evaluating the market quality of commercially stored LINSEED OIL

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PREFACE

This study is part of a broad program of research in the U. S. Department of Agriculture to improve efficiency in the marketing of farm products and to expand markets.

This report is part of a more comprehensive study of the economic aspects of the storage of vegetable fats and oils started in 1955 and still in progress. Data on the raw linseed oil stored under the flaxseed price support program during 1948 to 1955 were supplied by the Commodity Stabilization Service. These data should be representative of present conditions in the industry.

Members of the National Flaxseed Processors Association cooperated by evaluating some of the lots of oil.

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SUMMARY AND CONCLUSIONS

About 77 percent of approximately 490 million pounds of raw linseed oil stored by the Commodity Credit Corporation for 4 to 5 years met Federal specifications at the end of the storage period. About 97 percent of the 118 million pounds of fresh oil (up to a period of 1 year in storage) also met specifications on the basis of samples drawn from individual tank cars. These results are based on observations made during 1948 to 1955 of CCC's operation of its price support program for flaxseed.

It is estimated that the 23 percent of the stored oil which did not meet specifications had a decreased value of about 0.6 cent per pound on a market of 14 cents for oil meeting specifications. All of the 42 million pounds stored in the northern area of the United States met specifications, but negligible quantities stored in the California ports did not. About 83 percent of the 311 million pounds stored near New York met specifications. All of the 58 million pounds stored in the southern area of the country failed to meet specifications.

The causes for failure of oil to meet specifications were quite different in oil stored for a long time and that stored for a year or less. Usually in the fresh oil the causes were excessive amounts of heated and chilled "foots" and cloudy appearance. The principal reasons the stored oil did not meet specifications were: high acid number and high unsaponifiable matter. High heated foots, chilled foots, and cloudy appearance were of secondary importance.

About 111 million pounds of the stored oil did not meet specifications. It was in 73 lots that had been taken from 3 whole tanks, 39 bottoms, and 31 balances. Thirty-five lots failed to meet specifications due to only 1 characteristic being beyond tolerance, whereas 33 lots were "non-spec" due to from 2 to 5 characteristics being beyond tolerance. Five lots were "non-spec" owing to more than 5 characteristics being beyond tolerance. All lots of stored oil and fresh oil met specifications for color.

In the eastern and southern areas, the oil held in larger tanks filled to capacity showed less quality deterioration after storage than when held in partially filled or smaller tanks.

Similar quantities of oil stored in the warmer areas showed greater deterioration than oil 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 many cases mixing of the oil could increase the market value of all the oil because of the small quantity of oil in the bottom as compared to that in the balance.

There should be no decrease in the market value owing to quality deterioration for average quality raw linseed oil, as produced, when stored up to 5 years in large tanks filled to capacity and located in the cooler areas of the U. S.

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 2 cents per pound) than the cost of deterioration if stored in the warmer areas, except for oils which were of the poorest quality at time of production. Some oils were estimated as having values as much as 4 cents per pound under the market for oil meeting specifications at 14 cents.

Since 1952 the highest market price (monthly average) has been 16 cents per pound and the lowest, 12.3 cents, with maximum difference of 3.7 cents and minimum difference of 0.7 cent in any 1 year. Storage costs average around 0.5 cent per pound per year and possible deterioration costs around 0.6 cent. Therefore, there was little opportunity for storage gain during the 1952-58 period if interest on capital investment also is taken into account.

The greater variations of most of the characteristics, in the bottoms oil in tanks after storage, indicate that with an average test value of the several samples taken to make up the composite of the balance oil instead of using the composite sample for testing of the balance--and using the relationships shown in the report for the several characteristics--the owner could arrive at more accurate estimates of the characteristics of the bottoms oil.

The methods of the 2 tests for foots are even more unreliable when applied to oil stored for 2 or more years than when used with fresh oil stored for less than a year.

There are no established methods to evaluate raw linseed oil that does not meet specifications. Methods used in the project to evaluate all of the lots of oil not meeting specifications are based on a summary of opinions from several members of industry who studied 6 of the 26 lots not meeting specifications with each lot having one or more characteristic beyond tolerance.

EVALUATING THE MARKET QUALITY OF COMMERCIALLY STORED LINSEED OIL

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BACKGROUND

During the crop years of 1948 and 1949, and later during 1952, 1953, and 1954, the Commodity Credit Corporation (CCC) acquired large quantities of flaxseed in the operation of the price support program. A large proportion of this was crushed for linseed oil and stored for periods up to 5 years prior to sale.

For the crop years of 1944, 1945, and 1946 (beginning July 1), flaxseed production in the United States had dropped to around one-half that of 1942 and 1943. During the war years of 1943 and 1944, considerable quantities of linseed oil were imported. With oil prices near 30 cents per pound during 1946, and even higher prices forecast for imported oil, price supports were increased under the support program from 96 percent of parity in 1945, and 115 in 1946, to 160 for the crop year of 1947. The producers of flaxseed responded to this higher support by doubling production in 1947 over 1946 and with a further increase in 1948.

With a support price of $5.75 per bushel (on a farm basis) for the crop years of 1947 and 1948 and the greatly increased production, the market price for oil dropped to below 18 cents per pound during the crop year of 1949. (table 1). The support price was lowered immediately (in 1949), and was further decreased in 1950, as shown in the table.

This set of conditions, as well as expired loans to producers in the support program, placed a big percentage of the flaxseed crop of 1948 in the hands of CCC (table 2).

The market price of the seed decreased further in 1949 and 1950 and for several years thereafter (table 1). During the years 1948-50 the seed acquired in 1948 was crushed for oil (table 2).

During 1951 some 300 million pounds of oil were set aside for possible needs in connection with the Korean war. This oil was not released for sale until late in 1953.

As shown in table 2, sales of CCC-owned oil were small between 1948 and 1953, except to some extent in 1950 and 1951. Up to July 1, 1953, only around 93 million pounds of oil of the almost 590 million pounds acquired since July 1, 1948 were sold.

During the crop years of 1952, 1953, and 1954, CCC again acquired some quantities of flaxseed (table 2), but a big percentage of this was sold as seed, and most of the oil produced from some of this seed in 1953 and 1954 was sold during these 2 years. This oil remained in storage for periods probably no longer than 1 year and, in this report, is called "fresh" oil. (Raw

Table 1.--Yield, price, and value of flaxseed products per bushel of flaxseed crushed, price received by farmers, and price-support level, 1947-58

Year beginning July	Oil			Meal			Total value	Season average price received by farmers	Level of support	
	Yield	Price 1/	Value	Yield	Price 1/	Value			Average support (farm basis)	Percentage of parity
	Lb.	Ct.	Dol.	Lb.	Ct.	Dol.	Dol.	Dol.	Dol.	Pct.
1947	19.8	29.5	5.84	35.1	4.0	1.40	7.24	6.15	5.75	160
1948	19.8	26.8	5.31	35.9	3.2	1.15	6.46	5.71	5.75	143
1949	19.5	17.7	3.45	37.1	3.2	1.19	4.64	3.63	3.74	90
1950	20.0	18.8	3.76	36.5	2.9	1.06	4.82	3.34	2.57	60
1951	20.1	16.7	3.36	36.1	3.3	1.19	4.55	3.72	2.65	60
1952	20.1	15.0	3.02	36.4	3.6	1.31	4.33	3.73	3.77	80
1953	19.8	14.8	2.93	36.0	3.3	1.19	4.12	3.64	3.79	80
1954	19.6	13.6	2.67	36.7	3.1	1.14	3.81	3.05	3.14	70
1955	19.9	14.0	2.79	36.8	2.8	1.03	3.82	2.90	2.91	65
1956	20.4	13.1	2.66	37.0	2.7	.99	3.67	2.99	3.09	70
1957	19.6	14.2	2.78	37.0	2.5	.92	3.70	2.94	2.92	65
1958								2/2.69	2.78	65

1/ Simple average price per pound using prices quoted at Minneapolis for raw oil in tank cars, and for 34 percent protein meal in bulk.
2/ Preliminary.

