Evaluating the Market Quality of Commercially-Stored Linseed Oil[1]

LEWIS A. BAUMANN, Marketing Research Division, Agricultural Marketing Service, U.S.D.A., Washington, District of Columbia

During the crop years of 1948 and 1949 and later during 1952, 1953, and 1954 the Commodity Credit Corporation acquired large quantities of flaxseed under the operations of the Price Support Program. A large proportion of this was crushed for linseed oil under CCC ownership by privately-owned mills.

Of the almost 590 million pounds of oil owned by CCC and crushed mostly from the 1948 crop of flaxseed, almost 500 million pounds were stored from four to five years. This is referred to as "stored oil" in the report, as distinguished from the "fresh oil" produced mostly in 1952, 1953, and 1954 from the flaxseed crops of 1952 and 1953 and held in storage probably no longer than one year.

Government Commodity Examination Reports were available for study covering most of this linseed oil (about 550 million pounds[2]) at the time of sale in 1952, 1953, and 1954, including some reports on identity-preserved oil prior to that time. No reports were available at the time of production of any of the oil.

This project is concerned primarily with an analysis of the characteristics reported under federal specifications, with particular relation to changes during storage causing deterioration in quality which could have influenced the market value of the oil.

Other objectives include the determination of factors which could affect the rate of deterioration of the quality of the oil because of storage and the economic aspects of the decrease in market value because of deterioration with relation to other costs of storage.

Although all oil produced for CCC was required to meet Federal Specifications[3] at the time of production, much of the stored oil did not meet these specifications at the time of sale. All of the oil was sold on world markets, and prices received have no relation to a domestic market value that might be placed on such oil. Large quantities of the oil sold by CCC at that time were sold on an "as is" basis, and the specifications did not enter the transactions from a price standpoint.

Industry Evaluations of the Characteristics Under Specifications

A very small percentage of raw linseed oil produced enters the market as oil not meeting specifications. Estimates from industry vary from no oil offered for sale (not meeting specifications) up to a possible 2 to 3% of the total production of all oil during 1957. Fresh oil (up to one year in storage) sold by CCC showed about this same percentage not meeting specifications; however lots of oil stored for periods from four to five years showed larger percentages not meeting specifications.

There are no established methods to place a value on oil not meeting specifications. Discounts may vary, depending on a variety of conditions from either the buyer's or seller's viewpoint. The industry places varying degrees of importance on the characteristics causing oil not to meet specifications. Their estimates show that the frequency of these characteristics causing "non-spec"[4] oil is about of the following order, from the most frequent occurrence as well as the most important, to the least frequent and least important: heated foots, chilled foots, appearance, iodine number, acid number, color, loss on heating, specific gravity, unsaponifiable matter, and saponification number.

All of these characteristics under specifications are commonly tested for in all drying oils, with the exception of heated and chilled foots. The methods used in the foots tests have been under criticism for many years as not being an accurate means of measuring the nonoil constituents in linseed oil. The unreliability of the methods for determining foots has important economic aspects in view of the frequency with which these characteristics are responsible for oil not meeting specifications.

The Quality of Fresh Oil

Oil Not Meeting Specifications. Of the 118 million pounds of fresh oil sold by CCC in 1953 and 1954 for which Commodity Examination Reports were available, all but about three million pounds met specifications if the lots of oil were qualified on the basis of samples taken from individual tank cars while being filled from large field tanks. This percentage of oil not meeting specifications agrees well with the estimates of industry for 1957. This "non-spec" oil was caused mostly by excessive amounts of heated and chilled foots and an unclear appearance. This also is in agreement with the estimates of industry as to the frequency with which these characteristics cause fresh oil not to meet specifications.

Variations of Characteristics. During the CCC operations many tank cars were tested from samples taken at the discharge line while loading from large field tanks to the tank cars. Tests were made on the samples within a few days and usually by the same laboratory. A number of the data were identifiable from eight large field tanks. The statistical analyses for each of the characteristics (except appearance and color) provide coefficients of variation in each of the tanks as well as coefficients of variation for all the samples on the basis of a common average for each characteristic (*Table I*).

On the basis of these data it appears that the two tests for foots are far from being as reliable as some of the other tests, such as saponification number and iodine number. For example, when a number of samples from the same source are tested for chilled foots with an average value of 4.0% by volume (the limit under specifications), one out of three samples could test higher than 4.9%.

