ERS 425

FLAXSEED PRODUCTION AND USE:

PAST TRENDS AND FUTURE PROSPECTS

U.S. DEPARTMENT OF AGRICULTURE ECONOMIC RESEARCH SERVICE

PREFACE

This study was initiated by suggestion of Dwight L. Miller, Assistant Director, Northern Utilization Research and Development Division, Agricultural Research Service.

Dr. Lyle E. Gast and William L. Kubie, chemists of the Oilseed Crops Laboratory (NURDD) and Dr. William F. Kwolek, biometrician, Agricultural Research Service, aided in the technical aspects of the study. Dr. Verne E. Comstock, Professor of Agronomy, University of Minnesota, assisted in the production aspects of the study. The author is, however, fully responsible for the content.

Use of trade names in this report is for identification only, and does not constitute endorsement of these products or processes or imply discrimination against other similar products or processes.

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SUMMARY

Flaxseed is competitive for cropland with oats and barley, is less competitive with corn and soybeans, and seldom competes with wheat. Flaxseed has lost competitive strength as a crop since World War II.

These findings from a study of the competitive strength of flaxseed in production and linseed oil in the market are indicated from costs and returns data for individual crops in the tri-State region of Minnesota, North Dakota, and South Dakota.

Flaxseed's yield potential declines the longer planting is delayed after mid-April. However, its competitive strength increases with late-season plantings. The reason is that flaxseed can be planted late and still make a crop when other grains would fail. As a late-season crop, flaxseed apparently has no substitute. It also is strong as a nurse crop and in weed control.

Flaxseed's declining price since the war has severely weakened its ability to compete with other crops in early plantings during favorable seasons. It is still competitively strong in years when unfavorable weather forces late plantings. Thus, an increasing proportion of the crop has been late (lower yielding) plantings. Although improved and higher yielding varieties have replaced those used earlier, the average annual yield of flaxseed has remained relatively constant since World War II.

Before the war, large quantities of flaxseed were imported for domestic use. As stocks increased following the war, an active search began for markets abroad and exports increased. In recent years, nearly one-third of U.S. flaxseed moved into export markets--60 percent as flaxseed and 40 percent as linseed oil. Expanding export markets, however, have not deterred the increasing seriousness of problems in the domestic market.

During World War II, linseed contributed almost four-fifths of total oils used in drying-oil products. It currently supplies less than two-fifths to a 20-percent smaller market. Major losses were to soybean and tall oils.

Linseed oil's major use is in protective coatings. Lost sales in this market amounted to 880 million pounds annually, based on the oil-per-gallon ratio of 1935-39. The loss was nearly three times the annual sales for 1965-67. Roughly, one-fourth of the loss was due to competing oils (soybean and tall oils), one-half to synthetic resins that replaced oils in non-oil paints, and one-fourth to synthetic resins that partly replaced oils in oil-containing paints.

Present sales of all coatings are about 800 million gallons annually and are almost evenly divided between trade (retail shelf) and industrial types of coatings. About half the trade sales are for interior use, where water-emulsion, non-oil types now have about two-thirds of the market. About one-third of trade sales are for exterior use, the last "stronghold" of the complete-oil, film-former paints; non-oil types have about one-third of this market.

Latest estimates indicate water-based non-oil coatings probably have no more than 10 percent of the industrial market. The combination resin-oil film-formers predominate. However, the non-oil acrylic types are threatening the oil-containing alkyds (industry's "workhorses") in this market.

Linseed oil's loss of the linoleum and oilcloth markets amounts to 100 to 150 million pounds in annual sales. A part of the loss is due to increasing use of hardwood and carpeting, but most of it is the result of a growing use of synthetic resin materials such as vinyl and asphalt.

Although flaxseed is crucially important as a late-season crop in the tri-State region, linseed oil's loss of markets has threatened the crop's economic survival in production. The crop's importance in production justifies considerable resources devoted to research and development effort to maintain and enlarge its product markets.

Potential for strengthening linseed markets exists in both conventional and new uses. Most promising among conventional uses are improved oil-based protective coatings. In new uses, highway treatment with a linseed oil anti-spalling compound could greatly improve linseed's future. Research and oil treatment of unsound aggregate in concrete; development of high-performance lubricants; and preparation of resins, special purpose plasticizers, and other products are under consideration. Success in any of these areas could open up large markets for linseed oil.

FLAXSEED PRODUCTION AND USE: PAST TRENDS AND FUTURE PROSPECTS

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INTRODUCTION

Recent declines in production and substantial loss of markets raise questions about flaxseed's long-term ability to compete with other crops for farm resources and with other products for industrial markets.

Domestic flaxseed crushing mills imported about half their supply in the 1920's and more than half in the 1930's (fig. 1). The flaxseed industry, as measured by total production, crushings, and imports, was in recession during the late 1920's and early 1930's. Crushings and imports began increasing again about 1933. Domestic production did not recuperate until the spread of war in the late 1930's made it increasingly difficult for the United States to maintain its sources of vegetable oil imports. Domestic requirements were increasing, as were the needs of our allies. These economic forces stimulated rapid expansion in domestic flaxseed production during the early war years. Imports dwindled to negligible quantities.

Mill demand for flaxseed declined after reaching a peak in the early 1940's. Production did not decline during the war, became larger than crushings in the mid-1940's, and increased in the late 1940's. Slightly less than half the peak 1948 crop of 54.8 million bushels and one-fourth of the 1949 crop of 43.0 million bushels was acquired by the Commodity Credit Corporation (CCC) under the price-support program. In the late 1940's, the United States began exporting flaxseed and linseed oil, and carryover stocks increased.

Thus, flaxseed underwent a contraction in the late twenties and early thirties and a war-induced expansion beginning in the late thirties. There was a general trend to lower levels in the 1950's and early 1960's. The United States, formerly a large importer of flaxseed, has increasingly sought export outlets since World War II.

Recent declines in production could be the result of short-term weather and price variations or of longer term change in flaxseed's competitive situation. If the condition is long term and chronic, it is necessary to know whether its origin is in production or in the markets, what the main causes are, and whether the situation will likely change within the next decade or two. This study attempts to answer such questions by evaluating flaxseed's competitive position (1) as a crop in the main producing areas and (2) as an industrial product in the major markets.

COMPETITIVE POSITION IN PRODUCTION

Analysis of the competitive strength of the flaxseed crop mainly involves the relative costs and other conditions affecting its supply. Demand conditions, the chief concern of this report's later section on markets, are included here only as reflected in prices paid the farmer for flaxseed and competing crops. Discussion is divided into (1) production characteristics and trends, (2) costs and returns, (3) acreage and yields, and (4) support programs and price trends.

Production Characteristics and Trends

The national flaxseed crop fluctuates widely from year to year. The increase or decrease from the preceding year's production was greater than 30 percent in about half the 33 years from 1935 through 1968. It was less than 10 percent in only 1 of every 6 years. This is partly a consequence of a greater degree of localized production in weather-hazard areas than is true of some crops. However, other factors are involved as well and will be dealt with in later sections.

The 5-year moving average "irons out" annual variations and indicates trends. For example, the peak annual flaxseed crop in 1948 was 54.8 million bushels but the peak 1947-51 average was only 42.7 million bushels.

Figure 1 shows a period of declining production in the late 1940's and early 1950's and another in the late 1950's. 1/ From the immediate postwar high average crop of over 40 million bushels, production fell to an average of about 28 million bushels a year in the first half of the 1960's. Recent production generally has been lower.

The postwar contraction in flaxseed production occurred in all areas where flax was grown. Many "fringe" producing States practically abandoned flaxseed. Nebraska, Idaho, and Ohio stopped reporting on flaxseed in the 1940's. Oklahoma, Michigan, Missouri, Oregon, Washington, Arizona, Kansas, Wyoming, and Illinois stopped reporting in the early and middle 1950's. Flaxseed production was never very important in the total farm economy of most of these States.

North Dakota, Minnesota, and South Dakota produce more than 90 percent of the U.S. flaxseed crop (fig. 2). Prior to World War II, Minnesota was the largest producer, contributing more than 50 percent of national production. North Dakota was second with about 20 percent. Their positions are now reversed, with North Dakota producing more than 50 percent and Minnesota

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1/ Figures appear at end of the text, beginning on page 34.

about 20 percent. South Dakota's production has increased from 6 percent of the prewar figure to 20 percent in recent years, although quantities produced have been comparatively steady, averaging 5 to 6 million bushels annually by 5-year periods since the late 1940's.

There is a wide difference among States in the direction, time, and extent of the postwar production decline. For example, Minnesota's production decreased in the immediate postwar period, while production in North Dakota, California, and Texas increased.

Costs and Returns

Because past performance indicates flaxseed's competitive position in production is strongest in North Dakota, Minnesota, and South Dakota, its future as a farm crop will likely depend on developments in the tri-State region. Therefore, this study is mainly based on experience in those States.

The relative cost-return structure for flaxseed and competing crops varies widely from one area to another, from one farm to another within a given area, and from one year to another within areas and on individual farms. Complementarities between crops also affect total farm profits in ways that cannot be precisely allocated in costs and returns to specific crops. Too, factors other than profits sometimes affect a farmer's choice of crops. Consequently, the relative costs and returns computed from historical averages give little insight into the comparative competitive strength of crops at a particular time.

The following analysis does not show the competitive strength of different crops but does show (1) flaxseed's weakest and its strongest competitors for cropland and (2) flaxseed's gain or loss of competitive strength over a period of time. Flaxseed was planted on 2.0 to 2.5 million of approximately 50 million acres devoted to principal crops in the tri-State region during recent years. That, in one sense, is the most precise measurement available of its present competitive strength as a crop. Plantings represent farmers' ultimate assessments of the competitive advantages and disadvantages of different crops in a particular year.

For the tri-State region as a whole, the cost of producing corn is about double that of flax; soybean cost is about 50 percent higher; wheat about 20 percent higher; and oats and barley about the same (5, pp. 33-36). 2/

These rough estimates of relative costs were used with 1960-64 average State yields to determine for the various crops the prices (relative to flaxseed's price) that would equate their net returns with net returns to flaxseed. For example, under assumed cost and yields in Minnesota, returns per acre for soybeans equal returns for flaxseed when the price of soybeans is 80 percent of the price of flaxseed. (See underlined figures in table 1.) A soybean price higher than this means soybeans are more profitable; if lower, flaxseed is more profitable.

2/ Numbers in parentheses refer to Literature Cited, as listed at the end of this report.

Table 1.--Comparison of net returns of various crops relative to flaxseed, tri-State region, 1960-67

State and year	Corn	Wheat	Oats	Soybeans	Barley
	Percent	Percent	Percent	Percent	Percent
Minnesota:					
Relative price necessary to equate net returns with flax returns 1/	37.4	55.9	24.1	80.0	35.2
Relative price (actual):					
1960	33.2	68.2	19.7	78.5	29.9
1961	30.7	62.8	17.9	67.0	31.8
1962	36.0	75.3	20.2	80.1	28.8
1963	36.7	71.5	20.6	86.5	29.2
1964	37.7	52.6	20.4	90.0	30.8
1965	37.1	52.1	20.6	92.7	35.7
1966	39.1	59.3	20.9	90.2	35.0
1967	33.7	52.0	20.7	83.7	34.7
North Dakota:					
Relative price necessary to equate net returns with flax returns 1/	53.7	51.9	23.1	88.2	30.2
Relative price (actual):					
1960	34.9	71.4	17.3	84.7	27.8
1961	32.8	70.6	16.9	67.5	30.0
1962	36.7	79.9	18.3	79.5	28.8
1963	35.2	72.2	18.7	87.5	27.5
1964	36.5	50.4	18.8	88.3	30.1
1965	36.1	50.2	18.1	89.2	35.0
1966	37.6	58.2	19.2	89.9	34.8
1967	35.5	53.8	19.0	83.4	32.4
South Dakota:					
Relative price necessary to equate net returns with flax returns 1/	48.7	42.6	26.1	73.4	35.9
Relative price (actual):					
1960	33.0	67.0	19.1	77.2	27.3
1961	29.6	60.5	17.1	65.6	26.9
1962	35.3	73.4	19.2	77.3	26.9
1963	35.7	69.3	20.2	86.3	26.0
1964	39.4	50.7	20.6	87.9	28.0
1965	39.2	51.2	19.8	87.3	32.5
1966	40.1	56.8	20.7	90.5	32.7
1967	35.7	48.7	20.0	81.3	32.0

1/ Based on the 1960-64 average State yield and assuming that costs of producing corn are double, soybeans 50 percent of, wheat 20 percent of, and oats and barley the same as costs of producing flaxseed (estimated from data in (5) and (17). Price and yield data used were those reported by the Statistical Reporting Service, U.S. Department of Agriculture. Data are per bushel.