Bureau of the Census and U. S. Department of Agriculture.

Table 2.--Flaxseed production and flaxseed and linseed oil acquired and sold by the Commodity Credit Corporation in price support programs, 1947-58

Year beginning July	Flaxseed			Linseed oil under CCC price support operations					
	Production	Acquired by CCC		Acquired from crop of--					Sales
		Total	Proportion of production	1947	1948	1949	1952	1953	
	Mil. bu.	Mil. bu.	Pct.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.
1947	40.6	0.1	2	6.5					1/27.2
1948	54.8	24.6	45		297.6				3.1
1949	43.0	9.7	23		183.2				6.0
1950	40.2	2/	--		100.6	3/2.1			4/52.8
1951	34.7	2/	--						22.3
1952	30.2	4.9	16						9.2
1953	37.7	17.5	47				90.0	0.9	332.2
1954	41.3	8.7	21					97.7	282.2
1955	41.2	5/	--						--
1956	48.0	16.1	34						--
1957	25.8	3.3	13						--
1958	39.5	6/14.0							--

1/ Includes oil from flaxseed crushed prior to July 1, 1947.
2/ Less than 50,000 bushels.
3/ Only a small percentage of 1949 crop flaxseed crushed for oil.
4/ Does not include 300 million pounds set aside for possible defense needs. Sales of this oil as non-price support oil were not made until 1953 and 1954.
5/ Negligible.
6/ Preliminary.

Bureau of the Census, U. S. Department of Agriculture, and the Commodity Credit Corporation.

linseed oil is held in field tanks over such periods as general practice in industry.)

By July of 1953, some 490 million pounds of oil produced in 1948, 1949, and 1950 were held by CCC (including the 300 million pounds held for possible defense needs). This oil varied in age in storage around 4 to 5 years and for purposes of this report is called "stored" oil. It is so designated to distinguish it from the "fresh" oil produced in 1952 and 1953.

All oil produced for the account of CCC was required to meet Federal Specifications. U. S. Department of Agriculture commodity examination reports were available mostly from the years of 1953 and 1954 (and a few reports as far back as 1950), which was the time of sale for most of the oil handled by CCC between July 1947 and July 1955.

During 1953 and 1954 some 614 million pounds of oil were sold by CCC. These sales included 490 million pounds produced in 1948, 1949, and 1950 (stored oil) and 124 million pounds of the 190 million produced in 1952 and 1953 (fresh oil). Government commodity reports on 550 million of this 614 million pounds were studied and the data comprise this report.

OBJECTIVES AND ECONOMIC ASPECTS

This project is concerned primarily with analysis of data available for the linseed oil acquired by CCC prior to and during the years of 1953 and 1954, with particular attention to deterioration in quality during storage that might influence the market value of the oil.

Other objectives include determination of factors that affect the rate of deterioration of quality of oil in storage, and the costs of this decrease in relation to other costs of storage.

Although all oil produced for CCC was required to meet Federal specifications at time of production, some of the oil did not meet such specifications by the time it was sold. All of the oil was sold on world markets and prices received had no relation to domestic market value. Large quantities of the oil sold by CCC were sold on an "as is" basis.

A very small percentage of raw linseed oil enters the market as oil not meeting specifications. During 1957, a representative year, such oil offered for sale amounted to only 2 to 3 percent of total oil produced. Industry generally uses the specifications established by the National Flaxseed Processors Association which are similar to those set up by the American Society for Testing Materials, and to those of the Federal Government. (Oil for export often has to meet specifications established in foreign countries.)

Flaxseed can be mixed so as to produce oil meeting specifications; oil not meeting specifications is blended with a better grade of oil. In some cases oil can be reprocessed to bring it up to specifications. Any oil not meeting specifications has a lower market value. There are no methods established to place a value on this oil. Discounts may vary depending on a variety of conditions from either the buyer's or the seller's viewpoint.

In CCC's sales of fresh oil, the percentage of total oil not meeting specifications was about the same as that reported by industry for 1957. However, lots of oil stored for 4 to 5 years showed larger percentages not meeting specifications and, in order to determine the economic significance of these changes, some estimates of market value were necessary. Several members of the industry have cooperated in the project by estimating the value of several lots of oil not meeting specifications. From these estimates, values were placed on all the oil not meeting specifications.

The CCC operations in the storage of linseed oil are not part of an experimentally controlled project. However, the data represent large quantities of oil, crushed from large portions of several crops of flaxseed, and the conclusions drawn from them should be of value in any future operations of Government or industry involving the storage of large quantities of linseed oil.

FEDERAL SPECIFICATIONS FOR RAW LINSEED OIL

Flaxseed owned by CCC was crushed on a custom basis by privately owned mills. The oil produced was required to meet Federal specifications TT-O-369 for raw linseed oil, adopted January 28, 1948, which superseded Federal Specifications JJJ-O-336 dated April 28, 1931. These requirements are shown in table 13.

All of the analytical factors given in specifications for raw linseed oil are commonly used in testing most drying oils with the exception of "foots." 1/ The tests for "foots" are presumed to measure those constituents in linseed oil which are foreign to oil used for most purposes and that detract from its market value. The methods used do not measure these foreign materials accurately. At the present time, in spite of considerable research, no better methods have been devised.

Industry attaches varying degrees of importance to the various characteristics which determine the quality of raw linseed oil. The importance varies also, depending upon the use for which the oil is intended (table 14).

In spite of the unreliability of the tests for "heated" and "chilled" foots, when the oil does not meet the specifications in this respect, it is discounted in market value in greater amounts than when faulty in some other respect.

Several members of the industry were asked to record the frequency with which several characteristics caused raw linseed oil to fail to meet specifications. The following is a summary of their opinions of the causes of oil not meeting specifications, from the most to the least frequent:

1/ "Foots" are constituents not of use to oil in future processing. They are heavier than oil, include water, and settle to the bottom of the tank. The quality of the balance of the oil is thereby improved.

1. Heated foots
2. Chilled foots
3. Appearance
4. Iodine number
5. Acid number
6. Color
7. Loss on heating
8. Specific gravity
9. Unsaponifiable matter
10. Saponification number

When all the uses of oil are grouped together (table 14), the order of importance of the various characteristics compares closely with the frequency of the causes of oil not meeting specifications. In other words, excess amounts of heated and chilled foots are not only the most important of the characteristics, but occur most frequently as well. Also, specific gravity, unsaponifiable matter, and saponification number are least important and also occur least frequently.

