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OIL CONTENT OF FLAXSEED, WITH COMPARISONS OF TESTS FOR DETERMINING OIL CONTENT

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PRODUCTION AND CONSUMPTION OF FLAXSEED IN THE UNITED STATES

In this country flax is grown almost wholly for its seed. On this basis, it ranks seventh in acreage and eighth in value among the grain crops. It is exceeded in acreage and in monetary value by corn, wheat, oats, barley, rye, and the grain sorghums.

The seed flax crop of the United States is grown in the western north central division. North Dakota, South Dakota, Montana, and Minnesota produce 95 per cent of the total crop. Kansas, Iowa, Missouri, Nebraska, with limited acreage, come next in relative importance in flaxseed production. Colorado, Idaho, and Oregon produce some flaxseed, although in such small quantities that statistics on their production are usually lacking. Some seed may also be expected from the fiber flax regions of Michigan and Oregon. Over half the seed flax crop is grown in North Dakota.

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At the beginning of this century the United States was approaching its maximum production of flaxseed. The production in 1902 was 29,285,000 bushels. From 1910 to 1922 there was a heavy decline in production. The average annual production of flaxseed for the 10-year period, 1913 to 1922, inclusive, was 11,890,000 bushels. In the five-year period from 1918 to 1922, inclusive, the yearly production of flaxseed was only 9,960,000 bushels. During the period 1913–1922 the importation of flaxseed and linseed oil in terms of flaxseed averaged 16,177,000 bushels a year; the average net consumption was about 27,500,000 bushels.

Because of the relatively low prices paid for wheat in 1921 and 1922, and a need for diversified farming in the spring-wheat belt, many farmers began to raise flaxseed as a cash crop or to increase their flaxseed acreage. To stimulate an industry which seemed to be rapidly declining, Congress increased the duty on flaxseed imports to 30 cents per bushel in 1921, and to 40 cents per bushel in 1922. This tariff also placed a duty of 3.3 cents per pound on linseed oil, or the equivalent of 62 cents per bushel on flaxseed. This protection and the prevailing high prices of flaxseed renewed interest in the crop, so that by 1924 production increased to 31,711,000 bushels. Unusual building activities during a part of this period stimulated the use of linseed oil and the net consumption was equivalent to 37,000,000 bushels of flaxseed.

The production, net imports including linseed oil in terms of flaxseed, and the net supply available for consumption each year from 1911 to 1925, inclusive, are given in Table 1. The domestic production in 1924 was 31,711,000 bushels and the imports from July 1 to December 31, 1924, 5,124,033 bushels, a total of 35,297,033 bushels. These imports cover only the first half of the import year. In addition, Argentine seed en route to this country as well as large quantities of seed in terminal storage in Canada awaiting importation to the United States would increase this figure considerably. Linseed crushers believe that in the future the industry will require approximately 40,000,000 bushels annually if present conditions of consumption continue.

TABLE 1.—*Flaxseed acreage, production, importations, exporations, and net supply, 1911–1925*

Year beginning July 1	Acreage	Production	Imports [1]	Exports [1]	Net supply
		Bushels	*Bushels*	*Bushels*	*Bushels*
1911	2,757,000	19,370,000	7,136,708	125,327	26,381,381
1912	2,851,000	28,073,000	5,363,772	710,641	32,727,131
1913	2,291,000	17,853,000	8,730,148	401,571	26,181,577
1914	1,645,000	13,749,000	10,880,331	552,030	24,077,301
1915	1,387,000	14,030,000	14,699,292	288,279	28,441,013
1916	1,474,000	14,296,000	12,438,311	481,639	26,252,672
1917	1,984,000	9,164,000	13,386,860	498,548	22,052,312
1918	1,910,000	13,369,000	8,822,811	454,791	21,737,020
1919	1,503,000	7,256,000	25,212,090	505,786	31,962,304
1920	1,757,000	10,774,000	16,960,049	226,000	27,508,049
1921	1,108,000	8,029,000	22,629,693	150,886	30,507,807
1922	1,113,000	10,375,000	28,033,335	165,840	38,242,495
1923	2,014,000	17,060,000	20,528,198	140,174	37,448,024
1924	3,469,000	31,711,000	14,677,053	(2)	46,388,053
1925	3,012,000	22,007,000	(2)	(2)	(2)

[1] Including seed and oil expressed as bushels of seed.
[2] No report.

WORLD PRODUCTION AND TRADE IN FLAXSEED

Previous to the World War, the principal countries producing flaxseed were Argentina, India, Russia, the United States, and Canada in the order named. Pre-war production, 1909 to 1913, averaged 111,000,000 bushels annually. In 1923 the estimated world production was 125,000,000 bushels and for 1924, 133,000,000 bushels. World consumption of linseed is also increasing. Since the war, Russia has not produced much seed flax for export. Argentina, India, and Canada are thus the chief surplus-producing countries.

Western Europe and the United States with intensive paint, varnish, and linoleum industries, are the chief importers of flaxseed. There is also a large demand from the dairy industries for linseed cake and meal as a feeding concentrate.

PRINCIPAL MARKETS FOR FLAXSEED IN THE UNITED STATES

Minneapolis and Duluth, Minn., and Superior, Wis., are the primary markets for most of the flaxseed grown in the United States. Nearly all of the domestic northwestern-grown seed is crushed at mills located at Minneapolis, St. Paul, and Redwing, Minn.; Chicago, Ill.; Milwaukee and Superior, Wis.; and Toledo, Ohio. Mills located at Des Moines, Iowa, and at Fredonia, Kans., crush all local offerings.

A large percentage of the flaxseed imported from Argentina enters the port of New York. Canadian seed enters chiefly by the way of Duluth and ports on the Great Lakes. Linseed mills at Buffalo, N. Y., Toledo, Ohio, and Undercliff and Newark, N. J., depend largely upon imported seed for their raw material. Very little of the domestic supply reaches eastern mills. On the Pacific coast, mills located at Portland, Oreg., receive some domestic seed, but rely mainly on seed from the Orient and Argentina.

CLASSES OF FLAXSEED FOUND IN THE TRADE

The trade recognizes three commercial classes of flaxseed: That grown in North Dakota, South Dakota, Minnesota, and Montana, which is known as northwestern-grown seed; that grown in Kansas, Nebraska, Iowa, and eastern Colorado, which is known as southwestern-grown seed; and that imported from Argentina, India, and Manchuria, which is known as imported or foreign-grown flaxseed. Most of the Canadian crop is imported into this country, but it is seldom considered as foreign-grown seed and is usually deliverable on contract as domestic northwestern-grown seed.

At the present writing crushers rate northwestern-grown seed as superior in quality to either of the other two classes of flaxseed, and foreign and imported flaxseed next in quality.

Car lots of flaxseed from the fiber-flax industry are appearing in larger quantities each year. Indications are that this type of seed will continue to increase in quantity.

OIL CONTENT OF FLAXSEED, BY CLASSES

During the crop years 1918 to 1924, inclusive, 4,370 samples of flaxseed representing the three commercial classes of seed were analyzed for their oil content.[1] The data from these studies are given by classes in Table 2.

TABLE 2.—*Oil content* [1] *of flaxseed of the commercial classes*

	Crop year [2]							
	1918	1919	1920	1921	1922	1923	1924	Yearly average
Northwestern seed (domestic):								
Total number of samples	144	84	211	716	625	1,237	490	[3] 3,507
Average percentage of oil	40.50	40.00	40.19	39.97	40.46	40.70	41.11	40.42
Maximum percentage of oil	43.47	45.25	43.05	43.30	43.98	45.40	46.43	44.41
Minimum percentage of oil	35.89	36.29	35.29	33.63	33.34	30.30	35.73	34.35
Range in oil content	7.58	8.96	7.76	9.67	10.64	15.10	10.70	10.06
Northwestern seed (Canadian):								
Total number of samples			20	72	218	23		[3] 333
Average percentage of oil			40.58	41.34	41.12	42.67		41.43
Maximum percentage of oil			42.06	43.23	44.01	43.40		43.18
Minimum percentage of oil			39.85	38.67	38.94	40.40		39.46
Range in oil content			2.21	4.56	5.07	3.00		3.72
Southwestern seed:								
Total number of samples	25		10	23	22	37	61	[3] 178
Average percentage of oil	35.67		37.47	39.45	38.72	40.83	38.73	38.48
Maximum percentage of oil	36.25		38.78	42.04	40.44	44.37	44.87	41.12
Minimum percentage of oil	33.93		35.01	37.53	37.08	38.30	34.57	36.07
Range in oil content	2.32		3.77	4.51	3.36	6.07	10.30	5.05
Fiber flaxseed:								
Total number of samples		7		17			5	[3] 29
Average percentage of oil		38.80		40.02			39.55	39.46
Maximum percentage of oil		41.86		41.46			40.77	41.36
Minimum percentage of oil		34.44		38.55			36.13	36.37
Range in oil content		7.42		2.91			4.64	4.99
Foreign-grown seed (Argentine):								
Total number of samples	57	101	14	22	72	5	3	[3] 274
Average percentage of oil	41.11	42.16	42.89	42.11	42.11	43.57	41.40	42.19
Maximum percentage of oil	43.04	44.90	44.16	45.42	44.48	44.81	41.53	44.05
Minimum percentage of oil	35.09	32.71	41.54	40.14	36.31	41.19	41.36	38.33
Range in oil content	7.95	12.19	2.62	5.28	8.17	3.62	.17	5.71
Foreign-grown seed (Indian):								
Total number of samples	29							[3] 29
Average percentage of oil	42.99							42.99
Maximum percentage of oil	44.62							44.62
Minimum percentage of oil	41.54							41.54
Range in oil content	3.08							3.08
Foreign-grown seed (Manchurian):								
Total number of samples				3	17			[3] 20
Average percentage of oil				40.83	43.45			42.14
Maximum percentage of oil				43.25	44.48			43.87
Minimum percentage of oil				37.52	37.29			37.40
Range in oil content				5.73	7.19			6.46

[1] Moisture-free basis. [2] Beginning Sept. 1. [3] Total number of samples analyzed.

The highest average oil content was found in the samples of imported flaxseed. With the exception of a few samples of Indian flaxseed obtained in 1918, which had an average oil content of 42.99 per cent, the greatest quantity of oil was found in Argentine seed. The average oil content of the 274 samples of Argentine seed was 42.19 per cent.

There was a difference between the oil content of the flaxseed grown in the Northwestern States and that grown in the southwestern portion of the United States. The northwestern-grown flaxseed averaged 40.42 per cent, whereas the southwestern-grown flaxseed contained, on the average, 38.48 per cent of oil.

Canadian-grown seed, as analyzed, had a higher oil content than did the domestic northwestern-grown seed. The average oil content of the samples analyzed was 41.43 per cent, 1 per cent above the average of the domestic crop.

[1] By the method adopted by the Association of Official Agricultural Chemists (*1*).[2]
[2] Figures in italic in parentheses refer to "Literature cited," p. 33.

Samples of fiber flaxseed were analyzed from crops grown in 1919, 1921, and 1924. The average oil content of all samples tested was 39.46 per cent. Over 90 per cent of the samples tested contained 37 per cent or more of oil.

The variation in oil content of flaxseed of the classes by crop years is shown in Table 3. These data are given on a moisture-free basis in order to eliminate errors due to the presence of moisture in the samples. All samples, with the exception of the Argentine seed, at the time of analysis contained less than 0.5 per cent of foreign material and were commercially sound.

Within the northwestern group of domestic origin, in almost every crop year, the flaxseed in the great majority of the carlots tested contained between 38 and 42 per cent of oil. With the exception of one crop year—1919—90 per cent or more of all the samples in any crop year contained at least 38 per cent of oil.