Wheat generally is a more profitable crop than flaxseed in the tri-State region. Data for corn, especially in Minnesota, are questionable. Corn has replaced flaxseed in the southern part of Minnesota, causing an increasing concentration of flaxseed acreage further north and west. Thus, the State's averages probably do not well represent the relative situation in areas where the two crops compete more intensely.

Wheat is considered a major crop in the three States (as is corn in some areas) and thus has a prior claim on available cultivated land. Other crops compete for acreage withheld from wheat (and corn) due to acreage controls, rotation considerations, or adverse planting seasons.

Thus, flax competes mainly with barley and oats in most of the region, with soybeans in the Red River Valley, and with other minor crops in local areas. Data in table 1 show flax fairly competitive with oats and barley in acreage returns in recent years. Flax is less competitive with soybeans.

Costs and yields, assumed constant at average levels in table 1, vary widely from one area to another and even among farms within a given area. For example, although production operations and costs for flax and the small grains are often said to be about the same, average wheat production costs reported for the seven economic areas of North Dakota varied from 13 to 31 percent more than flax production costs (17). There were similar variations among areas in the relative costs of other crops.

Too, the 1956-60 average yield of wheat varied from 12 bushels per acre in economic area 2 of North Dakota to 24 bushels per acre in area 4. The State average (used in computing data in table 2) was 18.7 bushels per acre. Average yield by economic areas varied from 18 to 28 bushels for barley and from 5 to 9 bushels for flax.

Consequently, a general comparison, as in table 1, has many exceptions. Corn is likely more favorable in southwestern Minnesota than the relative costs indicate. Oats and barley are more favorable in some areas and on some farms. Flax, too, is more favorable than indicated in some areas and less in others.

Although some farmers contract to sell flax straw, its return is not included in table 1's computations. Sales of the straw enhance returns to flax and improve its cost-return picture.

Table 2 shows the trend of competing crops in gross returns per acre. Since production costs probably remained about the same, the change in returns reflects change in relative profitability. Other crops have gained in returns relative to flaxseed since the late 1940's.

While the cost-return comparison does not indicate the absolute competitive level of the different crops, it is adequate evidence that flaxseed has declined in competitive strength relative to other crops. A crop that shows a decline in relative returns is expected to decline in production, as flaxseed has in the postwar period.

Table 2.--Gross returns per acre for selected crops relative to flaxseed, tri-State region, averages 1945-49, 1954-58, and 1962-66 1/

State and period	Wheat	Corn	Barley	Soybeans	Oats
	Percent	Percent	Percent	Percent	Percent
Minnesota					
Average:					
1945-49	73.8	125.4	73.8	95.4	58.6
1954-58	161.5	225.2	93.5	151.6	85.1
1962-66	135.1	220.1	100.2	165.5	89.5
North Dakota					
Average:					
1945-49	76.2	87.9	71.9	134.9	52.5
1954-58	161.9	144.2	104.1	152.7	75.5
1962-66	143.5	133.8	107.3	157.7	82.5
South Dakota					
Average:					
1945-49	58.1	87.4	62.4	78.5	47.4
1954-58	115.5	141.0	80.1	127.1	74.5
1962-66	92.3	144.1	80.0	162.1	74.4

1/ Based on the average annual price times the average annual yield for each crop. These were summed, divided by 5, and the ratios computed in percentage terms for each period. Price and yield data used are those reported by the Statistical Reporting Service, U.S. Department of Agriculture.

Acreage and Yield

Factors that influence farmers in the acreage they plant and factors that affect yield per acre are those that determine production and set its pattern of change. For any one season, acreage is mainly a matter of choice by the farmer, while yield is mainly determined by weather and growing conditions. Thus, change in production due to a change in acreage is controlled, but that due to a change in yield is largely uncontrolled.

Figure 3 shows annual variations in production, acreage, and yield by the proportion of years in which the change (increase or decrease) from the previous year was less than 20 percent, 20 through 40 percent,or more than 40 percent. Production varied widely in the three States, but more in North Dakota and South Dakota than in Minnesota. Perhaps the surprising point, however, is that acreage varied more than yield in North Dakota and Minnesota and almost as much as yield in South Dakota. Consequently, decision (regarding acreage) was a stronger influence than chance (determining yield) in annual production changes in the tri-State region.

Annual acreage change is relatively large for all crops in the Great Plains because of the region's greater weather hazards and their effect on farmers' decisions during the planting season. However, flax acreage varies more than acreage for the main crops. In North Dakota, for example, the change in wheat acreage from the previous year has been greater than 20 percent in only 1 of every 10 years since 1935, whereas the change in flax acreage has exceeded 20 percent in more than half the years since then.

This greater change in flax acreage from one year to another is consistent with the position flax has in farm planning in the tri-State region as an alternative among crops planted on acreage left after the major cash crop is planted, or as a crop in a rotation. Flax also is used as a nurse crop; as a weed control crop; and as a "hazard" crop; that is, one resorted to when drought conditions necessitate late plantings. Farmers who use a crop to serve such purposes will vary its acreage considerably from one year to another.

A common belief is that flaxseed is more risky than other crops grown in the tri-State region; consequently, a somewhat higher return for flax is believed necessary to pay farmers for the additional risk involved (14, pp. 15, 18). Since risk affects farmers' decisions, it is important to know whether the belief is valid.

The crop does vary considerably in yield as well as acreage. However, available evidence indicates flax probably is <u>no more risky than other crops</u> in the tri-State region. One measure of risky yield is the extent to which acreage planted to a crop is abandoned before harvest (table 3). Acreage abandoned over three decades was greater for flaxseed than other crops in Minnesota. Generally, abandonment of wheat acreage was less than that of flaxseed acreage in the Dakotas, but abandonment of flaxseed acreage was somewhat lower than abandonment of acreage planted to barley and oats.

Another measure of risk is the coefficient of variation of annual yields computed for selected crops for a recent 20-year period (table 4). In general, corn yields varied less than flax yields but wheat yields were greater than those for flax. Yield variations for barley, oats, and soybeans were less than for flax in Minnesota but about the same in North Dakota and South Dakota.

It is likely, however, that both greater abandonment of flax acreage and greater variation in yield could be expected--not because flax is a more risky crop but because it is subjected to more risky growing conditions than other crops. Flax acreage is increased if drought conditions necessitate late plantings. Too, its use as a weed control crop requires that it be planted late.

The concept that flax is a more risky crop is contrary to other widely held beliefs. Flax is said to be resistant to both excessive moisture and excessive droughts, can be planted later with greater expectations of producing than other crops, and is less susceptible to yield-decreasing insects and diseases (6, pp. 13, 19). Also, it can be left in the field longer when ready for harvest with less likelihood of damage than other crops (15, p. 3).

Table 3.--Proportion of years that acreage abandonment was less than 5 percent, 5 through 10 percent, and more than 10 percent, tri-State region, 1935-68 1/

State and crop	Less than 5 percent	5 through 10 percent	More than 10 percent
	Percent	Percent	Percent
Minnesota:			
Flaxseed	58	30	12
Wheat	94	3	3
Barley	82	6	12
Oats	73	18	9
North Dakota:			
Flaxseed	55	21	24
Wheat	64	15	18
Barley	55	27	18
Oats	27	42	30
South Dakota:			
Flaxseed	52	30	18
Wheat	64	9	24
Barley	24	42	33
Oats	48	24	27

1/ Acreage abandonment is defined here as that acreage reported planted but not harvested.

Source: Computed from State acreage planted and harvested reported by the Statistical Reporting Service, U.S. Department of Agriculture.

Table 4.--Coefficients of variation in yields of specified crops, tri-State region, 1944-64 1/

Crop	North Dakota	Minnesota	South Dakota
	Percent	Percent	Percent
Flax	19.7	16.9	20.0
Wheat	26.4	19.7	31.2
Corn	12.9	9.7	19.6
Barley	17.6	12.3	23.6
Oats	21.4	11.4	18.2
Soybeans	22.7	9.2	19.7

1/ Coefficient after removal of linear trend and multiplied by 100 to compare on a percentage basis.

Flax is, however, more susceptible to weed competition for moisture. Experiments in Minnesota indicate that weedy plots (compared with weed-free plots) produced only 10 to 15 percent less yields for other crops but cut flax yields in half (5, pp. 33-36). Flax must be planted on comparatively weed-free acreage and weed control practices are important. This may be an advantage in a rotation program since it encourages better cultural practices for other crops (6, p. 4).

Flax gains some competitive strength because farmers favor it for complementary and supplementary contributions to the overall farm operation. One complementary contribution is as a nurse crop for grass seedings. Oats, its main competitor here, is generally used more often as a nurse crop on those farms with considerable livestock, and flax is preferred elsewhere. Another complementary contribution is in weed control. Wild oats is a serious weed problem on many farms where flax is grown. Flax can be planted late enough most years for wild oats to establish growth and be plowed under. Many farmers feel it pays to plant late flax to control wild oats even though the yield of late flax is considerably less than that of early flax.

Discussion thus far concerns farmers' short-term acreage decisions and yield considerations. Flaxseed's competitive strength in the long run depends on how its productive capability improves. Improvements in culture, more productive varieties, and insect and disease control measures represent the expanding productive technology that characterizes American agriculture. The competitive strength of a particular crop over time depends on whether it sets a faster or slower pace than other crops in the technology race.

Data in table 5, based on average State yields for a 20-year period, give a pessimistic view of flaxseed's ability to compete with other crops over the long run. Flaxseed yield has not improved significantly, but yields of other crops have shown rather consistent increases. For example, the rate of annual increase in wheat and soybean yields per acre in North Dakota during 1944-64 was about one-third of a bushel; for corn and barley, it was half a bushel, and for oats it was two-thirds of a bushel. In contrast, the rate of increase in flaxseed yield was hardly registerable and was not statistically significant.

The linear relationship did not test statistically significant at the 95-percent probability level for wheat, barley, oats, and soybeans in South Dakota. However, annual yields followed the upward slope of the trend line in a scatter chart, and parallelism of yields among States did test statistically significant.

An earlier study showed similar results for 1920-44 (14, p. 24). The conclusion was:

"It may be reasonable to conclude that the odds seem to favor an increase of flaxseed yields as compared with yields of the competing crops. This view was taken by the State Production Adjustment Committee, most of whom were of the opinion that there were greater possibilities for increasing the yields of flaxseed than the yields of most of the other crops."

