Projection and Prospects for Rapeseed and Mustard Seed[1]

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ABSTRACT

Rapeseed is number five among the oilseeds of the world. During the last 10 years the crop has increased more in per cent than any other oilseed crop. In the FAO prospects an annual rate of increase of 4.7% is foreseen. The fatty acid composition will change during the next years so that erucic acid will be practically removed. The content of glucosinolates will also be reduced dramatically, and consequently the meal will be accepted much more readily.

INTRODUCTION

Today rapeseed ranks fifth among the major oilseeds of the world. During the last 10 years the rapeseed crop has increased from ca. 3.7 million tons in 1960 to 6.5 million tons in 1970. In per cent no other oilseed crop has increased that much during the same period, but in absolute figures soybeans and sunflower seed have increased more. The forecast for 1971 for rapeseed is a crop of ca. 7.2 million tons, which corresponds to 2.5 million tons of rapeseed oil.

Rapeseed oil has become an increased part of the international trade in oils and fats. Among oilcakes, rapeseed is now number one in order of rate of increase. Cultivation of the plant for oilseed production is almost entirely confined to the temperate and warm temperate zones of Asia, America and Europe where both summer and winter varieties are common. Rapeseed thrives best in rich soil in a cool, moist climate. Principal producing areas are India, Mainland China and Pakistan in Asia, Canada in the Western Hemisphere and Poland, France, Germany and Sweden in Europe.

Before discussing any projections, it would be worthwhile to have a look at the nature of rapeseed. Hopefully you will then have a chance to agree or disagree with my prospects for rapeseed later on in this talk.

BOTANY

The oilseed denoted rapeseed on the world market does not derive from one species in the way that soybean, linseed, peanut and other oilseeds do, but may come from several species, generally belonging to the genus *Brassica*. Sometimes rapeseed will be a mixture of two or more types or species. The species from which commercial rapeseed may be derived are: *Brassica napus* (*forma biennis*, winter rape; *forma annua*, summer rape); *Brassica campestris* (*forma biennis*, winter turnip rape; *forma annua*, summer turnip rape); and *Brassica juncea* (Brown mustard).

These species are related and rather similar in appearance. They are also divided into subspecies, formae and varieties or cultivars. Turnip rape (*Brassica campestris*) seems to be the most variable and was originally the most widespread of the various *Brassica* species. Winter and summer types of rape (*Brassica napus*) as well as turnip rape occur and do not differ in morphological characteristics but differ greatly in physiology. The winter type, for example, does not come into the generative phase (forming of seed) if the crop has not been exposed to subzero temperatures for a certain period.

Rapeseed from Europe generally consists of winter rape, and rapeseed from Canada is generally summer turnip rape. Rapeseed from the Far East may be either summer turnip

[1]One of 11 papers presented in the symposium "The World Supply of Edible Oils and Proteins," AOCS Meeting, Atlantic City, October 1971.

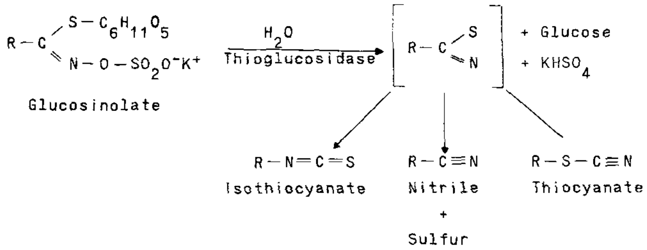

FIG. 1. The general structures of glucosinolates and products formed by enzymatic hydrolysis.

TABLE I

World Production of Main Oilseed Crops (1000 Tons)

Oilseed	1960	1970
Soybeans	26.585	45.250
Cottonseed	18.542	20.190
Peanuts	13.652	17.000
Sunflower seed	5.929	9.300
Rapeseed	3.741	6.450
Copra	3.246	3.260
Linseed	3.135	3.900
Sesame	1.329	1.750

TABLE II

1970 Production of Rapeseed in Different Countries

Geographical area	Amount produced, 1000 tons
America	1.690
Canada	1.617
Europe	1.860
France	558
Poland	525
East Germany	200
Sweden	194
West Germany	182
Asia	2.900
India	1.520
China	975
Pakistan	384
World Total	6.450

TABLE III

Composition of seeds of rape. (Brassica napus cv. Tanka)

Component	Per cent
Oil[a]	
Seed	41.5
Hull	16.0
Meats	47.1
Protein[b]	
Seed	44.7
Hull	18.7
Meats	53.6
Crude fiber[b]	
Seed	11.8
Hull	34.3
Meats	3.0

[a]Moisture-free basis.