QUALITY OF FRESH LINSEED OIL

Oil Not Meeting Specifications

During 1953 and 1954 over 124 million pounds of raw linseed oil were produced for CCC from the flaxseed crops of 1952 and 1953. All but about 64 million pounds of this oil was sold up to July 1955. There were no commodity examination reports available for about 6 million pounds of this oil. Some 115 million of the 118 million pounds sold, met specifications.

The main reasons the "non-spec" oil 2/ did not meet specifications were that it contained excessive amounts of heated and chilled foots, and was not clear in appearance (table 3). This agrees with industry's opinion as to the frequency with which these characteristics cause fresh oil not to meet specifications.

High unsaponifiable matter was the cause of non-spec oil in 6 samples. This does not agree with industry's opinion and could be accounted for in that these lots of oil may have been held in field tanks somewhat longer than in regular commercial practice. (It is shown later in this report that unsaponifiable matter can increase with storage.)

The table also shows that the characteristics causing non-spec oil other than foots and appearance, such as saponification number, iodine number, unsaponifiable matter, and loss on heating were not far from the tolerances allowed to meet specifications and altogether account for only about one-fourth of the total non-spec oil.

Of the 45 samples of non-spec oil (table 3), one characteristic alone was the cause in 28 samples, 2 characteristics in 9 samples, and 3 characteristics in 8 samples.

2/ "Non-spec" oil refers to oil not meeting Federal specifications.

Table 3.--Number of samples, quantity of fresh linseed oil not meeting specifications, and characteristics causing failure to meet them 1/

Number samples taken	Amount of non-spec oil	Characteristics of oil: Heated foots (range) 2/	Chilled foots (range) 3/	Saponification number 4/	Iodine number 5/	Unsaponifiable matter (range) 6/	Loss on heating 7/	Appearance 8/
	Lb.	Pct. by vol.	Pct. by vol.	ASTM units 9/	ASTM units 9/	Pct.	Pct.	
4	278,320	1.2-1.6						
7	433,490	1.4-2.4						Cloudy
8	494,700	1.2-11.2	4.8-13.2					Cloudy
8	434,710		4.8-7.6					
1	76,260			188				Cloudy
1	20,000				175			
1	283,000					1.67		
5	343,000					1.60-1.76		
1	61,520						0.36	Cloudy
9	568,860							Cloudy
45	2,993,860							
Number of samples not meeting specifications		19	16	1	1	6	1	26

1/ Oil crushed from 1952-53 crop in 1953-54. Age of oil from 0-1 year. designated as "fresh" oil. All oil met specifications for specific gravity, acid number, and color.
2/ Maximum limit under specifications - 1.0 percent by volume.
3/ Maximum limit under specifications - 4.0 percent by volume.
4/ Minimum limit under specifications - 189 in ASTM units.
5/ Minimum limit under specifications - 177 in ASTM units.
6/ Maximum limit under specifications - 1.5 percent.
7/ Maximum limit under specifications - .3 percent.
8/ Specifications for appearance - must be clear.
9/ Units in use in Standard Methods of the American Society for Testing materials.

Variations in Fresh Oil

During the CCC operations many samples were taken while the oil was being transferred from large field tanks to tank cars. Tests were made on the samples within a few days and mostly at the same laboratory. The data (table 15) represent 8 large field tanks. The statistical analysis for each of the characteristics (except appearance and color) provide coefficients of variation for all tanks and all characteristics.

The coefficients of variation allow for a comparison between the several tanks and the several characteristics, and can be considered as measuring inversely the degree of reliability or accuracy of the tests between the tanks and the characteristics shown.

From these data, it appears that the tests for "foots" are not as reliable as some of the other tests, such as saponification number and iodine number. For example, when a number of samples (which were almost identical) are tested for chilled foots with an average value of 4.0 percent by volume (the limit under specifications), 1 out of 3 samples could test higher than 4.9 percent.

QUALITY OF STORED LINSEED OIL

Almost 23 percent--111 million pounds--of approximately 490 million pounds of the oil held in storage did not meet Federal specifications and normally would be discounted in price. This oil was part of the some 584 million pounds crushed during 1948, 1949, and 1950 from mostly the 1948 crop of flaxseed (table 2). (About 93.4 million pounds were sold by CCC through the fiscal year of 1952 for which no data are available.) It is estimated that this 490 million pounds of oil had been held in storage from 4 to 5 years at the time of the final tests. There are no established methods to determine the value of the 111 million pounds of oil not meeting specifications. Some estimates are reported under the heading, "Market Evaluation of Linseed Oil Not Meeting Specifications."

Areas of Storage

The oil was placed in field tanks for immediate or future sale. (CCC had no intentions of retaining oil any longer than is done in commercial practice.) Most of the oil was stored at or near seaports. Climate and size of tanks used were not considerations.

In general, inspectors reported that the tanks used were in good condition, except for some in the New York City area. Tanks were used to capacity in most cases. Tank capacities varied from around 200,000 pounds of oil up to around 20,000,000 pounds and most tanks were cylindrical.

The inventory reported by CCC as of May 15, 1953, can be divided into general areas of the country, as shown in table 4.

The table also shows the amount of oil not meeting specifications in each of the 4 areas. There is clearly a relationship shown between the areas and the proportion of oil in the area not meeting specifications. This relationship is discussed further under the heading, "Location of Storage," in connection with "Conditions Affecting Quality of Stored Oil." 3/

3/ From related and unpublished work now in progress, high ambient temperature during the storage of vegetable oils is a most important factor causing degrading of the quality.

Table 4.--Quantities of linseed oil in storage 4 to 5 years and proportions not meeting Federal specifications, by storage location, May 15, 1953 1/

Area number	General location 2/	Total oil in storage	Oil not meeting specifications	
			Amount	Proportion
		Pounds	Pounds	Percent
I	Northern	42,220,625	0	0
II	Western	77,274,551	223,720	.3
III	Eastern	311,671,973	52,755,542	16.9
IV	Southern	57,992,402	57,992,402	100.0
	Total	3/489,159,551	3/110,971,664	22.7

1/ All the oil met specifications at time of production. Specifications did not enter sales transactions which were made after this date, as the oil was sold "as is." Tests were made at time of release from storage.

2/ Areas include the following:
- I Northern - General area of Minneapolis, St. Paul-Chicago and Great Lakes ports.
- II Western - General area of San Francisco and Los Angeles.
- III Eastern - General area of Baltimore, Philadelphia, and New York.
- IV Southern - General area of Southeastern Texas and New Orleans.

3/ The figures do not include some oil sold previous to May 15, 1953.

Oil Not Meeting Specifications

Characteristics of the various lots of stored oil (just prior to sale by CCC) are shown in table 5 for the almost 111 million pounds not meeting specifications.

Of the 42 tanks listed in the table, only 3 samples were taken from the tanks as a whole. These samples represented 10,837,594 pounds of oil or about 10 percent of the oil not meeting specifications. After around 1 year in storage, "foots" had started settling to the bottom of the tanks and separate samples were taken for tests of the "bottoms" of the tank and the rest of the tank, which is the "balance." 4/

None of the bottoms met specifications, but 8 of the balances did. Samples of the bottoms represented 2,701,317 pounds of oil or over 2 percent of all the oil not meeting specifications and the balances, 97,432,753 pounds or about 88 percent of the total oil not meeting specifications.