Table 5.--Changes in yield per acre of flax and competing crops, selected States, 1944-64 1/

State and crop	Yield per acre 1944	Yield per acre 1954	Yield per acre 1964	Annual increase in yield per acre, 1944-64		Significant at 95-per-cent level	Years required for a 5-bu. increase
	Bushels	Bushels	Bushels	Bushels 2/	Pounds 3/		Years
North Dakota:							
Flaxseed	7.7	7.8	8.0	.01	0.6	No	433
Wheat	12.3	15.5	18.7	.32	18.9	Yes	16
Corn	21.3	26.4	31.5	.51	28.7	Yes	10
Barley	18.8	23.7	28.6	.49	23.3	Yes	10
Oats	24.0	30.7	37.4	.67	21.5	Yes	7
Soybeans	10.8	13.9	16.9	.31	18.5	Yes	16
Minnesota:							
Flaxseed	9.5	10.3	11.0	.07	4.0	No	69
Wheat	15.3	20.9	26.5	.56	33.5	Yes	9
Corn	39.8	51.2	62.6	1.14	63.6	Yes	4
Barley	24.1	28.2	32.4	.41	19.8	Yes	12
Oats	35.3	41.5	47.7	.62	19.8	Yes	8
Soybeans	15.7	18.9	22.0	.32	19.1	Yes	16
South Dakota:							
Flaxseed	8.9	8.8	8.6	-.01	-0.8	No	4/
Wheat	11.4	12.8	14.2	.14	8.6	No	35
Corn	26.5	31.2	36.0	.48	26.7	Yes	11
Barley	17.4	20.9	24.4	.35	16.8	No	14
Oats	27.8	30.9	34.0	.31	10.0	No	16
Soybeans	13.5	15.6	17.8	.21	12.9	No	23

Continued--

Table 5.--Changes in yield per acre of flax and competing crops, selected States, 1944-64 1/--Continued

State and crop	Yield per acre			Annual increase in yield per acre, 1944-64		Significant at 95-percent level	Years required for a 5-bu. increase
	1944	1954	1964				
	Bushels	Bushels	Bushels	Bushels 2/	Pounds 3/		Years
Montana:							
Flaxseed......	6.6	7.3	7.9	.07	3.7	No	76
Wheat.........	13.4	16.1	18.7	.26	15.8	Yes	19
Corn..........	12.8	32.0	51.2	1.92	107.6	Yes	3
Barley........	24.5	26.7	28.9	.22	10.6	No	23
Oats..........	31.4	33.9	36.3	.25	7.9	Yes	20

1/ All values are theoretical in the sense they are computed from the least-square linear equation fitted to average State yields, 1944 through 1964.
2/ Rounded to nearest one-hundredth from b-values carried to 8th decimal in the linear equation.
3/ b-Values times pounds per bushel.
4/ Declining yields.

That prediction failed to materialize in the form of an increasing average State yield, according to evidence in table 6.

Flaxseed's long-term capabilities are better than the data indicate on the surface. There are two propositions which might explain why higher yields have not shown in the average State yield. First, a movement of flaxseed acreage from higher productive areas to lower productive areas has hidden area increases within the State average. Second, an increasing proportion of the total crop has been planted late, and yield potential declines as the season advances. Thus, it is proposed that yields have increased where flax is planted as early and on as productive land in the same area as formerly.

The average 1947-49 and 1964-66 yields by districts in Minnesota were used to test the first proposition (table 6). Results did not support the proposition that a shift in the proportion of acreage grown from higher to lower producing areas "hid" yield increases (see footnote, table 6). Evidence that the proposition was not valid included the addition of a mid-1950 period and checking other crops for consistency of yield data.

However, the proposition apparently is valid that yield improvements were hidden in the State average yield because an increasing proportion of the crop has been lower yielding late plantings.

First, the proposition "fits" logical expectations. Flaxseed is competitively strong as a late-season crop. Its yield potential declines possibly as much as a bushel per week for plantings delayed past April 15-25 (7). However, in the latter part of May and the first part of June, the probability of making a crop becomes greater for flaxseed than for other crops; that is, the yield potential of other crops planted then declines more rapidly. Flaxseed essentially has little or no competition for cropland if planting is delayed until the middle of June.

The price of flaxseed increased relative to the price of other crops during World War II. Consequently, flaxseed competed effectively for cropland even in early planting seasons. As its relative price declined following the war (see subsequent analysis of price trends), other crops took acreage from flaxseed in early season plantings. It would be expected that as flaxseed's relative price became more unfavorable it would lose acreage in the early planting season to other crops and a higher proportion of its acreage would be planted late (and thus yield less).

Flax breeders at State experiment stations have developed improved varieties that were higher yielding than older varieties in experiment plots, and they have been adopted by farmers. Culbertson estimated that newer varieties being grown in early 1960 were about 10 and 20 percent higher yielding than those previously used for early and late sowing, respectively (4, p. 3).

Culbertson concluded from variety tests that "it would be economically impossible to produce flax in the Dakotas and Minnesota if breeders had not developed rust-resistant varieties to replace Bison." The larger increase in yield of late-sown varieties also indicates that late-planted flax gained

Table 6.--Effects on flaxseed yield of acreage shifts between districts of Minnesota from 1947-49 through 1964-66, based on average State yields

District	1947-49				1964-66			
	Acreage dist.	Yield per acre	Production factor 1/		Acreage dist.	Yield per acre	Production factor 1/	
			1947-49 acreage	1964-66 acreage			1947-49 acreage	1964-66 acreage
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Percent	Bushels	1 x 2/100	5 x 2/100	Percent	Bushels	1 x 6/100	5 x 6/100
1.....	29.6	8.13	2.4065	2.6666	32.8	8.23	2.5841	2.8634
2.....	2.6	9.13	0.2374	0.7213	1.5	7.90	0.2054	0.1185
3.....	0.1	8.31	.0083	.0665	0.8	6.08	.0061	.0486
4.....	28.2	10.74	3.0287	4.7363	44.1	12.39	3.4940	5.4640
5.....	6.6	12.30	0.8118	0.1107	0.9	11.20	0.7392	0.1008
6.....	0.5	9.51	.0476	---	---	---	---	---
7.....	21.9	12.48	2.7331	2.4336	19.5	12.97	2.8404	2.5292
8.....	7.8	13.48	1.0514	0.0270	0.2	13.27	1.0351	0.0265
9.....	2.7	12.04	0.3251	.0241	.2	12.55	0.3389	.0251
State.	100.0	10.65	10.65	10.79	100.0	11.21	11.24	11.18

1/ Acreage distribution of both periods applied to yield for specified period. To support the proposition that a shift in the crop to less productive areas has negated yield increases would require that the sum of the district's 1964-66 acreage distribution x 1947-49 yield (col. 4) be less than the sum of the 1947-49 acreage distribution x 1947-49 yields (col. 3). Similarly, the 1947-49 acreage distribution x 1964-66 yield (col. 7) should total higher than the 1964-66 acreage distribution x 1964-66 yields (col. 8) to validate the proposition.

over early-planted flax in competitive strength (4, p. 3). Thus, evidence favors the view that the increasing proportion of the flaxseed crop being planted late has tended to offset the attainment of higher yields to give a constant State average yield over time.

Flaxseed has unique competitive characteristics that favor its continued production even when prices turn adverse, as within the last decade. Too, farmers in the tri-State region seek more, not fewer, crop alternatives and are hesitant to abandon a crop that strengthens some aspects of their farm operations.

The Support Program and Price Trends

The price-support program for flaxseed probably has had less impact on domestic market pricing and production than is generally believed. Prior to 1948, in 1950-51, in 1955, and in 1959-61, the market price was sufficiently favorable to the support loan price for the entire crop to move into the market (fig. 4). The support price was sufficiently favorable to cause rather large acquisitions by CCC during 1948-49, 1952-54, 1956-58, and 1962-65.

One proposition is that the Government's price-support operations maintained artificially high prices, supported unneeded production, and were a major factor in linseed oil's loss of markets after World War II. The readily available evidence does not support this view. The price-support program probably has been more effective in "ironing out" wide seasonal fluctuations and longer term "ups and downs" than in maintaining a price significantly higher over a period of years than that which would have prevailed without supports. Without supports, prices, no doubt, would have dropped lower during the periods of CCC acquisitions discussed above. Later, however, the lower prices presumably would have caused lower acreage, less production, and a higher market price than with supports.

The support loan rate apparently has been adjusted to market conditions over the years. The rate was $5.75 per bushel in 1947 and 1948. Following large CCC acquisitions in 1948, the average support price was dropped to $3.74 for the 1949 crop and further lowered to $2.57 for the 1950 one. The decline overshot the market level and price support became inoperative, so the support level was increased in 1951 and 1952. Data in figure 4 seem to show a record of such adjustments to market conditions, with both support and market prices leveling off at less than $3.00 per bushel in recent years.

Another view of the weakness of the "high-maintained price" argument concerning flaxseed's problems is displayed in table 7. Flaxseed's price was free of support program influence during 1945-47. A pertinent question is: Have support operations subsequently maintained a more favorable price for flaxseed than for other crops in the tri-State area? Data for North Dakota clearly portray the contrary. Wheat, corn, and soybean prices have been considerably higher relative to flaxseed's price during the 1950's and 1960's than in 1945-47. The flaxseed price has declined relative to prices of other crops, a consequence of its weakening competitive position in the markets

Table 7.--Index of average farm price of wheat, corn, and soybeans, relative to that of flax, North Dakota 1/

(1945-47 = 100)

Period	Wheat	Corn	Soybeans
	Percent	Percent	Percent
Average:			
1950-54	134	120	118
1955-59	148	113	109
1960-64	147	107	131
1965-67	115	110	140

1/ Based on data for crop years beginning July 1 of year indicated. Annual prices were weighted averages of monthly prices. Simple averages of annual prices were used in computing the period data.

since World War II. The support price apparently has not forestalled that decline; rather, it has been adjusted to conform to the adverse market conditions.

In periods when price support is effective, it apparently has greater impact on decisions concerning early-planted flax acreage where competition with other crops is vigorous and mainly on a cash returns basis. Decisions concerning late-planted flax are influenced more by rapid late-season declines in potential yield of alternative crops, weed-control considerations, and other factors, such as the nurse-crop function.

The fact that other crops obtained a more favorable price relative to flaxseed during the 1950's and 1960's than in the late 1940's is a reflection of flaxseed's failing strength in the product markets. The following sections will consider what has happened, the forces at work, and the future of those markets.

INTERNATIONAL PRODUCTION AND TRADE

Declining and uncertain foreign supply sources for vegetable oil imports spawned the wartime expansion of the domestic flaxseed crop and changed the United States from an importing to an exporting status. The export market is relatively large, varies considerably from year to year, and is subject to more uncertainty in the long run than are domestic markets.

About 21 percent of U.S. flaxseed produced during 1965-67 was exported and 71 percent moved to domestic crushing mills (fig. 5). Twenty-two percent of the linseed oil and 30 percent of the linseed meal from domestic crushings were also exported. Consequently, about one-third of the flaxseed crop during the period ultimately moved into foreign markets.

This section specifies the major producers of the world crop, the suppliers in world trade, and the main world markets, and discusses the United States' place in world trade of flaxseed.

World Production

The United States, Canada, Argentina, the U.S.S.R., and India produce about 85 percent of the world's flaxseed (table 8). Argentina and Canada export most of their production. India produces for domestic consumption and the Soviet Union is a net importer. The Soviet Union cultivates considerable flax for fiber, whereas the other major producing nations cultivate it almost exclusively for linseed (2, p. 23).

U.S. production increased from 8 percent of the world total prior to World War II to over 30 percent in the late 1940's and early 1950's. It then dropped to 21 percent during 1960-67, which is nonetheless the largest proportion among producing nations. Canada, with 1 percent of the prewar world crop, presently contributes about 16 percent.

Argentina formerly produced almost half the world flaxseed crop, but lost its leadership position during World War II. Recently, it was producing at about the same level as Canada. The Soviet Union grew almost one-fourth of the world crop before World War II and presently produces between 15 and 20 percent. India's contribution to world production has been stable, varying from about 11.5 to 14.5 percent by period averages.