[b]Moisture-free, oil-free basis.

TABLE IV

Typical Ranges of Variation in Content of Common Fatty Acids in Oils of Some Cultivars of Breeding Lines of Some Cruciferous Seeds (2)

Species and type	Ranges in wt % of fatty acids			
	Oleic	Linoleic	Linolenic	Erucic
Brassica campestris				
Winter turnip rape	14-16	13-17	8-12	42-46
Summer turnip rape[a]	17-34	14-18	9-11	24-40
Summer turnip rape[b]	48-55	27-31	10-14	0
Sarson and Toria	9-16	11-16	6-9	46-61
Brassica juncea	7-22	12-24	10-15	18-49
Brassica napus				
Winter rape[a]	8-14	11-15	6-11	45-54
Winter rape[b]	40-48	15-25	10-15	3-11
Summer rape[a]	12-23	12-16	5-10	41-47
Summer rape[b]	52-55	24-31	10-13	0-1
Brassica Tournefortii	6-12	11-16	10-16	46-52
Sinapis alba	16-28	7-10	9-12	33-51

[a]Classical cultivars
[b]Low-erucic acid lines

TABLE V

Peptization of Proteins in Seed Meals of Rape and Turnip Rape by the Osborne Series of Four Solvents (4)

Species and cultivars	Total meal nitrogen soluble in				
	H_2O, %	5% NaCl, %	70% EtOH, %	0.2% NaOH,%	Nitrogen in residue
B. CAMPESTRIS					
Polish	44.6	24.0	4.1	6.3	21.0
Echo	44.5	25.0	4.4	6.6	19.5
Zero erucic	44.7	24.7	4.3	5.5	20.8
B. NAPUS					
Argentine	51.3	20.5	3.9	8.1	16.2
Target	50.6	20.5	4.0	9.1	15.8
Oro	48.4	22.4	3.3	8.5	17.4

TABLE VI

Amino Acid Composition of Rapeseed Protein Concentrate and Soybean Meal (g/16 gN)

Amino acids	Rapeseed protein concentrate	Soybean meal
Isoleucine	4.0	4.2
Leucine	7.6	7.0
Lysine	6.2	5.8
Phenylalanine	4.2	4.5
Tyrosine	3.1	3.1
Cystine	1.1	0.7
Methionine	1.8	1.1
Treonine	4.1	3.8
Valine	5.2	4.3
Histidine	2.9	2.4
Arginine	6.9	7.0
Aspartic	7.1	10.2
Glutamic	18.3	16.5
Serine	4.7	5.0
Proline	6.6	4.8
Glycine	4.9	3.8
Alanine	4.6	3.9

TABLE VII

Comparison between soybean oil and rapeseed oils now and in the future

Oil	Soybean oil	Rapeseed oil		
		Today	Experimental	Expected
Taste	2	2	2	2
Erucic acid, %	0	50	0	0
Linoleic acid, %	50	15	35	40
Linolenic acid, %	8	10	8	5