On the average, there was a difference of approximately 8 per cent in the oil content of the different carlots tested and in one crop year an extreme range of 15 per cent was found.

Lesser variations were found in the lots of Canadian seed than were noted in the domestic crop. Over 90 per cent of the Canadian samples tested from the four crop years, 1920 to 1923, inclusive, contained 40 per cent or more of oil.

The oil content of the southwestern-grown flaxseed varied to a greater extent than the oil content of any of the other classes studied. The number of samples analyzed was small, but it is believed that this number was representative of this class. Since 1921 there has been some improvement in the quality of the seed grown in this area, very few samples containing less than 36 per cent of oil.

The fiber flaxseed tested was rather uniform in oil content.

The oil content of the Argentine seed tested was uniformly good, the majority of the samples containing over 40 per cent of oil. There was also less variation in the oil content of various lots of this class of flaxseed than in the other commercial classes of flaxseed, but certain lots of imported seed contained less oil than many lots of the current run of domestically grown flaxseed.

Because of the small number of samples received of other types of foreign-grown flaxseed, data regarding their variation have not been compiled. The indications are that they are similar in nature to the Argentine seed in oil content.

Foreign-grown flaxseed, of which Argentine seed is the most important in this country, although having the advantage of containing the greatest quantity of oil, is said to contain oil of a slightly inferior quality to that found in the domestic crop. For this reason it is often discounted in price when the supply and demand warrant it. Because of the higher quantity of oil in the samples of Argentine seed, the percentage of crude protein is somewhat lower than that found in the domestic crop. This also reacts against the price paid for Argentine seed, inasmuch as linseed meal or cake of a high protein content is an important by-product of the linseed-oil industry.

Ranged in the order of their oil content, the classes of flaxseed rank as follows: Foreign-grown seed, northwestern-grown (Canadian) seed, northwestern-grown (domestic) seed, fiber flaxseed, and southwestern-grown seed.

TABLE 3.—*Variation of the percentage of oil*[1] *in flaxseed of commercial classes for the crop years,*[2] *1918 to 1924, inclusive*

NORTHWESTERN-GROWN FLAXSEED

Crop year	Number of samples	Percentage of samples containing specified percentages of oil																
		30 to 30.99	31 to 31.99	32 to 32.99	33 to 33.99	34 to 34.99	35 to 35.99	36 to 36.99	37 to 37.99	38 to 38.99	39 to 39.99	40 to 40.99	41 to 41.99	42 to 42.99	43 to 43.99	44 to 44.99	45 to 45.99	46 to 46.99
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1918	144						0.7	0.7	5.6	14.6	20.1	30.6	20.8	6.3	0.6			
1919	84							1.2	16.7	15.5	20.2	20.2	11.9	3.6	9.5		1.2	
1920	211						1.0	.5	1.3	10.0	37.8	24.2	18.5	6.2	.5			
1921	716				0.1		.1	1.4	1.9	5.4	13.8	24.8	25.7	21.3	5.5			
1922	625				.2			.8	1.9	9.6	22.5	31.4	21.8	10.4	1.4			
1923	1,237	0.1	0.1	0.1		0.1	.2	.7	2.7	9.2	18.3	25.1	21.5	15.2	6.1	0.5	.1	
1924	490						.2	.8	1.7	5.4	15.1	21.5	25.0	19.8	6.8	2.5	.6	0.6
Total number of samples	3,507																	
Yearly average		.02	.02	.02	.04	.02	.31	.37	4.55	9.95	21.1	25.4	20.8	11.83	4.3	.4	.27	.10

CANADIAN-GROWN FLAXSEED

Crop year	Number of samples	30 to 30.99	31 to 31.99	32 to 32.99	33 to 33.99	34 to 34.99	35 to 35.99	36 to 36.99	37 to 37.99	38 to 38.99	39 to 39.99	40 to 40.99	41 to 41.99	42 to 42.99	43 to 43.99	44 to 44.99	45 to 45.99	46 to 46.99
1920	20									4.8	14.2	42.9	28.6	9.5				
1921	72									2.8	8.3	18.1	45.8	25.0				
1922	218									.8	2.5	8.5	30.5	43.2	13.6	0.9		
1923	23											17.4		39.1	43.5			
Total number of samples	333																	
Yearly average										2.1	6.2	21.7	26.2	29.2	14.4	.2		

SOUTHWESTERN-GROWN FLAXSEED

1918	25				16.0	40.0	20.0	24.0										
1920	10						20.0	20.0	10.0	50.0								
1921	23								21.7	26.1	13.1	21.7	8.7	4.3	4.4			
1922	22							4.5	22.7	36.4	22.7	13.7						
1923	37									18.9	18.9	24.4	16.2	8.1	8.1	5.4		
1924	61					5.0	5.0	19.7	24.6	29.5	13.0	1.6	1.6					
Total number of samples	178																	
Yearly average					2.68	7.50	7.50	11.36	13.16	26.81	11.29	10.23	4.42	2.07	2.08	.90		

ARGENTINE FLAXSEED

1918	57									3.5	1.8	17.5	45.6	24.6	7.0			
1919	101									1.0	2.0	4.0	27.6	49.5	12.9	3.0		
1920	14											21.4	7.1	28.6	35.7	7.2		
1921	22											27.3	9.1	50.0	9.1		4.5	
1922	72										2.8	9.7	20.8	45.8	16.7	4.2		
1923	5												20.0	60.0		20.0		
1924	3												100.0					
Total number of samples	274																	
Yearly average										.64	.97	11.41	32.88	36.92	11.92	4.91	.64	

FIBER FLAXSEED

1918	11					9.1			63.6	9.1	9.1		9.1					
1921	18									5.6	50.0	38.8	5.6					
Total number of samples	29																	
Yearly average						4.6			31.8	7.4	29.5	19.4	7.3					

[1] Per cent oil on moisture-free basis.

[2] Beginning Sept. 1.

CONDITIONS WHICH CAUSE OIL CONTENT OF FLAXSEED TO VARY

CLIMATIC CONDITIONS

From an examination of numerous plants with respect to oil content and composition it has been found that the nature and the quantity of the oil in the plant is influenced by climatic and soil conditions. The conditions vary in different localities. The extremes and means act either in facilitating or retarding the growth of plants, and therefore affect favorably or unfavorably the formation of oil in the seeds.

The availability of the plant food in soils is due to a large extent to the amount of moisture present, which in turn is dependent upon certain other conditions, such as heat, light, humidity, and altitude.

Retention of moisture by some soils and lack of retention by others naturally affect the growth and development of the plant and the formation of oil in the plant.

Any cause which tends to modify the growth or nutrition of a plant has a material effect upon the formation of oil in the seed. This has been brought out by the work of Garner, Allard, and Foubert (*4*), Pigulevskii (*5*), Rabak (*7*), and others.

The amount of precipitation during the growing season is one of the most influential factors affecting the oil content of flaxseed, since the proper growth and maturity of the flax plants are dependent largely upon the amount of moisture available.

In North Dakota the average annual precipitation ranges from about 23 inches in southwestern counties to about 14 inches in certain areas in the western part of the State. Local rains, especially during the critical growing period of the crop, should influence the oil content of the seed. In Table 4 is a comparison of the oil content of the flaxseed grown in North Dakota with flaxseed grown in areas having the indicated inches of rainfall. Drawing conclusions on the basis of averages, there is a rather decided relation between the inches of rainfall and the percentage of oil in flaxseed. The seed grown in areas having 15 to 16 inches of rain contained the highest percentage of oil. The percentage of oil in the samples became progressively smaller as the moisture increased up to and including 23 inches of rainfall.

TABLE 4.—*Influence of total rainfall in North Dakota on oil content of flaxseed, crop of 1923*

	Rainfall (inches for the year)				
	14 to 15	15 to 16	16 to 18	18 to 20	20 to 23
Number of samples	3	87	115	95	47
Average percentage of oil	41.47	42.41	41.04	40.91	40.40
Maximum percentage of oil	41.81	44.33	43.94	43.13	43.29
Minimum percentage of oil	40.81	39.09	37.12	31.28	38.76
Range in percentage of oil	1.00	5.24	6.82	11.85	4.53

According to Rabak (7) geographical conditions influence the oil content of flaxseed. To obtain further knowledge on this point, the flaxseed-producing area was divided latitudinally and from a knowledge of the shipping point of the car lots of seed and the oil content of the samples the figures in Table 5 were obtained.

TABLE 5.—*Geographical distribution versus oil content of flaxseed*

Crop year	Degrees of latitude					
	49	48	47	46	45	44
1921						
Number of samples	131	93	89	59	27	15
Average percentage of oil	40.76	40.64	39.81	39.76	39.14	40.28
1922						
Number of samples	133	164	118	54	12	11
Average percentage of oil	40.97	40.55	40.40	40.13	40.76	39.74
1923						
Number of samples	108	142	175	58	23	10
Average percentage of oil	41.65	41.56	41.13	40.51	40.06	41.10
YEARLY AVERAGE						
Number of samples	372	399	382	171	62	36
General average percentage of oil	41.13	40.92	40.44	40.13	39.99	40.37

The data in Table 5 bring out the fact that on the average there is a gradual increase in the percentage of oil in flaxseed as the point of production changes progressively from south to north. But the data emphasize the fact that a practice of buying on geographical information is not reliable. Even though, on the average, the oil content of samples of flaxseed grown in the most northern areas is greater than that in samples grown in the most southerly areas, groups of samples grown in any area may have as great an oil content as is to be found in any of the areas more favorable to flaxseed production.

OIL CONTENT OF FLAXSEED OF DIFFERENT VARIETIES

Variety of seed influences the oil content of flaxseed. Table 6 gives the oil content of flaxseed of seven varieties supplied by the Office of Cereal Crops and Diseases, Bureau of Plant Industry, and by the North Dakota Agricultural Experiment Station. On the average there was an extreme range of 5.2 per cent in the oil content of flaxseed of the different varieties grown at any one station for any given year.

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TABLE 6.—*Oil content of flaxseed of the varieties grown during the years 1919 to 1924, inclusive, at the designated experiment stations*

Variety name	C. I. No.	Number of samples	Crop years								
			1919	1920	1921	1922			1923		
			Experiment stations at—								
			Fargo, N. Dak.	Fargo, N. Dak.	Fargo, N. Dak.	Dickinson, N. Dak.	Fargo, N. Dak.	Moccasin, Mont.	Dickinson, N. Dak.	Fargo, N. Dak.	Mandan, N. Dak.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Damont	3	12	41.87	40.77	35.91	42.45			40.23		41.53
N. Dak. R. No. 52	8	14	37.71	40.43	35.88	38.53	39.99	40.45		37.48	
Primost	12	13	37.80	41.72	36.38	40.90	40.37	40.59	37.95		39.03
N. Dak. R. No. 114	13	17	39.00	42.66	36.75	40.12	40.40	40.59	36.84	39.73	38.69
N. Dak. R. No. 73	14	6	37.53	39.45	36.96	38.44	39.82	39.42			
Frontier	17	5	40.31	38.05	38.05		40.61			39.31	
Reserve	19	9				40.84		40.56	40.27		41.22
Variety			4.30	3.60	2.20	4.00	1.20	.80	3.40	2.30	2.80

Variety name	C. I. No.	Number of samples	Crop years							
			1923			1924				
			Experiment stations at—							
			Moccasin, Mont.	Newell, S. Dak.	San Antonio, Tex.	Dickinson, N. Dak.	Bozeman, Mont.	Mandan, N. Dak.	Moccasin, Mont.	San Antonio, Tex.
			Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Damont	3	12	43.26	42.46	38.78	45.81	36.97			41.36
N. Dak. R. No. 52	8	14	41.35	39.76	37.50	40.62		40.06	39.13	41.45
Primost	12	13	42.95	41.10	39.28	41.02				43.21
N. Dak. R. No. 114	13	17	43.16	40.08	38.55	42.04	40.18	40.50	39.82	41.64
N. Dak. R. No. 73	14	6								
Frontier	17	5								
Reserve	19	9	42.78		38.64			42.29	41.97	42.28
Variety			1.90	2.70	1.80	5.20	3.20	2.20	2.80	1.90

PHYSICAL TESTS FOR DETERMINING OIL CONTENT OF FLAXSEED

Knowing something of the range in oil content of different lots of flaxseed, and knowing in a general way why these variations occur, it is important to know what tests can be applied to lots of flaxseed which will indicate satisfactorily their oil content.