Linseed oil from flaxseed is almost universally considered an industrial drying oil, mainly used in paints and varnishes. In parts of Asia, particularly India, and in eastern Europe it also moves into food uses (18, p. 582). More than half the Indian production went to food uses in the early and middle 1950's, but only about one-third now goes into edible uses (8, p. 18).

World Trade

Flaxseed and Linseed Oil

Both flaxseed and linseed oil are important in world trade. World exports of linseed oil during 1963-67 averaged 287,000 short tons annually, compared with 675,000 for flaxseed. However, using a 2.77 conversion rate, about 767,000 tons of flaxseed are required to produce 287,000 tons of linseed oil, an amount 14 percent greater than the total flaxseed exported.

The United States contributed about 16 percent to net world exports of flaxseed and linseed oil during 1963-67 and was the third largest exporter. 3/ Argentina and Canada, supplying 45 and 32 percent, respectively, are major U.S. competitors in flaxseed and linseed oil exports. The period data may

3/ "Net world exports" designates data that exclude (1) reexports of flaxseed and (2) exports of linseed oil produced from imported flaxseed.

Table 8.--Flaxseed production of major producing countries as a percentage of world total, averages 1935-39 and 1945-67

Country	Average					
	1935-39	1945-49	1950-54	1955-59	1960-64	1965-67
	Percent	Percent	Percent	Percent	Percent	Percent
United States	8.2	30.4	33.4	25.9	21.3	21.3
Canada	1.1	7.2	8.5	17.0	14.3	16.4
Argentina	44.2	24.6	16.3	17.5	22.7	16.4
U.S.S.R.	23.8	11.5	10.2	15.0	14.2	19.6
India	14.4	11.9	13.4	11.4	12.7	11.7
Others	8.2	14.3	18.2	13.2	14.8	14.5
World	100.0	100.0	100.0	100.0	100.0	100.0
	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.	Mil. bu.
Total world production	134.7	128.5	110.2	132.1	131.9	122.8

Source: Foreign Agricultural Service, Foreign Agricultural Circular, U.S. Dept. Agr., April 1968, and earlier issues on world flaxseed production.

have been influenced to some extent by the Payment-in-Kind export subsidy program of the United States in effect from 1965 until mid-1967, but preceding and subsequent exports indicate any influence probably was minor. Since Argentina mainly exports linseed oil and Canada flaxseed, the United States is second largest exporter of each of these categories measured separately (fig. 6). The United States supplied an average of 22 percent of world flaxseed exports during 1963-67, mainly in competition with Canada's 64 percent. U.S. exports of linseed oil were only 9 percent of the world total and competed mainly with Argentina's 74 percent. Linseed oil was about one-third (in flaxseed equivalent) and flaxseed two-thirds of the combined U.S. exports.

The main customers in the international market are shown in figure 7. The major portion of the market is in Western Europe. The United Kingdom, West Germany, France, the Netherlands, and Italy are large European importers. Japan imports large quantities of flaxseed and the Soviet Union imports considerable linseed oil. From one-fourth to one-third of the imports of both flaxseed and linseed oil are taken by a rather large number of countries, illustrating the broad country base of import demand.

Some changes have occurred in the structure of international trade in flaxseed and linseed oil. Most noticeable was a wartime decline in flaxseed trade and an increase in linseed oil trade. World exports of flaxseed in the immediate postwar period were only one-fifth their prewar level, whereas linseed oil exports were almost double. 4/ Argentina supplied three-fourths of

4/ Based on average annual trade figures for 1934-38 and 1948-52.

the prewar export trade in flaxseed, has shipped insignificant amounts of flaxseed since the mid-1950's, and now supplies about three-fourths of world exports of linseed oil. Canada has moved from insignificance to dominance in exports of flaxseed. India provided 13 percent of the world exports of flaxseed during the prewar period, but shipments declined to nonreportable amounts by the mid-1950's. The United States, of course, was formerly an importer but has increased exports of both flaxseed and linseed oil since World War II.

Linseed Meal and Cake

The United States also exports the byproduct cake and meal from flaxseed crushings and has contributed between 10 and 20 percent of total world exports of these products in recent years. U.S. exports increased from 3.5 percent of domestic production in the early 1950's to 29.6 percent in 1965-67 (table 9). Part of this increase in proportion is simply a consequence of lower production. However, exports have also increased in quantity because of the growing world demand for livestock feed since World War II. Argentina is the major supplier, and consequently a U.S. competitor, in world linseed cake and meal export trade. Canada and India also are large exporters.

Most of our exports of linseed cake and meal also go to Europe. The Netherlands, a major customer, took more than half the U.S. exports during the late 1950's and early 1960's. Canada formerly purchased considerable amounts but now produces sufficient amounts to export. West Germany has been a major customer since the mid-1950's. The United Kingdom took about 8 percent of our total exports in 1950-54, purchased less than 1 percent in the latter 1950's and early 1960's, and came back to import almost 20 percent in 1965-67. Poland recently came into the market for U.S. linseed cake and meal. In general, the European market reflects the postwar emphasis on increasing livestock in the various countries, but there may be considerable reexport trade in feeds within Europe.

THE DOMESTIC MARKET

Linseed oil and linseed meal are joint products of flaxseed crushing mills. The oil presently represents about two-thirds and the meal one-third of the value of crushed flaxseed (table 10). The oil and meal extraction rate per bushel has remained relatively constant at 19 to 20 pounds of oil and 35 to 37 pounds of meal, respectively. Consequently, their proportion of flaxseed's value varies with time--mainly because of change in their relative prices.

The price of meal declined relative to that of oil from the late 1930's through the war period, but has increased since. Thus, linseed has become more disadvantaged in the oil market than in the meal market. This study concentrates on the oil market because oil is the main product and its market has signs of chronic depression. In contrast, the market for the meal byproduct appears strong, the overall feed market is growing at a healthy rate, and there are no major linseed meal disposal problems.

Table 9.--U.S. linseed cake and meal production and exports by destination, averages 1950-67

Item	Average 1950-54	1955-59	1960-64	1965-67
	Short tons	Short tons	Short tons	Short tons
Production	573,800	493,400	373,000	360,300
Exports	20,123	64,194	42,717	106,771
	Percent	Percent	Percent	Percent
Exports as a percentage of production	3.5	13.0	11.5	29.6
Export destination:				
Canada	37.5	12.8	1.1	0.4
Belgium-Luxembourg	15.1	7.3	1.6	.9
Netherlands	22.6	52.8	83.0	28.8
France	6.1	1.7	3.1	5.3
United Kingdom	8.1	0.8	0.5	19.7
West Germany	---	11.1	6.9	37.8
Switzerland	0.3	0.6	1.7	3.8
Denmark	2.6	4.0	---	0.1
Poland	---	---	---	1/ 3.0
Others	7.7	8.9	2.1	0.2
Total exports	100.0	100.0	100.0	100.0

1/ 1,577 tons in 1966 and 7,990 tons in 1967.

Source: Based on data in periodic reports by the Foreign Agricultural Service, U.S. Department of Agriculture.

Practically all linseed oil used domestically has gone to nonfood uses, predominantly in drying-oil products. Drying oils traditionally competitive with linseed oil are tung, fish, castor, and oiticica. Soybean oil and tall oil have increasingly penetrated drying-oil markets since World War II. Figure 8 shows that linseed oil reached a peak of slightly less than 80 percent of total oils used in drying-oil products during the war, lost rapidly during the late 1940's, and gradually declined further afterwards. Its major losses were to soybean oil and tall oil. Linseed currently supplies slightly less than 40 percent, but still is the major drying oil in use. However, all oils used in drying-oil products declined about 20 percent from the mid-1950's to the mid-1960's.

The coatings industry currently takes more than four-fifths of linseed oil used domestically (table 11). Linoleum and oilcloth, formerly heavy users of linseed oil, took only about 10 million pounds in 1967. About

Table 10.--Value of linseed oil and meal per bushel of flaxseed crushed, averages 1935-67

Period	Average value per bushel crushed			Proportion of total value	
	Linseed oil	Linseed meal	Total	Linseed oil	Linseed meal
	Dollars	Dollars	Dollars	Percent	Percent
Average:					
1935-39	1.81	.63	2.44	74.1	25.9
1940-44	2.37	.71	3.08	76.9	23.1
1945-49	4.67	1.20	5.87	79.6	20.4
1950-54	3.15	1.18	4.33	72.8	27.2
1955-59	2.70	1.05	3.75	72.0	28.0
1960-64	2.75	1.14	3.89	70.7	29.3
1965-67	2.66	1.34	4.00	66.5	33.5

Source: Economic Research Service, U.S. Fats and Oils Statistics, 1909-65, U.S. Dept. Agr., Stat. Bul. 376, August 1966, p. 34, for data through 1963. Economic Research Service, Fats and Oils Situation, FOS-243 and 244, June and September 1968 for data for 1964 through 1967.

20 million pounds is used in producing resins and plastics. Subsequent discussion concerns the future potential of linseed oil in these various uses.

Paint and Varnish

Linseed oil's use in the coatings industry is affected by those economic forces that determine how much paint, varnish, and lacquer is produced as well as those forces that determine how much linseed oil is used in their formulation.

The coating industry's competitive situation is favored by some trends and threatened by others. The industry had the potential of enjoying a strong rate of annual growth over the last three decades as a consequence of the aggregate influence of (1) increases in population, (2) industrial growth, (3) new constructions, and (4) increasing per capita incomes (inasmuch as people tend to both protect and decorate more with coatings as their incomes increase). 5/ However, some "unfavorable" forces tended to offset these favorable ones. The trend toward replacing wood in construction with materials needing no preservatives--such as aluminum, brick, glass, plastics, stainless steel, and stone--tended to reduce the demand for protective coating materials. Too, technological improvements in protective coatings tended to decrease the quantity needed to cover a given area and to increase its durability; that is, a given amount now "goes further" and "lasts longer."

5/ A product for which demand increases as incomes increase is termed a "superior" product in economic literature.

Table 11.--Annual use of linseed oil in selected products, averages 1935-44 and 1950-64, annual 1965-67 1/

Use	Average 1935-39	Average 1940-44	Average 1950-54	Average 1955-59	Average 1960-64	1965	1966	1967
	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.
Paint and varnish	433.6	580.4	421.8	367.4	320.6	283	275	230
Linoleum and oilcloth	56.6	91.0	87.8	44.8	18.6	14	14	10
Resins and plastics	---	---	19.6	18.2	19.4	19	21	19
Lubricants and similar oils	---	---	---	2/3.5	3.4	5	6	3
Fatty acids	---	---	---	2/4.0	6.6	7	3/	4
Printing inks 4/	5/18.2	21.0	6/19.7	---	---	---	---	---
Total consumption 7/	517.4	740.4	583.4	483.4	372.8	336	326	276

1/ Unless otherwise specified, 1935-64 data are based on Economic Research Service, U.S. Fats and Oils Statistics: 1909-65, Stat. Bul. 376, U.S. Dept. Agr., August 1966 and subsequent fats and oils situation reports. 1965-67 data are from Economic Research Service, Fats and Oils Situation, FOS-244, U.S. Dept. Agr., September 1968.

2/ 1958-59 average.

3/ Less than 0.5.

4/ U.S. Tariff Commission, Flaxseed and Linseed Oil, Industrial Materials Series Report M-7, November 1952. (Note: 1945-49 average annual consumption was 22.9 mil. pounds.)

5/ 1937-39 average.

6/ 1950-51 average.

7/ Exceeds the sum of use in products listed. Miscellaneous other uses plus those listed for years when unreported make up the difference.

