the meal from old kernels will not plasticize when subjected to heat and pressure. When these kernels were mixed with new kernels no difficulty was experienced in expressing the tung oil from the meal.

6. Tests indicated that hulling the moist tung fruit in the grove does not interfere with the expression of the oil if the moist dehulled tung fruits are properly dried before pressing.

7. A process was developed for producing a clear tung oil by treating the crude oil with a chemical agent to precipitate certain non-oil constituents in the crude tung oil followed by either pressure filtration or centrifugation.

8. When tung oil filter cake was mixed with an equal amount of tung press cake, over 98 percent of the oil could be solvent-extracted by petroleum solvents.

Predicting the Flavor Stability of Soybean Oil

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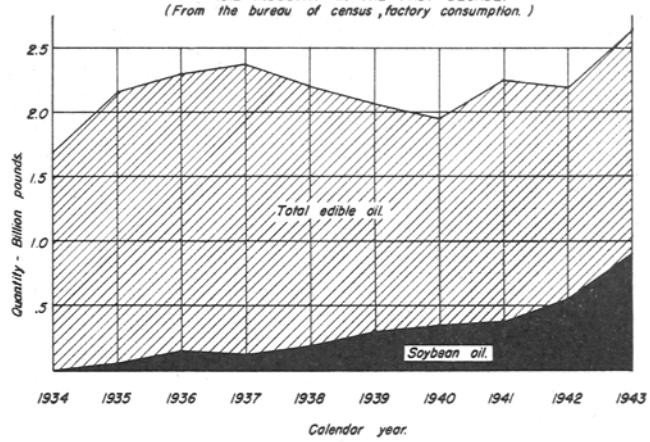
FOR upwards of 5,000 years the flavor of soybean oil has been of interest to man (1). The crude oil has been and is today one of the principal foods to the poorer classes of China. It was not until 1910 (2), however, that industry in the U. S. became actively interested in the soybean as a source of oil. The soap and paint manufacturers consumed most of the oil produced. By 1918, however, due to a wartime shortage of edible fats, soybean oil usage in margarine and shortenings had reached a total of 62½ million pounds annually—about 5% of the total U. S. production of these products. The poorer flavor of these earlier soybean oil products did not encourage development of a domestic soybean crop as a source of edible oil. In the early 1930's, due to a number of factors, the domestic soybean crop expanded rapidly; and once again the oil became of increasing importance to the edible oil industry, until today it has become a major raw material. Perhaps it will be of interest to you to trace the usage of the oil in the food industry over the past decade. In 1934 the amount of soybean oil used as edible oil was about 3 million pounds, or 0.2% of the total edible oil produced in the United States. In 1939, at the start of World War II, the quantity had reached 300 million pounds, equivalent to 15% of the total. By 1943 it had reached 891 million pounds, or one-third of the total. While wartime needs may have raised the proportion of soybean oil to a higher level than peacetime conditions will support, there is no doubt that soybean oil will remain an important raw material to the edible oil industry.

As in the case of any vegetable oil, and perhaps to a greater extent in the case of soybean oil, the flavor quality of the derived food products is affected by the history of the bean both on the farm and in the oil mill. It is important to the refiner and to the processor alike that the segregation into quality classes be made as early in the history of the oil as possible. The purpose of this paper is to suggest a basis on which such segregation can be made.

Experimental

OIL samples were obtained from tank car receipts of crude soybean oil by the official A.O.C.S. sampling procedure. Good coverage of the bean producing areas was obtained by testing tank car receipts from all sections and from all suppliers. The sampling period covered most of the crushing season.

FIGURE-1
THE INCREASED USAGE OF SOYBEAN OIL IN THE EDIBLE OIL INDUSTRY IN THE PAST DECADE.
(From the bureau of census, factory consumption.)



For a study of the effect of frost damaged and field damaged beans on oil quality, beans were obtained directly from the producing areas, and processed in our pilot plant equipment.

Crude oils thus obtained were processed to finished edible products in the laboratory, under conditions simulating commercial operations. The flavor characteristics of the finished oils were correlated with the more commonly used physical characteristics of the crude and refined oils.

No attempt was made to determine by chemical analysis any variation in the usual minor constituents of the glyceride oil. Markley and Goss in their recent book have covered thoroughly the chemical composition of the oil (3).

More should be said about the laboratory method of processing these crude oils into edible fats. The overall procedure is defined among ourselves as the "edibility test".

Figure 2 shows the unit in which gallon quantities of the crude oils are alkali refined. Four samples can be carried as a group through the refining operation. After refining, the oils are settled overnight, decanted from the soap stock, and clarified by filtration.

Figure 3 shows the bleaching unit in which the refined and filtered oil (designated hereafter as RF oil) is treated with commercial bleaching earth. A portion of this bleached oil (designated hereafter as RB oil), is deodorized, and a second portion hydrogenated to an iodine value of 75—about the range for shortening or margarine oil.

