Factors Affecting the Composition of Canadian Oil Seeds[1,2]

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Abstract

Importance of climate, plant breeding, and economics to production of oil seeds in Canada is considered. The influence of temperature and rainfall on the oil content and fatty acid composition of linseed and rapeseed is discussed. Major changes in the fatty acid composition of rapeseed oil can be effected by modern techniques in plant breeding and selection, i.e. erucic acid content can be reduced from approximately 40% to 0. The impact on the oil meal market of continued selection for high oil in crops and varieties is discussed.

Introduction

THE FACTORS that determine whether or not a crop will be produced in a given area are: 1) climate, 2) economics and 3) adaptation of crops through plant breeding and selection. In the present discussion, the effects of climate and technological advances in breeding will be considered with a few references to economic effects.

Two major agricultural areas are presently producing oil seed crops in Canada. The first of these is located in the southern part of Ontario and is bounded on three sides by the Great Lakes. Rainfall is relatively high and the growing season ranges from 120–160 frost-free days with climatic extremes being mitigated by the proximity of the lakes. Under these conditions soybeans thrive, and in 1961 production reached an all time high of 8.5 million bu, with average yields approaching 30 bu/acre. Quality of the beans is excellent and the limiting factor on expansion is competition in dollar return per acre from crops such as tobacco, corn, vegetables, and fruits. A limited expansion of production in this area is possible. Attempts to develop early maturing soybean varieties suitable for production in the Western Prairie region have not been successful. Small trial plantings in southern Manitoba and Alberta have given low yields and only moderately good quality beans.

The climatic factors in the Western Prairie area differ markedly from those in Eastern Canada. This region is an inland plain and subject to wide extremes in temp and rainfall both within and between seasons. A successful oil seed crop must 1) mature in about 100 days, 2) be relatively drought resistant, and 3) compete with wheat, barley, and oats in net return per acre. In the early development of the prairies these requirements restricted oil seed production to flax. Under normal conditions a price ratio of 2.25:1 for flax in relation to wheat is sufficient to secure production. At the present time the ratio is ca. 1.8:1.0 and flax production yields about 15–20 million bu/ year because of: 1) pressure of surplus wheat on delivery quotas, 2) improved flax varieties, and 3) the application of chemical weed killers in flax culture.

In 1942 rapeseed was introduced into Canada to supply a wartime shortage of rapeseed oil for marine engine lubrication. The crop appeared to be well adapted to the northern prairie areas where it gave high yields. Through breeding and selection for earliness and uniformity of maturity, strains have been developed that yield oil of quality acceptable for use in edible products. Currently, at a price ratio of 1:1, it appears to be competitive with wheat and production has reached 10–12 million bu annually. While approximately 90% of the crop is exported as seed, recent developments indicate that there could be a marked increase in the domestic use for edible products.

For a number of years small amounts of sunflower seed have been grown in the southern prairies, particularly in Manitoba. Domestically produced hybrid varieties produce yields of around 700 lb/acre of seed having an oil content of ca. 32–35%. Recent introductions from Russia have produced seed of 40–42% oil content, with yields in excess of 1000 lb/acre. Within the next few years a profitable sunflower crop could be established in this area.

About 1.5 million bu mustard seed is grown annually. Three types, brown, yellow and oriental, are produced mainly in the southwestern area for use in the condiment trade. Production is on a contract basis and quality characteristics vary quite markedly and are specified by the contractor.

Discussion

Influence of Climate

The prairie area of Western Canada has a wide enough range in climate to permit an assessment of factors such as temperature and rainfall on the composition of seeds. Seasonal variations are quite marked but the average long term macrofeatures of climate and vegetation are reflected in soil types. Figure 1 is a soils map of the area. As one moves from east to west, the elevation rises from about 800–3000 ft above sea level with a resulting decrease in the mean temp and length of growing season. A similar effect occurs in moving from south to north. The true prairie area corresponds to the triangular brown soil zone. This region is characterized by low precipitation about 15 in./year and hot dry winds. As temperature falls, due to changes in elevation and latitude, effective rainfall increases to produce a parkbelt corresponding to the dark brown soil zone. This shades into the black soil zone which was originally covered by deciduous trees. The grey wooded soils correspond to the area covered by conifers.

On Oil Content. The main storage of energy in cereal grains is in the form of starch, while in oil crops it is stored as oil. In Western Canada, where these two types of crops are grown together, a close similarity in the effects of climate on composition is evident. Low rainfall with resulting low soil moisture and higher temp are conducive to producing low yields of wheat with a high protein to starch ratio. Similar climatic conditions produce low yields of oil seeds with a high protein to oil ratio. In wheat, high protein is desirable; thus the best area for production of high quality wheat is in the south central prairie area. With oil crops, high oil content is a requisite of quality; hence the best crops are produced in the more northerly areas. The two types of crops are complimentary in their climate requirements.