The adverse forces dampened but did not deter the growth in paint production. Its production increased from 298 million gallons annually in 1935-39 to 810 million in 1965-67, an annual growth rate of 3.5 percent. From the relatively high average of 417 million gallons during 1940-44, the increase to 810 million gallons represents a 2.8-percent annual growth rate. Consequently, the growth in protective coatings has provided a potentially growing market for linseed oil.

Linseed's Loss in Coatings Manufacture

Table 12 provides estimates of the market loss by all oils and by linseed oil in protective coatings. An average of 299 million pounds of linseed oil was used annually during 1965-67. At the 1935-39 rate of use per gallon of paint, about 1,180 million pounds would have been used annually. Coating production almost tripled, while linseed oil used in its manufacture declined about 30 percent within three decades. Linseed oil's loss in the market, as computed above, amounted to 881 million pounds annually by 1965-67. About one-fourth of that amount was lost to competing oils and three-fourths to (1) other materials that replaced oil in coating formulas and (2) increased production of coatings with lower oil content.

The major oil competitors that made recent gains were soybean and tall oils (table 13). Tung, fish, castor, and (recently) safflower oils are used in paints in lesser amounts. The loss to both soybean oil and tall oil involved price competition. Usually, that product whose price declines relative to the price of competing products gains a larger share of the market. However, the tall oil price increased from 20 to 50 percent of the linseed oil price during the same period its rate of use advanced from 2 to 9 percent of oils used in paints. 6/ Such an increase in tall oil's price as its use increased was possible because the price was so far below that of linseed oil to begin with and its technical performance in coatings was becoming more favorable and certain in the minds of coating manufacturers.

Soybean oil's large gains in use were in the late 1940's and early 1950's, periods when the soybean oil price relative to the linseed oil price was favorable. The price of soybean oil was less than half that of linseed oil in 1949. In 5 of the 7 years from 1946 through 1952, the soybean oil price was less than 80 percent of the linseed oil price. It exceeded 80 percent in each of the 5 years preceding and 5 years following the 1946-52 period.

Competition of both soybean oil and tall oil in the paint market was made possible by improvements in their performance. Price became a meaningful factor only after their use became technically feasible.

About three-fourths of linseed's loss in paints was due to greater use of resins in manufacturing some paints with no oil and other paints with less oil per gallon than formerly. The nature of the loss is better explained by reference to the components of paint and the functions of oil in its formula.

6/ Prices used were wholesale for "refined" tall oil and "raw" linseed oil.

Table 12.--Linseed oil's market loss in the paint and varnish industry, annual averages 1935-67

Period	Paint and varnish production	Total oils used 1/		Linseed oil used 1/			Linseed market loss 3/		
		Actual	Hypothetical 2/	Actual	Hypothetical 2/	As percentage of total oil	Total	To other oils	To other factors
	Mil. gal.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Percent	Mil. lb.	Mil. lb.	Mil. lb.
Average:									
1935-39..	298	641	641	434	434	67.7	0	0	0
1940-44..	417	739	897	580	607	78.5	27	4/80	107
1945-49..	553	698	1,190	431	805	61.7	374	42	332
1950-54..	623	850	1,340	441	907	51.9	466	134	332
1955-59..	665	803	1,430	386	968	48.1	582	158	424
1960-64..	666	747	1,433	340	970	45.5	630	166	464
1965-67..	810	779	1,742	299	1,180	38.4	881	228	653

1/ Total oils include oils listed by Census Bureau as used in synthetic resins which end up in protective coatings. Linseed oil used in producing resins was added to that used in producing paint and varnish.

2/ Hypothetical amounts assume the same rate used per gallon of paint as in 1935-39.

3/ Difference between the actual and hypothetical amounts. Loss to other oils based on linseed's 1935-39 ratio of 67.7 percent of total oils.

4/ Gain--not a loss.

Source: Based on data from Economic Research Service, U.S. Fats and Oils Statistics, 1909-65, Stat. Bul. 376, U.S. Dept. Agr., August 1966 and Fats and Oils Situation, FOS-243 and 244, June and September 1968.

Table 13.--Drying oils used in paint and varnish as percentage of total oil used, averages 1935-67 1/

Type of oil	Average						
	1935-39	1940-44	1945-49	1950-54	1955-59	1960-64	1965-67
	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Linseed	67.7	79.1	62.1	57.7	57.3	54.1	47.8
Tung	16.5	4.2	9.4	7.5	6.2	4.4	4.4
Fish	3.6	4.4	4.5	3.4	1.7	6.6	12.7
Soybean	2.5	3.7	10.7	17.1	17.6	15.7	16.5
Castor	0.9	6.0	6.0	3.6	4.1	6.9	6.8
Tall	---	---	2.0	4.4	6.2	6.9	8.7
Other	8.8	2.6	5.3	6.3	6.9	5.4	3.1
	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.	Mil. lb.
Total oil used annually	641	733	691	731	641	594	581

1/ Excludes oils used in synthetic resins that end up in protective coatings.

Source: Based on data in Economic Research Service, U.S. Fats and Oils Statistics, 1909-65, U.S. Dept. Agr., Stat. Bul. 376, August 1966, table 156, page 139, and various fats and oils situation reports.

Basically, paint is composed of a pigment (solid) and a "vehicle" (liquid). The vehicle is differentiated into (1) the binder, which is the film-former, and (2) the solvent or thinner, which improves ease of application (1, p. 356). Oils are used essentially as film-formers. Their performance and cost relative to the performance and cost of competing film-forming materials determine their competitive strength in the paint industry. Major competing film-forming materials are the plastic and the latex water emulsion types. Oil paints use mineral spirits and turpentine as the solvent or thinner. However, paint technology has grown rapidly and coating formulas have increased in complexity during the last two or three decades. Some coatings now include combinations of two or more film-forming materials as well as minor additives such as plasticizers, driers, extenders, emulsifiers, stabilizers, and antifoam agents.

The Economic Research Service, USDA, reported production of coatings containing drying oils through 1958. Had the same level of oil use prevailed in 1954-58 as in the early 1940's, an additional 365 million pounds would have been taken annually. About 105 million pounds of this loss was due to a decline from 2.5 to 1.8 pounds of oil per gallon in coatings containing drying oils. Assuming these data represent the relative loss to oil and non-oil resin paints (the 75 percent reported earlier as not due to oil substitutes), we can roughly allocate total loss. About half of linseed oil's loss was due to its complete replacement by synthetic resins in non-oil paints, one-fourth was due to replacement by other oils, and another fourth was due to partial replacement by synthetics in the oil-resin film-formers such as the alkyds. Increases in the oil-resin paints probably accounted for most of the decline in oil per gallon in oil-based paints (11, p. 25).

Linseed Oil Coatings in Different Uses

That linseed oil lost a considerable part of its former market in protective coatings has been established and the major responsible trends described. The kinds of coatings and the end uses where the losses occurred are now considered.

The two major types of coatings are designated as trade sales and industrial. Trade sales coatings are sold in small quantities at retail level for household and consumer use. Industrial coatings are for large volume sales to the automobile industry, the major household appliance industry, finished wood factories, the machinery and equipment industry, furniture manufacturers, and other industries.

Total production of coatings is presently divided about evenly between trade and industrial uses (fig. 9). Trade sales averaged 407 million gallons annually and industrial sales 402 million in 1966-67. Compared with trade sales, industrial sales have fluctuated more widely and increased at a somewhat higher rate in recent years, and are expected to grow faster in the future (10, p. 80).

Interior coatings in trade sales increased from about 154 million gallons in 1954 to 200 million annually in 1965-66. Exterior coatings increased from 104 million gallons to about 130 million during the same period. Interior coatings are about one-half and exterior coatings one-third of total trade sales.

Generally, oil is considered as having lost to water emulsion types in interior coatings and as losing its market in exterior coatings. Oil-type coatings have fallen from over two-thirds of interior coatings to about one-third in little more than a decade. Their primary remaining use, apparently, is in trimming and woodwork. However, recent developments of semigloss and gloss water-based coatings threaten even that small part of the interior market retained by the oil-based coatings. Oil-type coatings have decreased from 98 percent to 68 percent of exterior coatings since the mid-1950's. They face continued stiff competition in this market.

The competitive strength of the water-based coating has been its convenience in application, ease in cleanup, and quick-dry characteristics. These advantages were sufficient for it to make immediate and large inroads in the interior market. However, because of its less durable features (particularly in the early developed types), water-based coating was strongly disadvantaged in the exterior market. The research and development competitive struggle at present revolves around improving synthetic resin paint's durability to exterior conditions and improving oil-type paint's convenience in application, ease in cleanup, quick-dry characteristics, and other such features.

Water-based coatings have been less successful in industrial than in trade sales coatings. It is estimated that only 25 of the 365 million gallons of coatings produced for industry in 1965 were water-based (13, p. 46A). However, oil-based coatings for industrial use are predominantly the resin-oil combination film-formers that use considerably less oil per gallon than the oil paints used in exterior house coatings. Too, the water-based systems threaten to penetrate some of the larger industrial coatings markets.

Most coatings used in industry are based on alkyds, vinyls, acrylics, and epoxies, with numerous types existing within these major groups. The alkyds (oil-containing) have been labeled industry's "workhorse" coatings; the acrylics (non-oil) are considered the most likely threat as a large-scale replacer of currently used alkyd types.

For example, the automobile industry currently absorbs about 60 million gallons of coatings annually. Solvent-based epoxies are mainly used for autobody base coats, and alkyd super-enamels have been preferred for top coats (9, p. 103). However, one of the major automobile companies shifted to thermoplastic acrylic lacquers for top coats a few years ago. More recently, it seems that thermosetting acrylic enamels are gaining favor as top coats. The market is a relatively large one and is growing; oil-based types of coatings probably will continue to retain a large part of it.

The wood and metal furniture industry uses large quantities of coatings, and apparently manufacturers change formulas frequently. Nicrocellulose lacquers are used in high-quality furniture, various alkyd types predominate the bulk of the market, and polyester and polyurethane coatings are bidding for a share (9, p. 106).

Metal cans are the largest user of coatings in metal decorating. An oleoresinous or polybutadiene base coat and a vinyl top coat are typical for cans used in the beer and soft drink industries, and cans used for food are usually coated with an oleoresinous-type base (9, pp. 195-196).

The trend in major appliance coatings apparently is from two-coat to one-coat systems and toward thinner (but more durable) coatings. Epoxies are typically used as base coats in the two-coat systems. Modified alkyds have been widely used for top coats and for the one-coat systems, but thermosetting acrylic enamels are posing a strong threat (9, p. 104).

Most industrial markets use a wide variety of coating formulas, individual firms tend to shift from one type to another, and there is widespread willingness to "try the new." Water-based systems will likely make further gains in the market. For example, electrodeposition as a method of applying base coatings in a two-coat application uses water-based coatings, and the method is gaining favor in industry (13, p. 49A).

Coating Technology in the Future

The onslaught of synthetic resins in coatings had its initiation in the synthetic rubber industry of World War II. The industry's research interest in coatings as a new use for latex materials occurred when strong market demand for linseed oil created an atmosphere conducive to market penetration. By the mid-1950's, latex coatings had achieved a significant share of the interior coatings market. As a result, research and development efforts to improve oil-based coatings received increased attention in the latter half of the 1950's and led to the development of products remarkably superior to those used a decade or so ago. Such improvements helped to dampen penetration of the coatings markets by latex products. However, the competitive onslaught of the growing and productive family of fast-drying, easily applied, and convenient-in-use synthetic resin coatings will continue.

The future of oil-based coatings will be determined by technology; that is, whether the non-oil-using synthetic resins or the oil-based coatings make improvements more acceptable to coating users. Research that delays linseed oil's widespread loss of the coatings market may well be justified. Should unexpected results enable it to recapture some of the market, the linseed oil industry could be considerably strengthened.