4/ The "bottoms" of the tank should contain all the settled foots and little of the clear oil which makes up the "balance" of the tank. The amount of "bottoms" decreases as the foots settle. After several years of storage, usually the foots have all settled to the bottom 6 inches of the tank.

Table 5.--Quantity and characteristics of linseed oil not meeting Federal specifications at end of storage period of 4 to 5 years

Tank number	Storage area	Laboratory number	Quantity and location of oil in tank		Characteristics of oil not meeting specifications 2/: Heated foots	Chilled foots	Specific gravity	Acid number	Saponification number	Iodine number	Unsaponifiable matter	Loss on heating	Appearance
			Lb.		Pct. by vol.	Pct. by vol.	G./ml.	ASTM units	ASTM units	ASTM units	Pct.	Pct.	
1	II	6	216,270	Balance				4.10					
			7,450	Bottoms				4.20					
2	III	10	174,413	Balance				4.63			1.69		
			4,672	Bottoms				4.83			1.89		Not clear
3	III	10	251,203	Balance							1.80		
			7,809	Bottoms							1.65		
4	III	10	190,385	Balance				4.79					
			4,720	Bottoms				5.31			1.65	0.63	Not clear
5	III	10	428,135	Balance							1.63	.37	
			10,615	Bottoms				4.82			1.67	.37	Not clear
6	III	10	192,744	Balance							1.70		
			4,701	Bottoms	1.6	8.0		4.22			1.70		Not clear
7	III	10	178,211	Balance							1.70		
			4,731	Bottoms	3.2	5.6		6.17			1.65		Not clear
8	III	10	9,628	Bottoms				4.23			1.82		
9	III	10	440,066	Balance				4.54			1.61		
			9,601	Bottoms	2.0			5.21			1.67	.38	Not clear
10	III	10	4,848,743	Balance				4.52					
			57,382	Bottoms	1.2	8.0		4.58			1.57		Not clear
11	III	10	14,859	Bottoms				4.26					
12	III	10	756,999	Balance				4.40					
			14,194	Bottoms				4.39					
13	III	10	5,075,246	Balance				5.36					
			57,025	Bottoms				6.68			1.67		Not clear
14	III	10	1,832,922	Balance							1.61		
			36,658	Bottoms				4.18			1.85		
15	III	10	439,359	Balance				4.12					
			11,716	Bottoms	2.0			4.19			1.72		Not clear
16	III	10	368,642	Balance				5.35					
			9,178	Bottoms	2.0		0.944	6.81	164	157	1.62		Not clear
17	III	10	411,212	Balance				4.26					
			9,038	Bottoms	3.2	4.8		4.42			1.67		Not clear
18	III	10	36,094	Bottoms	1.6	4.8		4.48			1.73		Not clear
19	III	10	36,467	Bottoms							1.62		Not clear
20	III	10	214,032	Balance				4.40					
			7,368	Bottoms				5.34				.41	Not clear
21	III	10	765,042	Balance				4.63					
			14,389	Bottoms				5.10					Not clear
22	III	10	760,256	Balance				4.22					
			14,858	Bottoms				4.52			1.67		
23	III	10	3,968,945	Balance							1.62		
			69,226	Bottoms	4.5	12.0	.938				2.11		Not clear

- Continued

24	III	10	3,863,074	Balance							1.65		
			70,238	Bottoms	1.5	8.0					1.63		Not clear
25	III	10	54,713	Bottoms	2.6	6.0							Not clear
26	III	10	55,876	Bottoms	16.0	40.0		4.53			1.86		Not clear
27	III	10	29,932	Bottoms	4.0	8.0							Not clear
28	III	10	2,799,349	Balance							1.82		
			36,434	Bottoms							1.66		
29	III	10	3,244,927	Balance						174			
			80,955	Bottoms	1.2		.938		183	162	1.84	5.40	Not clear
30	III	10	3,244,513	Balance						173			
			47,136	Bottoms	3.6	10.0				172			Not clear
31	III	10	3,309,054	Balance						173			
			41,106	Bottoms						172		2.50	Not clear
32	III	10	423,477	Whole tank	28.0	60.0		8.99		166	1.90	1.80	Not clear
33	III	10	2,996,385	Balance						171			
			56,182	Bottoms						169	1.66		Not clear
34	III	10	2,161,297	Whole tank	24.0	40.0	.939	5.13		176	1.82	.33	Not clear
35	III	10	8,252,820	Whole tank							1.68		
36	III	10	246,591	Bottoms									Not clear
37	IV	7	15,534,219	Balance							1.68		
			589,907	Bottoms							1.61		
38	IV	7	17,310,670	Balance							1.66		
			473,184	Bottoms	4.0	12.0					1.67		Not clear
39 3/	IV	8	16,742,681	Balance				4.20			1.57		Not clear
			308,147	Bottoms	2.0			5.68			1.60		Not clear
40 3/	IV	8	3,810,293	Balance				5.32					
			102,981	Bottoms				5.32					Not clear
41 3/	IV	8	1,525,590	Balance				8.50					
			27,571	Bottoms				12.22		176		1.65	Not clear
42 3/	IV	8	1,539,174	Balance				7.10					
			27,985	Bottoms	2.2			17.40		176	1.89	.89	Not clear
Total			110,971,664		20	14	4	44	2	13	43	11	33

1/ See table 4 for storage areas. Bottoms of tanks were in most cases 6 inches deep.
2/ See table 13 for Federal specifications. All oil met specifications for color.
3/ Contained oil tested several times during storage. Last characteristics only are shown.

Of the 73 lots of oil (3 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 due only to 1 characteristic beyond tolerance, whereas 33 lots were non-spec due to from 2 to 5 characteristics being beyond tolerance. Two lots were non-spec due to all characteristics being beyond tolerance except color. All oils (fresh and stored) met specifications for color.

Differences in Fresh and Stored Oil

The causes of not meeting specifications were quite different in oil stored 4 to 5 years and in oil stored only a short period of up to 1 year. Whereas the fresh oil did not meet specifications mostly due to high heated foots, high chilled foots, and cloudy appearances, the stored oil was non-spec because of high acid numbers and high unsaponifiable matter, with high heated and chilled foots, and cloudiness being of secondary importance (table 6).

Table 6.--Comparison of number of samples of fresh and stored linseed oil not meeting Federal specifications, by characteristics 1/

Characteristics tested 2/	Fresh oil		Stored oil		Difference stored from fresh oil
	Samples	Proportion of total samples	Samples	Proportion of total samples	
	Number	Percent	Number	Percent	Percent
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	-.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 characteristics	70	100.0	184	100.0	
Total samples	45		73		

1/ Fresh oil in storage 1 year or less, located mostly in eastern area of U. S. and made from 1952-53 crop of flaxseed. Stored oil in storage from 4 to 5 years, located mostly in eastern area of U. S. and made mostly from 1948 crop of flaxseed.

2/ See table 13 for specifications.

