SUNFLOWER OIL - THE VIEW IN LIPIDS RESEARCH

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The previous papers in this program have dealt with important aspects of sunflower production such as breeding programs, insect, disease and marketing problems. Dr. Putt offered the title for this paper to leave room for a lipid chemist and has introduced the area with his paper on the fatty acid composition of sunflower oils.

I would like to examine sunflower oil and its uses from the point of view of fatty acid composition. We can compare this oil to other oils in our economy, study the advantages and disadvantages and examine an interesting area of research.

Vegetable oils can be classified as shown in Table 1, according to the end use of the oil. Drying oils such as linseed are industrial oils for use in paints, varnishes, linoleums, printing inks, etc. Non-drying oils such as olive and cottonseed are edible oils for consumption in margarines, shortenings, salad and cooking oils. The semi-drying oils such as soybean, safflower and sunflower are dual purpose oils which can be used either as industrial products or as edible products. The uses of these different vegetable oils depend on the fatty acid composition.

Table 1 Classification and uses of some vegetable oils

Oil Class	Oils	Uses
Drying	Linseed	Paints Varnishes Linoleums Printing Inks
Semi-drying	Soybean Sunflower Safflower Corn	Paints Salad Oils Cooking Oils Margarine Shortenings
Non-drying	Olive Peanut Rapeseed Cottonseed	Salad Oils Cooking Oils Margarine Shortenings

Today the fatty acid composition of oils and fats is measured by gas liquid chromatography. The analysis is rapid, quantitative and can be done on very small samples since the amount required for the analysis can be one milligram or less. Typical GLC charts are shown in Fig. 1 for linseed, soybean, sunflower and olive oils. The area under the peak for each fatty acid measures the amount of that acid in the mixture, and the typical shorthand system used to designate the fatty acids is as follows: 16:0, palmitic; 18:0, stearic; 18:1, oleic; 18:2, linoleic and 18:3, linolenic. These charts show that linseed oil, a member of the drying oil class, has 50% linolenic acid and around 20% of linoleic acid. These two acids comprise around 70% of the total fatty acids. Soybean oil which can be used as an industrial oil in the paint and varnish trade has 10% of linolenic acid and 50% of linoleic acid, making a total of 60% polyunsaturated acids. Sunflower oil contains 60% of linoleic acid but has no linolenic acid, and olive oil contains 70% of oleic acid but also has no linolenic acid.

The linolenic acid with three double bonds or units of unsaturation is favored for polymer formation in paints and varnishes, but has the disadvantage of being a major contributor to after-yellowing. The modern paint chemist has been able to incorporate petrochemical derivatives to satisfy the polymer requirements and to eliminate the need for linolenic acid in many paint formulations. Thus, linseed oil has not been favored in paints because of the after-yellowing characteristic. Linolenic acid in edible food products is the major contributor to off flavors and odors and the vegetable oils which do not contain this acid are favored. Thus, sunflower oil should be a high quality edible oil with the preferred stability factors.

The fatty acid compositions of a number of edible oils are shown in the form of bar graphs (Fig. 2) to compare oils which are in the drying, semi-drying and non-drying classes. As mentioned previously, the non-drying oils which are used only in edible food products are characterized by low levels of linolenic acids. The semi-drying oils such as soybean can be changed to non-drying oils by hydrogenation or hardening. Ideally, linolenic acid can be reduced or hydrogenated to linoleic acid and then to oleic and to stearic acids. Practically, the process of hydrogenation which is aided by the use of metal catalysts produces a mixture of reduction products. The process is, however, used commercially to produce margarines and shortenings in North America. These products contain a certain proportion of solid fatty acids which give the proper plastic product. The same process applied to an oil such as soybean oil to a limited extent will produce a salad and cooking oil with an improved keeping quality. It is necessary to remove the products which would become solid under storage conditions by filtration in the commercial process of winterization. It is possible, therefore, to chemically modify our present vegetable oils to make a desired end product. This means that the oils are interchangeable and the amount of any oil which will be used commercially will depend on the cost of the oil and the cost of the necessary processing. The oil chemists are conducting a great deal of research into hydrogenation catalysts. The ultimate aim of this research is control of the hydrogenation process to specifically reduce designated fatty acids, i.e., to reduce linolenic to linoleic.

