9-1-1927

A Study of Certain Physical and Chemical Characteristics of Flaxseed and Linseed Oil

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Bulletin 228 September, 1927

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Digest

1. The weight per bushel of flax and the weight per 100 seeds increase with the degree of maturity. At complete maturity the weight per bushel and the weight per 100 seeds is greatest. The specific gravity of the seed decreases as it approaches maturity.

2. Immature flaxseed has a lower percentage of oil than mature seed. Flax harvested in the green stage (August 25) contained 29.51 per cent oil while flax harvested when fully mature (September 21) contained as an average 36.84 per cent oil.

3. The iodine numbers vary inversely with the percentage of oil. The iodine numbers of the oil from the immature samples are higher than from mature samples. The oil from immature samples would apparently possess the better drying quality.

4. As the percentage of oil increases with maturity in flaxseed, the percentage of sucrose decreases. The percentage of nitrogen is higher in immature flaxseed and decreases as flaxseed becomes more mature.

5. There is a variation of from one to three per cent in the oil content of nine varieties of flax.

6. There is no apparent correlation between the oil content of flaxseed and the previous cropping system.

7. There is little variation in the oil content of flaxseed planted on different dates.

A Study of Certain Physical and Chemical Characteristics of Flaxseed and of Linseed Oil

A. L. Bushey, Leo Puhr, and A. N. Hume

The cultivation of flax for the production of flaxseed and for linseed oil is one of the important industries in the northwest. In 1924 there was approximately twenty-four million bushels of flaxseed produced in the United States.

Flaxseed is the source of linseed oil. From the manufacturers' standpoint linseed oil is the most valuable part of the flaxseed. Flaxseed yields from 30 to 40 per cent of its weight in oil, or about 2½ gallons to the bushel (56 pounds) of seed.

The usefulness of linseed oil in the industries is based upon the property of the oil to dry to a tough elastic film when exposed in thin layers to the air. Linseed oil is a typical example of a class of fatty oils known as drying oils. The absorption of oxygen by linseed oil alters its composition and is accompanied by the formation of a compound known as linoxyn, which constitutes the tough elastic skin so familiar when the oil is allowed to dry. The usefulness of linseed oil as a protective coating is due entirely to the formation of the compound linoxyn, which is resistant to the effects of heat and moisture to the outside elements to a remarkable degree.

Linseed oil is used in the manufacture of paints and varnishes in linoleum, oilcloth, printers' ink, patent leather and a few other products. It is the drying property or the property of absorbing oxygen that makes linseed oil valuable in the manufacture of the above products. The greater the drying property of the oil, the more durable and resistant is the product.

Up to the present time in the buying and selling of flaxseed, little attention has been given to the quality and quantity of the oil. Since there are many varieties of flax grown under various conditions, it seems desirable to know whether the oil in these varieties of flaxseed differ in quantity and drying qualities. This study is concerned largely with the problem of the physical characteristics of the seeds and quantity and drying properties of the oil in the seed.

Historical

Rabek (7) Bulletin 655, United States Department of Agriculture found differences in the chemical properties of the oils of four varieties of flax grown under several climatic conditions. The yields of oil were found to vary with the variety of flax as well as with the locality in which it was grown. It was found by him that certain varieties gave constantly high or low yields of oils during the two years in which the experiment was conducted, and certain stations yielded flax samples with constantly high or low oil content. A direct relationship appears to exist between the drying property of the oils, the specific gravity and iodine value. Oils combining high acidity with high specific gravity and possessing a relatively high iodine value invariably dried to a fine film most rapidly. The lightest colored oils invariably possessed the most rapid drying properties.

Games, Allard and Talbert (3) have shown in experiments with soybeans, that except for the period immediately following blooming, and directly preceding final maturity, there is a fairly uniform increase in oil content, both relative and absolute, throughout the development of the seed, and no evidence was found that there is an actual period of very intense oil formation at any stage of seed development. Different varieties of soybeans under the same conditions showed marked differences in oil content. They also found that the relative fertility of the oil appears to be a minor factor in influencing the oil content. They also found that the application of nitrogen did not affect the size of the seed, but lowered the percentage of oil, while the application of phosphorus did not affect either the oil content or the size of the seed.

Eyre, J. W. and Fisher, E.A. (2) report that after flowering of flax the seeds contain very little oil. After this comes another period of two weeks during which the formation of oil takes place with great rapidity. During the last two or three weeks, the increase in oil content was found to be extremely small, whereas the increase during the two previous weeks or middle period amounted to more than 21 per cent. He also found that the application of nitrogen, phosphorus and potassium had no appreciable effect on the oil content.

