the production of soybean meal with a superior protein. The "toasted" flakes contained less lysine than the hexane extracted, desolventized, raw flakes (average drop from 6.60% to 6.28%). There was no effect on the other "essential" amino acids.
8. In-vitro enzyme digestion followed by microbiological assay was applied to methionine, lysine, and tryptophane. When the results are considered in the light of the accuracy of these new methods, it appears certain that there are no significant differences between the varieties in available tryptophane, but there is some possibility of significant differences in the availability of methionine and lysine.

This work was planned with J. L. Cartter of the U. S. Regional Soybean Laboratory and R. T. Milner of the Northern Regional Laboratory to determine whether the genetic composition of various soybean strains differed in regard to their ability to produce oil of good quality and whether the oils from these various strains might differ in flavor stability for any reason. Also we desired to determine if by agronomic selection and development of soybean varieties it would be possible to reduce the linolenic acid content in soybean oil.

Some investigators working on the soybean oil flavor reversion problem have attributed flavor reversion to result from oxidation products of the more unsaturated portion of the oil. It has been suggested also that various minor constituents in the oil possibly affected flavor stability by acting as catalysts to promote a certain type of oxidation. Cottonseed, peanut, sesame, and sunflower seed oils contain no linolenic or triple unsaturated fatty acids, and flavor reversion of the soybean oil type is not encountered with these oils. If linolenic acid could be eliminated

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