Sunflower oil has been used in Canada as a salad and cooking oil. The oil has no linolenic acid and hence has excellent storage qualities. There have been some reports of problems in using sunflower oil as a cooking oil especially in commercial operations. The high content of linoleic acid would contribute to polymer formation and this characteristic could be changed by lowering the content of this fatty acid. This could be done by hydrogenation and winterization but the economics of this process would not likely be favorable. Another solution to this problem would be the production of sunflower oil with a lower content of linoleic acid through a plant breeding program.

The genetic control of fatty acid composition of vegetable oils is a relatively new research area. The discovery of safflower plants which produced an oil with a low linoleic content in Australia was the first development in this area. Safflower oil normally has a linoleic content of around 70% as shown in Fig. 2 and is very similar to sunflower oil. Dr. Paul Knowles at the University of California, Davis, California, continued the research on this oil crop and established the genetic patterns for inheritance of oleic and linoleic acids. The variation is illustrated in Fig. 3 where three variants are shown in terms of fatty acid composition. The high linoleic type would be preferred for the paint trade and the low linoleic type for the edible oil trade. This would mean two safflower oils more or less "tailor-made" for specific end uses. A short paper under the title "High oleic acid safflower oil: a new stable edible oil" appeared in the July issue of the Journal of the American Oil Chemists' Society.

A second example of genetic control in fatty acid composition of vegetable oils is taken from the research work on rapeseed. The fatty acid compositions of commercial rapeseed oils are shown in Fig. 4. These oils contain eicosenoic and erucic acids and the latter is a characteristic fatty acid in oils from the family of which rapeseed is a member. Dr. R. K. Downey and Dr. B. R. Stephansson discovered rapeseed plants which produced an oil that did not contain erucic acid. Further research conducted by Dr. Downey and his group established the genetic pattern for the inheritance of erucic acid. This new rapeseed oil, zero erucic acid rapeseed oil or Canbra oil is undergoing commercial testing to assess the potential of this crop. The oil offers some advantage over rapeseed oils and other vegetable oils in the production of salad and cooking oils by partial hydrogenation and winterization.

The success in these two areas and the similarity in fatty acid composition between safflower and sunflower oils stimulated interest in an investigation into variation in fatty acid composition in sunflowers. A preliminary study was carried out this year in collaboration with Dr. E. D. Putt, and you have already seen some of the results reported by Dr. Putt in his presentation.

Our laboratory worked with Dr. Downey in the investigation on rapeseed and the methods used in the present study were similar to those used previously. The "single seed technique" in which one half of the seed is used to provide the oil required for analyses and the other half is grown to a new plant offers many advantages in studies where the investigator is looking for the "odd ball" or the unusual. Some 700 single rapeseed analyses wered carried out in one investigation to yield around 7 seeds, the oil of which contained no erucic acid. In terms of population this means that one per cent are the individuals which represent the ultimate in change of fatty acid composition. It is therefore necessary to develop rapid analytical procedures to be able to handle the large number of analyses which are required. Modification of sample preparation, and gas chromatographic analyses coupled to the use of an electronic digital integrator permitted us to do 60-80 samples per eight-hour day and made it possible to do the preliminary survey involving