The tests in most general use are physical in nature, and are embodied in the grading rules of most grain-inspection departments. Outstanding among these tests is that for weight per measured bushel. Other tests are made for the presence of moisture in the sample and for the percentage of damaged seed and foreign material. Notations regarding the section of the United States in which the flaxseed was raised are usually made in connection with these tests.

A series of tests was made in the chemical research laboratory of the Bureau of Agricultural Economics, to find out how positive a relationship exists between the above factors and the percentage of oil in different lots of flaxseed.

RELATION BETWEEN TEST WEIGHT PER BUSHEL AND OIL CONTENT

There are marked differences in the test weight per Winchester bushel of flaxseed as it comes to market. These differences are due in part to the weather during the growing season, to storage conditions from harvest time until the flaxseed is marketed, and to varietal differences.

Some flax varieties naturally produce seed of heavier weight than others (*3*). During any crop year, the test weight per bushel of commercially clean flaxseed will vary from 43 to 55 pounds per measured bushel. This fact is brought out in Table 7 which shows the range in test weight per Winchester bushel found by analyzing 3,335 samples of flaxseed obtained during the seven crop years 1918 to 1924, inclusive.

TABLE 7.—*Range in pounds in test weights per bushel*[1]

Crop year	Number of samples	Percentage of samples having the indicated test weight per bushel												
		43 to 43.99	44 to 44.99	45 to 45.99	46 to 46.99	47 to 47.99	48 to 48.99	49 to 49.99	50 to 50.99	51 to 51.99	52 to 52.99	53 to 53.99	54 to 54.99	55 to 55.99
1918	141	------	------	------	0.7	1.4	2.1	2.1	10.6	20.7	26.3	22.7	9.9	3.5
1919	56	------	------	1.8	------	------	3.6	17.9	21.4	14.3	26.8	7.1	7.1	------
1920	182	------	------	------	1.1	------	4.4	2.2	9.9	37.4	37.9	3.3	3.8	------
1921	702	0.6	1.1	.7	1.6	1.9	4.1	9.7	20.9	37.0	18.1	4.3	------	------
1922	618	------	------	.1	.1	.1	1.0	2.3	13.8	37.1	39.0	5.7	.8	------
1923	1,226	------	------	.2	.1	.7	1.9	8.6	23.3	33.7	24.6	5.8	1.0	.1
1924	410	------	------	------	.5	.7	.7	2.3	12.2	30.5	43.6	9.5	------	------
Total number of samples	3,335	------	------	------	------	------	------	------	------	------	------	------	------	------
Yearly average	-------	.09	.16	.40	.59	.69	2.54	6.44	16.01	30.10	30.90	8.34	3.23	.51

[1] Winchester bushel, 2,150.4 cubic inches.

To determine whether test weight per bushel is an accurate index of the oil content of flaxseed the percentage of linseed oil in some 2,000 samples was determined and the resulting data were compared with the test weight per bushel of the same sample. For this comparison the oil content of the sample was converted to the basis of the moisture content of the sample at the time the test weight per bushel determination was made. The samples used had less than 1 per cent of damaged kernels and contained less than 0.5 per cent of foreign material. The comparison between test weight per bushel and oil content of the sample is given in Table 8.

TABLE 8.—*Relationship between test weight per bushel and oil content*[1] *of northwestern-grown flaxseed for the crop years 1920 to 1924, inclusive*

Crop year[3]	Test weight per bushel[2] in pounds										
	44 to 44.99	45 to 45.99	46 to 46.99	47 to 47.99	48 to 48.99	49 to 49.99	50 to 50.99	51 to 51.99	52 to 52.99	53 to 53.99	54 to 54.99
1920	*Per cent oil*	*Per cent oil*	*Per cent oil*	*Per cent oil*	*Per cent oil*	*Per cent oil*	*Per cent oil*	*Per cent oil*	*Per cent oil*	*Per cent oil*	*Per cent oil*
Total number of samples	------	------	------	1	------	2	15	59	64	14	----
Average percentage of oil	------	------	------	38.59	------	36.80	36.39	36.12	36.80	37.61	------
Maximum percentage of oil	------	------	------	38.59	------	36.82	38.86	39.38	40.68	40.31	------
Minimum percentage of oil	------	------	------	38.59	------	36.79	35.01	32.71	34.17	36.85	------
Range in oil content	------	------	------	------	------	.03	3.85	6.67	6.51	3.46	------
1921											
Total number of samples	9	5	6	11	25	54	125	211	95	23	2
Average percentage of oil	36.56	35.56	37.19	36.72	37.72	36.89	36.69	36.79	36.62	35.07	34.23
Maximum percentage of oil	39.26	37.25	38.50	38.56	39.05	40.39	40.69	40.31	39.32	37.60	34.49
Minimum percentage of oil	32.00	35.67	34.31	34.62	35.35	34.10	32.61	34.00	33.80	33.76	33.96
Range in oil content	7.26	1.58	4.19	3.94	3.70	6.29	8.08	6.31	5.52	3.84	.53
1922											
Total number of samples	------	1	------	------	3	13	80	219	222	34	2
Average percentage of oil	------	36.17	------	------	37.70	37.07	37.62	37.40	37.20	37.05	37.64
Maximum percentage of oil	------	36.17	------	------	38.60	38.17	40.85	41.64	40.57	39.50	38.26
Minimum percentage of oil	------	36.17	------	------	36.69	35.11	35.14	33.97	29.94	34.08	37.03
Range in oil content	------	------	------	------	1.91	3.06	5.71	7.67	10.63	5.42	1.23
1923											
Total number of samples	------	------	------	2	14	25	83	188	205	60	3
Average percentage of oil	------	------	------	37.47	37.80	37.34	37.66	37.49	37.20	36.65	35.61
Maximum percentage of oil	------	------	------	38.23	39.11	38.99	40.28	40.37	41.15	40.16	38.34
Minimum percentage of oil	------	------	------	36.70	36.95	34.18	27.96	33.93	34.61	33.55	33.63
Range in oil content	------	------	------	1.53	2.16	4.81	12.32	6.44	6.54	6.61	4.71
1924											
Total number of samples	------	------	2	3	3	9	50	125	179	39	------
Average percentage of oil	------	------	39.04	38.14	37.22	37.90	37.61	37.72	37.22	36.71	------
Maximum percentage of oil	------	------	39.38	39.01	38.59	39.38	41.23	43.32	42.96	39.18	------
Minimum percentage of oil	------	------	38.70	36.92	36.17	36.44	35.26	32.87	33.26	32.73	------
Range in oil content	------	------	.68	2.09	2.42	2.94	5.97	10.45	9.70	6.45	----
AVERAGE OF ALL CROP YEARS.											
Total number of samples	9	6	8	17	45	103	353	802	765	170	7
Average percentage of oil	36.56	35.87	38.12	37.73	37.61	37.19	37.19	37.10	37.01	36.61	35.83
Maximum percentage of oil	39.26	36.71	38.94	38.59	38.84	38.75	40.38	41.00	40.93	39.35	37.03
Minimum percentage of oil	32.00	35.92	36.50	36.70	36.29	35.32	33.20	33.49	33.15	34.19	34.87
Range in oil content	7.26	.79	2.44	1.89	2.55	3.43	7.18	7.51	7.78	5.16	2.16

[1] Oil content on moisture basis of sample as received at Minneapolis or Duluth, Minn.
[2] Winchester bushel, 2,150.4 cubic inches.
[3] Beginning Sept. 1.

The data in Table 8 are evidence enough that the test weight per bushel determination is of little significance as an index to the oil content of flaxseed. As much oil was found in samples weighing 48 pounds to the bushel as was present in seed testing 50, 51, and 52 pounds to the bushel. In fact, there is a tendency for samples of very high test weight to contain less oil than flaxseed of lesser weight per bushel. On the average, the oil content of flaxseed weighing 47 to 53 pounds in 1-pound increments contained practically the same quantity of oil. The maximum oil content found in single samples testing 50, 51, 52, and 53 pounds to the measured bushel was higher than samples weighing less than this, but, on the other hand, it is pointed out that the minimum oil content in samples of these test weights is lower than the samples of lesser weights.

Objection to these deductions relative to test weight as an index of oil content can be entertained on the grounds that comparisons were made with samples of different amounts of moisture. Therefore samples were chosen with the same moisture content but varying in test weight per bushel. The average moisture chosen was 7.5, 8.5, 9.5, and 10 per cent. The data showing the results of this comparison are given in Table 9. The same results were found as before, namely, that test weight per bushel and oil content have no close positive relationship, at least not until the moisture content of the sample is rather high.

TABLE 9.—*Influence of moisture and test weight on the oil content of flaxseed, crop year 1921* [1]

Number of samples	Moisture range	Average moisture	Range in pounds in test weight per bushel [2]										
			43 to 43.99	44 to 44.99	45 to 45.99	46 to 46.99	47 to 47.99	48 to 48.99	49 to 49.99	50 to 50.99	51 to 51.99	52 to 52.99	53 to 53.99
	Per cent	*Per cent*	*Per cent oil*	*Per cent oil*	*Per cent oil*	*Per cent oil*	*Per cent oil*	*Per cent oil*	*Per cent oil*	*Per cent oil*	*Per cent oil*	*Per cent oil*	*Per cent oil*
46	7–7.99	7.50	32.00	-------	-------	-------	37.02	-------	36.77	37.05	37.85	37.27	-------
188	8–8.99	8.50	-------	37.62	-------	-------	35.66	36.59	35.05	36.05	36.26	36.70	34.06
140	9–9.99	9.50	-------	-------	36.81	38.25	-------	35.75	36.42	36.76	36.56	35.32	34.96
65	10–10.99	10.10	-------	-------	-------	36.19	34.62	37.25	36.18	36.14	35.90	35.62	35.16

[1] Beginning Sept. 1. [2] Winchester bushel, 2,150.4 cubic inches.

In the case of cereal grains there is usually a rather close relationship between moisture and test weight per bushel but this relationship does not appear to hold with flaxseed. One possible explanation is that with flaxseed the reserve material, linseed oil, has a specific gravity close to that of water, and a reduction in the percentage of moisture does not materially affect the specific gravity of the sample. With cereal grains starch is the reserve material with a specific gravity of 2.5, water having a specific gravity of 1, thus a change in the moisture content will materially change the specific gravity of the sample.

RELATION BETWEEN MOISTURE CONTENT AND OIL CONTENT

At the present writing none of the various grain-inspection departments have moisture limitations in effect for grading flaxseed although the moisture content of flaxseed varies, depending upon the crop year, as much as 8 per cent and moisture in flaxseed may exert an influence in any of three different ways:

(1) Damp or moist flaxseed is of less intrinsic value than dry flaxseed because dry seed contains more oil than damp seed. For each additional 1 per cent of moisture in flaxseed over any given basic amount there will be a corresponding change of 1 per cent in the total oil content of the sample;

that is to say, if a sample of flaxseed contains 40 per cent of oil at a moisture content of 10 per cent, at 11 per cent of moisture the oil content would be only 39.6 per cent.