The fresh oil was held in field tanks in the eastern area of the U. S., which area also provided storage for most of the stored oil. In other words, the fresh and stored oils were held under similar conditions and probably came from the same general area, namely, the northern flaxseed belt. (No records are available of production of any of the oils.) The table therefore can be used as an indication of possible changes that could occur in oils while stored in the eastern area. The following estimates of changes in the characteristics during storage can be made:

(1) Some decrease in the heated and chilled foots (settling no doubt would greatly improve the bulk of the oil, with most of the foots in the bottoms).
(2) Increase in the acid number.
(3) Increase in the unsaponifiable matter.
(4) Some improvement in appearance.
(5) Some decrease in the iodine number.

Changes During Storage

Although there were a number of tanks of oil stored by CCC without commingling, or with their identity preserved, reports are available for only 4 of these tanks (table 7). All of the oil in these tanks increased in acid number and unsaponifiable matter. High acid number was the only reason that the oil in tank No. 101--containing almost 4 million pounds--did not meet specifications. The oil in tank No. 104--containing over 17 million pounds-- was non-spec, due to both acid number slightly over 4 and unsaponifiable matter just beyond tolerance of 1.5 percent. The oil in the two smaller tanks (Nos. 102 and 103) showed all characteristics beyond tolerances in the bottoms (except color), to cause this oil to be rejected under specifications. However, only excessive acid number and high unsaponifiable matter were the causes of the oil in the balances not meeting specifications (table 8).

Table 7.--Quantity and height of oil, size of tank, and samples taken from four tanks of linseed oil after 4 to 5 years' storage 1/

Tank number	Quantity of oil in pounds	Height of oil in tank 2/	Size of tank		Samples taken	
			Height	Diameter	Location in tank 3/	Number
101	3,912,528	18' 11¾"	35'	70'	Balance	8
					Bottoms	8
102	1,553,161	28' 2 1/8"	29' 9 7/8"	35'	All oil	7
					Balance	10
					Bottoms	10
103	1,567,159	28' 4 3/8"	29' 8½"	35'	All oil	7
					Balance	10
					Bottoms	10
104	4/17,050,828	27' 7¾"	41' 5"	117' 6"	Balance	10
					Bottoms	7

1/ Oil from same mill, stored on the same tank farm at same time in southeastern Texas. 2/ Measurements taken during July 1953. 3/ Bottoms were mostly 6 inches deep, except for first few samples which ranged from 3 feet down to 18 inches. Where "all oil" is shown no foots were observed until after 27 months. 4/ Weight in tank after 36 months.

Table 8.--Characteristics of samples of linseed oil taken from two tanks after specified periods in storage 1/

Tank number	Location of oil sampled in tank	Length of time oil had been in storage when tested	Heated foots	Chilled foots	Acid number	Saponification number	Iodine number	Unsaponifiable matter	Loss on heating	Specific gravity
		Months	Pct. by vol.	Pct. by vol.	ASTM units	ASTM units	ASTM units	Pct.	Pct.	G./ml.
102	All oil 2/	10	0.22	1.17	4.64	192.61	181.75	1.13	0.09	0.9346
		27	.33	2.07	5.89	190.92	178.77	1.63	.11	.9319
	Balance	32	.16	.65	5.95	191.35	179.01	1.48	.14	.9322
		53	.17	.59	8.55	190.86	178.05	1.50	.18	.9320
	Bottoms	32	.95	9.05	8.31	189.42	177.07	1.51	1.26	.9306
		53	2.66	11.43	17.74	184.50	170.97	1.53	3.94	.9367
	Total 3/	10	.28	1.75	4.40	192.31	180.76	1.34	.09	.9336
		53	.19	.64	8.30	190.73	177.77	1.54	.20	.9317
103	All oil 2/	10	.07	.30	3.66	192.54	180.62	1.18	.07	.9336
		27	.22	1.04	5.74	191.04	178.96	1.57	.08	.9322
	Balance	32	.16	.41	5.77	192.74	179.99	1.48	.08	.9316
		53	.15	.43	7.11	191.09	178.33	1.47	.09	.9321
	Bottoms	32	.26	2.94	5.11	192.48	179.09	1.49	.10	.9313
		53	3.58	10.13	14.17	188.97	176.09	1.74	.76	.9343
	Total 3/	10	.19	.84	3.96	192.13	180.36	1.34	.07	.9330
		53	.21	.52	7.16	191.56	178.29	1.52	.09	.9317

1/ Oil from same source and mill, placed at same tank farm at same time in southeastern Texas and stored for 4 to 5 years. Quantities of about 1,560,000 pounds in tanks of about same dimensions. All data taken from correlations (not shown), except heated and chilled foots which were laboratory analyses.

2/ Oil was mixed before samples were taken.

3/ Calculated from characteristics of "all oil" and weighted balance and bottoms.

Great decreases in quality were noted in the oil in the smaller tanks. In order to arrive at the most probable extent of change in characteristics of the oil in these tanks, characteristics for both tanks were combined statistically around a common average of each. Further, in order to obtain characteristics for all the oil in each tank as a lot, characteristics of the oil in the balances and bottoms were averaged on a weighted basis (32d through the 53rd months) and combined with the characteristics from samples (taken between the 10th and 27th months) after the oil was previously mixed by agitation. The results are shown in table 16.

The changes in quality over the storage period that in general confirm the differences between fresh and stored oil shown in table 6, are as follows:

1. Acid number--a much higher incidence of oil not meeting specifications after storage than for fresh oil.
2. Saponification number--very little difference between fresh and stored oil, although the table shows a tendency for this characteristic to decrease with storage.
3. Iodine number--small decreases over the storage period (only a few lots of oil showed low iodine number to be a cause of non-spec oil).
4. Unsaponifiable matter--definite increases over the storage period to cause the stored oils to become non-spec more often than in the case of fresh oil.
5. Loss on heating--very little increase for the oil as a whole; however, as previously shown, there can be large increases in loss on heating in the bottoms, while the balances of the tank remain quite constant during storage. 5/
6. Specific gravity--there were small decreases; however, only a few of the stored oils did not meet specification for this characteristic.

Table 8 shows that the oil not meeting specifications due to high heated and chilled foots was almost entirely from the bottoms of tanks. Due to the smaller amount of oil in the bottoms than in the balances, the total oil was within tolerance for both the foots tests.

CONDITIONS AFFECTING QUALITY OF STORED OIL

Quantity of Oil

Oil stored in large quantities showed better quality than oil stored in smaller quantities at the same location. The oil in the smaller tanks had higher acid numbers both in the balances and bottoms. However, although few of any of the tanks containing various quantities of oil had iodine number

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5/ The test "loss on heating" measures essentially the amount of water in the sample, which may be present in solution in the oil, suspended in the oil, or as free water. Although water can enter the tank from rain, snow, or moisture in the air, no doubt most of it gets in through condensation in the air space above the oil due to atmospheric variations. The oil can only hold so much water in solution at a definite temperature; excess moisture drops to the bottom of the tank.

below specifications, there were decreases in this characteristic as the tanks were larger (containing greater amounts of oil). There were little differences in the loss on heating in the balances of all tanks, but the larger tanks showed large increases over the small tanks in the bottoms.

During December 1953, after 4 to 5 years' storage at or near the port of New York City, data were available from 30 tanks of oil totaling almost 46 million pounds. A big proportion of this oil did not meet specifications.