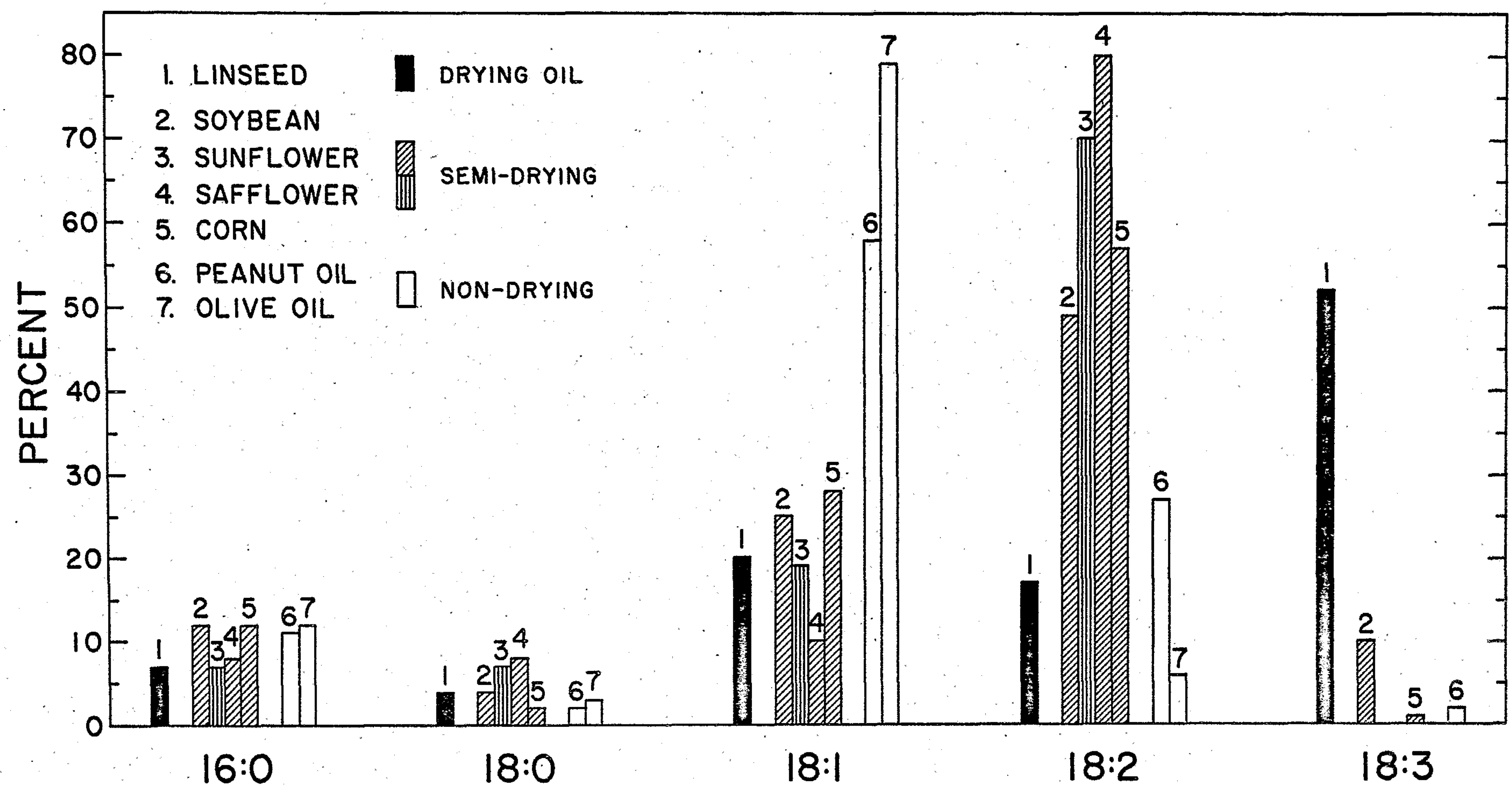

Figure 2. Fatty acid composition of a number of vegetable oils. (16:0, palmitic; 18:0, stearic; 18:1, oleic; 18:2, linoleic, 18:3, linolenic acids)