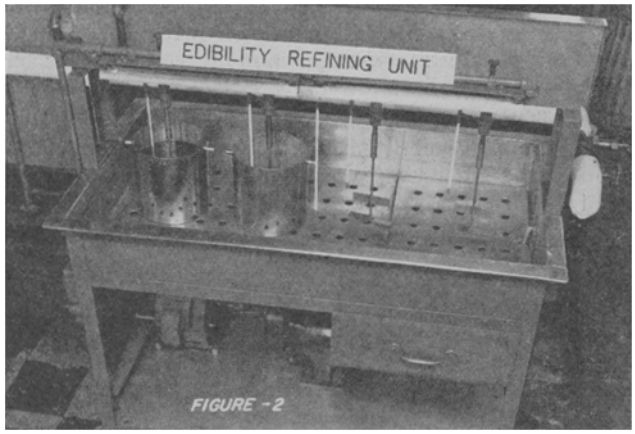


Figure 4 shows the two-place hydrogenation unit. A sample of 3 to 7 lb. size can be handled in each vessel.

After removal of the hydrogenation catalyst, the hydrogenated oil is ready for deodorization.

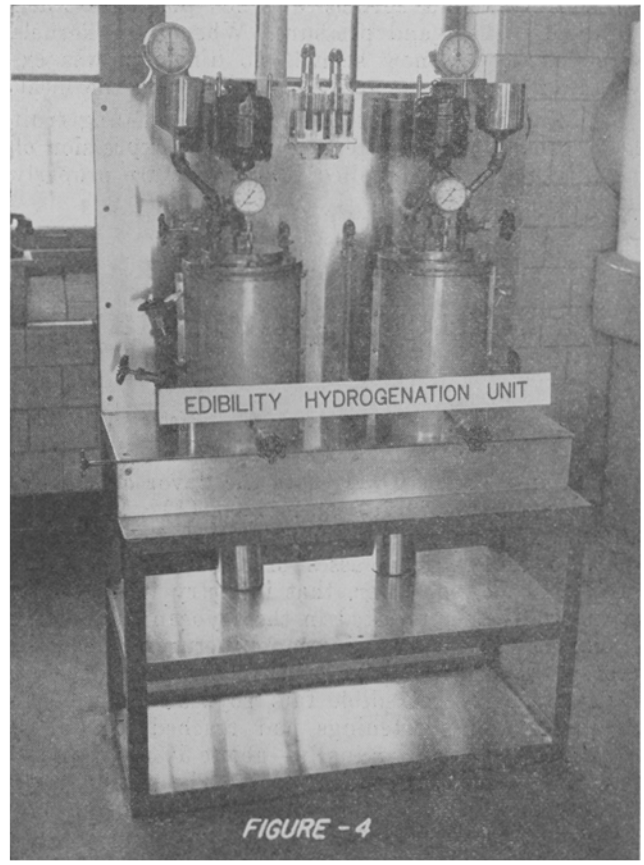
Figure 5 shows the deodorizing unit in which eight one-pound samples can be deodorized in a group. Each pot is of stainless steel, is electrically heated, and has an inside coil through which the distilled water from the reservoir above is flashed to steam. An absolute pressure of about 0.25 inches Hg is maintained by a small three-stage steam ejector visible at the left end. The four larger pots hold water, and can be raised around the deodorizer pots for cooling.

The deodorized samples are filtered directly into new tinned cans. Their fresh flavor quality is determined. They are then stored in an oven at 140°F for accelerated aging. Unhydrogenated oils are again flavored after 48 hours, and hydrogenated oils after 72 hours. The flavor quality of the aged oils from the foregoing procedure is the measure of the flavor stability of the oil, since fresh flavors of all oils are usually good.

Results

Among the earlier broad laboratory studies of a season's production of soybean oil was the one made on the 1936-37 crush. One hundred and fifty-five samples from tank cars received at widely separated refineries were subjected to the edibility test. The flavor quality was correlated with the values obtained in other tests.

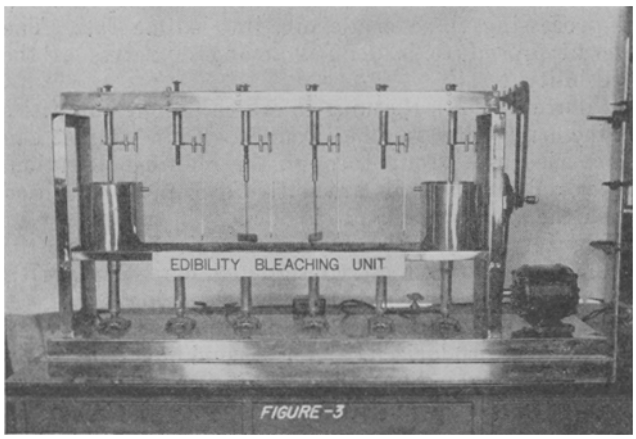
Figure 6 shows the relationship between the color of the crude oil and the flavor quality. Each point represents the average flavor value for all samples



falling within an arbitrarily selected color range—10 units of red in this case. Obviously the color of the crude oil cannot be used generally for predicting the flavor quality of the finished oil.