The Quality of Stored Oil

Areas of Storage. Of the some 584 million pounds of oil crushed mostly from the 1948 crop of flaxseed during 1948, 1949, and 1950 it is estimated that about 490 million pounds were held in storage from four to five years. This oil was stored in four general areas of the country: a northern area comprising Minneapolis, St. Paul, Chicago, and several of the Great Lakes ports; a western area around the ports of Los Angeles and San Francisco; an eastern area around Baltimore, Philadelphia, and New York; and a southern area, including southeastern Texas and the port of New Orleans.

Specifications were met for all of the some 42 million pounds stored in the northern area. Only about 0.3% of the more than 77 million pounds stored in the western area failed to meet specifications. Almost 17% of the almost 312 million pounds stored in the eastern area failed to meet specifications, and all of the about 58 million pounds stored

---

[1] Presented at 50th annual meeting, American Oil Chemists' Society, April 21, 1959, New Orleans, La.

[2] Includes some 300 million pounds of oil set aside for defense requirements because of the Korean war.

[3] *Federal Standard Stock Catalogue, Section IV (Part 5), Federal Specifications for oil;* Linseed, Raw (for use in Organic Coatings) TT-0-369, January 28, 1948, p. 2.

[4] "Non-spec" oil refers to oil not meeting specifications.

TABLE I

Coefficients of Variation of Characteristics of Samples Taken from Eight Tanks of Fresh Linseed Oil [a]

Tank number	Total weight of oil sampled	Samples taken	Coefficients of variation [b]							
			Heated foots	Chilled foots	Acid number	Saponification number	Iodine number	Unsaponifiable matter	Loss on heating	Specific gravity
	Pounds	*Number*	%	%	%	%	%	%	%	%
1	1,320,000	22	11.28	25.03	16.89	0.33	0.84	4.45	14.96	0.05
2	1,589,558	26	35.41	27.21	13.03	.32	.73	4.57	20.90	.06
3	2,092,962	34	23.31	28.85	10.74	.29	.80	12.47	17.09	.05
4	1,176,700	19	0	23.86	4.59	0	.53	4.45	22.71	.07
5	7,442,020	118	34.93	24.38	13.24	.22	.23	5.11	23.32	.03
6	2,625,710	42	24.80	23.89	3.99	.29	.26	4.30	19.69	.05
7	1,844,400	30	26.26	17.64	4.59	.22	.22	4.74	14.65	.02
8	6,255,280	102	0	16.62	6.77	.20	.43	4.38	17.49	.05
All	24,346,630	393	24.96	22.75	10.30	.24	.47	5.77	19.82	.05

[a] All samples drawn from line while loading tank cars from field tanks and tested by the same laboratory, generally over a period of several days.
[b] A measurement of variation on a comparative basis (100 times the standard deviation divided by the average).

in the southern area was "non-spec." Of the total oil stored, almost 23% did not meet specifications.[5]

Oil Not Meeting Specifications. Of the 42 tanks containing all of the stored oil not meeting specifications, three tanks were sampled after agitation and the samples represented all the oil in the tanks, in the total quantity of almost 11 million pounds. Of the other 39 tanks, samples were taken which represented oil from the balances and bottoms of the tanks.[6] All of the bottoms representing almost three million pounds of oil did not meet specifications, and 31 of the balances of these tanks representing over 97 million pounds of oil did not meet specifications.

Of the 73 lots of oil (consisting of three whole tanks, 39 bottoms, and 31 balances), there were 184 instances where characteristics caused failure of the oil to meet specifications. Thirty-five lots were "non-spec" because of only one characteristic beyond tolerance whereas 33 lots were "non-spec" because from two to five characteristics were beyond tolerance. Two lots were "non-spec" since all characteristics except color were beyond tolerance. All lots of stored oil (and fresh oil) met specifications for color.

Differences in Fresh and Stored Oil. The causes for oil not meeting specifications were quite different in storage after four to five years compared to oil that was held in storage only up to one year. The fresh oil failed to meet specifications mostly because of excessive heated and chilled foots with cloudy appearance. The "non-spec" stored oil was so classified, more because of high acid numbers and high unsaponifiable matter; high heated and chilled foots and cloudiness were of secondary importance (Table II).

[5] From related and unpublished work now in progress for the over-all project it is indicated that the rate of deterioration of vegetable oils increases with time-temperature and is proportional to atmospheric conditions. The average temperatures for the four areas are approximately: northern, 48°; western, 63°; eastern, 53°; and southern, 69° (1958 Weather Bureau records). The greater proportion of "non-spec" oil in the eastern area compared to the western area, where annual average temperature is about 10° lower, can be accounted for by greater variations in temperature in the eastern area (particularly in the summer months) and by a far greater proportion of the oil stored in small tanks at this location.