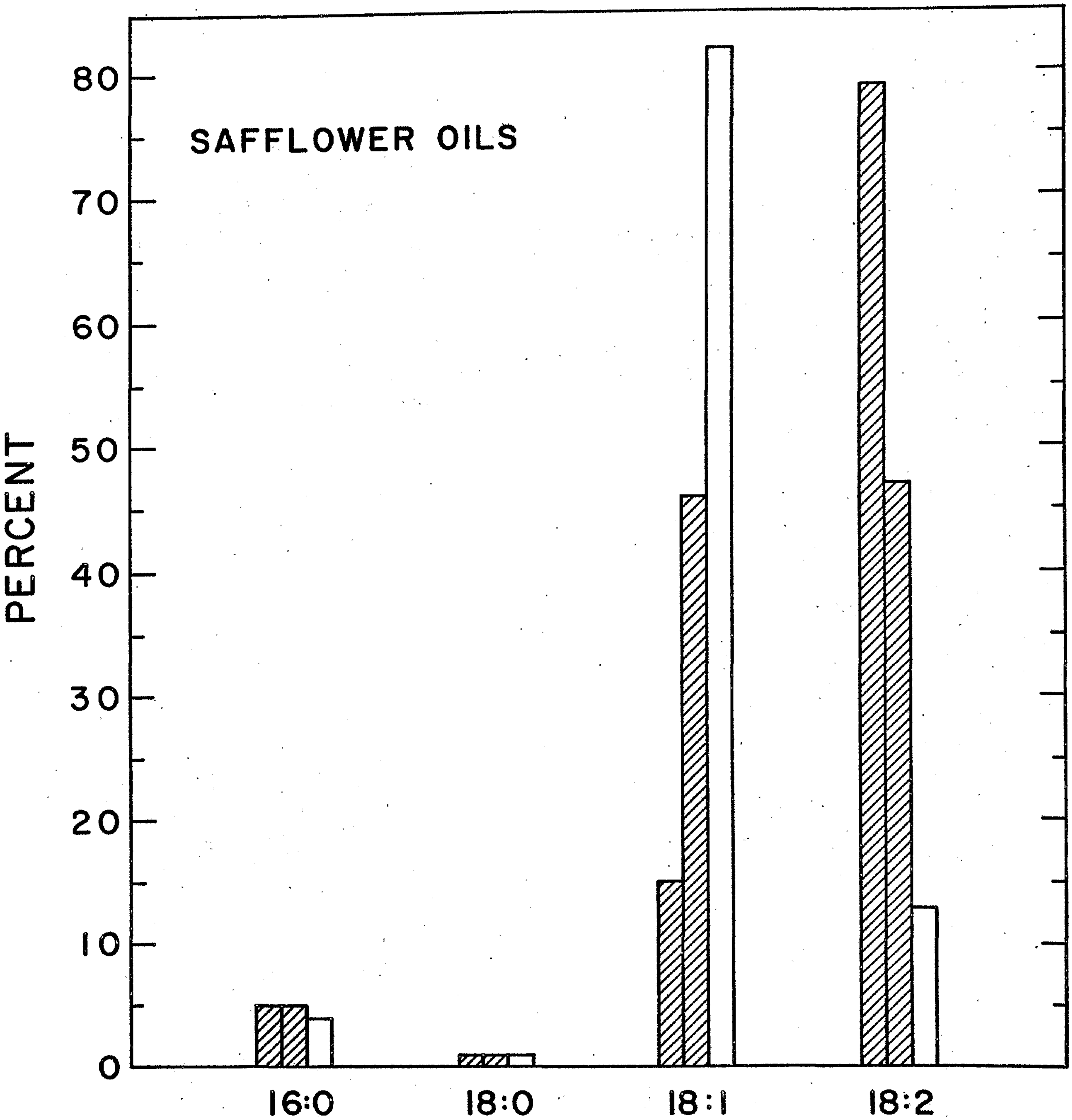

Figure 3. Fatty acid composition of genetic lines of safflowers showing high, intermediate and low contents of linoleic acids.