(2) Flaxseed containing a high moisture content, 10.5 per cent and over, is a dangerous storage risk.

(3) From a processing standpoint flaxseed containing over 8.5 per cent of moisture usually must be mixed with dry seed or must be dried artificially before grinding and pressing because flaxseed meal that contains moisture in excess of 8.5 per cent, when going to the press cloths, will spread and run, and this breaks the expensive camel's-hair press cloths.

RELATION BETWEEN DAMAGED FLAXSEED AND OIL CONTENT OF SAMPLE

Soundness or freedom from damaged kernels is at present a factor in determining the quality of flaxseed. Damaged kernels in flaxseed are of two kinds—field-damaged seed and seed that has been damaged incident to storage.

Field-damaged seed consists of immature and undeveloped kernels and kernels injured during growth by disease, drought or frost, and by field exposure after harvest. The kernels damaged by field exposure may be moldy, scabby, sprouted, or thickly covered with dirt or mud.

Flaxseed stored under unfavorable conditions, that is, with excessive moisture and high temperature conditions that encourage bacterial growth will ferment and become either musty, sour, or rancid, depending upon the extent of the fermentation. Under these conditions, kernels will also sprout. When air is excluded, intramolecular oxidation takes place with the formation of what is known as heat damage. If these processes proceed far enough, rotting eventually takes place. Flaxseed may also be injured in storage by fire (decomposition by external heat), with an accompanying smoky odor. Because of its inherent nature (oil bearing), flaxseed readily absorbs and holds odors. It is, therefore, often in a damaged condition because of contamination with mineral oil, putrid animal and vegetable matter, or other substances with a pronounced and lasting odor. Insect injury to flaxseed is not common, although nests of insects frequently develop in foreign material within the bulk flaxseed.

From the crops of 1920 to 1924, inclusive, samples of flaxseed were chosen containing field-damaged seed in amounts varying from 0 to 100 per cent. Oil determinations were made on these samples and the influence of damaged seed upon the oil content of the flaxseed samples was noted. The resulting data are given in Table 10. They indicate the lack of any close relationship between the oil content of flaxseed and the percentage of oil in the damaged samples. Samples having 50 and 75 per cent of damaged kernels contained as much oil as samples having only 1 and 2 per cent of damaged seed. In no crop year was there evidence, in the samples tested, that an increased damaged condition resulted in a decrease in the oil content.

TABLE 10.—*Influence of field-damaged seed upon the oil content of flaxseed*

Crop year	Percentage of damaged seeds									
	0 to 0.99	1 to 2.99	3 to 6.99	7 to 9.99	10 to 14.99	15 to 24.99	25 to 34.99	35 to 49.99	50 to 74.99	75 to 100
1920 [1]										
Number of samples	58	45	47	10	9	3	1	------	------	------
Average percentage of oil	40. 40	40. 00	40. 14	40. 17	40. 90	39. 84	31. 12	------	------	------
Maximum percentage of oil	43. 05	42. 26	42. 43	41. 88	41. 56	40. 14	31. 12	------	------	------
Minimum percentage of oil	38. 22	37. 77	38. 27	37. 86	39. 69	39. 69	31. 12	------	------	------
Range in oil content	4. 83	4. 49	4. 16	4. 02	1. 87	. 45	0	------	------	------
1921 [1]										
Number of samples	48	74	131	71	53	48	17	26	5	------
Average percentage of oil	39. 86	39. 16	40. 30	40. 52	40. 34	40. 35	40. 73	39. 88	40. 02	------
Maximum percentage of oil	43. 30	42. 30	42. 71	42. 89	43. 04	42. 88	43. 11	42. 51	41. 81	------
Minimum percentage of oil	35. 37	37. 52	38. 02	36. 30	37. 00	36. 60	38. 55	35. 99	39. 40	------
Range in oil content	7. 93	4. 78	4. 69	6. 59	6. 04	6. 28	4. 56	6. 52	2. 41	------
1922 [1]										
Number of samples	89	86	89	20	17	7	2	------	------	4
Average percentage of oil	40. 53	39. 86	40. 63	40. 48	40. 66	40. 30	40. 04	------	------	39. 56
Maximum percentage of oil	43. 25	42. 36	43. 11	42. 42	42. 47	41. 96	41. 09	------	------	40. 19
Minimum percentage of oil	36. 42	36. 07	37. 18	37. 61	37. 78	37. 64	39. 00	------	------	38. 90
Range in oil content	6. 83	6. 29	5. 93	4. 81	4. 69	4. 32	2. 09	------	------	1. 29
1923 [1]										
Number of samples	94	140	96	37	29	30	5	1	------	------
Average percentage of oil	40. 97	40. 71	41. 52	41. 35	41. 76	41. 34	42. 23	42. 96	------	------
Maximum percentage of oil	44. 22	44. 33	43. 65	43. 84	43. 68	43. 61	42. 62	42. 96	------	------
Minimum percentage of oil	38. 01	36. 55	39. 39	38. 27	38. 55	37. 73	42. 03	42. 96	------	------
Range in oil content	6. 21	7. 78	4. 26	5. 57	5. 13	5. 88	. 59	0	------	------
1924 [1]										
Number of samples	76	95	133	12	6	4	1	0	2	2
Average percentage of oil	41. 16	41. 05	41. 10	41. 67	41. 15	41. 12	39. 38	------	40. 78	42. 17
Maximum percentage of oil	44. 44	44. 48	44. 26	43. 13	43. 82	41. 52	39. 38	------	42. 03	42. 97
Minimum percentage of oil	36. 83	38. 30	35. 23	39. 49	39. 80	40. 32	39. 38	------	39. 53	41. 38
Range in oil content	7. 61	6. 18	9. 03	3. 64	4. 02	1. 20	0	------	2. 50	1. 59
AVERAGE OF ALL CROP YEARS										
Number of samples	365	440	496	150	114	92	26	27	7	6
Average percentage of oil	40. 58	40. 15	40. 92	40. 83	40. 96	40. 63	38. 70	41. 42	40. 40	40. 87
Maximum percentage of oil	43. 65	43. 14	43. 23	42. 83	42. 91	42. 02	39. 46	42. 73	44. 92	41. 58
Minimum percentage of oil	36. 97	37. 24	37. 62	37. 90	38. 50	38. 39	38. 01	39. 47	39. 47	40. 14
Range in oil content	6. 68	5. 90	5. 61	4. 93	4. 41	3. 63	1. 45	3. 26	5. 45	1. 44

[1] Crop year begins Sept. 1.

It is believed, however, that a fairer representation of the relationship between damaged condition and oil content would obtain if, instead of basing conclusions on the law of averages, comparisons were made of the oil content of sound and damaged kernels from within the same sample. Acting on this assumption, separations were made and studied with samples containing varying quantities and kinds of damaged kernels, samples containing varying degrees of field damage, and samples containing damage caused by fire, by water, and by heat from fermentation.

The various separations were made by hand and ground in a mortar with sand to a condition suitable for extraction. In this way, no loss of the individual types occurred during grinding. The data from this study are given in Table 11. In this table the field-damaged seed has been divided into three groups, and damage caused by storage conditions has been divided into four groups. Type A, field-damaged kernels, are those kernels having a slight to medium blister or scab. Damage has not progressed to an extent that the seed has swollen. Type B, field damage, shows badly swollen seed, heavily blistered or scabby, that would not pass through a one-sixteenth by five-sixteenth-inch wire screen. Type C, field damage represents the green to brown immature kernels, resulting from drought or frost. These kernels are popularly called "flywings." Type D, storage damaged, represents seed damaged by external heat, that is, fire. In this type of kernel the seed coat is uniformly charred. Damage caused by heat of fermentation in storage is represented in Type E. Type F, storage damage, represents the darkest kernels of this type of fire damage. The seeds when in this condition are dark brown or black. Later it is shown that in this type of seed not only the quantity of oil but the quality is changed. Type G represents water-damaged seed—that is, damage resulting from wetting during storage.

A study of Table 11 shows that a damaged condition of a sample does not necessarily mean a reduction in the percentage of oil as compared to a sample free from damage. In fact, with kernels of type A, in a great many instances, there was a decidedly greater percentage of oil in the damaged seed than in the sound kernels. But kernels of this type do not invariably contain more oil than sound seeds. Numerous instances were found where the sound seed contained more oil than the damaged seeds. The reason why damaged seed may contain more oil than sound seed can not be stated fully. Field-damaged seed is the result of numerous factors—water, heat, air, and bacteria or fungi. If the temperature and moisture are favorable and the oxygen supply is good, rapid respiration and oxidation take place, the reserve materials—carbohydrates—are used up resulting in a loss in weight of the kernel. Inasmuch as the starches and sugars are dissipated more rapidly than the oil, because of the loss in kernel weight there is an apparent increase in the oil content. If the conditions are such that sprouting occurs, losses of both oil and carbohydrates take place which result in a reduction of the oil content.

OIL CONTENT OF FOREIGN SEEDS FOUND IN FLAXSEED AND THEIR INFLUENCE UPON OIL CONTENT OF CAR LOTS OF FLAXSEED

Flaxseed on the average contains more foreign material than any other grain crop coming to market. The average percentage of dockage found in flaxseed for the crop year 1924 for the State of North Dakota was 17.4 per cent, for South Dakota 15.6 per cent, and for Minnesota 13.8 per cent.

An analysis of the foreign material shows it to contain, in addition to varying quantities of chaff, sticks, dirt, etc., weed seeds of such plants as lamb's-quarters, pigweed, green and yellow foxtail, millet, Russian thistle, wild buckwheat, flat and round-seeded false flax, Indian mustard, hare's ear mustard, tubling mustard, ball and black mustard, barnyard grass, smartweed, cockle, dock, wild oats, and wheat.