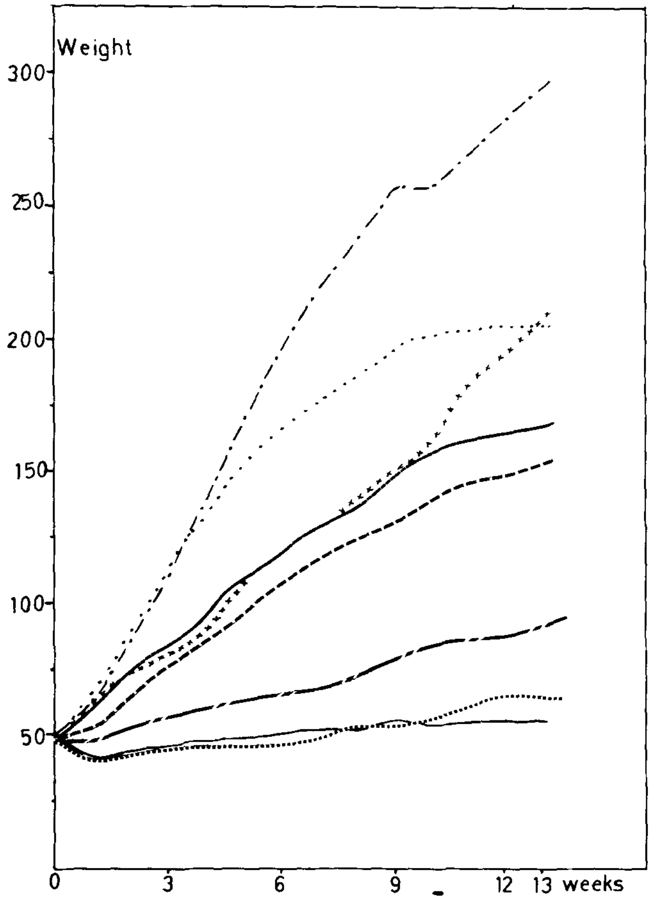

FIG. 2. Rat feeding tests. ▬▬▬ ♀ Caseine; x x x x x x x x x ♂ caseine; .... ♀ rapeseed protein concentrate; . – . – . – ♂ rapeseed protein concentrate; ▪▪▪▪▪ ♀ caseine 60 % + rapeseed meal (nonheated) 40 %; ———— ♂ caseine 60 % + rapeseed meal (nonheated) 40 %; ▬ ▬ ▬ ♀ rapeseed meal, heated; and ▬▬▬ ♂ rapeseed meal, heated.

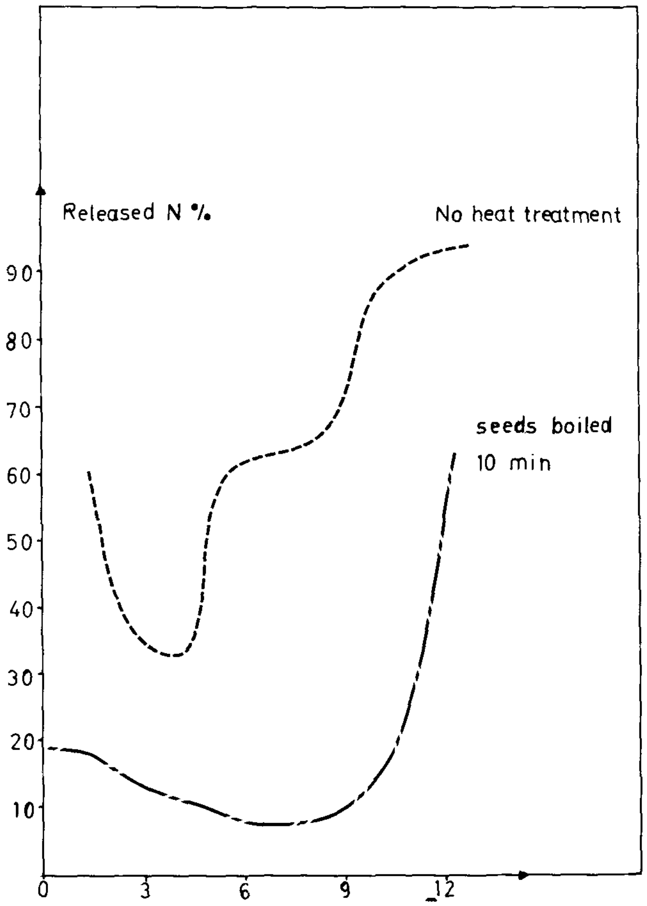

FIG. 3. Nitrogen solubility in rapeseed meals after different heat treatments.

rape, brown mustard (*Brassica juncea*), or a mixture of these two species.

The seeds of *Brassica napus* are generally larger than those of *Brassica campestris*, and the winter types give larger seeds than the summer types. The gross composition of the seed is given in Table III (1).

CHEMICAL COMPOSITION

The major components of dry rape seeds are lipids, proteins, carbohydrates and glucosinolates. Typical figures for the oil content of the seeds are 36-50%.

Lipids

Triglycerides generally account for 95-98% of the total lipids of mature *Brassica* seeds.

Due to the large number of fatty acids that occur in *Brassica* oils (15 fatty acids in amounts of 0.5% or more in typical cultivars), it is easily understood that no sample of such oils has been fully characterized with regard to its triacylglycerol composition. The fatty acids are not randomly arranged but strongly associated with the 1, 2 or 3 carbon of the triacylglycerol.

From studies that have reported data of well-defined seed materials, the following patterns have been disclosed. (a) All saturated and very long chain (20-24 carbon atoms) monounsaturated fatty acids are almost exclusively esterified at the 1 and 3 positions, whereas the unsaturated C18 acids are preferentially located at the 2 position. (b) The diunsaturated C20 and C22 acids appear at the 1 and 3 positions. (c) There appears to be no relationship between the erucic acid content of the triacylglycerols and that recorded for the 2 position. (d) There is a slight difference in strictness in positioning of the various fatty acids of rape and white mustard seeds, the latter having a slightly more random pattern. Although small, this difference is of technological importance, since the solidification range of these oils is close to 0 C. (e) In "zero-erucic" acid oil, there is a preference for linoleic and linolenic at the 2 position, which might be of importance for the technological value of such oils in comparison with soybean oil, which has a random distribution of linolenic acid.