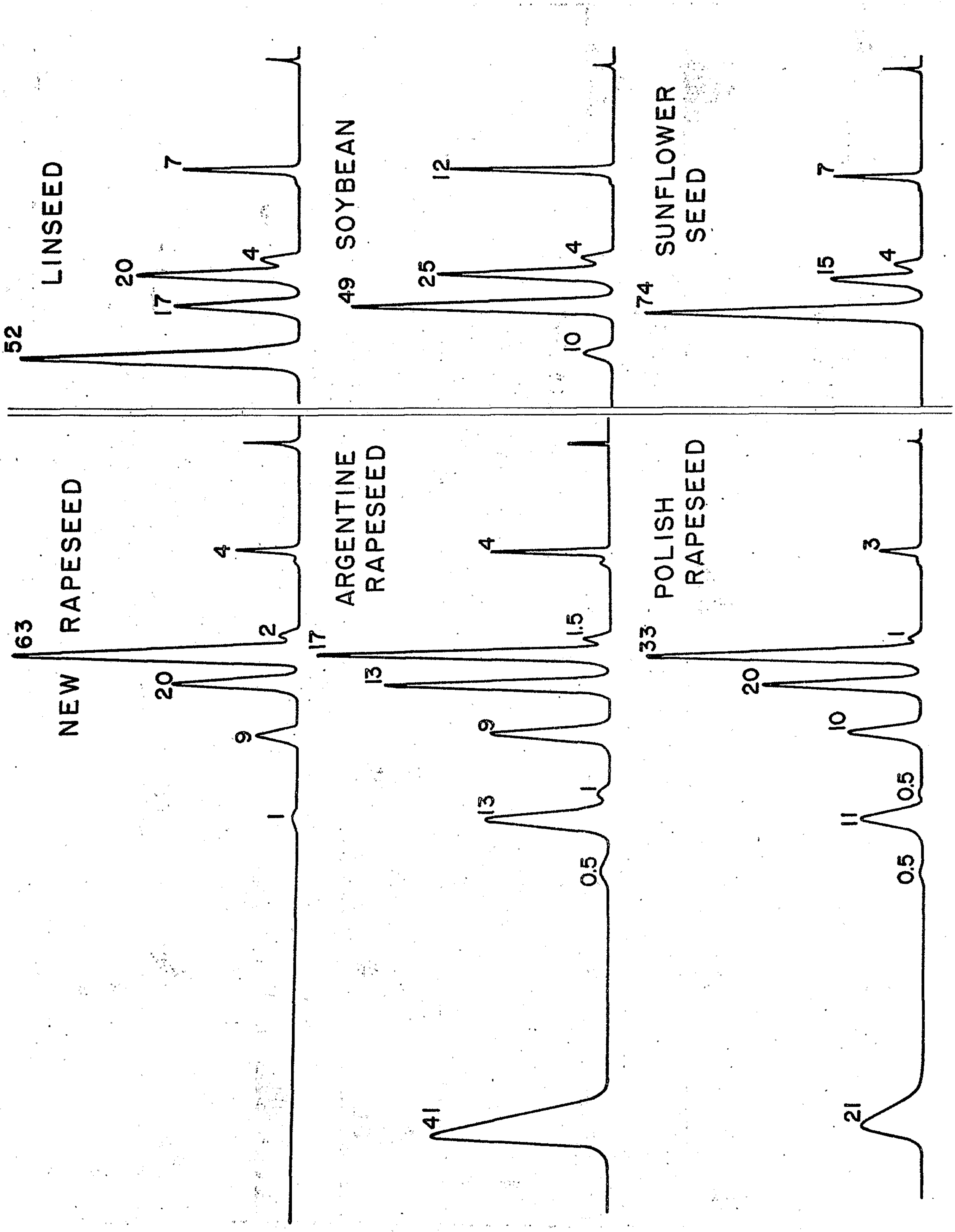

Figure 4. Gas liquid chromatographic charts of rapeseed oils showing the zero erucic rapeseed.