The upper part of Figure 2 shows the distribution of flax by oil content for the crop year 1959 (1). This year was selected as being typical of a normal

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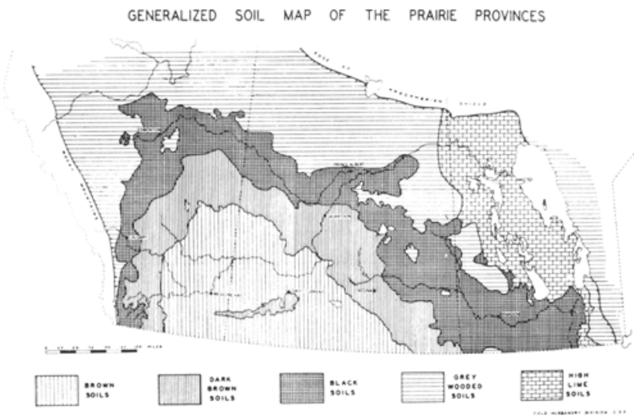

FIG. 1. Map of western prairie area showing major soil zones.

crop distribution and oil content. A comparison with Figure 1 indicates that flax production tends to be concentrated in the dark brown and black soil zones. The data are for commercial samples and reflect some varietal effects which tend to counteract the climate influence. Later maturing varieties tend to be higher in oil content and are concentrated in the central part of the flax belt. Early varieties are concentrated in the northern fringe of the area, with the result that the highest oil contents are obtained at about the mid-point of the belt. The normal range in oil content is from 37–45%, with a mean of 42% on a dry basis.

Data for oil content in rapeseed for the 1961 crop are shown in the lower portion of Figure 2 (2). This is the first year for which such a map is available and cannot be considered typical. The season was unusually dry in the northern part of Manitoba and Saskatchewan, and hence the oil contents are lower than would normally be obtained. It is quite evident that production of rapeseed extends farther north than flax production, the major areas being the black and grey wooded soil zones. Polish types are concentrated in the area, and varietal effects are not as pronounced as those noted for flax. Normal ranges for

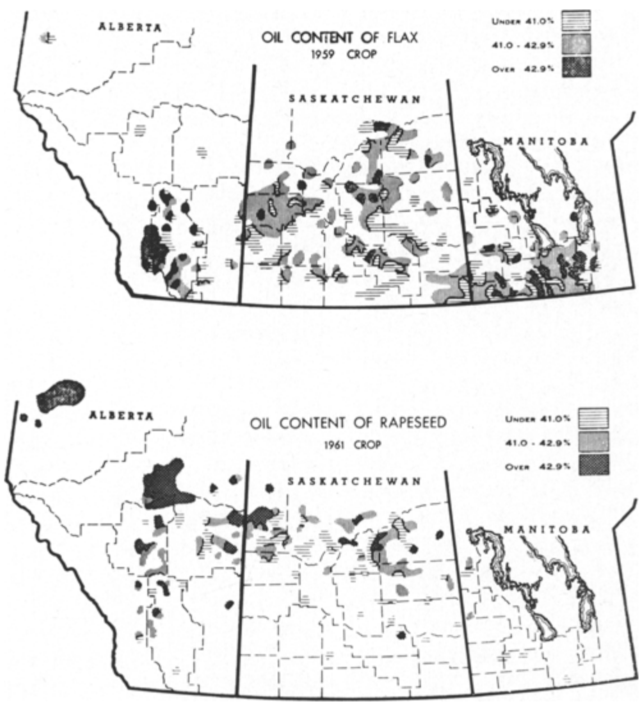

FIG. 2. Outline maps of western prairie area showing (upper) oil content distribution in flax 1959 and (lower) oil content distribution in rapeseed 1961.

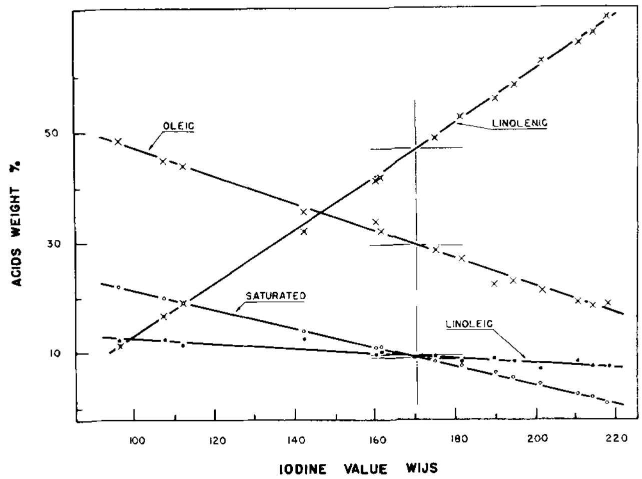

FIG. 3. Regression of fatty acid compositions on I.V. of linseed oil.

the crop have not yet been established, but the level of oil content will probably exceed that for flax.