Purpose of Experiment

From the review of the foregoing literature it is evident that little work has ever been done on the chemical composition of flax. Most of the work on flax up to the present time has been confined to diseases, principally the securing of varieties that are resistant to wilt.

In an attempt to secure information in regard to the factors affecting the physical characteristics and chemical composition of flaxseed, the following work has been done in this experiment:

1. The effect of time of harvesting upon physical characteristics of the seed.
2. The relation of the time of harvesting to the quantity and drying properties of the oil.
3. The effect of time of harvesting upon the nitrogen and carbohydrate content of the seed.
4. The variation in oil content due to varietal differences.
5. The influence of the date of planting to the oil content.
6. The effect of the previous cropping system upon the oil content.

Experimental Methods

Weight Per Bushel:—The weight per bushel was determined by filling a 25 cc. pycnometer to the mark with seeds. The seeds were poured through a funnel held at a height of one-half inch above the 25 cc. mark. The weight of the pycnometer and seeds minus the weight of the pycnometer gave the weight of the seeds occupying a 25 cc. volume. From the weights obtained in grams the weight per bushel was calculated.

Specific Gravity of Seeds:—A 10 cc. pycnometer was filled with toluene at a temperature of 20 degrees and weighed. Part of the toluene was poured out and one gram of flax seed was introduced into the pycnometer. The air bubbles were expelled by shaking and heating. The pycnometer was refilled to the top of capillary tube in glass stopper and weighed.

The weight of the pycnometer full of toluene plus the weight of flax added, minus the weight of the full pycnometer containing the flax gives the weight of toluene displaced by the seed. The weight of one cubic centimeter of toluene at 20 degrees centigrade equals .866 grams.

Then $\frac{\text{Weight of flax in grams}}{\text{Volume of toluene displaced}}$ equals Specific Gravity.

The same pycnometer was used throughout all of the determinations and all of the specific gravity determinations were done at the same temperature of 20 degrees centigrade.

Oil Determinations:—Two gram samples in duplicate of flaxseed were dried, at a temperature of 80 degrees, in a vacuum oven in an atmosphere of carbon dioxide. The samples were dried until a constant weight was obtained.

The water-free samples were extracted for eighteen hours with anhydrous ethyl ether. A Bailey-Walker extraction apparatus was used. After extraction the samples were re-weighed and the oil content was obtained by the loss in weight.

Iodine Numbers:—The iodine numbers were determined according to the Hanus Method (4). An iodine monobromide solution was prepared by dissolving 13.6 grams of powdered iodine in 825 cc. of glacial acetic acid. An amount of bromide equivalent to 13.6 grams of iodine was added to the solution.

The oil which remained in the ether solution after the extraction was carefully transferred to a 500 cc. glass stoppered iodine flask. The ether was evaporated off at reduced pressure in an atmosphere of carbon dioxide. The oil left in the flasks after the ether was removed was dissolved in 10 cc. of chloroform and then 25 cc. of the iodine monobromide was added. The flasks were stoppered and allowed to stand for 30 minutes, shaking occasionally.

At the same time the iodine monobromide was measured into the oil solution, the same amount was measured into two flasks containing chloroform but no oil. This was for the blank determination.

At the end of the absorption period 15 cc. of potassium iodide* solution and 100 cc. of water were added to each flask.

$$IBr + KI \longrightarrow KBr + I_2$$

The unabsorbed iodine was immediately titrated with sodium thiosulphate

$$2Na_2S_2O_3 + I_2 \longrightarrow Na_2S_4O_6 + 2NaI$$

The amount of unabsorbed iodine subtracted from the total amount of iodine in the blank is equal to the iodine absorbed by the oil.

Sugar Determinations:—Two gram samples of flaxseed in duplicate were extracted with ether in alundum crucibles in a Bailey-Walker extraction apparatus. After the oil was completely removed from the samples, the samples were extracted with 70 per cent alcohol. The alcoholic solution of sugars was evaporated in a steam bath to remove the alcohol.

*The addition of potassium iodide after absorption gives a titration which may be calculated as though iodine was the only halogen present.