TABLE 11.—*Comparison of the oil content of damaged flaxseed with sound seed separated from the same sample*

Laboratory number	Separations														
	Sound kernels	Field-damaged kernels			Percentage of excess or deficiency of oil content of damaged kernels compared with sound kernels			Storage-damaged kernels				Percentage of excess or deficiency of oil content of damaged kernels compared with sound kernels			
		A	B	C	A	B	C	D	E	F	G	D	E	F	G
	Per cent oil	*Per cent oil*	*Per cent oil*	*Per cent oil*	*Per cent*	*Per cent*	*Per cent*	*Per cent oil*	*Per cent oil*	*Per cent oil*	*Per cent oil*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	41.75	42.66			+2.19										
2	41.83	42.32	40.89		+1.17	−2.24									
3	41.94	42.86			+2.19										
4	40.01	43.49			+8.69										
5	42.10	43.19			+2.58										
6	41.23	42.42	41.55		+2.88	+.77									
7	40.07	40.72	40.37		+1.62	+.74									
8	39.36	40.35	40.48		+2.51	+2.84									
9	41.07	41.47	40.01		+.97	−2.58									
10	42.52	42.91			+.91										
11	40.71	42.42	39.27		+4.20	−3.53									
12	39.93	42.20	40.66		+5.68	+1.82									
13	41.02	42.75	42.20		+4.21	+2.87									
14	40.32	40.47	39.51		+.37	−2.00									
15	39.86	41.17	41.39		+3.28	+3.83									
16	41.90	42.19	41.79		+.69	−.26									
17	39.86	40.47			+1.53										
18	39.02	40.04	39.05		+2.61	+.07									
19	40.70	42.47	41.60		+4.34	+2.21									
20	39.16	40.31			+2.93										
21	38.53	39.75	39.18		+3.16	+1.68									
22	39.29	40.31			+2.59										
23	34.68	32.48			−6.34										
24	39.94	39.67			−.67										
25	40.54	40.41	40.51		−.32	−.07									
26	40.95	39.96			−2.41										
27	39.05	38.42			−1.61										
28	41.32	40.33			−2.39										
29	38.34	38.03	37.25		−.80	−2.84									
30	38.07	37.64	37.13		−1.12	−2.46									
31	38.82	38.02			−2.06										
32	42.27	41.88			−.92										
33	43.56	42.82			−1.69										
34	39.32	35.62			−9.40										
35	39.34	39.31			−.07										
36	40.82	40.09			−1.78										
37	37.00			30.02			−18.86								
38	41.52			35.38			−14.78								
39	43.24			31.81			−26.43								
40	43.78			29.53			−32.54								
41	43.80			36.40			−16.89								
42	42.42			35.90			−15.37								
43	41.29			27.41			−33.61								
44	37.74			34.50			−8.58								
45	41.70							42.30				+1.43			
46	38.95							38.94				.02			
47	38.95							41.11				+5.54			
48E	39.02								37.88				−2.92		
48F	39.02									37.07				−4.99	
49E	39.32								34.58				−12.05		
50E	43.88								39.50				−9.98		
50F	43.88									36.54				−16.72	
51E	40.99								40.60				−.95		
52G	34.60										33.49				−3.20
52G	34.60										33.71				−2.57

NOTE. A.—Field-damaged seed, slight to medium scab or blister.
B.—Field-damaged seed, heavy scab, evidence of sprouting, considerable swelling and splitting.
C.—Field-damaged seed, immature and frosted. So-called flywings.
D.—Storage-damaged seed, fire-burned seed.
E.—Storage-damaged seed, slightly damaged by heat of fermentation.
F.—Storage-damaged seed, badly damaged by heat of fermentation.
G.—Storage-damaged seed, water-damaged seed.

Some of these seeds are easily removed by common cleaning devices commonly employed at cleaning houses. Others, on account of their shape and size, can not be removed without serious loss of the flaxseed itself. Among these are green and yellow foxtail, wild buckwheat, barnyard grass, cow cockle, dock, smartweed, ragweed, flalse flax, and many kinds of mustard.

Inasmuch as their presence in commercially clean flaxseed influences the quantity of oil in direct relation to the percentage of such foreign material present, a study was made of the oil content of the foreign material which can not be removed by the usual methods of grain cleaning and which is generally referred to as inseparable foreign material. This material was grouped into two divisions. Seeds of a pronounced oil-bearing nature were placed in one group and seeds of a small or negligible oil content were placed in a second group.

The data from these tests are given in Table 12. The average oil content of the 55 samples of oil-bearing seeds was 31.18 per cent. The lowest quantity noted was 17.43 per cent obtained from a sample of mustard seed. The highest oil content noted was 46.52 per cent, also found in a sample of mustard seed and in a sample of charlock. The oil content of such oil-bearing seeds as are here analyzed will vary 29 per cent. This is almost three times the average variation found in flaxseed.

TABLE 12.—*Oil content and iodine value of foreign material (weed seeds) commonly present in market samples of flaxseed*

OIL-BEARING SEEDS

	Charlock (*Brassica arvensis*)	Mustard (*Brassica* sp.)	False flax (*Camelina dentata*)	Winter rape (*Brassica napus*)	Wild sunflower (*Helianthus annuus*)	Cress (*Lepidium* sp.)	Average all oil-bearing seeds
Number of samples	7	38	6	1	1	2	55
Average per cent of oil	35.10	33.73	33.41	44.07	20.53	19.68	31.18
Maximum per cent of oil	46.52	46.52	36.16	44.07	20.53	20.28	
Minimum per cent of oil	26.21	17.43	29.91	44.07	20.53	19.09	
Range in oil content	20.31	29.09	6.25			1.19	

IODINE VALUE

	Charlock	Mustard	False flax	Winter rape	Wild sunflower	Cress	Average all oil-bearing seeds
Average	120.7	113.9	143.8	105.0	148.1		
Maximum	125.4	118.5	149.9	105.0	148.1		
Minimum	116.1	99.7	137.7	105.0	148.1		
Range	9.3	18.8	12.2				

NONOIL-BEARING SEEDS

	Green foxtail (*Chaetochloa viridis*)	Cockle (*Vaccaria pyramidata*)	Wild buckwheat	Lambsquarters (*Chenopodium album*)	Pigweed (*Amaranthus retroflexus*)	Dock (*Rumex patentia*)	Average all nonoil-bearing seeds
Number of samples	10	5	6	3	3	2	29
Average per cent of oil	6.17	4.76	3.65	8.45	6.80	3.90	5.74
Maximum per cent of oil	6.31	7.41	5.31	9.34	9.56	4.64	
Minimum per cent of oil	6.03	2.94	2.27	7.19	2.76	3.17	
Range in oil content	.28	4.47	3.04	2.15	6.80	1.47	

The average oil content of the seeds designated as nonoil bearing was 5.74 per cent. The maximum amount was 9.56 per cent found in a sample of pigweed, and the lowest 2.27 per cent found in a sample of wild buckwheat.

Green foxtail, the most common and most persistent weed seed found in dockage-free flaxseed, averaged 6.17 per cent of oil. One per cent of this weed when present in flaxseed reduces the oil content of the lot approximately 0.6 per cent. Not only are such types of weed seed deficient in oil but they have the further disadvantage of reducing the oil yields from a crushing standpoint, inasmuch as they absorb approximately their own weight or volume of linseed oil.

It has been shown that the average oil content of clean flaxseed is 40.3 per cent. The inclusion of weed seeds in commercial flaxseed will reduce the oil content of the lot, the amount of reduction depending upon the percentage of weed seeds present, and whether these weed seeds are rich or poor in oil. Illustrative of this are the data in Table 13, showing the decrease in oil content with an increase in the foreign material present.

TABLE 13.—*Influence of the foreign material remaining in flaxseed after dockage has been removed upon the oil content of flaxseed*

	Percentage of foreign material				
	0 to 0.99	1 to 2.99	3 to 6.99	7 to 9.99	10 to 14.99
Number of samples	4	11	15	14	10
Average per cent foreign material	0.70	1.13	3.6	7.7	12.1
Average decrease in oil content due to foreign material	.35	.82	.91	1.44	3.09

Even though certain weed seeds are rich in oil content, the quality of the oil is not so desirable as that from flaxseed. This is particularly true with reference to the absorptive qualities of the oil, and the percentage of free fatty acids which are present. The absorptive or drying qualities of the oil from these weed seeds average only 68 per cent as good as the absorptive qualities of the oil in flaxseed.

It is evident, therefore, that the oil content of any given lot of flaxseed which contains appreciable quantities of inseparable foreign material can not be determined by observation but must be tested in order to determine accurately its oil content.

RELATION BETWEEN COLOR OF FLAXSEED AND QUANTITY OF OIL

Color of the seed does not appear to be an important index to the quantity of oil in flaxseed. During the last six years many samples of northwestern-grown flaxseed were analyzed that varied in color from a light tan to a deep mahogany brown. A comparison of the color of the seed with the oil content of the sample revealed no definite relationship between depth of color and content of oil.

Samples of flaxseed of a rich mahogany brown color contained no more oil than did samples of a much lighter tint.

These findings are contrary to those of Synder (*8*) whose data show that one would expect appreciable differences in the oil content of flaxseed of different shades of color. But it should be pointed out that as a rule foreign-grown seed, a class which usually is a rich brown color, contains on the average a greater quantity of oil than the domestic crop. On the other hand, fiber flaxseed is also deep brown in color, but contains on the average 1 to 3 per cent less oil than either the domestic-grown seed or the foreign-grown crop.

RELATION BETWEEN SIZE OF FLAXSEED AND OIL CONTENT OF SEED

Large plump flaxseed kernels have generally been considered to contain more oil than seeds smaller in size. Rabak (*7*) reports that small-seeded flax varieties consistently contained a smaller quantity of oil than the varieties having larger seed. Birchard (*2*) also reported that plump, fully matured seeds contained more oil than did smaller seeds.

In connection with the other investigations reported in this bulletin, a comparison was made of the plumpness of flaxseed and its oil content. As a measure of plumpness, the weight of 1,000 average kernels was taken. To afford a fair comparison, the figures for both (weight per 1,000 kernels and percentage of oil) are given on the same basis—moisture free. The results of these tests as given in Table 14, show that there is a gradual increase in oil content as the kernels grow larger.

TABLE 14.—*Relation of size of kernel and oil content*

Number of samples analyzed	Weight per 1,000 kernels	Average oil content	Maximum oil content	Minimum oil content	Range in oil content
	Grams	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	3.50 to 3.59	37.67	37.67	37.67	0.00
2	3.60 to 3.69	39.46	40.17	37.53	2.64
4	3.70 to 3.79	38.68	41.00	37.17	3.83
8	3.80 to 3.89	39.27	40.77	37.71	3.06
9	3.90 to 3.99	39.73	41.12	37.71	3.41
8	4.00 to 4.09	39.78	41.13	39.39	1.74
8	4.10 to 4.19	40.02	41.38	39.98	1.40
3	4.20 to 4.29	41.18	42.26	40.81	1.45
5	4.30 to 4.39	41.33	41.85	40.43	1.42
5	4.40 to 4.49	41.19	41.85	40.43	1.42
1	4.50 to 4.59	40.21	40.21	40.21	.00
2	4.60 to 4.84	40.84	40.89	40.80	.09

The frequency with which a larger percentage of oil was found occurred more often in the large, plump seeds. However, it must be pointed out that the relationship is not specific and that small plump seeds often contain as great a percentage of oil as a sample containing very large kernels.

These tests would seem to bear out the point that, whereas in the same sample of flaxseed there may be a difference in the oil content of kernels caused by size of kernel, it does not necessarily hold that all large kernels of flaxseed from different lots of seed will have a high oil content.

Eleven samples of flaxseed secured from different lots of seed varying in size and plumpness were studied to find if there is any positive relationship between the specific gravity of the flaxseed kernels and the percentage of oil in the samples. The data found from this study are given in Table 15. The kernels having the lowest specific gravity usually contained the greatest percentage of oil. The change in specific gravity, however, is not accompanied by a corresponding unit change in oil content, so that such a determination could not be used as a reliable index of the oil present in the flaxseed.

Table 15.—*Relation of specific gravity of flaxseed to its oil content*

Sample number	Moisture-free basis		Sample number	Moisture-free basis	
	Oil content	Specific gravity		Oil content	Specific gravity
	Per cent			*Per cent*	
1	37.17	1.1574	7	39.98	1.1519
2	37.53	1.1601	8	41.12	1.1383
3	37.89	1.1568	9	41.48	1.1361
4	38.72	1.1591	10	41.87	1.1378
5	39.00	1.1525	11	42.26	1.1379
6	39.49	1.1358			

INSPECTION AND GRADING OF FLAXSEED

Commercial standards for any commodity, to be of the greatest value, must be such as to classify the commodity according to its value for those industries for which it is most extensively used. The grades in these standards should be definite enough to insure uniformity of application, simple enough to be practicable of application where the commodity is first marketed, and stringent enough to indicate real differences in value.

Flaxseed or linseed, as it is sometimes called, is used almost entirely for the production of linseed oil. If the standardized grades are to be of value to the industry for which the product is destined, therefore, grading factors for flaxseed must be used which reflect both the quality and quantity of the oil in the seed.