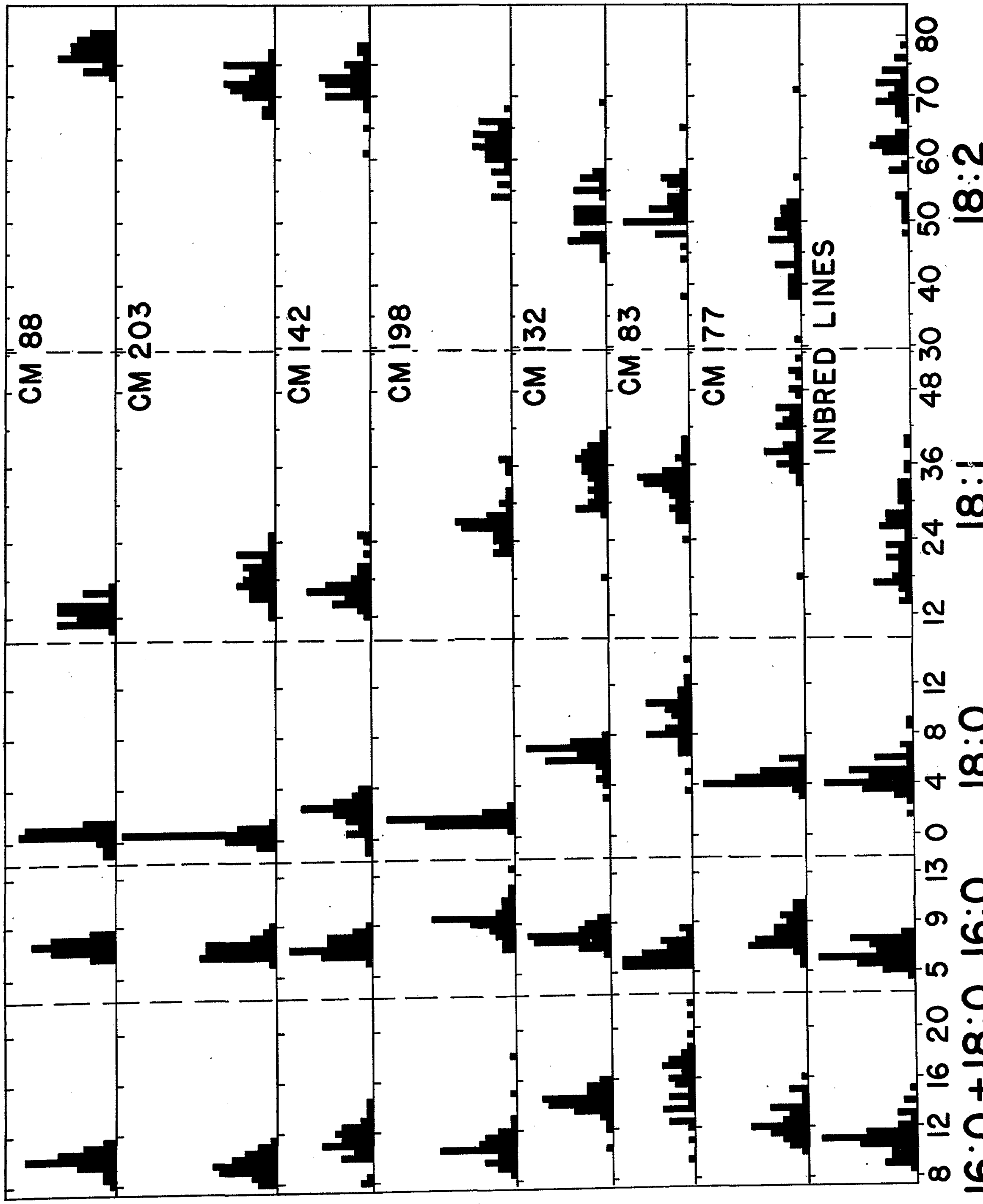

Figure 5. Variation in fatty acid composition of inbred lines and single seeds in seven inbred lines.