The residue was transferred to 50 cc. volumetric flasks. To clear solution, 10 cc. of neutral lead acetate was added to each volumetric flask and the solution was then made up to the mark and filtered. The excess lead acetate was precipitated with sodium carbonate and again filtered. Ten cc. aliquots were taken from each sample and placed in 100 cc. centrifuge tubes. Forty cc. of Benedicts solution was added and the tubes were boiled for six minutes and cooled. The tubes were centrifuged for six minutes. Ten aliquots of the clear solution were withdrawn by means of a pipette. This solution was made acid with sulphuric acid, 10 cc. of potassium iodide was added and the copper remaining in the solution was titrated with standard sodium thiosulphate. Blank determinations were run at the same time. The amount of copper remaining in the solution subtracted from that in the blank multiplied by five gives the total amount of copper reduced by the sugar.

The above method determined the reducing sugars. The non-reducing sugars of succrose was determined in the same manner, except that .5 cc. of hydrochloric acid was added to each tube and the tubes were allowed to stand over night. The solution was made alkaline with sodium carbonate and the sugar was determined in the usual manner.

Nitrogen:—The nitrogen was determined by the ordinary Kjeldahl method.

Plan of Procedure

History of Seed Selected for Analysis:—In order to determine the effect of maturity on the quantity and quality of oil, five samples of flax in duplicate were harvested at the following dates: August 25, August 31, September 10, September 21, and October 1. These samples will be designated as Lots 1, 2, 3, 4, 5, commencing with August 25. After harvesting the samples were stored in a dark room, and the samples were threshed when thoroughly dry.

The field from which the above samples of flax were taken was planted rather late—June 10.

Description of Samples Harvested:—Following is a description of the samples harvested at the five successive dates:

August 25—About one-third of seeds greenish in color, one-half seeds shrunken. As a whole sample immature. Straw green. Some flowers were still present.

August 31—Sample immature. Many black to greenish colored seeds. Seeds more plump than August 25 sample. Straw green.

September 10—Seeds fairly well developed. Very few green seeds. Straw turning brown.

September 21.—Seeds well developed and mature. Bright in color. Should be harvested.

October 1—Plants dead ripe. A large portion of bolls dropped.

The samples selected for studying the varietal variation in the oil content were secured from the Highmore substation. The following varieties were selected: Damont 686, Promost S. D. 25, Russian S. D. 695, Frontier S. D. 155, Acro S. D. 1102, Common S. D. No. 30, Novo Rossick S. D. 697, Select Russian, Stephen S. D. 361, Tashkent S. D. 383.

From the Eureka substation samples were selected from ten plots that represent five different dates of seeding.

Plot Number 221, Planted 4-15-25, Ripe 7-27-25
222, Planted 4- 1-25, Ripe 7-27-25
223 Planted 4-15-25, Ripe 7-27-25
224, Planted 4-15-25, Ripe 7-27-25
225, Planted 4-15-25, Ripe 7-27-25
226, Planted 4-15-25, Ripe 7-27-25
227, Planted 4-15-25, Ripe 7-27-25
228, Planted 6- 1-25, Ripe 8-24-25
229, Planted 6-15-25, Ripe 8-26-25
230, Planted 4-15-25, Ripe 7-27-25

Samples were also selected from the Eureka substation representing various crop rotations.

Effect of Time of Harvesting on the Physical Characters of Seed

In order to determine the effect of date of harvesting on the physical properties of the seeds, the weight per bushel, the weight per 100 seeds, and the specific gravity was determined on each lot.

Table I.—THE EFFECT OF DATE OF HARVESTING ON WEIGHT PER BUSHEL

		I*	II*	
Lot No.	Date of Harvesting	Wt. per Bu.	Wt. per Bu.	Average
1	August 25	49.95	49.85	49.90
2	August 31	51.41	51.20	51.30
3	September 10	53.42	53.00	53.21
4	September 21	53.83	53.83	53.83
5	October 1	53.11	53.12	53.115

The results indicate that the weight per bushel increases consistently from August 25 to September 21, the date of complete maturity. The samples harvested on October 1 had a slightly lower weight per bushel, probably due to the weathering of the grain after ripening.

The flaxseed harvested on September 21 had the highest weight per bushel (53.83) and the immature sample harvested on August 25 had the lowest weight per bushel (49.90).