Tanks varied in size from 14 to 55 feet in diameter and from 21 to 42 feet in height. All were cylindrical. All the tanks were filled to capacity. Tests were made of the oil in both the balance and bottoms of each tank. A relation between the total quantity of oil in the tanks and several of the characteristics in the balance, bottoms, and total oil of the tanks is evident in table 17.

Mixing of the oil at the end of the storage period in this area probably would not have improved the market value to any great extent over the total values of the balances and bottoms disposed of separately.

Of the total oil stored in the New York City area, 10 tank balances met all specifications but only 2 bottoms were satisfactory.

Calculations were made by combining on a weighted basis the characteristics of the balances and bottoms to arrive at a characteristic for all the oil in each tank. These data are not shown in the report. Appearance can not be calculated for such mixtures (25 tanks were cloudy in the bottoms).

If it is assumed that the mixtures would pass specifications for appearance, the calculated characteristics for the tanks of oil showed only 2 tanks could be mixed to meet specifications. These data are not shown.

Although the other 28 tanks in the area meet specifications (by calculations) for heated foots, chilled foots, saponification number and specific gravity, the high incidence of high acid number and high unsaponifiable matter in the balances of the tanks, as well as in the bottoms, precluded the possibility of upgrading the oil by mixing. 6/

Location of Storage

For similar quantities of oil stored in the southern area and in the eastern area the quality was not as good in the South. Acid number increased far more in Texas than in the New York area for both balance and bottoms of the tanks. Loss on heating increased in the bottoms of tanks in Texas far more than in New York by the end of the storage period. There were greater differences between the balance and bottoms of tanks in Texas compared to New York for saponification number, iodine number, unsaponifiable matter, and specific gravity.

6/ No information is available as to the equipment in the tanks at that time to provide agitation for mixing.

The warmer atmospheric conditions in the South no doubt contributed more to deterioration of the oil. This was shown in a previous discussion and with further data a better comparison between the 2 areas can be made.

Although the oil in the 2 areas came from the same crop of flaxseed and was held in storage during the same period, there is no information available as to the source. Bearing this limitation of the data in mind, characteristics of a tank of oil in the eastern area can be compared to the tanks (of similar size) in the southern area. In order to eliminate variations in sampling and testing as much as possible, data are taken from table 16 and calculations made from table 17 to give the data shown in table 9.

Under the column headed "New York City," acid number, loss on heating, and iodine number were calculated from table 17 for a tank of oil holding around 1,560,000 pounds (about the average of the 2 tanks of oil in the Texas area). It was assumed that saponification number, unsaponifiable matter, and specific gravity varied little as to the quantity of oil in the New York area and averages for these characteristics were taken.

Under the "Texas" column, characteristics shown in the table are averages for the 2 tanks numbered 102 and 103 (tables 7 and 8) at the end of 53 months of storage.

The difference in quality of the oil in the two areas can be summed up as follows:

(1) The New York oil 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

(2) The Texas oil 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

There are significant relationships between the balance and bottoms oil in tanks for some of the characteristics. For 80 samples each of the oil in the balance and bottoms of tanks, all characteristics showed significant degrees of relationship except specific gravity and loss on heating. Samples include 38 taken during storage and 42 at the end of storage.

Previous discussion has shown the variability of characteristics of samples taken of the same lots of oil, due not only to the methods and techniques used in testing but more particularly to 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 greater than in the balance of the tanks. (Foots in the bottoms of tanks can cause stratification; free water makes representative samples difficult to obtain.) The oil in the balance of the tank is more

Table 9.--Comparison of selected characteristics of linseed oil stored in New York City and Texas areas 1/

Characteristic 2/	Location in tanks 3/	New York City 4/	Texas 5/
Acid number....ASTM units 6/	Balance	3.87	7.83
Do.	Bottoms	4.38	15.95
Loss on heating....Percent 7/	Balance	.12	.14
Do.	Bottoms	.16	2.35
Saponification number....ASTM units 8/	Balance	190.76	190.97
Do.	Bottoms	190.17	186.73
Iodine number....ASTM units 9/	Balance	181.27	178.19
Do.	Bottoms	179.30	173.52
Unsaponifiable matter....percent 10/	Balance	1.51	1.48
Do.	Bottoms	1.63	1.64
Specific gravity....g./ml. 11/	Balance	.9328	.9321
Do.	Bottoms	.9343	.9350

1/ Oil stored 4 to 5 years at same time in both locations. Oil probably from different sources. Tanks approximately 35 feet in diameter and 30 feet in height filled to within a few feet of top.
2/ In accordance with Federal specifications TT-0-369.
3/ Bottoms were 6 inches deep in Texas area.
4/ Data taken from table 17 for a tank holding approximately 1,564,000 pounds of oil.
5/ Average of tanks numbered 102 and 103 (holding 1,556,091 pounds and 1,572,042 pounds of oil, respectively), at end of storage period.
6/ Specifications permit maximum of 4.
7/ Specifications permit maximum of 0.3.
8/ Specifications permit a minimum of 189 and maximum of 195.
9/ Specifications permit a minimum of 177.
10/ Specifications permit a maximum of 1.5.
11/ Specifications permit a minimum of 0.931 and maximum of 0.936.

homogeneous and the several samples taken to make a composite give more representative samples for the balance.

In view of the large number of samples taken in the CCC operations, correlations were made to determine the relationship between the characteristics of the balance and bottoms samples. If enough significance can be attached to these relationships, the characteristics of the balance in the tank of oil could predict the characteristics of the bottoms. Only the one sampling would be necessary and from the relationships the characteristic for the bottoms could be provided of less variability and more accuracy than by actual sampling and testing the bottoms.

There were only small differences in the relationships between the characteristics in the balances and bottoms of the tanks during the storage period and at the end of storage. Accordingly, all 80 observations were grouped together to get the relationships shown in table 18.

No relationship is shown for specific gravity; however, from statistical correlation there were no differences in the bottoms (around 0.936) where the balance varied between 0.930 and 0.936. (Few oils did not meet specifications due to specific gravity not being within tolerances.)

There can be no relationship for loss on heating between the balance and bottoms of tanks. It has been previously indicated that the loss on heating in the balance remains quite constant throughout the storage period while loss on heating in the bottoms increases with storage, the rate of increase depending on several conditions.

Based on the previous tables, some estimates can be made of the characteristics in the balance of the tanks, when the bottoms have reached a value causing non-spec oil.

Characteristic	Balance	Bottoms
Acid number	3.5	4
Saponification number	190.5	189
Iodine number	178.9	177
Unsaponifiable matter	1.35	1.50

THE HEATED AND CHILLED FOOTS TESTS

Not only are the heated and chilled foots tests unreliable when applied to the fresh oils (due to sampling and testing methods), the variations for stored oils are far greater.

There were insignificant relationships between these characteristics in fresh oil; however, with large numbers of samples of stored oils, there were significant relationships.

In view of the economic importance of these characteristics and their high incidence of frequency causing the oils to not meet specifications, the large number of tests made during the CCC operations have provided data which confirm the unreliability of these tests, which has been recognized by industry for a period of years.

Variations in Fresh and Stored Oils

The wide variations of a number of samples taken from the same tanks of fresh oil were discussed under the heading, "Variations in Fresh Oil." The coefficients of variation for all 393 samples taken for these tests have been given in table 15.