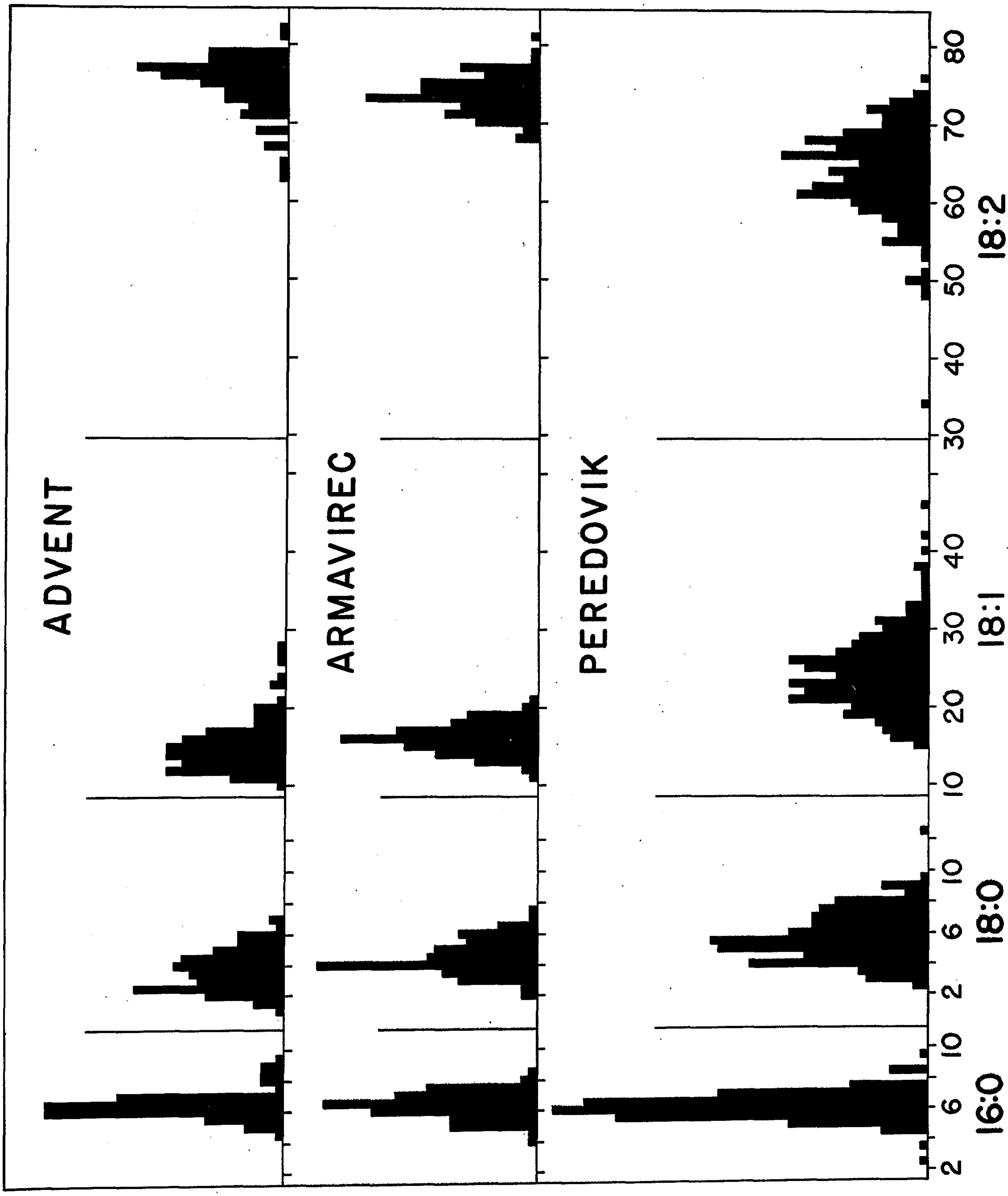

Figure 6. Variation in fatty acid composition of single seeds in commercial sunflower varieties.
(16:0, palmitic; 18:0, stearic; 18:1, oleic and 18:2, linoleic acids)