[6] After about a year in storage "foots" had settled to the bottoms of the tanks, and samples were taken of the oil in both the balance and the bottoms.

TABLE II

Comparison of Number of Samples of Fresh and Stored Linseed Oil Not Meeting Federal Specifications, by Characteristics [a]

Characteristic	Fresh oil		Stored oil		Difference stored from fresh oil
	Samples	Proportion of total samples	Samples	Proportion of total samples	
	No.	%	*No.*	%	%
Heated foots	19	27.1	20	10.7	−16.4
Chilled foots	16	22.9	14	7.6	−15.3
Specific gravity	0	0	4	2.2	+ 2.2
Acid number	0	0	44	23.9	+23.9
Saponification number	1	1.4	2	1.1	− 0.3
Iodine number	1	1.4	13	7.1	+ 5.7
Unsaponifiable matter	6	8.6	43	23.4	+14.8
Loss on heating	1	1.4	11	6.0	+ 5.0
Appearance	26	37.2	33	18.0	−19.2
Total	70	100.0	184	100.0	......

[a] Fresh oil in storage one year or less, located mostly in eastern area of U.S. and made from 1952–53 crop of flaxseed. Stored oil in storage from four to five years, located mostly in eastern and southern areas of U.S. and made mostly from 1948 crop of flaxseed.

The fresh and stored oils probably came from the same general area of the northern flaxseed belt. The table therefore can be used as an indication of possible changes that could occur during storage in the eastern area. These estimates of changes in the characteristics during storage can be made: some decrease in the heated and chilled foots (settling improves the bulk of the oil; most of the foots are in the bottoms of tanks), increase in acid number, increase in unsaponifiable matter, some improvement in appearance, some decrease in iodine number, and insignificant changes in the other characteristics. These estimates are confirmed to a great extent where tests are made over a large part of the storage period in the instance of some identity-preserved oils.

Changes During Storage. Although there were a number of tanks of oil stored by CCC without commingling or on an identity-preserved basis, reports are available throughout the greater part of the storage period for only four of these tanks. These were in the southern area. All of the oil in these tanks increased in acid number and unsaponifiable matter. High acid number was the only cause for the oil in a tank, containing almost four million pounds, not meeting specifications and the oil in one of the tanks containing around 17 million pounds was "non-spec" because both acid number over 4 and unsaponifable matter were just beyond a tolerance of 1.5%. The oil in the other two tanks containing around one-and-a-half million pounds each showed all characteristics changed in the bottoms (except color) to reject this oil under specifications. However only excessive acid number and high unsaponifiable matter caused the oil in the balances not to meet specifications. There were greater decreases in the quality of the oil in the smaller tanks compared to the larger quantities (in the larger tanks).

Statistical analyses were made of the characteristics in each of these four tanks. In the two larger tanks there were insignificant relationships shown between time in storage with all the characteristics except acid number and unsaponifiable matter. This indicates little change in the other characteristics during storage.

To arrive at the most probable change in characteristics of the oil in the two smaller tanks with time of storage, characteristics for both tanks were combined statistically around a common average for each. Further, to obtain characteristics for all the oil in each tank as a lot, characteristics of the oil in the balance and bottoms were averaged on a weighted basis (32nd through 53rd months) and combined with the characteristics from samples taken (between the 10th and 27th months) after the oil was previously mixed by agitation (Table III).

The changes in quality over the storage period confirm, in general, the difference between fresh and stored oil as shown in Table II:

1) acid number—a much higher incidence, causing oil not to meet specifications after storage, than incidence in fresh oil;

2) saponification number—very little difference in stored and fresh oils although Table III shows a tendency for this characteristic to decrease;

3) iodine number—small decreases with storage (only a few lots of oil showed low iodine number to be the cause of "non-spec" oil);

4) unsaponifiable matter—definite increases with storage to cause "non-spec" oil more often than in fresh oil;

TABLE III

Factors for Correlation of the Relationship Between Specified Characteristics and Time of Storage of Linseed Oil [a]

Characteristic [b]	Mean of Y [c]	Regression coefficient b [d]	Standard error of estimate $S_{y.x}$	Correlation coefficient r
Acid number	6.2197	0.0727	0.0046	0.9410
Saponification number	191.5917	—.0204	.0160	—.2121
Iodine number	179.0889	—.0503	.0171	—.4546
Unsaponifiable matter	1.4436	.0044	.0015	.4502
Loss on heating	.0972	.0005	.0006	.1573
Specific gravity	.9324	......[e]	0	—.5127

[a] In two tanks each holding 1,564,000 lbs. of oil in the Texas area for 53 months.
[b] There were insignificant changes in heated and chilled foots.
[c] There were 18 samples taken from each tank, making a total of 36 observations with a mean of 33.8888 in months.
[d] Unit change in characteristic with each month of storage.
[e] —0.000038.