Linoleum and Oilcloth

Linseed oil used annually in linoleum and oilcloth manufacture exceeded 100 million pounds for several years during the 1940's. From an average of 88 million pounds annually in 1950-54, its use in these products declined to 45 million pounds in 1955-59 and 19 million pounds in 1960-64 and was estimated at only 10 million pounds in 1967. A market for more than half a million acres of flaxseed was lost within two decades.

Both linoleum and oilcloth served a demand based on the desire to "protect and decorate" in the home. Such demand usually expands rapidly with rising income. Assuming per capita demand for "protective and decorative" products increased at the same rate as real personal consumption expenditures and that linseed oil kept its major share of the growing market for linoleum and oilcloth products, it could have contributed annually 140 to 190 million pounds during 1960-64 instead of 18 million pounds (table 14). Had it even maintained the same per capita use in the market as in the prewar and war periods, the market would have taken 85 to 125 million pounds annually.

Part of the loss was due to changing preferences. More housewives turned to carpeting and hardwood floors. However, a large part was lost to "like products" made from synthetic resins rather than oils. Vinyl resin floor coverings largely replaced linoleum because of superior performance properties.

Some of linseed oil's loss in the market was due to its replacement by other oils. Linseed oil comprised 86 percent of fats and oils used in linoleum and oilcloth in the early 1940's, compared with only 48 percent in the early 1960's. The loss was due to increased use of tall oil, although some soybean oil was used in the late 1940's and early 1950's. The loss from replacement by other oils accounts for about 10 percent of the total market loss computed in table 14.

Oilcloth was formerly used mainly as table covering and has lost that market to vinyl film. Linseed oil's use in the market at present is confined to fabric wall covering and "sign" cloth.

There is little possibility for linseed oil to recapture the floor and table covering market. At best, it is likely to maintain sales of only a few million pounds annually.

Plastics and Resins

The market for oils in manufacturing resins and plastics is growing. Total fats and oils used for this purpose increased from an annual average of 130 million pounds during 1950-54 to 212.5 million pounds during 1964-67, for a 3.7-percent growth rate compounded annually (table 15). The rate was 3.2 percent in the 1950's, compared with 5.4 percent in the 1960's--indicating that the market is growing at an increasing rate.

Linseed oil did not share in the growth of the market. It did hold its sales at approximately 20 million pounds annually from 1950-54 to 1964-67, but its share declined from 15 percent of the total market to less than 10 percent during that period. Soybean oil accounted for 40 to 50 percent of the total. Castor oil's share increased from 10 percent to 21 percent. Safflower, coconut, fish, tung, tall, and other oils are also used in plastics and resins.

Fractionation makes linseed oil more competitive with expensive oils like tung and perilla. Linseed raffinate, a byproduct resulting from fractionation, is also used in the manufacture of alkyd resins (14, p. 47).

Table 14.--Estimated market loss of linseed oil in linoleum and oilcloth manufacture, annual averages 1935-44 and 1960-64

Item	Unit	Average		
		1935-39	1940-44	1960-64
U.S. population	Thou.	128,765	134,748	185,846
Increase:				
From 1935-39	Percent	---	---	44
From 1940-44	do.	---	---	38
Per capita personal consumption expenditures in 1958 dollars	Dol.	1,077	1,213	1,825
Increase:				
From 1935-39	Percent	---	---	70
From 1940-44	do.	---	---	50
Use of linseed oil in linoleum and oilcloth	Mil. lb.	56.6	91.0	18.4
Hypothetical use 1/:				
Using 1935-39 base	do.	---	---	139
Using 1940-44 base	do.	---	---	189
Linseed oil's annual loss 1/:				
Using 1935-39 base	do.	---	---	120
Using 1940-45 base	do.	---	---	170

1/ Assuming per capita use increased from the designated base equivalent to the increase of personal consumption expenditures in real terms.

Most linseed oil, as well as other oils, used to produce resins ends up in paints and varnishes. In view of linseed's past performance in the resins market it is unlikely it will make surprising gains in the future.

New Uses and Potential Markets

There is insufficient data to evaluate minor markets for linseed oil. Current usage is small in printing inks, lubricants, fatty acids, patent leather, core oils, and pharmaceutical items. About 5 million pounds annually are used in lubricants and a similar quantity in fatty acids, for example. There is no strong basis for expecting a large expansion of linseed oil in these markets in the future.

The World War II period was one in which demand for linseed oil was strong and supply limited. In fact, it was necessary to ration linseed oil's use in protective coatings, linoleum, oilcloth, coated fabrics, and printing inks during the war (19, p. 65). This induced greater interest and more

Table 15.--Average annual use of specified oils in resins and plastics, 1950-54 and 1960-67

Year	Linseed oil		Soybean oil		Castor oil		Other oils		Total oils used	
	Amount used	Percentage of total	Amount used	Percentage of total	Amount used	Percentage of total	Amount used	Percentage of total	Amount	Percentage change from previous period 1/
	Mil. lb.	Percent	Mil. lb.	Percent	Mil. lb.	Percent	Mil. lb.	Percent	Mil. lb.	Percent
Average:										
1950-54..	19.6	15.1	61.2	47.1	12.8	9.9	36.2	27.9	129.8	NA
1960-64..	19.8	11.2	75.8	42.8	43.4	24.5	38.0	21.5	177.0	3.2
1964-67..	20.1	9.5	96.4	45.4	44.2	20.8	51.8	24.4	212.5	5.4

1/ 1950-54 to 1964-67: 3.7 percent.

Source: Economic Research Service, U.S. Fats and Oils Statistics 1909-65, Stat. Bul. 376, U.S. Dept. Agr., August 1966, table 158; Bureau of the Census, Current Industrial Reports, Series M20K, U.S. Dept. Commerce; and Economic Research Service, Fats and Oils Situation, U.S. Dept. Agr., recent issues.

research on the use of synthetics from nonagricultural sources in these markets. The rapid breakdown of demand for linseed after the war induced a belated search for a course of action that could improve its future.

The major hope among conventional markets is probably that of maintaining linseed oil's present level of use in the coatings industry. This use may absorb its production as a late-season crop. However, maintaining the present level of use in coatings will likely require considerable investment in research and development. Moreover, manufacturers of competing materials are active in this respect.

Exterior trade sales paints take a large part of the linseed oil moving into the coatings industry. Considering that synthetic emulsion paints would be linseed oil's greatest threat in exterior paints, researchers began looking for ways to incorporate linseed oil into emulsion systems a decade ago.

Some of the properties wanted in an emulsion paint are easy wash and cleanup of equipment; rapid-dry, "tack-free" film; adherence to substrata; durability and tint retention; stability in the can; mildew and water resistance; and ease and convenience in application (3). Water-thinned linseed oil paints that allowed easy cleanup with water and rapid drying of paint film were developed in the early 1960's by the Northern Utilization Research and Development Division, Agricultural Research Service, USDA. The September 23, 1963, issue of Chemical Week described a major paint company's introduction to the market of a new linseed oil emulsion vehicle claimed to have greater durability, better adhesion to chalky surface, more coverage, and less reliance on primers than latex coatings. Other improvements have been made since 1963. Most recently, a "glossy finish" was built into a linseed oil water emulsion paint by chemists at the ARS Northern Utilization Research Laboratory. The glossy finish depends on a microlayer of oil around each paint pigment particle.

Improvements in oil paints, particularly emulsion vehicles, within the last decade have certainly enhanced linseed's competitive status and opportunity in coatings. Whether it recuperates lost markets, maintains those it has at present, or loses further ground depends on continued research improvements.

Among potential new uses, that of concrete treatment involving the Nation's highway system appears most promising. Plastic sheets or coating waxes are used extensively on freshly poured concrete to prevent excessive water loss while curing, a critical factor in strength development. A linseed oil film applied on freshly poured concrete serves this purpose as well as that of protecting against freeze-thaw damage after the concrete has set.

Spalling is the cracking, splitting, or breaking up of a material (such as concrete) due to temperature change. Freeze-thaw damage to roadways often results from moisture penetrating the concrete and expanding as it freezes. Widespread and increasing use of salt for de-icing highways contributes to concrete deterioration by causing such effects as scaling and pitting, and thus increases highway maintenance cost.

The linseed oil antispalling compound is applied to the road surface in a film thin enough to allow moisture vapor from underneath to escape to the surface but thick enough to prevent water and salt solutions on the surface from penetrating the concrete (16, p. 6). This antispalling compound is made of boiled linseed oil mixed with kerosene and other mineral spirits in equal proportions. For about 200 square feet of surface, 1 gallon of the compound is recommended for an initial application of two coats. This requires approximately 1 gallon of linseed oil per 50 square yards of treated concrete. Subsequent treatments in 1 or 2 years for the second coat and every 3 or 4 years thereafter would require only one coat and half as much oil.

Linseed oil's competitors in this market are said to be epoxy-based compounds that are more durable, more versatile, and usable as patch material for highway repair work (12, p. 48). However, these compounds are well above linseed in price. Treatment costs would be several times that of linseed oil antispalling compound. 7/ Thus, while such compounds are used for patching, it is unlikely they have wide use in highway antispalling treatment.

Estimates of the potential size of the antispalling market vary from about 20 to 150 million pounds of linseed oil annually. The larger figure is divided into 50 million pounds used on new roads and 100 million for older surfaces, bridge decks, sidewalks, and other surfaces (12, p. 47). About three-fourths of the States are currently using linseed oil antispalling compound on a trial or accepted basis; this use was possibly as high as 4 million pounds in 1968.

A realistic market figure to expect if widespread adoption occurred would be about 50 million pounds annually within the next 5 to 10 years. This estimate is sufficient to create excitement among those interested in flaxseed's future although it may fall far short of solving all its market problems.

There are further potential uses for linseed oil that presently are a matter of research speculation. For example, roughly half a billion tons of concrete are poured annually in this country and about half the mixture is comprised of coarse aggregate. Sound materials for coarse aggregate are severely limited or nonexistent in some areas of the country and are quickly being depleted in others. Unsound "porous" and "alkali-reactive" materials used as coarse aggregate lower the durability of concrete. Possibly, a linseed oil treatment may be developed that would prolong the life of concrete made with unsound aggregate.

Another potential use concerns high-performance jet lubricants, a market that is likely to display rapid growth for many years. Lubricants presently used are based on esters of various organic acids and alcohols and have some basic weaknesses, such as lack of high-temperature oxidative stability or lack

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7/ The linseed compound cost was estimated in one source (12, p. 48) at 3 cents a square yard for materials and 3 cents a square yard for application. However, application costs vary widely depending on method and total costs are now estimated at 10 to 15 cents a square yard.

of good lubricity. The desired lubricant is difficult to develop because attempts to attain the sought-after properties can also cause the development of adverse properties in the product. New types of ester fluids based on modified linseed fatty acids may produce lubricants that have improved properties.

The potential markets are there. It remains for research to discover and develop the products from linseed that perform better than alternatives in those markets. Although research and development effort does not assure success for linseed oil, lack of such effort almost surely assures failure.