Where the same beans are milled under several test conditions, the test oil giving the highest refining loss, frequently gives the poorest flavor quality. Figure 7 shows a trend toward poor quality as the loss increases; but the correlation on commercial receipts is not sufficiently good to permit the use of refining loss for predicting flavor quality.

One characteristic of crude soybean oil that is useful in defining the quality of the oil to the paint manufacturer is the Gardner Heat Break—an analytical procedure by which the quantity of certain mucilaginous impurities is determined. Figure 8 shows that the flavor quality of the oil is not closely related to the amount of material that separates in



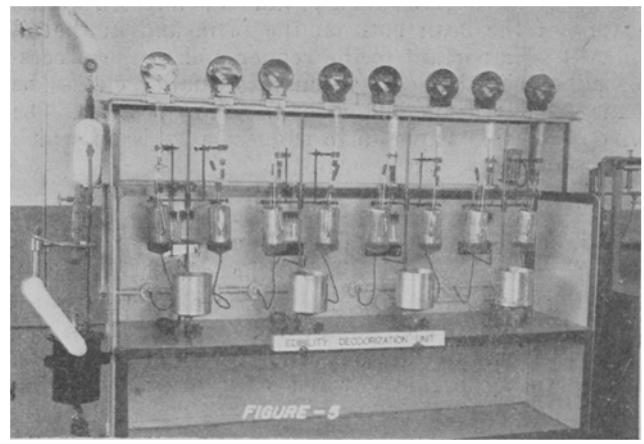
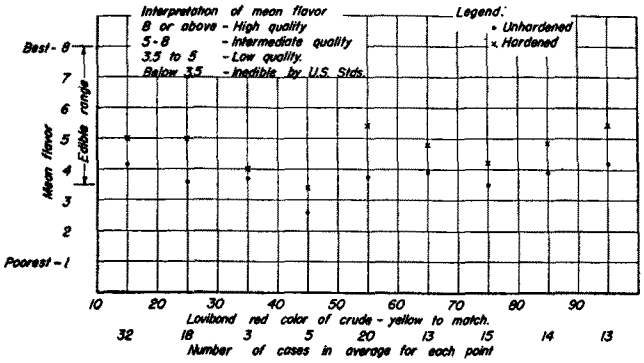
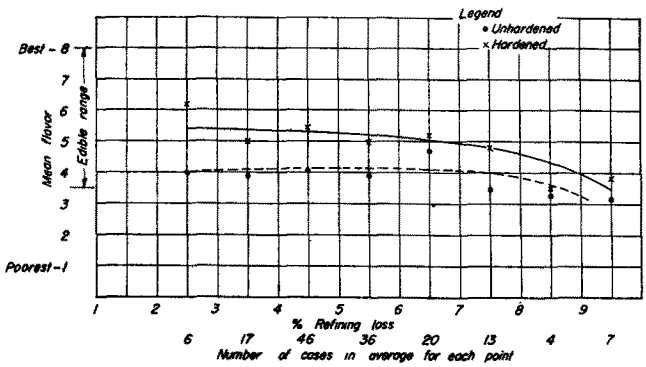


FIGURE-6
LABORATORY EDIBILITIES ON CRUDE SOYBEAN OIL
AGED FLAVOR VS CRUDE COLOR



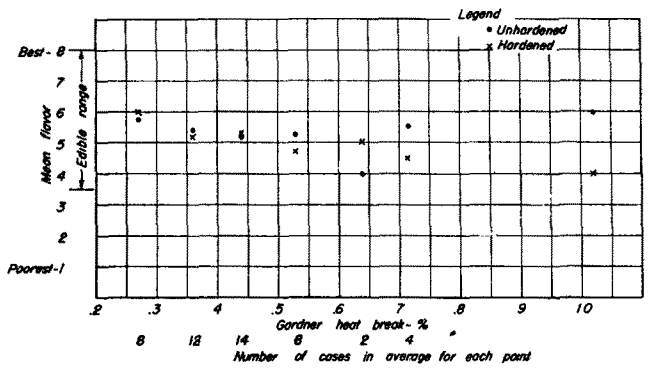
this determination. In the case of the hardened oil, there is a slight trend toward poorer flavor at high break values. Experience shows that merely degumming the crude oil will reduce the break value almost to zero, without corresponding improvement in flavor quality. Hence the break value cannot be relied upon for segregating oils into flavor classes.