On Iodine Value. For flax the normal range in iodine value (I.V.) is from 175–200 units with an average of 186. As the temp of the growing season falls and rainfall increases, the degree of unsaturation increases. In unusually cool moist years it is not uncommon to obtain a considerable quantity of flax with oil having I.V. as high as 205. Since our early maturing varieties tend to be high in I.V., this regional adaptation tends to accentuate the normal climatic influence. Hence the highest I.V. come from the most northerly areas.

With soybean, linseed, and sunflower oils, there appears to be a regular relation between fatty acid composition of the oil and the I.V. For Canadian flax it was found that the varieties did not differ significantly in this relation (6). Furthermore, when linseed oil was fractionated, similar relations persisted between I.V. and fatty acid composition of the fractions. Figure 3 illustrates this relation for fractions varying from 100–220 in I.V. that were prepared by furfural extraction of a linseed oil of I.V. 183.

Studies on rapeseed have shown surprisingly small variations in I.V. with climatic factors and no consistent pattern has been demonstrated. The application of GLC (4) to rapeseed oil has shown that it is possible to have two samples of rapeseed oil having the same I.V. that differ by as much as 20% in erucic acid content. This breakdown of I.V. as an index of composition arises because rapeseed contains three monoethenoid fatty acids that make up 70–75% of the oil. It has been shown (4) that oleic and erucic acids are negatively correlated, i.e., $r = -0.975$. There is also a negative association between erucic and linoleic acids ($r = -0.890$), while no significant association exists with linolenic acid. In general there appears to be a tendency for erucic acid to increase with lower temperatures and higher rainfall.

Breeding and Selection

Conventional methods of breeding and selection have been applied to all Canadian oil seed crops with resulting improvements in yield, oil quality, disease resistance, and climatic adaptation. Since an important new development has been achieved in rapeseed, discussion will be restricted to this crop.

Basically there are two types of rapeseed that can be grown in Canada: *B. napus* or Argentine, and *B. campestris* or Polish. Both of these are known as

TABLE I

Rapeseed Type Grown in Canada

Property	*B. napus* (Argentine)	*B. campestris* (Polish)
Oil content, %	40–47	36–43
I.V.	93–106	102–114
Wt/1000 seeds, g	1.2–2.0	0.9–1.5
Chromosomes, 2 N	38	20
Maturity	Same as wheat	2–3 wk earlier
Yield, lb/acre	700–3000	25% less

spring and winter types, but Canadian production is exclusively of the spring variety. General characteristics of the types are listed in Table I. Argentine, with the same maturity as wheat, can be grown over the wheat producing area, but is grown to best advantage in the dark brown soil zone. While Polish yields considerably less, its earlier maturity permits production in the more northerly areas, with best adaptation being in the black and grey wooded zones. Polish is the preferred type, as the early maturity reduces hazards from fall frost and permits more orderly planning of seeding and harvesting operations.

By using the usual breeding methods varieties of *B. napus,* Golden and Nugget (8) were derived from the original strain of Argentine and were selected for high oil content and low I.V. The varieties of *B. campestris* were introduced from Europe: one from Poland and Arlo from Sweeden. Fatty acid compositions for representative samples of oils from these different types and varieties are shown in Table II. Note that in addition to the normal C_{16} and C_{18} fatty acids found in oils from the temperate zone, the named varieties contain appreciable amounts of eicosenoic and erucic acids. The Polish types are lower in erucic acid and higher in oleic acid than the Argentine types.

Zero Erucic Acid Strains. When rapeseed was first introduced into Canada there was some objection to using the oil in edible products because of its high erucic acid content. While this objection was proved unfounded (3) attention was focused on a breeding program to reduce erucic acid content of the oil. A note in *Nature* indicated that single plant selections of safflower having oil of I.V. ca. 100 units had been obtained. It was observed that 70% linoleic acid normally contained in the safflower had been replaced by an equivalent amount of oleic acid.