At the present time, quality and value of a given lot of flaxseed are judged largely from a knowledge of the area in which it was produced and by such physical factors as relate to its general appearance and condition. Test weight per measured bushel, absence of damaged seed and of foreign material, and freedom from excessive moisture and objectionable odors, enter largely into the grade now given to any lot of seed.

FOREIGN FLAXSEED

Most of the foreign-grown flaxseed entering the United States is bought on the standard form of contract of the Linseed Association of New York. This is an association of crushers, brokers, and commission men who deal in flaxseed and other oil-bearing seeds. The aim of the association is to regulate trade conditions in flaxseed and to provide suitable contracts and certificates of analysis for buyers and sellers.

The seed is analyzed for purity, percentage of oil-bearing and of nonoil-bearing seeds, and percentage of linseed oil in the pure seed. Settlement is on the basis of 56 pounds to the bushel.

The contracts differ depending upon the source of the seed. The basis for La Plata or Argentine seed is 96 per cent purity. Other oil-bearing seeds are taken at one-half the value of linseed. If the sample analyzed runs less than 96 per cent of flaxseed with the other oil seeds taken at one-half of their value, the seller must allow the buyer the difference. If the analysis shows above 96 per cent of flaxseed, the buyer pays the difference.

With Indian seed, pure linseed is the basis, and the buyer receives an allowance equal to the percentage of impurities. If the quantity of flaxseed is less than 92 per cent, the buyer is allowed an additional discount equal to the excess of such impurities over 4 per cent.

To receive the highest price, all seed when delivered at the port of destination must be in a sound and merchantable condition, subject to any country-run damaged grains, and warranted to be a fair average quality of the season at the time of shipment. The average quality of the seed is determined by comparison with a monthly standard, made up by compositing the monthly arrivals from producing countries. Similar samples are sent to the Incorporated Oil Seed Association of London, England, which organization acts as a final referee in case disputes can not be settled in this country.

Shipments are sampled by commercial inspectors who sample every sack. When the cargo has been unloaded, all the bag samples are thoroughly mixed together and then as many small samples as are necessary are made up in approximately 1-bushel size. Usually there is one sample for analysis, one for file, and one for the purchaser or seller if he wishes it. These samples are sealed and one is forwarded to the secretary of the association, who arranges for the anlyses to be made in the official laboratory. Any dispute arising over the percentage of impurities or the quality of the flaxseed is usually settled by the interested parties themselves, although the custom of the trade of having a committee of referees appointed is sometimes resorted to. As a rule, no seed is refused but is taken at an allowance to be fixed by agreement.

DOMESTIC FLAXSEED

For the domestic crop there is no central agency or organization with a uniform set of rules and regulations applicable to the inspection and grading of domestic flaxseed. On the contrary, the States of Minnesota, Montana, Oregon, Washington, and Wisconsin and the boards of trade at Chicago, Ill., and Sioux City, Iowa, and the chamber of commerce at St. Louis, Mo., each has its own grades for domestic flaxseed.

RELATION BETWEEN NUMERICAL GRADE OF DOMESTIC FLAXSEED AND OIL CONTENT OF THE SAMPLE

The physical tests previously discussed are used by several grain-inspection departments as part of their work with official grades. The Minnesota State Grain Inspection Department is an example. It therefore becomes of interest to correlate the oil content of the samples with the numerical grade given them under the Minnesota State Grain Inspection Department rules. These data are given in Tables 16 and 17.

TABLE 16.—*Oil content*[1] *of northwestern-grown flaxseed, by grade,*[2] *by crop year 1918 to 1924, inclusive*[3]

Crop year	Commercial grade [2]			
	No. 1 northwestern flaxseed	No. 1 flaxseed	No. 2 flaxseed	Sample grade
1918				
Total number of samples	73	5	6	3
Average percentage of oil	37.66	37.02	36.93	33.96
Maximum percentage of oil	41.65	37.89	38.18	34.60
Minimum percentage of oil	33.50	36.04	33.64	32.35
Range in oil content	8.15	1.85	4.54	2.25
1919				
Total number of samples	23	17	5	----------
Average percentage of oil	36.45	36.17	36.25	----------
Maximum percentage of oil	39.42	37.56	39.11	----------
Minimum percentage of oil	33.89	33.26	34.03	----------
Range in oil content	5.53	4.30	5.08	----------
1920				
Total number of samples	----------	162	2	7
Average percentage of oil	----------	36.86	38.33	37.03
Maximum percentage of oil	----------	40.68	38.58	37.94
Minimum percentage of oil	----------	32.15	38.07	36.21
Range in oil content	----------	8.53	.51	1.73
1921				
Total number of samples	----------	436	50	53
Average percentage of oil	----------	37.20	36.89	36.13
Maximum percentage of oil	----------	40.31	40.30	41.36
Minimum percentage of oil	----------	32.61	34.40	22.58
Range in oil content	----------	7.70	5.90	18.78
1922				
Total number of samples	----------	602	2	4
Average percentage of oil	----------	37.36	37.42	36.56
Maximum percentage of oil	----------	40.68	38.18	36.95
Minimum percentage of oil	----------	29.94	36.68	36.17
Range in oil content	----------	10.74	1.50	.78
1923				
Total number of samples	----------	545	34	5
Average percentage of oil	----------	37.33	36.09	36.10
Maximum percentage of oil	----------	41.15	36.93	36.75
Minimum percentage of oil	----------	27.96	34.54	34.30
Range of oil content	----------	13.19	2.39	2.45
1924				
Total number of samples	----------	298	63	7
Average percentage of oil	----------	37.32	36.90	37.06
Maximum percentage of oil	----------	42.20	39.62	38.49
Minimum percentage of oil	----------	32.87	32.73	35.44
Range of oil content	----------	9.33	6.89	3.05
AVERAGE SEVEN CROP YEARS				
Total number of samples	96	2,065	162	79
Average percentage of oil	37.05	37.04	36.97	36.14
Maximum percentage of oil	40.53	40.07	38.70	37.68
Minimum percentage of oil	33.69	32.12	34.87	32.84
Range in oil content	6.84	7.95	3.83	4.84

[1] Moisture as received at markets.
[2] Minnesota Grain Inspection Department grades for the year in question.
[3] Beginning.

TABLE 17.—*Variation of oil[1] content within the same grade[2] of northwestern-grown flaxseed, crops 1918 to 1924, inclusive*

Crop year	Number of samples	Percentage of samples having the indicated percentages of oil									
		32 to 32.99	33 to 33.99	34 to 34.99	35 to 35.99	36 to 36.99	37 to 37.99	38 to 38.99	39 to 39.99	40 to 40.99	41 to 41.99
NO. 1 FLAXSEED											
1920	162		1.2	6.8	20.4	27.2	22.8	14.2	6.2	1.2	
1921	436	0.4	2.7	8.6	19.7	29.8	23.3	12.8	2.5	.2	
1922	602		1.2	2.3	13.9	22.6	28.2	24.9	5.2	1.7	
1923	545		.7	1.5	11.4	27.3	28.8	18.7	8.8	2.6	0.2
1924	298	.7	.7	3.0	10.1	26.5	27.5	20.8	7.1	3.0	.3
Total samples	2,043										
Yearly average		.2	1.3	4.4	15.1	26.7	26.1	18.3	6.0	1.8	.1
NO. 2 FLAXSEED											
1918	6		16.7			33.3		50.0			
1919	5			40.0		20.0	20.0		20.0		
1920	2							100.0			
1921	50			9.3	20.4	25.9	20.4	13.0	5.5	5.5	
1922	2					33.3		66.7			
1923	34		2.9		8.9	20.6	44.1	14.7	5.9	2.9	
1924	63	1.6		1.6	14.3	39.7	28.6	11.1	3.1		
Total samples	162										
Yearly average		.2	2.8	7.3	6.2	24.7	16.1	36.5	5.0	1.2	
SAMPLE GRADE FLAXSEED											
1918	3	33.3		66.7							
1920	7					57.1	42.9				
1921	53	3.8	1.9	5.7	13.2	26.4	18.9	22.6	7.5		
1922	4			25.0	25.0	50.0					
1923	5			20.0		60.0			20.0		
1924	7			14.3	14.3	14.3	14.3	42.8			
Total samples	79										
Yearly average		6.2	.3	21.9	8.5	34.6	12.7	10.9	4.9		

[1] Oil content on moisture basis of sample as received at Minneapolis or Duluth, Minn.
[2] Minnesota State Grain Inspection Department grades of current date.

From consideration of Tables 16 and 17 it is apparent that commercial grades for flaxseed built entirely about the physical standards of quality here discussed are of doubtful value when it comes to indicating the true oil content of the sample.

Within the same grade of flaxseed a spread of as much as 18 per cent in oil content was found. Moreover, no consistent relationship existed between the oil content of the different lots of flaxseed and any of the commercial grades.

DEVELOPMENT OF A SIMPLE, RAPID TEST FOR OIL CONTENT OF FLAXSEED

The physical tests here discussed were no doubt developed because of lack of a simple and rapid chemical test for determining the oil content of flaxseed.

Such a test would be of great assistance to the vegetable-oil industry, for with it (1) the buyers and sellers of oil-bearing seeds would be in a position to make their price on an oil-content basis, (2) the crusher could know within a short time the composition of the raw materials, and (3) the crushing plant could be more efficiently operated, as frequent tests could be made at short intervals to determine just how much oil was being left in the cake by the presses.

Early attempts have been made by different vegetable-oil chemists to simplify the ether-extraction method for making accurate oil determinations or to develop some rapid test which, although perhaps not so reliable so far as extreme accuracy is concerned, would give results sufficiently accurate for routine use in testing raw and finished products. As a practical matter only one of the proposed short methods has proven worth while. Reasons for lack of practical success in the other tests include: (1) Time element not sufficiently reduced; (2) expense of making the test too great; (3) accuracy, as compared with the standard methods, not sufficient; or (4) method not simple enough for the average analyst to carry out.

Of all the proposed methods, Wesson's (*9*) observation that he could measure the quantity of oil in cottonseed meal and meats by noting the change in the refractive index of a solvent known as halowax (which, chemically speaking, is a substituted naphthalene) as it became diluted with cottonseed oil extracted from the sample of cottonseed under test, appeared to be the most worth while for consideration as a general method of study for the determining the oil content of many of the oil-bearing substances. Tests were, therefore, made to see if the principle of the Wesson test could be applied so as to determine the oil content of flaxseed or linseed.

Refractive index determinations were made on grade 1007 halowax oil and upon a composite sample of ether-extracted linseed oil at the grain research laboratory of the Bureau of Agricultural Economics. The refractive index of the halowax oil tested at 25° C. was 1.63354. The refractive index of the linseed oil tested was 1.47878 at the same temperature. The difference in the two readings was 0.15476—sufficient in size, it would seem, to make quantitive determinations of linseed oil in the presence of halowax oil possible.

To note to what extent varying quantities of linseed oil would change the refractive index of halowax oil, percentage mixtures by weight of halowax oil and linseed oil were made and their refractive indices read at 25° C., with a new type of Abbee refractometer made in this country. This instrument could be accurately read to the fourth decimal place, and interpolation could be had to the fifth decimal place.

The results of these tests are given in Table 18. It will be seen that as the percentage of linseed oil in the mixture changed, so likewise did the refractive index of the halowax oil change. The refractive index of the halowax oil without linseed oil present was 1.63354; with 10.697 per cent of linseed oil present this reading changed to 1.61313; and when 14.237 per cent of linseed oil was present the refractive index had changed to 1.60636. On the other hand, the change in the refractive index of the halowax oil per 1 per cent of linseed oil present was a constant, namely, 0.001906 per every per cent and fraction thereof of linseed oil present.