It was estimated that there were insignificant changes for these characteristics during storage of the 4 tanks of identity preserved oil in the southern area. In other words, during the periods of time shown in these tables these characteristics remained constant. These 131 samples were grouped according to source, namely, the balance, bottoms, all oil, and total oil in each of the 4 tanks. A summary of all of these groups statistically calculated show combined coefficients of variation around a common average which 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 percent by volume, 1 out of 3 samples in the fresh oil could test higher than 4.9 and in the stored oil higher than 8.4.

Relationship of Heated to Chilled Foots in Fresh and Stored Oils

There were insignificant relationships between the heated foots and the chilled foots in any of 8 large tanks of fresh oil, where samples of from 19 to 118 were taken in the tanks. Nor were there any significant relationships for all the 393 samples taken from all the tanks. 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 between the heated foots and the chilled foots when tests were made on samples taken from either the balances or bottoms separately or both together, for the oils during storage and at the end of storage. Good relationships were also found for all balances, all bottoms, and all total oil during storage, end of storage, and when both are taken together, and, as well, for all samples during storage, at end of storage, and all grouped together.

The heated and chilled foots of all the samples taken from the 4 tanks of identity preserved stored oil in the southern area throughout the entire storage periods were used for a series of correlations, along with those of the 38 samples of oil taken only at the end of the storage period in the eastern area. The former are said to be "during storage" and the latter "end of storage."

(End of storage also includes the last values of the identity preserved oils.) Heated and chilled foots tests were made of balances and bottoms of tanks and, as well, of the mixed oil prior to samples being taken of balance and bottoms. Table 19 also includes relationships for "total" oil, which includes characteristics for all oil and calculated characteristics on a weighted basis, as if the tanks were mixed throughout the storage period and only 1 sample taken instead of 1 each for balance and bottoms.

Although there are highly significant relationships shown in table 19 between the 2 characteristics, there are various differences in the relationships depending on the source of the samples. For a given heated foots taken during the storage period, higher values are shown for the chilled foots than at the end of storage. Or to further exemplify, with a heated foots of 1, the chilled foots varies all the way from 1.5 to as high as 5.6 depending on the source of the sample. This is shown in the following:

	Balance	Bottoms	Total
(1) During storage	5.8	4.0	5.6
(2) End of storage	1.5	2.9	1.8
(3) Both during and at end of storage	5.0	3.5	2.1
(4) 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 percent 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 was to measure the amount of the non-oil constituents in the sample. Limits in the specifications for satisfactory oil have been set at 1 percent by volume for heated foots and 4 percent by volume for chilled foots, or in a ratio of 1 to 4. For the fresh oils tested in the project the ratio was higher and for all of the stored oils, it was generally lower. 7/

7/ The correlation coefficient of 0.9153 (shown in table 19) obtained for the total of 264 tests each for heated and chilled foots is somewhat less than the 0.970 shown by N. J. Shaw, J. W. Garrett, and S. O. Sorensen in their paper, "A Comparison of Several Methods for Determination of Non-Oil 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 from some 49 samples of wide variation in heated and chilled foots.

The relations shown in the table combine tests made in 2 different laboratories. The tests made "during storage" which show a correlation coefficient of 0.8143 were made in a different laboratory from the test at the "end of storage" which give a correlation coefficient of 0.9780.

MARKET EVALUATION OF LINSEED OIL NOT MEETING SPECIFICATIONS

Several members of industry have cooperated in placing range of prices for several lots of oil not meeting specifications. The summary of these estimates is given in table 10.

Table 10.--Estimated prices of raw linseed oil not meeting specifications 1/

Sample number	Range of characteristics not meeting specifications 2/	Estimated prices 3/		Averages of medians 6/	Discount from 14 cents 7/
		Low 4/	High 5/		
		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

1/ Prices estimated by industry cooperators.
2/ The oils chosen were representative of the stored oils not meeting specifications.
3/ Each industry cooperator gave his estimate over a range of low to high for each oil.
4/ The lowest price of all the low prices in the ranges estimated.
5/ The highest price of all the high prices in the ranges estimated.
6/ The median price of all the estimates was averaged for each oil.
7/ A price of 14 cents was used for oil meeting specifications.

The estimated discounts shown in the table agree quite well with the importance of the various characteristics causing non-spec oil as shown previously in table 14.

The 6 oils shown in the table 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 also, 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 14 cents per pound for oil meeting specifications), by using the prices in table 10 and relating the importance of the various characteristics as shown previously from the opinions of industry. For example, a price of 13.594 cents per pound was placed on an oil not meeting specifications due only to appearance. It was assumed also that as more characteristics did not meet specifications, the price of the oil would be discounted further by adding discounts for each characteristic not meeting specifications. The 26 different combinations of characteristics causing all the stored non-spec oil are shown in table 11.

Using the estimated values as shown in the table, a summary gives estimated costs due to quality deterioration in table 12.

Table 11.--Estimated price and value of specified lots of stored raw linseed oil not meeting Federal specifications

Characteristics of oil not meeting specifications 1/	Number of non-spec characteristics	Numbers of tanks tested 2/	Quantity of oil not meeting specifications	Estimated price per pound 3/	Estimated value
			Pounds	Cents	Dollars
Acid number	1	1, 4, 10, 11-13, 15-17, 20-22, 40-42	20,957,746	13.355	2,798,907
Iodine number	1	29-31, 33	12,794,879	13.075	1,672,930
Unsaponifiable matter	1	3, 6, 7, 14, 23, 24, 28, 35, 38	54,818,307	13.797	7,563,282
Appearance	1	36	246,591	13.594	33,522
Acid, unsaponifiable matter	2	2, 8, 9, 14, 22	675,623	13.192	89,128
Loss on heating, unsaponifiable matter	2	5	428,135	13.152	56,308
Appearance, unsaponifiable matter	2	19	36,467	13.390	4,749
Acid number, appearance	2	21, 40	117,370	12.949	15,198
Acid number, unsaponifiable matter, appearance	3	2, 13, 39	16,804,378	12.746	2,141,886
Acid number, loss on heating, appearance	3	20	7,368	12.304	907
Heated foots, chilled foots, appearance	3	25, 27	84,645	12.080	10,225
Iodine number, loss on heating, appearance	3	31	41,106	12.024	4,942
Iodine number, unsaponifiable matter, appearance	3	33	56,182	12.466	7,004
Acid, unsaponifiable matter, loss, appearance	4	4, 5	15,335	12.101	1,856
Heated foots, acid, unsaponifiable matter, appearance	4	15, 39	319,863	11.994	38,364
Heated foots, chilled foots, unsaponifiable matter, appearance	4	24, 39	543,422	11.877	64,542
Acid, loss, iodine, appearance	4	41	27,571	11.379	3,137
Heated foots, chilled foots, iodine, appearance	4	30	47,136	11.155	5,258
Heated foots, chilled foots, acid, unsaponifiable matter, appearance	5	6, 7, 10, 17, 18, 26	167,822	11.232	18,850
Heated foots, acid, unsaponifiable matter, loss, appearance	5	9	9,601	11.552	1,109
Heated foots, chilled foots, specific gravity, unsaponifiable matter, appearance	5	23	69,226	11.674	8,081
Heated foots, acid, unsaponifiable matter, loss, iodine, appearance	6	42	27,985	10.627	2,974
Heated foots, gravity, acid, unsaponifiable matter, iodine, saponification, appearance	7	16	9,178	10.866	997
Heated foots, chilled foots, loss, acid, unsaponifiable matter, iodine, appearance	7	32	423,477	9.662	40,916
All except saponification number 4/	8	34	2,161,297	9.459	204,437
All except acid number 4/	8	29	80,955	9.901	8,015

1/ No oil was reported "off" in color at the end of the storage period.
2/ See table 5 for individual lots of oil and identification of balance and bottoms in tanks.
3/ Based on 14 cents per pound for oil meeting specifications. See table 10 for industry evaluations. Estimates of the following prices based on discounts, were made from tables 10 and 14: Unsaponifiable matter at 0.610 cents, appearance at 0.406 cents, specific gravity at 0.203 cents and saponification number at 0.203 cents. Where more than one characteristic did not meet specifications, discounts for each were added in order to estimate price.
4/ Color not included--all oils met color specification.