Similar methods with rapeseed resulted in isolation of plants that have no erucic acid and practically no eicosenoic acid in their oils (7). Results suggest that, of about 200 plants, one or more having no erucic acid can be isolated from Liho, a variety of *B. napus* which normally contains around 28% erucic acid. Similar plants have now been isolated from *B. campestris.* The fatty acid compositions of oils from these isolates are shown in Table II. Values for the saturated acids palmitic and stearic are quite low and typical of normal rapeseed oils. The major change has been a marked increase in oleic acid and a moderate increase in linoleic acid content. Erucic acid is completely absent and eicosenoic acid is present only in the *B. napus* selection in very small amount.

With these isolates it is now possible to backcross to the parent variety and continue to select zero erucic progeny to secure desirable agronomic characteristics. For example, a zero erucic plant, when crossed with one having 40% erucic acid, produces seed with an average erucic acid content of 22%. However, the individual seeds vary from zero erucic to 40%. By analyzing oil from individual seeds, it was found that on the average out of 16 seeds: 1 had 0, 4 had 10%, 6 had 20%, 4 had 30% and 1 had 40% erucic acid, respectively. This is the genetic ratio required for a property controlled by two genes with no dominance.

TABLE II

Fatty Acid Composition of Rapeseed Oils from Different Rapeseed Types and Varieties Compared with New Zero Erucic Acid Selections

Fatty acid %	*B. napus*			*B. campestris*		
	Golden	Nugget	Zero erucic	Polish	Arlo	Zero erucic
Palmitic	3.5	3.6	4.7	2.9	2.7	3.4
Stearic	1.2	1.4	1.8	1.2	1.5	1.1
Oleic	19.4	23.7	63.3	33.6	27.2	54.8
Linoleic	14.2	12.7	20.0	17.8	17.6	31.1
Linolenic	8.0	5.9	8.9	9.4	8.5	9.6
Eicosenoic	14.1	15.2	1.3	11.8	12.0	0.0
Erucic	39.6	37.5	0.0	23.3	30.5	0.0

The technique for analysis of single seeds has been developed so that one half the seed can be excised for analysis and the other half can be grown to maturity. This saves one generation in the breeding program with a great saving in greenhouse space required. Practical zero erucic varieties of rapeseed are being developed and the first field trials of the *B. napus* strain have already been made.

This new approach to breeding suggests that we are rapidly approaching the point where the composition of a natural vegetable oil can be changed. It may be time to think in terms of bringing the chemical composition of our vegetable oils more in line with the optimum composition desired for processing.

Economic Implications

Two of the three major food elements, i.e., fats and proteins, are related to oil seed production. Vegetable oils are used directly and are forming and increasing proportion of our consumption of fats and oils. The demand for animal products such as meat, eggs, and milk is rising rapidly as living standards rise. This in turn causes an increased demand for high protein animal feeds that are based on oil seed meals. Hence, if the requirements for these two important foodstuffs are not in reasonable balance, serious dislocations will appear in the supply-demand ratio and pricing structure for oils and meals.

From a base period 1935–39, average per capita consumption of fats and oils in Canada increased 2.7% by 1959. However, increases in consumption of animal products were as follows: meats, 21% poultry, 110%; eggs, 17%; milk and cheese solids, 27% (5). It seems probable that the consumption of oils will stabilize around current levels while the demand for animal products and oil meals will continue to expand. These trends are already evident in a downward pressure on oil prices and an upward pressure on meal prices. Similar conditions are encountered in all countries where the standard of living is undergoing rapid advance.

The relation between pounds of meal recovered per pound of oil produced and the percentage oil in the material crushed is shown in Figure 4. Under present conditions, the Canadian oil seed economy would require an oil bearing material containing between 15–20% oil to produce a balance between oil and meal requirements, or that for every pound of oil produced there is a market for 4.5 lb meal. The only available seed that comes close to meeting this requirement is the soybean where the ratio is 4 lb meal to 1 of oil. When linseed or rapeseed is processed, the ratio is 1.5–1.0. In 1960 approximately 12 million lb rapeseed oil was produced in Canada. If it is assumed that an equal quantity of soybean oil was

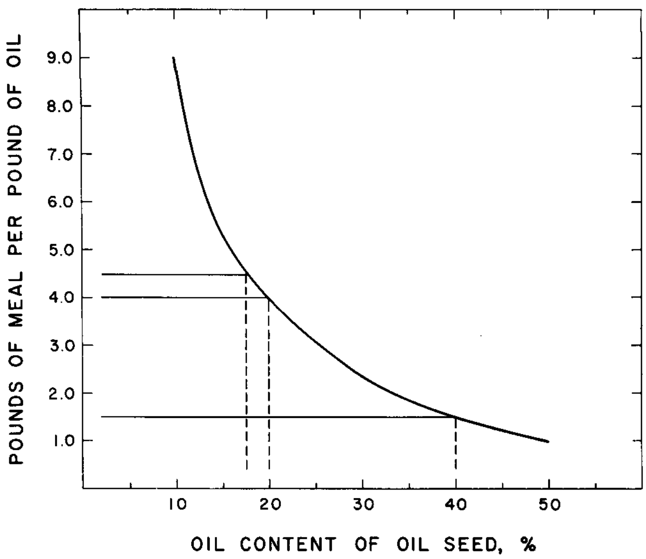

FIG. 4. Ratio of pounds of meal per lb of oil at different levels of oil content in the seed crushed.