TABLE 18.—*How the refractive index of halowax oil is changed per 1 per cent of linseed oil present*

[Readings taken at 25° C.]

Percentage of linseed oil in halowax oil	Refractive index of halowax-linseed oil mixture	Change in refractive index of halowax oil due to linseed oil present	Difference in refractive index of halowax per 1 per cent of linseed oil
10.697	1.61313	0.02041	0.001908
10.983	1.61255	.02099	.001911
12.099	1.61048	.02306	.001906
13.100	1.60863	.02491	.001902
13.546	1.60779	.02575	.001901
14.237	1.60636	.02718	.001909
Average	------------	------------	.001906

Refractive index of halowax oil, 1.63354.

Each factor in the Wesson method (*9*), as it related to flaxseed, was studied step by step, to obtain greater refinement and to obtain closer agreement with the ether-extraction method of the Association of the Official Agricultural Chemists (*1 p. 72, Nos. 9, 10, 11*) and after considerable effort the following method was evolved, hereafter called the optical method:

DESCRIPTION OF TEST

Apparatus required:

One motor-driven experimental flouring mill with 6 by 6 inch rolls, corrugated 40 to the inch.
Six 3-inch porcelain mortars, with pestles.
One analytical balance, sensitive to one-tenth of a milligram.
One electric hot plate, 8 by 8 inches.
One 25 cubic centimeter Shellbach burette.
Two dozen test tubes 5 by one-half inches, with wire rack for holding same.
Two dozen 40-millimeter glass funnels.
Supply of halowax oil, No. 1000 or No. 1007.
Supply of folded filter paper, absorbent cotton, and glass rods.
One fifth decimal place water-jacketed refractometer.
One temperature-regulating device.
Two 25 cubic centimeter pycnometers.

An assembled unit is shown in Figure 1.

DIRECTIONS FOR PREPARATION OF CONVERSION TABLES

(1) Into three 4-ounce bottles, previously weighed, place approximately 25 cubic centimeters of halowax oil and note the exact weight of the halowax oil added to each bottle. Next add linseed oil to each of the three bottles so that, by weight, a 10, a 12, and a 14 per cent solution of linseed oil in halowax oil will be obtained. Additional mixtures may be made if desired, but three will usually be enough. It is not necessary to obtain even percentages of linseed oil in the mixture. As the optical method is standardized against the ether-extraction method, linseed oil obtained by ether extraction is used for making up the mixtures with halowax oil.

When the bottles containing the known percentages of linseed oil have been thoroughly mixed, read the refractive index of each mixture, as well as the refractive index of the halowax oil used, at a temperature of 25° C., and from these data determine the change in the refractive index of the halowax oil per 1 per cent of linseed oil present in the mixture. The results will be of the order illustrated in Table 18. The constant obtained will depend upon the original refractive indices of the halowax oil and the linseed oil used.

(2) Determine the percentage by weight of linseed oil present in halowax oil when 4 cubic centimeters of halowax oil are mixed with a 2-gram sample of ground flaxseed. To do this the weight of 4 cubic centimeters of halowax oil must first be determined. This is accomplished by direct weighing of several 4 cubic centimeter portions of halowax oil or by determining the specific gravity of the halowax oil and by multiplying this value by 4, the volume of halowax oil used in the test.

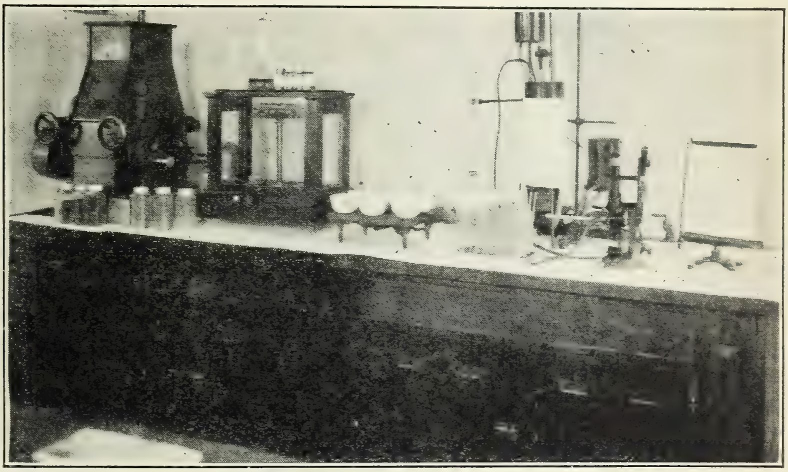

FIG. 1.—Apparatus for the optical method for determining oil content of flaxseed

Knowing the exact weight of the 4 cubic centimeters of halowax oil and the weight of linseed oil that would be present in flaxseed of known composition, the percentage of linseed oil in the halowax-linseed oil mixture when 2 grams of ground flaxseed are used in the test is now determined. To illustrate, suppose a sample of flaxseed contained 31 per cent of linseed oil. A 2-gram sample would contain 0.62 gram of oil. If this 0.62 gram of oil was mixed with 4 cubic centimeters of halowax oil which weighed 4.904 grams, the percentage of linseed oil in halowax oil would be 11.224 per cent. Conversions of this nature are then made over any part of the scale from 3 to 45 per cent as is illustrated in Table 19 in whole per cents and tenths of 1 per cent, depending on how extensive a table is desired. As an aid in preparing this step in the conversion table the following formula will prove useful:

$$\frac{\text{Weight of oil in 2-gram sample of flaxseed}}{\text{Weight of 4 cubic centimeters of halowax oil} + \text{weight of oil in 2-gram sample of flaxseed}} = \text{Percentage of linseed oil in the mixture.}$$

TABLE 19.—*Percentages of linseed oil in a halowax-linseed oil mixture made by adding 4 cubic centimeters (4.904 grams) of halowax oil to 2 grams of ground flaxseed containing 31, 31.1, 31.3, 31.5, 31.7, and 32 per cent of linseed oil*

Percentage of linseed oil in flaxseed sample	Percentage of linseed oil in the halowax-linseed oil mixture
31.0	11.224
31.1	11.256
31.3	11.320
31.5	11.384
31.7	11.448
32.0	11.544

(3) In Table 18 it was shown that for every 1 per cent of linseed oil present in halowax oil the refractive index of halowax oil changed in a definite and regular manner. In the case of the experiments cited this change was 0.001906. All that is necessary, therefore, to express refractive index values in terms of the percentage of linseed oil present in ground flaxseed is to multiply each per cent and tenth of 1 per cent of linseed oil, as described in section 2 above, by the constant described under section 1. Finally, point off nine decimal places and subtract the value obtained from the refractive index of the halowax oil used in the tests. The results will appear like those in Table 20, which is the section of the scale usually used for flaxseed.

(4) As is general with optical measurements, the temperature at which the readings are made is important. It is necessary when using this method to adjust individual readings to the same temperature basis. For general conditions 25° C. has been selected as an average laboratory temperature. Thus, for every degree above or below 25° C., 0.00045 is added to or subtracted from the original reading. This adjustment can not be overlooked, as this reading—0.00045—is equivalent to approximately 0.75 per cent of oil.

DETAILS OF METHOD FOR MAKING TEST

(1) Grind 25 grams of the flaxseed sample so that at least 80 per cent of the meal will pass through a 34-grits gauze sieve.

(2) Weigh out 2 grams of the ground sample and empty it into a 3-inch porcelain mortar, which has been previously heated to 70° C., and grind the flaxseed meal with 4 cubic centimeters of halowax oil, grade No. 1007, for at least two minutes.

(3) Filter through a small folded filter, using a 40-millimeter glass funnel seated on a flat-bottomed test tube.

(4) Let the tube and contents cool to room temperature. Place a drop of this mixture on the prism of the refractometer and take the average of three readings.

(5) Note the temperature, and for every degree above 25° C. add 0.00045 to the refractometer reading and for every degree below 25° C. subtract this amount.

TABLE 20.—*For converting refractometer reading into percentages of linseed oil*

[Readings made at 25° C.]

Refractometer reading	Linseed oil	Refractometer reading	Linseed oil	Refractometer reading	Linseed oil
	Per cent		*Per cent*		*Per cent*
1.61276	30.0	1.60967	35.1	1.60669	40.2
1.61270	30.1	1.60961	35.2	1.60663	40.3
1.61264	30.2	1.60955	35.3	1.60658	40.4
1.61258	30.3	1.60949	35.4	1.60652	40.5
1.61252	30.4	1.60943	35.5	1.60646	40.6
1.61246	30.5	1.60938	35.6	1.60641	40.7
1.61239	30.6	1.60932	35.7	1.60635	40.8
1.61233	30.7	1.60926	35.8	1.60629	40.9
1.61227	30.8	1.60920	35.9	1.60623	41.0
1.61221	30.9	1.60914	36.0	1.60618	41.1
1.61215	31.0	1.60908	36.1	1.60612	41.2
1.61209	31.1	1.60902	36.2	1.60607	41.3
1.61203	31.2	1.60896	36.3	1.60601	41.4
1.61197	31.3	1.60890	36.4	1.60595	41.5
1.61190	31.4	1.60884	36.5	1.60589	41.6
1.61184	31.5	1.60878	36.6	1.60584	41.7
1.61178	31.6	1.60873	36.7	1.60578	41.8
1.61172	31.7	1.60867	36.8	1.60572	41.9
1.61166	31.8	1.60861	36.9	1.60567	42.0
1.61160	31.9	1.60855	37.0	1.60561	42.1
1.61154	32.0	1.60849	37.1	1.60556	42.2
1.61148	32.1	1.60843	37.2	1.60550	42.3
1.61142	32.2	1.60837	37.3	1.60544	42.4
1.61136	32.3	1.60832	37.4	1.60539	42.5
1.61130	32.4	1.60826	37.5	1.60533	42.6
1.61124	32.5	1.60820	37.6	1.60527	42.7
1.61117	32.6	1.60814	37.7	1.60522	42.8
1.61111	32.7	1.60808	37.8	1.60516	42.9
1.61105	32.8	1.60802	37.9	1.60510	43.0
1.61099	32.9	1.60797	38.0	1.60505	43.1
1.61093	33.0	1.60791	38.1	1.60499	43.2
1.61087	33.1	1.60785	38.2	1.60493	43.3
1.61081	33.2	1.60779	38.3	1.60488	43.4
1.61075	33.3	1.60773	38.4	1.60482	43.5
1.61069	33.4	1.60767	38.5	1.60477	43.6
1.61063	33.5	1.60762	38.6	1.60471	43.7
1.61057	33.6	1.60756	38.7	1.60465	43.8
1.61051	33.7	1.60750	38.8	1.60460	43.9
1.61045	33.8	1.60744	38.9	1.60454	44.0
1.61039	33.9	1.60738	39.0	1.60449	44.1
1.61033	34.0	1.60733	39.1	1.60443	44.2
1.61027	34.1	1.60727	39.2	1.60437	44.3
1.61021	34.2	1.60721	39.3	1.60432	44.4
1.61015	34.3	1.60715	39.4	1.60426	44.5
1.61009	34.4	1.60710	39.5	1.60421	44.6
1.61003	34.5	1.60704	39.6	1.60415	44.7
1.60997	34.6	1.60698	39.7	1.60410	44.8
1.60991	34.7	1.60692	39.8	1.60404	44.9
1.60985	34.8	1.60687	39.9	1.60399	45.0
1.60979	34.9	1.60681	40.0		
1.60973	35.0	1.60675	40.1		

(6) Wipe off the prism of the refractometer with a piece of soft absorbent cotton.

(7) Note the percentage of oil in the sample under test by comparing the refractometer reading with a set of oil values which have been assigned to the refractometer readings.