Weight Per 100 Seeds Harvested on Five Successive Dates

Table II.—THE EFFECT OF THE DATE OF HARVESTING ON THE WEIGHT PER 100 SEEDS

		I	II	
Lot No.	Date of Harvesting	Wt. per 100 Seeds in Grams	Wt. per 100 Seeds in Grams	Average
1	August 25	.2617	.2430	.2523
2	August 31	.3080	.3260	.3170
3	September 10	.3875	.3650	.3762
4	September 21	.4016	.4060	.4038
5	October 1	.3880	.4025	.3952

The weight per 100 seeds increases regularly from immaturity (August 25) to September 21, the date of complete maturity. The increase in weight per 100 seeds up to the date of maturity corresponds very closely to the increase in the weight per bushel up to maturity. The increase in weight per 100 seeds up to the date of maturity corresponds very closely to the increase in the weight per bushel up to maturity. The weight of 100 seeds increases from an average of .2523 grams on Aug. 25 to .4038 grams on September 21, which is the date of complete ripeness. The average weight of 100 kernels for October 1 diminishes slightly as compared with that of Sept. 21, the average weight for October 1 being .3954 grams. The seeds were apparently not fully developed until September 21 and harvesting later causes them to lose weight, probably due to weathering.

Specific Gravity of Flaxseed Harvested on Five Successive Dates

Table III.—THE EFFECT OF THE DATE OF HARVESTING UPON THE SPECIFIC GRAVITY OF THE SEEDS

		I	II	
Lot No.	Date of Harvesting	Specific Gravity	Specific Gravity	Average
1	August 25	1.1875	1.1837	1.1856
2	August 31	1.1715	1.1743	1.1729
3	September 10	1.1590	1.1620	1.1605
4	September 21	1.1590	1.1590	1.1590
5	October 1	1.1580	1.1550	1.1560

The actual specific gravity of the seeds decreases consistently from the earliest to the latest date of harvesting. The average specific gravity on August 25 was 1.1856 as compared to 1.1590 on September 21, the date of complete maturity. The specific gravity of the October 1 sample was slightly lower than September 21.

Shepphard (8) found that flaxseed from northern Russia had a specific gravity of 1.1458 and a weight of .419 grams per hundred seeds.

The Relation of the Time of Harvesting to the Quantity and Drying Properties of Linseed Oil

Not only is the quantity but the quality of linseed oil the most important factor in determining the value of linseed oil for industrial purposes. Quality is used to denote drying properties of the oil.

Iodine numbers are indexes to the drying properties of the oil. Rabak (7) found that linseed oil having a high iodine number dried more rapidly when exposed as a thin film on a plate of glass.

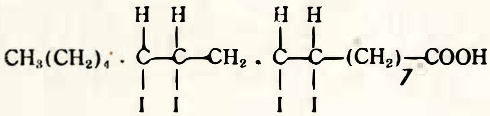
The iodine number is the number of grams of iodine absorbed by a hundred grams of fat. Linseed oil consists for the most part of glyceryl esters of linolenic and linolic acids. These unsaturated fatty acids possess the property of absorbing iodine. The iodine value is a direct criterion of the proportion of these fatty acids present in the oil, and since these acids determine the drying property of linseed oil the iodine value becomes an index of this property.

*Numbers I and II in tables designate two duplicate samples harvested on the same date.

Chemistry of Iodine Absorption

Linolic acid $C_{18}H_{32}O_2$ contains two pairs of doubly linked carbon atoms as indicated by formula $CH_3(CH_2)_4 \quad CH = CH . CH_2CH = CH (CH_2)_7 \quad COOH$

This acid will absorb four atoms of hologen or two atoms of oxygen as shown by formula



Linolenic acid

$$CH_3 . CH_2 . CH = CH . CH_2 . CH = CH . CH_2 . CH = CH — (CH_2)_7 \; COOH$$

This acid possesses three sets of double bonds and will absorb six hologen atoms or three oxygen atoms as shown by formula

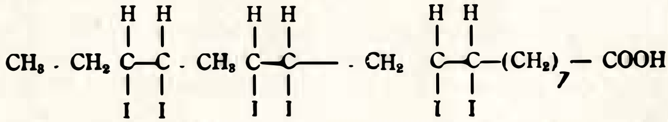


Table IV.—THE OIL CONTENT OF FLAXSEED HARVESTED IN VARIOUS STAGES OF MATURITY

Lot No.	Date of Harvesting	I	II	Average Per Cent
		Per Cent Oil		
1	August 25	29.75	29.27	29.51
2	August 31	32.50	32.44	32.47
3	September 10	36.84	36.87	36.85
4	September 21	36.73	36.96	36.84
5	October 1	36.69	37.33	37.01

An interesting relationship exists between date of harvesting and the total oil content. The most immature samples harvested August 25 have an average oil content of 29.56 per cent. The fully mature samples harvested on September 21 have an average oil content of 36.84. The October 1 sample which had weathered some had an average oil content of 37.01 per cent.