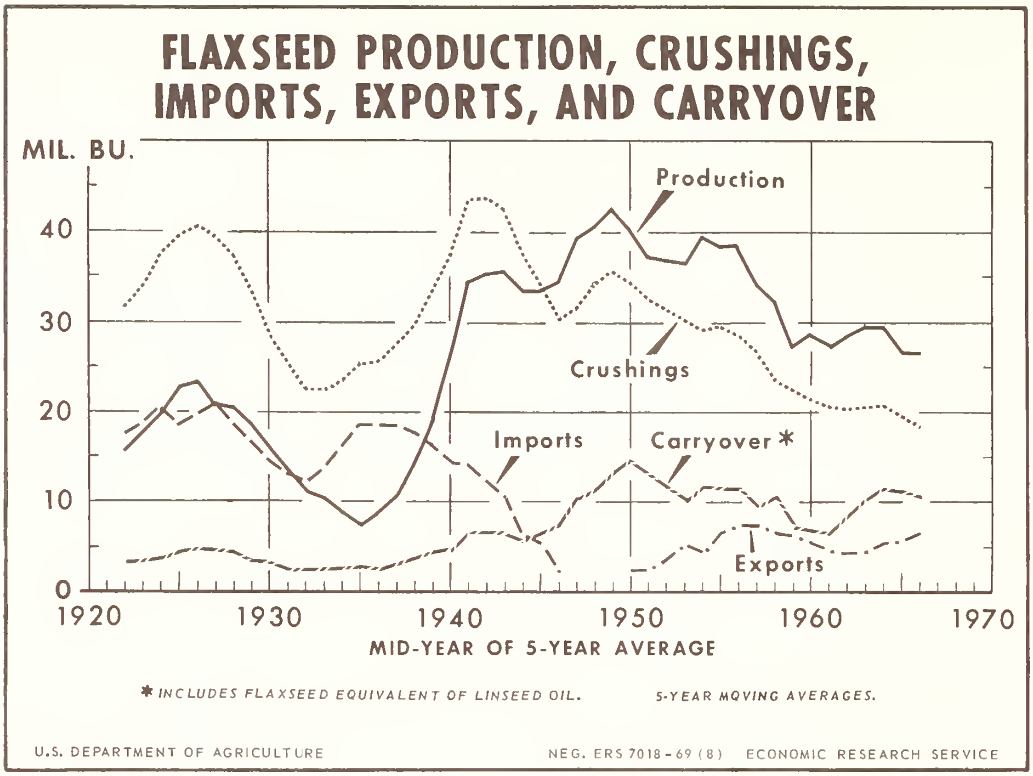


Figure 1

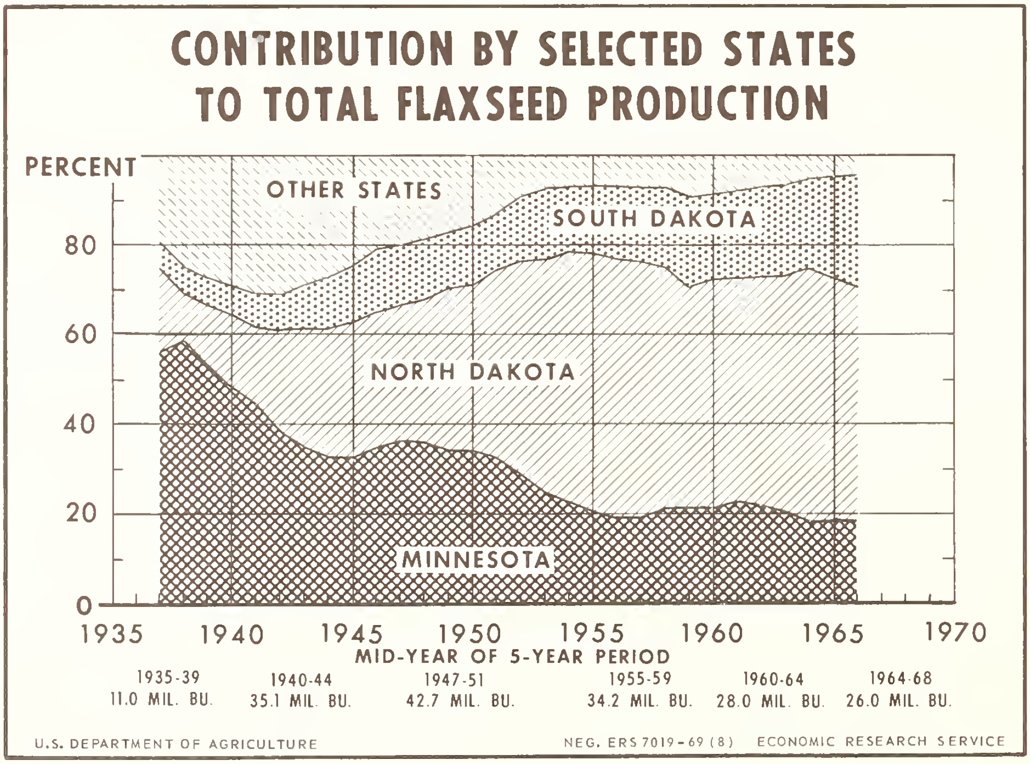


Figure 2

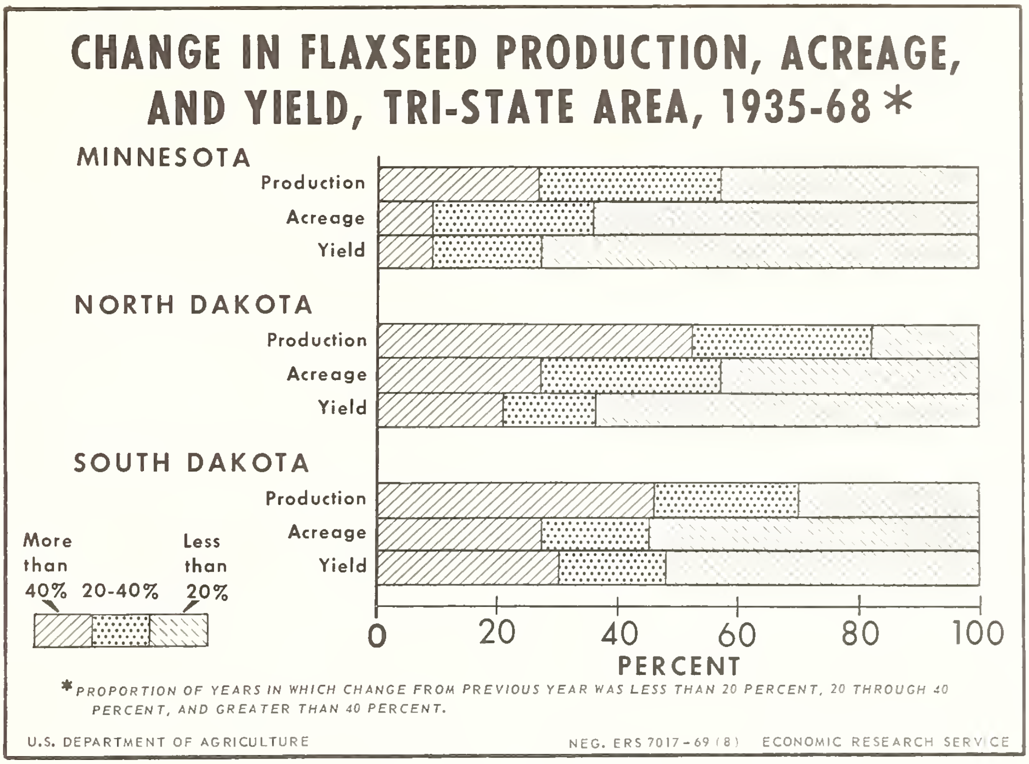


Figure 3

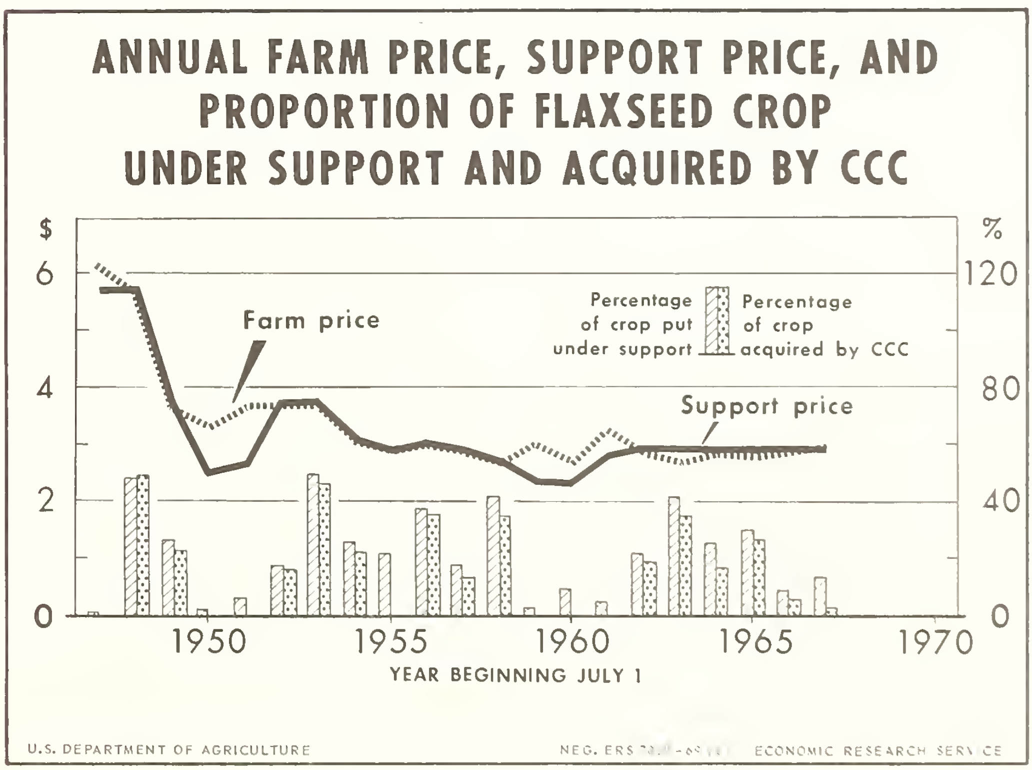
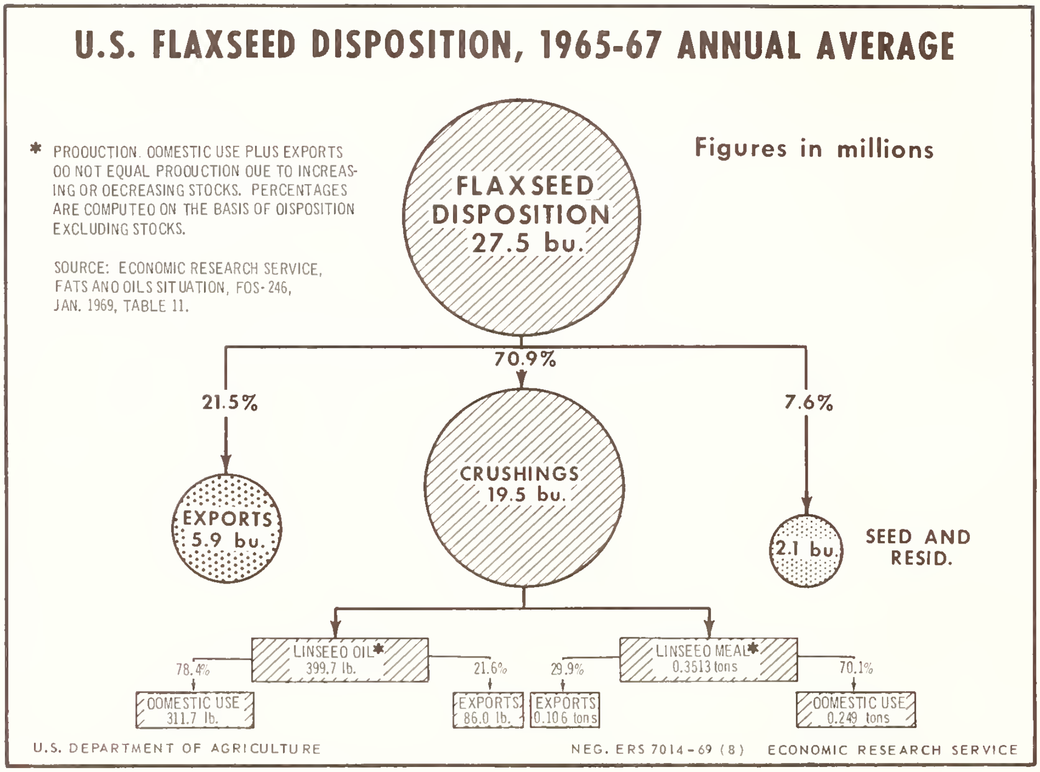