The data given in Table 21 compares the oil content of 120 samples of flaxseed, covering a wide range in oil content, as determined by the method outlined above, with the results of the method of analysis described as official by the Association of Official Agricultural Chemists (*1*).

TABLE 21.—*Comparison of oil content of 120 samples of flaxseed as determined by the method adopted by the Association of Official Agricultural Chemists and as determined by the proposed optical method*

Sample No.	Per cent oil ether extraction method	Per cent oil optical method	Difference [1]	Sample No.	Per cent oil ether extraction method	Per cent oil optical method	Difference [1]
			Per cent				*Per cent*
1	37.93	37.70	−0.23	61	41.71	41.92	+0.21
2	40.05	40.10	+.05	62	41.10	40.87	−.23
3	36.04	35.78	−.26	63	40.92	40.83	−.09
4	39.05	38.75	−.30	64	43.18	43.28	+.10
5	36.11	35.92	−.19	65	42.23	42.12	−.11
6	36.54	36.70	+.16	66	43.55	43.56	+.01
7	38.75	38.87	+.12	67	37.65	37.72	+.07
8	39.14	38.89	−.25	68	40.33	40.28	−.05
9	38.45	38.14	−.31	69	38.52	38.61	+.09
10	37.08	37.00	−.08	70	35.65	35.81	+.16
11	38.29	38.09	−.20	71	37.36	37.29	−.07
12	37.34	37.22	−.12	72	38.64	38.56	−.08
13	39.10	39.03	−.07	73	38.15	38.00	−.15
14	36.61	36.60	−.01	74	39.91	39.88	−.03
15	40.69	40.59	−.10	75	39.47	39.16	−.31
16	37.74	37.60	−.14	76	38.71	38.52	−.19
17	37.65	37.77	+.12	77	39.67	39.63	−.04
18	38.53	38.27	−.26	78	37.55	37.50	−.05
19	36.08	36.17	+.09	79	39.04	39.20	+.16
20	39.91	39.79	−.12	80	38.90	38.75	−.15
21	39.99	39.68	−.31	81	37.35	37.32	−.03
22	40.32	40.26	−.06	82	39.75	39.72	−.03
23	37.94	37.99	+.05	83	38.66	38.67	+.01
24	35.28	35.55	+.27	84	40.50	40.33	−.17
25	36.71	36.98	+.27	85	39.94	39.70	−.24
26	38.44	38.18	−.26	86	40.25	40.22	−.03
27	37.72	37.54	−.18	87	39.09	39.12	+.03
28	37.92	37.91	−.01	88	39.15	38.90	−.25
29	40.64	40.48	−.16	89	40.85	40.62	−.23
30	29.60	29.86	+.26	90	36.89	36.91	+.02
31	38.30	38.24	−.06	91	35.44	35.55	+.11
32	36.48	36.41	−.07	92	37.26	37.29	+.03
33	39.27	39.28	+.01	93	35.23	35.16	−.07
34	40.14	39.81	−.33	94	38.36	38.30	−.06
35	38.07	37.84	−.23	95	35.53	35.42	−.11
36	39.24	39.32	+.08	96	36.64	36.66	+.02
37	37.42	37.36	−.06	97	36.40	36.29	−.11
38	36.84	36.64	−.20	98	35.95	36.08	+.13
39	38.08	37.92	−.16	99	40.95	40.85	−.10
40	37.93	37.96	+.03	100	38.88	38.90	+.02
41	39.75	39.88	+.13	101	37.10	37.30	+.20
42	38.89	39.01	+.12	102	36.55	36.47	−.08
43	39.82	39.74	−.08	103	35.77	35.88	+.12
44	37.65	37.64	−.01	104	37.48	37.58	+.10
45	38.62	38.74	+.12	105	38.99	38.90	−.09
46	38.77	38.64	−.13	106	37.75	37.75	.00
47	38.85	38.78	−.07	107	39.78	39.70	−.08
48	39.28	39.17	−.11	108	39.07	39.15	+.08
49	37.58	37.47	−.11	109	38.87	39.00	+.13
50	38.05	38.11	+.06	110	38.62	38.63	+.01
51	38.37	38.33	−.04	111	38.68	38.52	−.16
52	37.00	37.10	+.10	112	38.57	38.52	−.05
53	38.45	38.26	−.19	113	38.84	38.70	−.14
54	37.29	37.32	+.03	114	38.59	38.50	−.09
55	38.48	38.57	+.09	115	39.92	39.88	−.04
56	38.56	38.24	−.32	116	39.01	38.98	−.03
57	37.35	37.49	+.14	117	41.32	41.27	−.05
58	37.16	37.15	−.01	118	41.37	41.23	−.14
59	36.94	37.10	+.16	119	40.01	39.85	−.16
60	37.30	37.20	−.10	120	39.85	39.85	.00

[1] Plus sign indicates greater percentage by optical method. Minus sign indicates greater percentage by ether-extract method.

A study of this table shows that the results of 45.8 per cent of the samples tested by the optical method varied less than 0.1 per cent from the results secured by the method of the Association of Official Agricultural Chemists; 35 per cent of the results varied 0.1 to 0.19 per cent; 14.2 per cent varied 0.2 to 0.29; and only 5 per cent varied 0.3 per cent or more, the greatest variation in any sample being only 0.33 per cent.

The method works equally well on linseed cake or meal, as will be seen by the data presented in Table 22, in which a comparison of the oil results obtained with 39 samples of linseed cake by the ether-extraction and by the optical method is given. With the linseed cake it was necessary to pass the material through a burr mill in order to grind it to a fine state of subdivision. For sake of uniformity the linseed meal was also passed through a burr mill.

TABLE 21.—*Comparison of results obtained in determining oil content of linseed meal and cake by the ether-extraction and optical methods*

Sample number	Per cent oil, ether-extract method	Per cent oil, optical method	Difference	Sample number	Per cent oil, ether-extract method	Per cent oil, optical method	Difference
1	6.34	6.39	+0.05	21	6.76	6.60	−0.16
2	6.33	6.31	−.02	22	6.04	6.12	+.08
3	6.18	6.13	−.05	23	5.60	5.17	−.43
4	6.34	6.13	−.21	24	5.37	5.25	−.12
5	5.54	5.26	−.28	25	5.84	5.80	−.04
6	6.50	6.27	−.23	26	5.53	5.45	−.08
7	5.65	5.50	−.15	27	6.48	6.40	−.08
8	6.51	6.50	−.01	28	6.83	7.00	−.17
9	5.84	5.63	−.21	29	6.36	6.10	−.26
10	5.75	5.45	−.30	30	7.96	7.78	−.18
11	6.02	5.72	−.30	31	5.06	4.89	−.17
12	5.82	5.41	−.41	32	5.86	5.82	−.04
13	5.61	5.65	+.04	33	6.12	6.28	+.16
14	5.53	5.42	−.11	34	6.29	6.20	−.09
15	7.19	7.12	−.07	35	7.93	7.70	−.23
16	6.84	6.60	−.24	36	8.55	8.23	−.32
17	4.57	4.80	+.23	37	7.40	7.32	−.08
18	5.61	5.30	−.31	38	6.13	5.97	−.16
19	5.33	5.20	−.13	39	8.11	8.28	+.17
20	5.79	5.73	−.06				

[1] Plus sign indicates greater percentage by optical method. Minus sign indicates greater percentage by ether-extract method.

Comparison of the data obtained by using the two methods shows an average difference of 0.16 per cent. Greater differences were obtained with the meal than with the ground flaxseed. No doubt this was due to the smaller quantities of oil in the cake, making the reading by the optical method more difficult to carry out.

SPECIAL POINTS FOR CONSIDERATION IN MAKING THE OPTICAL TEST

FINENESS OF DIVISION OF SAMPLE

As the method was being developed it was brought out that the seed had to be pulverized to a very fine state of subdivision before accurate results were obtainable. It was found that seed ground on an attrition mill was not in a satisfactory condition as it was too coarse for rapid and complete solvent action. Many trials were made with grinding devices of various kinds, and it was finally determined that a small flouring mill, having rolls 6 by 6 inches, corrugated 40 to the inch, was the most satisfactory device for grinding flaxseed samples for analytical work. Such a mill reduces and pulverizes flaxseed without difficulty, to a point where over 80 per cent will pass through a 34 grits gauze in about four to five minutes.

VOLUME OF HALOWAX OIL TO USE

Experiments have shown that 4 cubic centimeters of halowax oil is the optimum quantity to use with a 2-gram sample of flaxseed meal. With this quantity of solvent this method checks the ether-extraction method the closest. Although 3 cubic centimeters work well with some samples, with the majority this quantity is usually completely absorbed by the meal necessary for the test.

TEMPERATURE AT WHICH READINGS ARE MADE

The temperature at which reading are made should always be the same in order that different operators may obtain concordant results. This end can be accomplished by using a conversion chart or by the continued used of a temperature regulator. It is believed the chart system is preferable, inasmuch as less time is lost in making initial tests, because the operator does not have to wait until a specified temperature is reached.

TEMPERATURE OF EXTRACTION

The optimum temperature at which to allow the extraction to take place appears to be 70° C. Extracting in the cold reduces the percentage of oil extracted.

FILTERING THE HALOWAX-LINSEED OIL MIXTURE

The filtering of the halowax-linseed oil mixture is accomplished by the use of a small, dry, folded filter, instead of the absorbent-cotton filter recommended by Wesson. By using the small folded filter, a cleaner filtrate is obtained and with less effort than when using absorbent-cotton filter. Only a few drops of the filtrate are necessary for making the refractometer reading.

CLEANING PRISM

Warning.—Because of the highly solvent action of halowax oil, it is absolutely essential for accurate results that this material be completely removed from the faces of the prism after each test has been completed. Failure to do this will not only result in an incorrect oil test reading, but will also eventually result in a corrosive action on the back of the prism.

TIME REQUIRED FOR TEST

After the method was developed tests were made to determine the amount of time necessary for one man to complete a single determination, with the following results:

	Minutes
Preparing sample (25 grams)	5
Weighing and adding halowax	1
Grinding	2
Filtering	1½
Taking mixture and applying to prism	½
Reading and recording result and wiping prism	2
Total time	12

After the analyst has become thoroughly familiar with the method 10 to 12 tests an hour should be made easily. Moreover, when a volume of samples is being handled and help is supplied the time for making the test can be shortened.

SUMMARY

Large differences have been found in the oil content of flaxseed of various classes. Within given classes of flaxseed this variation in oil content amounts, in some crop years, to as much as 15 per cent.

This variation in oil content is due to climatic and varietal conditions and is further influenced by the manner in which the flaxseed is grown, harvested, and brought into commerce.

There is no close relationship between the test weight per bushel of flaxseed and its oil content.

The percentage of damaged flaxseeds contained in a sample is an expression of the quality of the oil in the flaxseed rather than of the amount of oil present.

Foreign material occurring in flaxseed is of two general types. The material of one type contains no oil; that of the other type is oil bearing. The amount of oil in such oil-bearing seeds varies from approximately 17 per cent to over 46 per cent. Thus the effect of foreign material present in flaxseed upon the oil content of the sample depends upon the character and quantity of the foreign material present. Nonoil-bearing seeds have the additional drawback of absorbing their own volume of oil during the crushing process.

Excessive moisture in flaxseed lowers its intrinsic value, makes it a storage risk, and influences the efficiency with which it can be handled in the plant.

As no close relationship exists between the physical factors now influencing the commercial grade flaxseed and the oil content of the seed, there can be no close relationship between present commercial grades of flaxseed and the oil content of the seed.

To obtain exact information regarding the oil content of flaxseed, therefore, it is necessary to make a careful chemical analysis. For this purpose the optical method, described in detail, is recommended.

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