5) loss on heating—very little increase with storage for the oil as a whole; however there were increases in the bottoms of the tanks while the balance remained quite constant;

6) specific gravity—only small decreases (only a few lots of oil showed specific gravity not within tolerance); and

7) heated and chilled foots (data not shown in the table)—insignificant relationships shown with time of storage; in spite of the large increases of these two characteristics in the bottoms of the tanks, the tanks of oil as a whole showed little change with storage.

Conditions Affecting Quality of Stored Oil

Quantity of Oil. Reports were available on 30 field tanks of oil, totalling almost 46 million pounds, after four to five years of storage in the eastern area. Tanks varied in size from 14 to 55 ft. in diameter and from 21 to 42 ft. in height. All were cylindrical. All the tanks were filled to capacity. Tests were made on samples both from the balance and bottoms of the tanks, and calculations were made to show characteristics for total oil.

The larger quantities of oil after storage showed better quality than smaller quantities at this location. The smaller quantities of oil had higher acid numbers, both in the oil of the balance and bottoms of tanks, than was the case in the larger tanks. Although few of the tanks had iodine numbers below specifications, either in the bottoms or balance oil, there were decreases indicated in this characteristic. There was little difference in the loss on heating in the balance oil of all tanks, but oil in the bottoms of the larger tanks showed large increases over that in the smaller tanks. The results of the statistical calculations are shown in Table IV.

Mixing of the oil at the end of the storage period in this location for these tanks probably would not have improved the market value of all the oil over that of the market values of the oil in the balance and bottoms, disposed of separately.[7]

TABLE IV

Factors for Correlation of the Relationship Between Specified Characteristics and Total Weight of Stored Linseed Oil in Balance, Bottoms, and Total Oil of Tanks [a]

Characteristic [b]	Oil represented by samples taken	Y Intercept a	Regression coefficient b[c]	Correlation coefficient r	Standard error of estimate $S_{y.x}$
Acid number	Balance	4.4314	—0.000447	—0.7586	0.5146
Acid number	Bottoms	4.9688	—.000478	—.2076	.7357
Acid number	Total oil [d]	4.4771	—.000469	—.7928	.4834
Iodine number	Balance	184.6602	—.002535	—.8325	2.2084
Iodine number	Bottoms	182.4269	—.002318	—.4704	5.8296
Iodine number	Total oil [d]	184.4680	—.002410	—.7995	2.4265
Loss on heating	Balance	.1877	—.000030	.2171	.1146
Loss on heating	Bottoms	.1148	.000232	.3022	.9788
Loss on heating	Total oil [d]	.1454	—.000011	.1908	.0782

[a] Samples taken of balance and bottoms of 30 tanks containing from about 200,000 to more than 4,000,000 lb. of oil, located in eastern area. All tanks were filled to capacity, and all bottoms were 6 in. Oil in storage four to five years.
[b] There were insignificant relationships for heated and chilled foots, saponification number, unsaponifiable matter, and specific gravity. Color met specifications in all tanks. All balances, but only nine bottoms, were clear in appearance.
[c] Unit change of characteristic for every 1,000 lb. of oil.
[d] Calculated from characteristic of balance and bottoms on a weighted basis.

Of the total oil stored at this location, oil in 10 tank balances met all specifications but only two bottoms oil were satisfactory. Calculations were made by combining on a weighted basis the characteristics of the bottoms and balances to arrive at a characteristic for all the oil in each tank. Appearances cannot be calculated for such mixtures (25 tanks were cloudy in the bottoms). If it is assumed that the mixtures would pass specifications for appearances, only the oil in two tanks (so calculated) would have met specifications. Although the other 28 tanks would meet specifications on this basis for heated foots, chilled foots, saponification number, and specific gravity, the high incidence of excessive acid numbers and unsaponifiable matter of the oil in the balance, as well as in the bottoms, precludes the possibility of upgrading the oil in the bottoms of the tanks by mixing.