The average percentage of oil increases regularly from the first cutting until the last. A difference of approximately 8 per cent in oil between early cutting and the mature flax should be a valuable consideration in determining the value of immature or frosted flaxseed.

Table V.—THE IODINE NUMBERS OF LINSEED OIL EXTRACTED FROM FLAXSEED HARVESTED ON VARIOUS DATES

Lot No.	Date of Harvesting	I	II	Average
		Iodine Numbers		
1	August 25	182	181	181.5
2	August 31	175	175	175.0
3	September 10	163	164	163.5
4	September 21	163	163	163.0
5	October 1	161	161	161.0

Lot 1, harvested on August 25 (most immature) has an average iodine number of 181.5. A decrease of 7 occurred between the iodine numbers of August 25 and August 31. Between August 31 and September 10 the iodine numbers decreased from 175 to 163. From September 10 to full maturity the decrease in the iodine numbers was slight.

The iodine numbers apparently vary inversely with the oil content. The lower oil percentages have the higher iodine numbers and the higher percentages the lower the iodine numbers.

From the industrial standpoint a difference of 20 between the iodine numbers of the immature and mature samples would be highly important. The early harvested seed would have a lower oil content but the oil would possess much better drying qualities.

The Effect of the Time of Harvesting Upon the Nitrogen and Carbohydrate Content of Flaxseed

From the physiological standpoint there is a close connection between fats and carbohydrates. It is thought that fats probably have a synthetic origin from proteins and carbohydrates. According to Haas and Hill (4) as the oil content of walnuts and almonds increase the per cent of glucose decreases.

In order to determine if there was any connection between the oil content and the distribution of nitrogen and sugars, the oil, nitrogen and sugars were determined on five lots of flaxseed harvested on five successive dates.

Table VI.—THE PERCENTAGE OF NITROGEN FOUND IN FLAXSEED AT VARIOUS STAGES OF MATURITY

Lot No.	Date of Harvesting	Percent Nitrogen		Average
		I	II	
1	August 25	4.90	4.68	4.790
2	August 31	4.63	4.62	4.625
3	September 10	4.53	4.66	4.590
4	September 21	4.46	4.56	4.510
5	October 1	4.56	4.55	4.550

The percentage of nitrogen is slightly higher in the immature samples, although the variation is not always consistent. The average percentage of nitrogen in the most immature sample, August 25, is 4.79 per cent nitrogen. The protein in flaxseed is probably laid down quite early in the development of the seed.

Table VII.—THE PERCENTAGE OF SUCROSE FOUND IN FLAXSEED AT VARIOUS STAGES OF MATURITY

Lot No.	Date of Harvesting	Percent Sucrose		Average
		I	II	
1	August 25	3.85	3.97	3.91
2	August 31	2.81	3.47	3.14
3	September 10	2.98	2.80	2.84
4	September 21	3.04	2.36	2.70
5	October 1	2.71	3.02	2.86

The average percentage of sucrose decreases quite consistently as the seed becomes more mature. The analysis showed no glucose or reducing sugars in the flaxseed. Starch was not determined because according to Walton and Coe (9) it is not a constituent of flaxseed.
NOTE—Sucrose in the above table is that portion of the sugar which does not reduce Benedicts solution without being hydrolized.

Table VIII.—A COMPARISON OF THE AVERAGE PERCENTAGES OF NITROGEN SUCROSE AND OIL IN FLAXSEED AT VARIOUS STATES OF MATURITY

Lot No.	Date of Harvesting	Percent Oil	Percent Nitrogen	Percent Sucrose
1	August 25	29.51	4.79	3.91
2	August 31	32.47	4.62	3.14
3	September 10	36.85	4.59	2.84
4	September 21	36.84	4.51	2.70
5	October 1	37.01	4.55	2.86

If carbohydrates are the substances from which fats are derived, a decrease in the percentage of sucrose should occur as the percentage of oil increases. Carbohydrates may be considered as transitory products in flaxseed, awaiting conversion into fats.

In Table VIII the immature samples which are low in oil have the highest percentage of carbohydrates or sucrose. As maturity approaches there is a rapid increase in oil content with a corresponding decrease in the amount of sucrose present in the seeds.

The nitrogen content shows some correlation with oil content. The immature samples which are low in oil have the highest nitrogen content. Such a correlation might suggest a possible origin of fats from proteins. According to Haas and Hill (4) fats may be derived from proteins.