DISCUSSION

Pawlowski: I want to make one comment. Are you familiar with some work done in South Africa? I can't recall the name of the person. He illustrated the importance of environment in his case with differences approaching what you have here in the same varieties on the basis of samples grown in South Africa as compared to northern Africa or Great Britain. So before you go into a single seed analysis either you should use seed from a particular head or grow under controlled environments to find out how much of this effect is environmental, how much is genetic.

Putt: Yes, I am familiar with the South African or the African work that you mention Sid, and I don't question that environment is important in the composition of the oil. At the same time these results that we have been able to get through the co-operation of Dr. Craig indicate that there are genetic factors controlling the composition of oil which function independently of date of maturity, or in other words, independently of the ambient temperatures.

Kinman: I would like to comment to Dr. Pawlowski. A recent work that we have done in the U.S. in the last five years and published bears out Hilditch's review. But you must remember that we were dealing with varieties and hybrids on a bulk sample basis not individual plants or individual seeds and, of course, we found that environment had an overwhelming influence which completely blanked out any genetic influence, except those that interacted to temperature at time of flowering. This work with a single seed, a single plant, or single inbred line had to be considered on an entirely different basis. I am going to be extremely interested in how Dr. Putt explains in a year or two these extreme variants within a single inbred line.

Putt: The inbred lines that we used had from 1 to 9 generations of selection on a single plant basis before bulking. In general the narrower range in the single seed analyses occurred in the longer-term inbreds. The wide range of acid contents occurred in our short-term inbreds which indicates that we were still getting segregation for genes controlling acid content.

Kinman: This is entirely possible.

Sackston: Might I comment and perhaps the Russian visitors would amplify this. I was very much interested in their approach in estimating quality of oil. They are looking for the higher linoleic rather than the lower linoleic acid content because of its theraputic value according to their lights in relation to atherosclerosis, cholesterol etc. They are very firmly convinced that what they need is the higher linoleic acid content because this is better for you.

Kinman: Of course this is one of the major reasons why any sunflower research at all was initiated in the U. S.; exactly the same reasoning. Since we don't seem to have the stability problem occurring in soybean due to linolenic we have a superior oil.

Craig: This is an area that I find very interesting. I can understand the Russian approach where sunflower oil is their major oil, they are using it primarily as a salad and cooking oil. I find it a little difficult on the North American continent to justify this type of approach.

Kinman: So do a lot of other people.

Craig: When you consider that we eat somewhere in the neighborhood of 45 pounds of oil in a year, I don't think I have heard of anything quite so ridiculous as taking a teaspoon of safflower oil once a day or something like this. If you take the amount you consume in a year compared to 45 pounds a year, you need more than a teaspoonful a day to change the linoleic level drastically. So a change from 50 to 70% in oil such as sunflower is not merited on this approach alone. That is just a personal observation.

Kinman: And a good one, I think.

Baldwin: There is a very extensive medical test being made on the effects of the composition of oil and fat in the diet versus the cholesterol content of the blood. If this can be put on a large enough scale it will be correlated with the actual effects on atherosclerosis and incidence of heart accidents. This is a very extensive test with which many of you are probably acquainted. If this turns out as many of the bio-medical people expect, then the demand for polyunsaturated fats will be tremendous.

Kinman: Of course we had one flurry of that in the U. S. It sort of died down when people began to get the point that Dr. Craig mentioned. I have wondered about this recent work in safflower where we got rid of most of the linoleic and increased the oleic simply for increased stability. This is a complete reverse of the original idea and - well time will tell about that.

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