Location of Storage. Some of the data previously shown in the report provide the means to arrive at an estimate of the changes of quality of the oil when similar quantities are stored in two different locations. A comparison can be made of storage changes in characteristics between similar quantities of oil in the eastern and southern areas at the end of the storage period.

Data from Table III (averages of the two small tanks in the southern area, each holding about 1,564,000 pounds of oil) are compared to data arrived at through use of Table IV for a tank of oil of about this same quantity in the eastern area. The results are shown in Table V.

TABLE V

Comparison of Selected Characteristics of Linseed Oil Stored in New York City and Texas Areas [a]

Characteristic	Location in tanks	New York City	Texas
Acid number	Balance	3.87	7.83
Acid number	Bottoms	4.38	15.95
Loss on heating	Balance	.12	.14
Loss on heating	Bottoms	.16	2.35
Saponification number	Balance	190.76	190.97
Saponification number	Bottoms	190.17	186.73
Iodine number	Balance	181.27	178.19
Iodine number	Bottoms	179.30	173.52
Unsaponifiable matter	Balance	1.51	1.48
Unsaponifiable matter	Bottoms	1.63	1.64
Specific gravity	Balance	.9328	.9321
Specific gravity	Bottoms	.9343	.9350

[a] Oil stored four to five years at same time in both locations. Oil probably from different sources. Tanks approximately 35 ft. in diameter and 30 ft. in height filled to within a few feet of top.

The quality of the oil in the eastern area was better after storage than of the same quantity stored in the south. This difference can be summed up as follows. The oil in the New York area did not meet specifications in the balance of the tank for unsaponifiable matter only, and in the bottoms for acid number and unsaponifiable matter, whereas the oil in Texas did not meet specifications in the balance of the tanks for acid number and in the bottoms for acid number, loss on heating, saponification number, iodine number, and unsaponifiable matter.

Variations in Oil from Settlings. Previous discussion and the data recorded in several of the tables have shown the variability of characteristics in samples taken from the same lots of oil, not only because of the methods and technique used in testing but more particularly because of methods of sampling. Some of the variations are quite large for several of the characteristics, such as heated and chilled foots. Also variations of characteristics in samples from the bottoms of tanks are far greater than in the balance of the tanks. (Foots in the bottoms of tanks can cause stratification, and other constituents, such as free water, make representative samples difficult to obtain.) The oil in the balance of the tank is more homogeneous, and the several

[7] No information is available as to the equipment in these tanks at that time to provide agitation for mixing.

samples taken to make a composite give more representative samples of the balance than in the bottoms.

Statistical correlations made of the large number of analyses recorded in the CCC operations show that there are good degrees of relationship between characteristics of the oil in the balance and bottoms of tanks for several of the characteristics. It appears that these relationships between balance and bottoms could provide a more reliable and less variable method of determining the characteristic of the bottoms than by sampling and testing the bottoms samples in the stored oil (Table VI).

TABLE VI

Factors for Correlation of the Relationship of Specified Characteristics in the Balance and Bottoms of Tanks of Stored Linseed Oil [a]

Characteristic [b]	Y intercept a	Regression coefficient b [c]	Correlation coefficient r	Standard error of estimate $S_{y.x}$
Heated foots	1.0051	3.6604	0.1759 [d]	2.1798
Chilled foots	3.7405	2.9907	.2895 [d]	6.6515
Acid number	−3.9786	2.2034	.8416	2.3174
Saponification number	.6338	.9909	.3622	3.6961
Iodine number	−6.9505	1.0284	.6341	3.7917
Unsaponifiable matter	.7948	.5274	.3733	.1471

[a] Based on 38 samples of oil taken during storage up to four to five years in the southern area and 42 samples taken at the end of storage of four to five years, mostly in the eastern area.
[b] No significant relationship found for specific gravity and loss on heating.
[c] Change of characteristic in bottoms with each unit change in balance.
[d] The relationships of the foots tests are barely significant in 19 analyses out of 20 and cannot be assumed to be reliable.

It has been shown previously that the loss on heating remains quite constant throughout the storage period of the oil in the balance of the tank while this characteristic increases in the oil in the bottoms.