The Variation in Oil Content Due to Varietal Differences

There are many varieties of flax grown for the production of oil. It would be desirable to know whether they are like or unlike in respect to the oil content. In this experiment nine varieties of flax were analyzed for oil. These varieties were all grown under the same soil conditions at Highmore, South Dakota.

Table IX.—THE PERCENTAGE OF OIL FOUND IN NINE VARIETIES OF FLAX

Variety	Per Cent Oil
Primost	34.32
Russian	34.90
Acro	36.47
Common	33.86
Select Russian	35.87
Tashkent	36.26
Novo Rossick	36.61
Stephan	37.13
Damont	37.36

The variety Primost has the lowest oil content of 34.32 per cent while the variety Damont has the highest oil content of 37.36, a difference of 3.04 per cent. This percentage, although small, would make a total difference of approximately 1.6 pounds of oil per bushel of flaxseed. Further work would be necessary in order to definitely determine whether there is consistent difference in oil content in the varieties of flax. Rabak (7) found that certain varieties of flax gave consistently high or low yields of oil during the two years the experiment was conducted.

The Influence of the Date of Planting to the Oil Content of Flaxseed

As there is a wide variation in the time in which flax is planted, extending in extreme case from early spring until summer, it is possible that such condtions may cause a difference in oil content. The late planted flax grows in the warmest time of the year while the early sown flax grows in the cool spring and matures in mid-summer. In order to determine the effect of such conditions, samples of flax were analyzed for oil representing planting dates from April 15 to June 15.

Table X.—THE EFFECT OF DATE OF PLANTING ON THE PERCENTAGE OF OIL FOUND IN FLAXSEED

Date of Planting	Date of Ripening	Per Cent of Oil
4-15-25	7-27-25	33.63
4-15-25	7-27-25	34.14
4-15-25	7-27-25	34.81
4-15-25	7-27-25	33.25
4-15-25	7-27-25	33.00
4-15-25	7-27-25	35.13
5- 1-25	7-27-25	32.11
5-15-25	7-27-25	33.20
6- 1-25	8-24-25	35.73
6-15-25	8-26-25	35.05

The average percentage of oil found in the April 15 planting is 33.99 while the last planting, June 15, has 35.05 per cent of oil.

The lowest percentage of oil is found in the May 1 planting while the highest is found in the June 1 planting.

It is probable that in all dates of planting in Table X there was sufficient time for the seeds to become fully ripe. From Table II it is evident that the oil content depends to a large extent on maturity, and if all samples are mature not much variation in oil content is to be expected.

The Effect of the Previous Cropping System on the Oil Content of Flaxseed

In order to determine the effect of a crop sequence on the oil content of flaxseed, samples of flax were analyzed for oil that were selected from ten plots representing ten different rotations. Each of the rotations had a legume and cultivated crop in the sequence.

Table XI.—THE PERCENTAGE OF OIL FOUND IN THE FLAXSEED GROWN IN THE VARIOUS ROTATIONS

Plot No.	Rotation	Percent Oil
321	Flax-Corn-S. Wheat-Sw. Clover-Millet-Oats-Potatoes-Flax	34.04
322	Flax-Corn-W. Wheat-Sw. Clover-Sudan Grass-Barley-Potatoes-Flax	34.03
323	Flax-Corn.-W. Wheat-Sw. Clover-Proso-Emmer-Potatoes-Flax	34.34
324	Flax-Corn-S. Wheat-Sw. Clover-Millet-Oats-Potatoes-Flax	34.11
325	Flax-Corn-S. Wheat-Sw. Clover-Millet-Oats-Potatoes-Flax	34.31
326	Flax-Corn-S. Wheat-Sw. Clover-Millet-Oats-Potatoes-Flax	35.16
327	Flax-Corn-S. Wheat-Sw. Clover-Millet-Oats-Potatoes-Flax	34.21
328	Flax-Corn-W. Wheat-Sw. Clover-Sudan Grass-Barley-Potatoes-Flax	35.08
329	Flax-Corn-W. Wheat-Sw. Clover-Proso-Emmer-Potatoes-Flax	35.97
330	Flax-Corn-W. Wheat-Sw. Clover-Millet-Oats-Potatoes-Flax	36.13

NOTE:—In Plot 321 Sweet Clover was removed. S—spring; W—winter.

A difference of 2.1 per cent can be noted between the highest and lowest sample in oil content. It is impossible to attribute this difference to the previous cropping system. As a whole, most of the various samples selected from the ten plots were quite uniform in the percentage of oil. The maximum difference is less than the maximum difference between varieties.

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