Figure-7
LABORATORY EDIBILITIES ON CRUDE SOYBEAN OIL
AGED FLAVOR VS REFINING LOSS



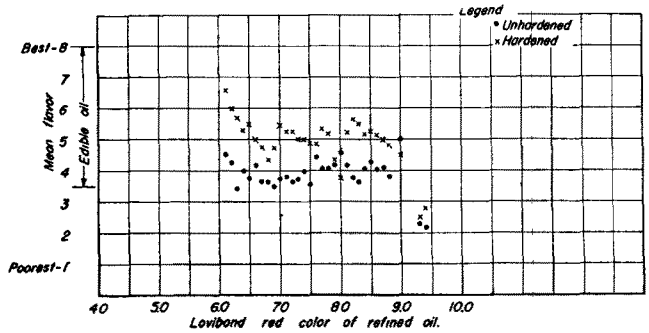
The color of the refined oil is one criterion of quality in the trading rules for cottonseed oil. It was hoped that in the case of soybean oil the flavor quality would show a good correlation with the RF color. Figure 9 shows that it was a vain hope.

FIGURE-8
LABORATORY EDIBILITIES ON CRUDE SOYBEAN OIL
AGED FLAVOR VS GARDNER HEAT BREAK



In Figure 9 the importance of each point was emphasized by including in the average value shown, all results in the immediate proximity of that value —i.e., each point is a sliding average.

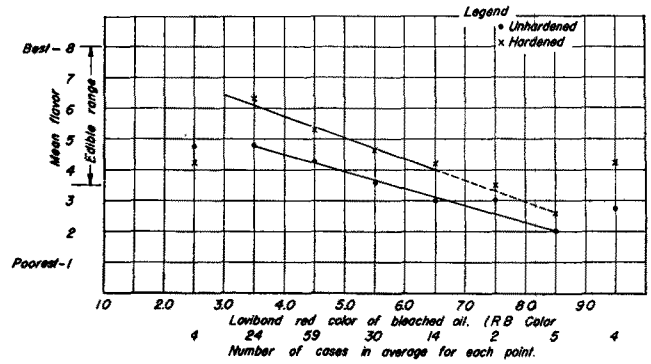
FIGURE-9
LABORATORY EDIBILITIES ON CRUDE SOYBEAN OIL
AGED FLAVOR VS RF COLOR



The distribution of the points into groups suggests that for a particular process or raw material, the RF color can be significant. In any event its general use seems impossible at the present.

The color obtained after earth bleaching—the RB color—is another generally used criterion of quality. Figure 10 shows the correlation between flavor and the RB color obtained with a 3% natural earth

FIGURE-10
LABORATORY EDIBILITIES ON CRUDE SOYBEAN OIL
AGED FLAVOR VS RB COLOR



bleach. It will be seen that a group of oils having an average RB color of 3.5 red is well in the edible quality range, whereas a group having an average RB color of 6.5 red barely meets the flavor requirements of edible oil.

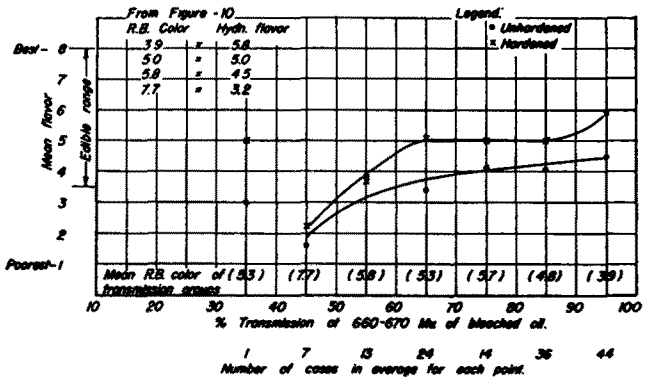
The groups of the lightest and the darkest bleach colors do not fall on the line. While the few values in the groups do not make these extreme points very significant, the agreement between the hardened and unhardened oils suggests that the anomoly has a real cause. Perhaps the crudes have received special treatments, or perhaps in these extreme ranges, RB color has less significance.

THE Lovibond red color reading is not a good indication of the amount of green pigment (chlorophyl) remaining in the oil after the bleach. Relative amounts can be shown by measuring the light transmission characteristics of the test oils in the spectrophotometer, at a wave length of 660-670 mu.

Figure 11 shows the relationship between transmission at 660-670 mu. and the flavor. In these meas-

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-II
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 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.

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.

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.

REFERENCES

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).
3. Klare S. Markley and Warren H. Goss, The Chemistry and Technology of the Soybean and Its Derived Products (1942).

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*