Based on the data in Table VI, some estimates can be made of several of the characteristics of the oil in the balance of the tanks when the oil in the bottoms has reached a limit under specifications, as follows:

Characteristic	Balance	Bottoms
Acid number	3.5	4
Saponification number	190.5	189
Iodine number	178.9	177
Unsaponifiable matter	1.35	1.5

The Heated and Chilled Foots Tests

Variations in Fresh and Stored Oil. The wide variation of heated and chilled foots in fresh oil has been previously discussed in connection with the data in Table I, which summarizes tests made on 393 samples. A total of 131 samples were also tested for these characteristics in the identity-preserved stored oils held in the southern area. These samples were grouped according to source, namely, the balance, bottoms, all oil, and total oil in each of the four tanks. Statistical correlation for each of these groups showed no significant change in either of these characteristics; accordingly coefficients of variation were determined for each group. A summary of all of these coefficients of variation around a common average can be compared to those of the fresh oils as follows:

Characteristic	Fresh oil	Stored oil
Heated foots	24.96	83.36
Chilled foots	22.75	110.63

The extent of the wider variation of the chilled foots in stored oil as compared to fresh oil can be determined from the above coefficients of variation. When this characteristic is at the limit under specifications with an average of 4.0% by volume, one out of three samples in the fresh oil could test higher than 4.9 and in the stored oil higher than 8.4.

The Relationship of Heated to Chilled Foots in Fresh and Stored Oils. There were insignificant relationships between the heated and chilled foots in any of the eight large tanks of fresh oil, where samples of from 19 to 118 were taken in the various tanks. There also was no significant relationship for all the 393 samples when correlated together. In other words, on the basis of these data it is not possible to estimate either of these characteristics from the other when the fresh oil was tested.

There were however significant relationships shown between these two characteristics, regardless of the source of the samples, taken from the stored oil used for statistical correlation (Table VII).

TABLE VII

Factors for Correlation of the Relationship Between Heated and Chilled Foots in Stored Linseed Oil

Designation of samples	Number of observations	Y intercept	Regression coefficient	Correlation coefficient	Standard error of estimate
	n	a	b	r	$S_{y.x}$
During storage					
Balance	54	−0.6188	6.4047	0.8360	6.4047
Bottoms	38	.8543	3.1155	.7375	3.1155
Total oil	51	−.5783	6.1607	.8614	6.1607
End of storage					
Balance	42	−.0030	1.5454	.6364	.1670
Bottoms	42	.4494	2.4102	.9592	1.7964
Total oil	40	−.1181	1.9460	.9926	1.3747
Both during and end of storage					
Balance	96	−.5563	5.5919	.7912	5.5919
Bottoms	80	.8433	2.6256	.8365	3.7836
Total oil	91	.1810	1.9395	.9866	1.2185
Balance, bottoms, and total oil					
During storage	140	.1730	3.3345	.8143	2.6995
End of storage	124	.2475	2.0433	.9780	1.5664
All samples	264	.5356	2.1596	.9153	2.4777

Although there are highly significant relationships shown in the table, there are various differences in the changes of chilled foots with unit differences of heated foots (regression coefficients), depending on the source of the samples. With a heated foots of 1.0 (limit under specifications) the following chilled foots are indicated from the table:

	Balance	Bottoms	Total
During storage	5.8	4.0	5.6
End of storage	1.5	2.9	1.8
Both during and end of storage	5.0	3.5	2.1
Balance, bottoms, and total:			
During storage	3.5	....	....
End of storage	2.3	....	....
All tests	2.7	....	....

The average of all heated foots for fresh oil was 0.37% by volume and for chilled foots was 2.43, which gives a ratio of 1 to 6.6, which can be compared to the above ratios.

The intent of the heated and chilled foots tests, when taken together, is to measure the amount of nonoil constituents in the sample. Limits in the specifications for satisfactory oil have been set at 1% by volume for heated foots and 4% for chilled foots, or in the ratio of 1 to 4. For the fresh oils (based on averages) tested in the project, the ratio was higher, and for the stored oils it was generally lower.[8]

Market Evaluation of Oil Not Meeting Specifications

Estimates Made by Industry. There are no established methods to determine discounts below market price for any oil, not meeting specifications, which may be offered for sale. Several members of industry have cooperated in placing the range of prices for such oil, but it must be emphasized that a summary of such estimates does not indicate with any degree of accuracy a price that would be acceptable for such oil in general trading operations.

The estimates submitted by these industry members for prices of several oils not meeting specifications show that discounts were made which agree quite well with the importance of the various characteristics causing "non-spec," oil as discussed previously (Table VIII).