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4/ Color not included--all oils met color specification.

Table 12.--Estimated costs of quality deterioration of stored linseed oil 1/

General location of storage 2/	Quantity of total oil stored	Oil not meeting specifications				Estimated loss in price per pound from storage deterioration 3/	
		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

1/ Oil stored 4 to 5 years at 4 general locations, mostly from 1948 flaxseed crop.
2/ See table 4 for areas.
3/ Oil meeting specifications was priced at 14 cents per pound.

Table 13.--Federal specifications for raw linseed oil 1/

Characteristics	Quantitative requirements	
	Minimum	Maximum
Foots:		
Heated oil (percent by volume)	---	1.0
Chilled oil (percent by volume)	---	4.0
Specific gravity $15.5^{\circ}/15.5^{\circ}$ C.	0.931	.936
Acid number	---	4.0
Saponification number	189	195
Unsaponifiable matter (percent by weight)	---	1.5
Iodine number (Wijs)	177	---
Loss on heating at $105^{\circ} \pm 2^{\circ}$ C. (percent by weight)	---	.3
	Qualitative requirements	
Color	The oil shall be no darker than a solution of 1.0 gram of reagent-grade potassium dichromate in 100 milliliters of concentrated sulfuric acid (sp. gr. 1.84). The No. 15 tube of the Gardner Color Scale (1933) or the No. 7 Standard of the Hellige Color Comparator may be used as secondary standards.	
Appearance	The oil shall be clear and transparent at 65° C. when examined by transmitted light.	

1/ All methods used are those of the American Society for Testing Materials under D-555-47, except specific gravity and loss on heating which use higher temperatures for these two determinations.

Source: Federal Standard Stock Catalog, Section IV (Part 5), Federal Specification for Oil; Linseed, Raw (For Use in Organic Coatings) TT-0-369, January 28, 1948, page 2.

Table 14.--Importance of characteristics in determining quality of raw linseed oil when used for specified end-products 1/

Order of importance	Characteristics of oil to consider when oil is to be used in--			
	Paint	Varnish	Linoleum	Printing ink
Most important	Iodine number	Chilled foots	Heated foots	Heated foots
	Acid number	Heated foots	Chilled foots	Chilled foots
	Heated foots	Acid number	Iodine number	Color
Less important	Color	Iodine number	Loss on heating	Acid number
	Loss on heating	Color	Acid number	Iodine number
	Appearance	Appearance	Color	Appearance
	Chilled foots	Loss on heating	Appearance	Loss on heating
Least important ...	Specific gravity	Specific gravity	Saponification number	Specific gravity
	Saponification number	Saponification number	Specific gravity	Saponification number
	Unsaponifiable matter	Unsaponifiable matter	Unsaponifiable matter	Unsaponifiable matter

1/ Summary of opinions of eight members of the crushing industry.

Table 15.--Coefficients of variation of characteristics of samples taken from eight tanks of fresh linseed oil 1/

Tank number	Total weight of oil sampled	Samples taken	Coefficients of variation 2/							
			Heated foots	Chilled foots	Acid number	Saponification number	Iodine number	Unsaponifiable matter	Loss on heating	Specific gravity
	Lb.	No.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	3/
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

1/ 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.

2/ A measurement of variation on a comparative basis (100 times the standard deviation divided by the average).

3/ In units (see specifications, table 13).

Table 16.--Factors for correlation of the relationship between specified characteristics and time of storage of linseed oil 1/

Characteristic 2/	Mean of Y 3/	Regression coefficient b 4/	Standard error of estimate of b	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	5/	0	-.5127

1/ In two tanks each holding 1,564,000 pounds of oil in the Texas area--for 53 months.

2/ There were insignificant changes in heated and chilled foots.

3/ There were 18 samples taken from each tank making a total of 36 observations, with a mean of 33.8888 in months.

4/ Unit change in characteristic with each month of storage.

5/ -0.000038.

Table 17.--Factors for correlation of the relationship between specified characteristics and total weight of stored linseed oil, in balance, bottoms, and total oil of tanks 1/

Characteristic 2/	Oil represented by samples taken	Y Intercept a	Regression coefficient b 3/	Correlation coefficient r	Standard error of estimate $S_{y.x}$
Acid number	Balance	4.4314	-0.000447	-0.7586	0.5146
Do.	Bottoms	4.9688	-.000478	-.2076	.7357
Do.	Total oil 4/	4.4771	-.000469	-.7928	.4834
Iodine number	Balance	184.6602	-.002535	-.8325	2.2084
Do.	Bottoms	182.4269	-.002318	-.4704	5.8296
Do.	Total oil 4/	184.4680	-.002410	-.7995	2.4265
Loss on heating	Balance	.1877	-.000030	.2171	.1146
Do.	Bottoms	.1148	.000232	.3022	.9788
Do.	Total oil 4/	.1454	-.000011	.1908	.0782

1/ Samples taken of balance and bottoms of 30 tanks containing from about 200,000 to over 4,000,000 lb. of oil, located in eastern area. (Most of these tanks appear in table 5 under "area III"; however, there were other tanks included where all specifications were met.) All tanks were filled to capacity and all bottoms were 6 inches. Oil in storage 4 to 5 years.

2/ 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.

3/ Unit change of characteristic for every 1,000 lb. of oil.

4/ Calculated from characteristic of balance and bottom on a weighted basis.

Table 18.--Factors for correlation of the relationship of specified characteristics in the balance and bottoms of tanks of stored oil 1/

Characteristic 2/	Y Intercept a	Regression coefficient b 3/	Correlation coefficient r	Standard error of estimate $S_{y.x}$
Heated foots	1.0051	3.6604	4/0.1759	2.1798
Chilled foots	3.7405	2.9907	4/.2895	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

1/ Based on 38 samples of oil taken during storage up to 4 to 5 years in the southern area and 42 samples taken at the end of storage of 4 to 5 years mostly in the eastern area.

2/ No significant relationship found for specific gravity and loss on heating.

3/ Change of characteristic in bottoms with each unit change in balance.

4/ The relationship of the foots tests are barely significant in 19 analyses out of 20 and cannot be assumed to be reliable.

Table 19.--Factors for correlation of the relationship between heated and chilled foots in stored linseed oil

Designation of samples		Number of observations	Y Intercept	Regression coeffi- cient	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
At 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 at 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 of 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

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