displaced then the loss in meal supply amounts to 2.5 lb per lb oil or a total of 30 million lb meal.

Even under present pricing conditions it is evident that for soybeans the meal has become the most valuable product, with the oil the by-product. As higher oil percentages in crops are obtained, and as demand for meal increases faster than for oil, the situation will become increasingly critical.

This brief analysis indicates the importance of developing auxiliary sources of high protein concentrates so that oil and meal supplies can be kept in reasonable balance. It appears uneconomic to process seeds with a lower oil content than soybeans; hence the answer lies in production of a high protein material that can be used directly in feed formulation. Present trends in feeding practice indicate that an oil content of 7–10% in the ration would be an advantage. This suggests that our oil bearing crops might well be adapted to produce high yielding low oil content varieties to supply this market. Such a development would be a constructive step in the solution of a problem that is rapidly becoming critical in the oil seeds industry.

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REFERENCES

1. Board of Grain Commissioners for Canada, "Canadian Flax and Rapeseed," Crop Bulletin 76, 1959.
2. *Ibid.*, Crop Bulletin 84, 1961.
3. Canada Department of Agriculture, "Oil and Oilmeal from Canadian Rapeseed," Canada Department of Agriculture, 1963, p. 5.
4. Craig, B. M., Can. J. Plant Sci. *41*, 204–210 (1961).
5. Dominion Bureau of Statistics, "Canada Year Book 1962," Queen's Printer and Comptroller of Stationery, Ottawa, 1962, p. 439–441.
6. Sallans, H. R., and G. D. Sinclair, Can. J. Research, F *22*, 132–145 (1944).
7. Stefansson, B. R., F. W. Hougen, and R. K. Downey, Can. J. Plant Sci. *41*, 218–219 (1961).
8. Canada Department of Agriculture, "Production of Rape in Western Canada," Publication 1021, May 1961.

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Determination of the Glyceride Structure of Fats: Gas Liquid Chromatography of Oxidized Glycerides[1]

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Abstract

A method has been developed for the determination of glyceride composition of natural fats, which involves oxidation of the fat by permanganate-periodate, esterification of the oxidized glycerides, and subsequent GLC using a flame ionization detector. Quantitative analyses, requiring about 4 hr and 20 mg of sample, are reported. The method gives the distribution of individual saturated acids within the glycerides. Glyceride composition of four vegetable oils has been determined, using the above procedure.

Introduction

THE QUANTITATIVE analysis of glycerides in a fat has always posed a difficult problem because of the similarity in physical properties between adjacent glycerides in a series. Several methods have been described for the determination of glyceride composition. In some methods fractionation of glycerides is carried out directly on the fat (3,24,25,27–29) and in others after oxidation of unsaturated fatty acid components (5,13,32). The observation (15,26) that pancreatic lipase cleaved the 1,3 positions in a glyceride leaving the fatty acid in the 2 position intact, gave another method (30) of getting information about glyceride structure. Recently (22,23) a micromethod involving ozonization of double bonds, followed by catalytic reduction of ozonides, has been described. The ozonides, as well as the aldehyde cores obtained by the reduction of ozonides, are then separated and quantitatively estimated by TLC.

A successful application of GLC for the separation of glycerides was reported by Fryer et al. (4) who obtained fingerprint chromatograms of various natural fats. Pelick et al. (20), using a temperature of 290–300C, recovered simple triglycerides within 40 min after injection. Huebner (11) achieved good separations of triglycerides from triacetin to tristearin, using temp from 110–370C. Kuksis and McCarthy (14) separated triglyceride mixtures according to their carbon number by GLC, with SE30 as liquid phase, using a flame ionization detector system and with temp from 200–320C. This method was later (16) applied to the determination of the triglyceride composition of molecular distillates of butter oil.

The above methods of glyceride analysis by GLC do not distinguish unsaturated glycerides from the saturated ones having the same carbon number. This could, however, be achieved by oxidizing the mixture which converts the unsaturated glycerides into compounds with smaller carbon numbers, GLC of which

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