Estimated Costs of Quality Deterioration. The data concerning the six oils shown in Table VIII were chosen for evaluation on the basis of their frequency of occurrence among all the lots of stored oil not meeting specifications. However there were other characteristics causing "non-spec" oil. In order to evaluate these other lots of oil, estimates were made of a discount (based on a market price of 14c per pound for oil meeting specifications), by using the prices in Table VIII and relating the importance of the various characteristics, as shown previously from the opinions of industry. For example, a price of 13.594c per pound was placed on an oil not meeting specifications only because of appearance. It was assumed also that as more characteristics did not meet specifications, the price of the oil would be discounted by adding discounts for each characteristic not meeting specifications. In this manner all of the oil not meeting specifications was valued. For all the stored oil there were 26 lots of oil, each having a different combination of characteristics beyond tolerance. A complete evaluation of all the stored oil is shown in Table IX.

Summary

About 77% of approximately 490 million pounds of raw linseed oil stored for periods from four to five years met federal specifications during the period 1948 to 1955 in the operations of the Commodity Credit Corporation in the support of flaxseed. It is estimated that the 23% which did not meet specifications had a decreased value around 0.6c per pound on a market of 14c for oil meeting specifications.

All of the 42 million pounds stored in the northern area

[8] The correlation coefficient of 0.9153 (Table VII) for the total of 264 samples is somewhat less than the 0.970 shown by J. N. Shaw, J. W. Garrett, and S. O. Sorenson in their paper, "A Comparison of Several Methods for Determination of Nonoil Constituents in Raw Linseed Oil," appearing in the Journal of the American Oil Chemists' Society, March 1952. The tests in their work are presumed to have been made in the same laboratory and on some 49 samples of wide variation in heated and chilled foots. The relations shown in Table VII combine tests made in two different laboratories. The tests made "during storage" which show a correlation coefficient of 0.8143 were made in a different laboratory from the tests at the "end of storage" which give a correlation coefficient of 0.9780.

TABLE VIII

Estimated Prices of Raw Linseed Oil Not Meeting Specifications [a]

Sample number	Range of characteristics not meeting specifications [b]	Estimated prices [c]		Av. of medians [f]	Discount from 14¢ [g]
		Low [d]	High [e]		
		Cents	*Cents*	*Cents*	*Cents*
1	Acid number, 5 to 7	12	13.9	13.355	0.645
2	Unsaponifiable matter, 1.6 to 1.8	12	14.0	13.390	.610
3	Heated foots, 2 to 4, and not clear	10	13.9	13.045	.955
4	Heated foots, 2 to 4, chilled foots, 5 to 8, and not clear	5	13.8	12.080	1.920
5	Iodine number, 172 to 176, and not clear	10	13.9	13.075	.925
6	Loss on heating, 0.4 to 1.0, and not clear	11	13.9	13.355	.645

[a] Prices estimated by industry cooperators.
[b] The characteristics chosen were representative of the stored oils not meeting specifications.
[c] Each industry cooperator gave his estimate over a range of low to high for each oil.
[d] The lowest price of all the low prices in the ranges estimated.
[e] The highest price of all the high prices in the ranges estimated.
[f] The median prices of all the estimates were averaged for each oil.
[g] A price of 14¢ was used for oil meeting specifications.

TABLE IX

Estimated Costs of Quality Deterioration of Stored Linseed Oil [a]

General location of storage	Quantity of total oil stored	Oil not meeting specifications				Estimated loss in price per pound from storage deterioration [b]	
		Quantity	Estimated price per pound	Estimated value	Estimated loss from deterioration	Based on oil not meeting specification	Based on total oil
	Pounds	*Pounds*	*Cents*	*Dollars*	*Dollars*	*Cents*	*Cents*
Northern	42,220,625	....	....	....	....	......	......
Western	77,274,551	223,720	13.355	29,878	1,443	0.645	0.002
Eastern	311,671,973	52,755,542	13.250	6,989,856	395,920	.750	.127
Southern	57,992,402	57,992,402	13.412	7,777,790	341,146	.588	.588
Total	489,159,551	110,971,664	13.335	14,797,524	738,509	.665	.151

[a] Oil stored four to five years at four general locations, mostly from 1948 flaxseed crop.
[b] Oil meeting specifications was priced at 14¢ per pound.

of the United States met specifications, and negligible quantities stored in the California port areas did not meet specifications. About 83% of the 311 million pounds stored at or near the port of New York met specifications; however all of the 58 million pounds stored in the southern area of the country failed to meet specifications.

About 97% of the 118 million pounds of fresh oil (up to a period of one year in storage) met specifications on the basis of samples drawn from individual tank cars. (Industry estimates that from 97 to 100% of the oil prdouced in 1957 met all specifications at the time of sale.)