Figure 4



U.S. FLAXSEED DISPOSITION, 1965-67 ANNUAL AVERAGE
* PRODUCTION. DOMESTIC USE PLUS EXPORTS DO NOT EQUAL PRODUCTION DUE TO INCREASING OR DECREASING STOCKS. PERCENTAGES ARE COMPUTED ON THE BASIS OF DISPOSITION EXCLUDING STOCKS.
SOURCE: ECONOMIC RESEARCH SERVICE, FATS AND OILS SITUATION, FOS-246, JAN. 1969, TABLE 11.
Figures in millions
FLAXSEED DISPOSITION 27.5 bu.
70.9%
21.5%
7.6%
EXPORTS 5.9 bu.
CRUSHINGS 19.5 bu.
2.1 bu.
SEED AND RESID.
LINSEED OIL* 399.7 lb.
78.4%
21.6%
DOMESTIC USE 311.7 lb.
EXPORTS 86.0 lb.
LINSEED MEAL* 0.3513 tons
29.9%
70.1%
EXPORTS 0.106 tons
DOMESTIC USE 0.249 tons
U.S. DEPARTMENT OF AGRICULTURE
NEG. ERS 7014-69 (8)
ECONOMIC RESEARCH SERVICE

Figure 5

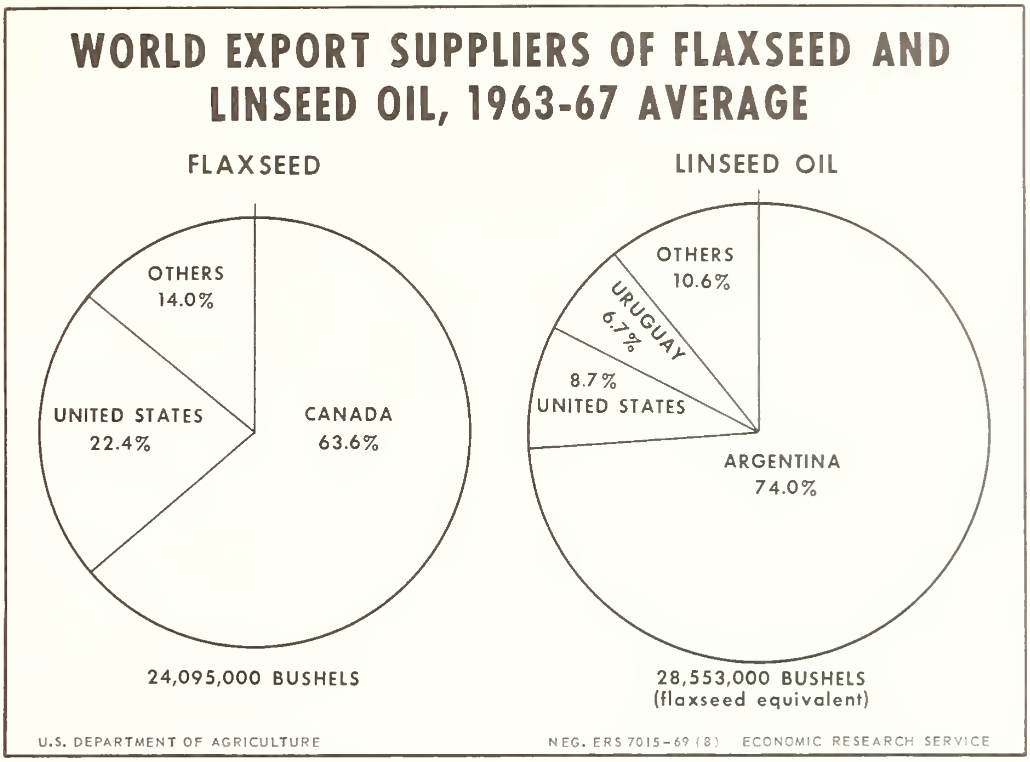


Figure 6

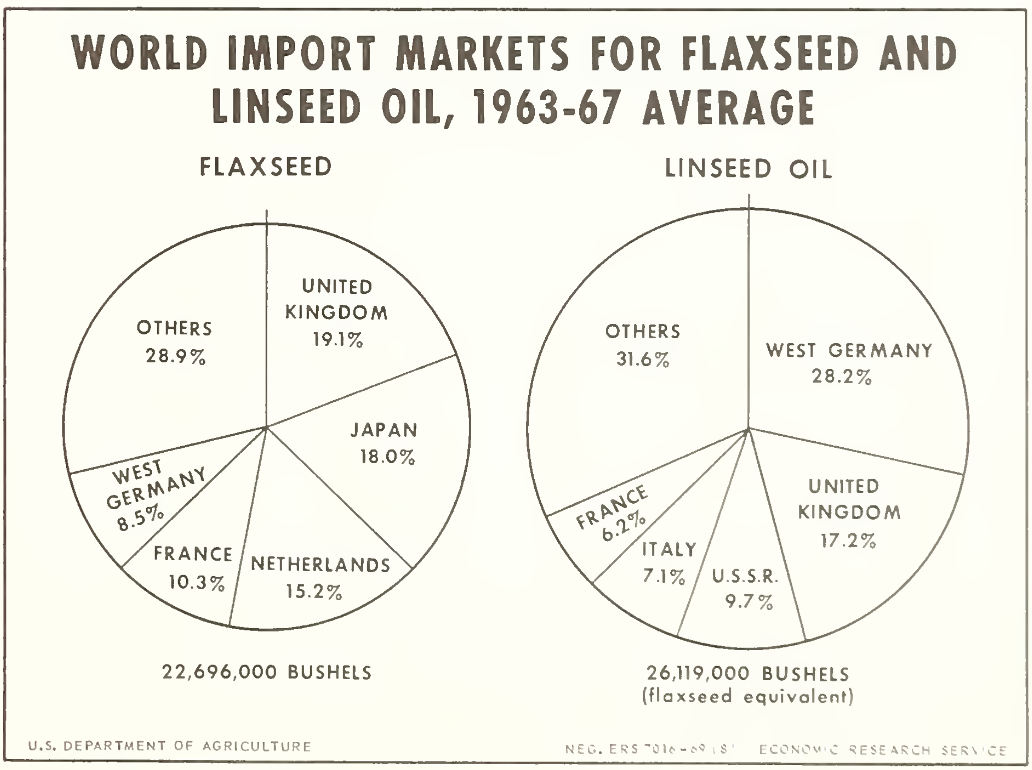


Figure 7

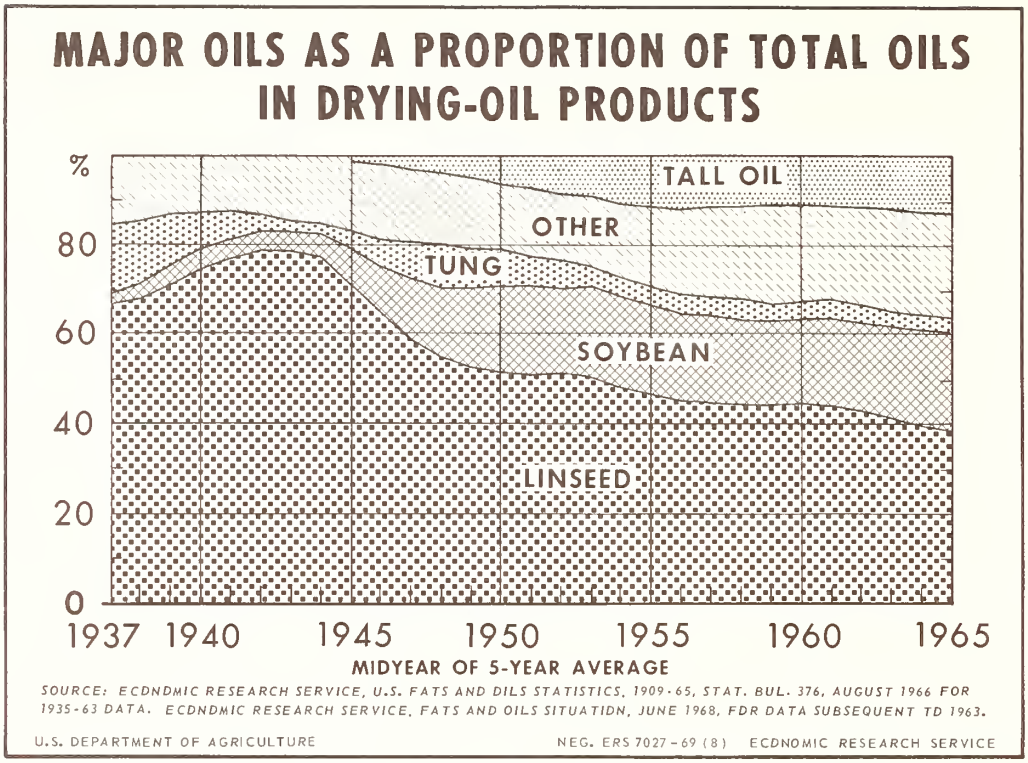


Figure 8

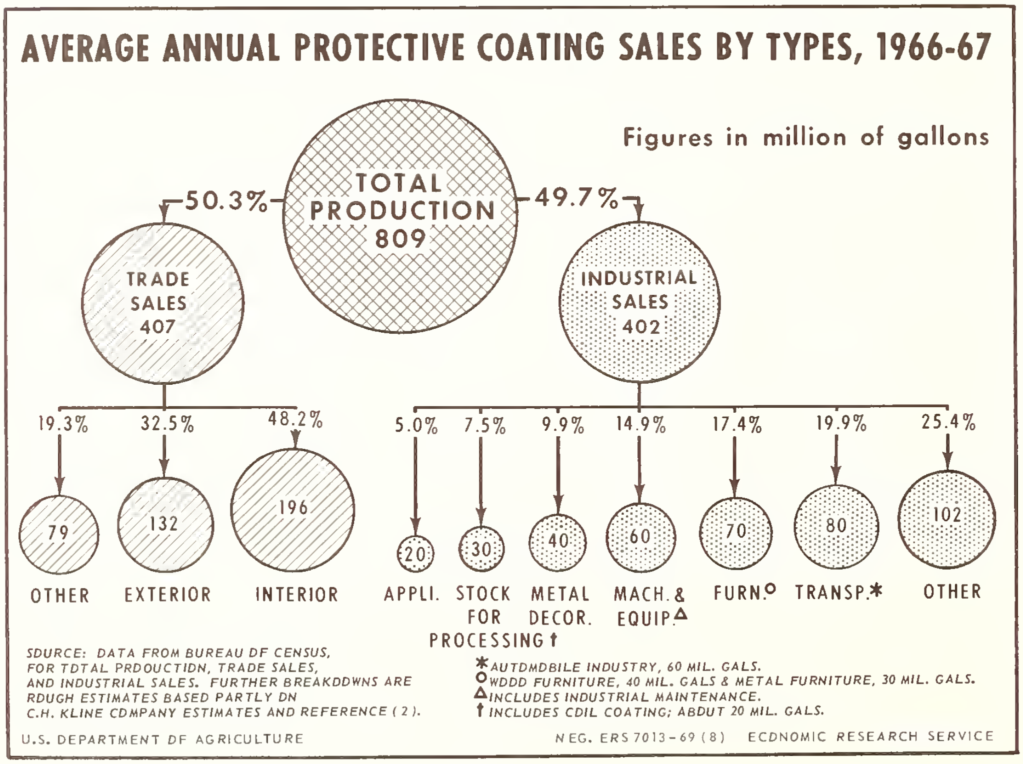


Figure 9

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