The causes for failure of the oil to meet specifications were quite different after long periods of storage compared to fresh oil. The fresh oil did not meet specifications mostly because of excessive heated and chilled foots and cloudy appearance. (According to industry opinions, this is typical in freshly-produced oil.) The causes for the stored oil not meeting specifications were mostly attributable to high acid number and high unsaponifiable matter; high heated and chilled foots and cloudy appearance were of secondary importance.

Variations in the several characteristics under specifications for some 393 samples of fresh oil, calculated to a common average for each, showed wide variations in the heated and chilled foots tests as compared to some of the other characteristics.

There were 73 lots of oil (taken from three whole tanks, 39 bottoms, and 31 balances) comprising the almost 112 million pounds not meeting specifications. Thirty-five lots failed to meet specifications due to only one characteristic beyond tolerance whereas 33 lots were "non-spec" because of from two to five characteristics beyond tolerances. Two lots were "non-spec" because all characteristics except color were beyond tolerance. All lots of stored oil (and fresh oil) met specifications for color.

At the same location (eastern and southern areas) the oil held in larger tanks (filled to capacity) showed less deterioration of quality after storage than when held in the smaller tanks.

Similar quantities of oil stored in the warmer areas showed greater deterioration than in cooler locations (eastern and southern areas).

In general, oil in the bottoms of tanks after storage showed greater deterioration than in the balance, but in some cases mixing of the oil (by calculation) could increase the market value of all the oil because of the small quantity of oil in the bottoms as compared to that in the balance. There were also far greater variations of the characteristics in the oil in the bottoms of tanks than in the balance. There are however significant relationships for several of the characteristics between the balance and bottoms oil. It is indicated that different methods could be employed other than sampling and testing the bottoms oil in order to obtain more accurate characteristics of the bottoms. Average characteristics of the balance oil can be obtained, by calculation, from testing the individual samples taken of the balance instead of compositing these samples for testing. The relationships between balance and bottoms oil for several of the characteristics shown in the report could be used to get characteristics of the bottoms instead of sampling and testing the bottoms.

The variations of either of the characteristics of foots are far greater in stored than in fresh oil, such that the use of these tests is of some economic importance in stored oil. There are however significant relationships between the heated and chilled foots in stored oil when large numbers of samples are tested and statistically correlated.

The methods of the two tests for foots are even more unreliable when applied to stored oil than when used with fresh oil. The frequency and economic importance of these characteristics which cause stored oil not to meet specifications indicate that improved methods are vitally needed to determine nonoil constituents over those now used under specifications.

There should be no decrease in the market value because of quality deterioration for average-quality, raw linseed oil as produced, when stored up to five years in large lots (in tanks filled to capacity) and stored in the colder areas of the United States. Even tanks of oil filled to capacity with quantities as low as one million pounds should store well in the general area of the Great Lakes ports, which is also close to the areas of the greatest production of flaxseed.

For the same-size lots of oil stored in tanks to capacity, the oil should decrease in quality to less market value more in the warmer areas of the country, with most deterioration in the South near the port of New Orleans.

However, even when the oil is stored in smaller lots and under the most undesirable conditions of temperature as in the warmer areas, the changes in the various characteristics do not decrease the value of such oil much under market value for oil meeting specifications.

The cost of transportation of oil from the warmer areas of production to areas where storage conditions are good would be much greater (around 1 to 2c per pound) than the cost of deterioration if stored in the warmer areas except for oils which were of the poorest quality at the time of production. (Some oils were estimated as having values up to 3c per pound under the market for oil meeting specifications at 14c).

[Received June 22, 1959]

• Obituary

LUCIEN BROWN FORBES (1918), owner of the L. B. Forbes Laboratory at Little Rock, Ark., until his retirement in 1947, died June, 1959, at St. Petersburg, Fla., according to information received from E. H. Tenent Sr. of Memphis.

He was a member of the Society of Cotton Products Analysts, which in 1920 changed its name to the American Oil Chemists' Society, and served as third vice president in 1930; second vice president in 1935; and third vice president in 1941.

A native of Alabama, Mr. Forbes opened his own laboratory at Little Rock in 1928 after having worked for General Electric in Schenectady, N.Y., and the American Cotton Oil Company at Memphis and Little Rock.

American Felt Company, New York, has recently introduced a new filter cartridge line, utilizing carefully processed new synthetic fibers in an uniquely constructed filter medium for controlled particle filtration.