Carbohydrates

There is still a lack of detailed information on rapeseed polysaccharides. Information available from the related crucifer mustard seed shows that there are large differences in both quantity and compositon of various polysaccharides of the seed coat to the embryo.

It is easily observed that the sugars that are typical constituents of pectic materials, i.e., galactose, arabinose and galacturonic acid, predominate in the more easily soluble materials. More severe extraction conditions dissolve "hemicellulosic fractions," with xylose and glucose as dominating sugars.

Glucosinolates

The general structure of the glucosinolates, which was definitely established in 1956, is shown in Figure 1.

Whereas some cruciferous seeds have very simple glucosinolate patterns, others contain at least nine different glucosinolates. No qualitative differences in glucosinolate patterns among Swedish cultivars were found in studies of *Brassica napus* and *B. campestris*. Generally the exact quantities of different glucosinolates are not reported, but the content is as high as ca. 3% of the seed. Winter rape, the predominant crop in Europe, has a higher content than summer turnip rape, the predominant crop in Canada. *Brassica napus* has four dominating glucosinolates; glucoallysin, progoitrin, gluconapin and glucobrassicanapin.

Under the influence of moisture and the enzyme thioglucosidase, the glucosinolates are split into different products as is shown in Figure 2. Some of these products are volatile and can be removed from the rapeseed meal by steaming. The nonvolatile products will act as goitrogens when fed to animals, and this has been a very limiting factor in the use of rapeseed meal. The finding of a cultivar of summer rape, "Bronowski," with markedly reduced levels of glucosinolates (about one-tenth) will have great implications for the production and utilization of rapeseed meal.

Another very interesting question is the localization of the glucosinolates in the cells. This is under study in Uppsala, Sweden. The content of "crude fiber," mainly cellulose and hemicellulose, amounts to ca. 15% in the defatted seed meals. This figure is high, compared to that for many oil crops, e.g., soybeans. The large amount of crude fiber in rapeseed meal is a consequence of the small seed size with large proportions of seed coat, rich in fiber. The content of minerals, called "ash," is typically 7-8% of the meal, and the variation among samples appears to be rather small.

Protein

The residue from hydrocarbon extraction of rapeseed, called rapeseed meal, contains ca. 40% protein. There are wide range variations in protein content. From surveys of the Canadian rapeseed crops, a total span in protein content of defatted meal from 33.0 to 47.9% involving species, varietal and environmental influences has been recorded for the year 1969 (3). Among many samples of a certain cultivar, a negative correlation of oil and protein content is recorded. Since the oil has always been considered the most valuable part of the seed, much more data are available on variations in oil content than in protein content. It should be pointed out that "nitrogen" x 6.25 does not yield a true figure for protein content. Recent investigations suggest that a factor of 5.53 is a more correct figure for rapeseed. By application of the latter factor, the true protein level would be ca. 12% lower than figures generally reported.

The rapeseed protein, in the same way as any other seed protein, can be considered to have a structural function (membrane components), a catalytic function (membrane-bound or free) or a "storage" function. In view of the small amounts of enzyme protein generally involved in enzymatic reactions, it is reasonable to assume that the major portion of the proteins represents storage protein with no enzymatic activity. In rapeseed the storage protein is located in specific organelles, the so-called protein bodies or aleurone grains.

The influence of a large number of parameters on the extraction and subsequent precipitation of protein from rapeseed has been reported in a series of publications.

Recently the solubility characteristics of the proteins of laboratory-defatted seed meals of three cultivars each of rape and turnip rape were reported. Table V shows that ca. 50% of the rapeseed protein was water-soluble, compared to ca. 45% of the turnip rape proteins. These figures are substantially lower than those for soybeans, but higher than those for the industrially processed rapeseed meal. The amount of insoluble nitrogen appeared to be of similar magnitude (ca. 20%) in both laboratory and industrially processed meals. The lower proportion of water-soluble proteins in turnip rape (by classical terminology called albumin) was balanced by a higher proportion of salt-soluble protein (globulins). There also appears to be a species difference in percentage of insoluble nitrogen, with turnip rape having the higher proportion. However it should be emphasized that each species and cultivar shows some differences in solubility characteristics. In this connection, it should also be pointed out that commercial samples of oil seeds can have been exposed to rather high temperatures during the artificial drying, which could affect the solubility characteristics. In unpublished Swedish work, the presence of a great number of proteins in aqueous and alkaline extracts of *B. napus*, has been demonstrated. Thus ca. 20 weakly acidic proteins, ca. 20 neutral proteins and 6 basic proteins were detected (5).

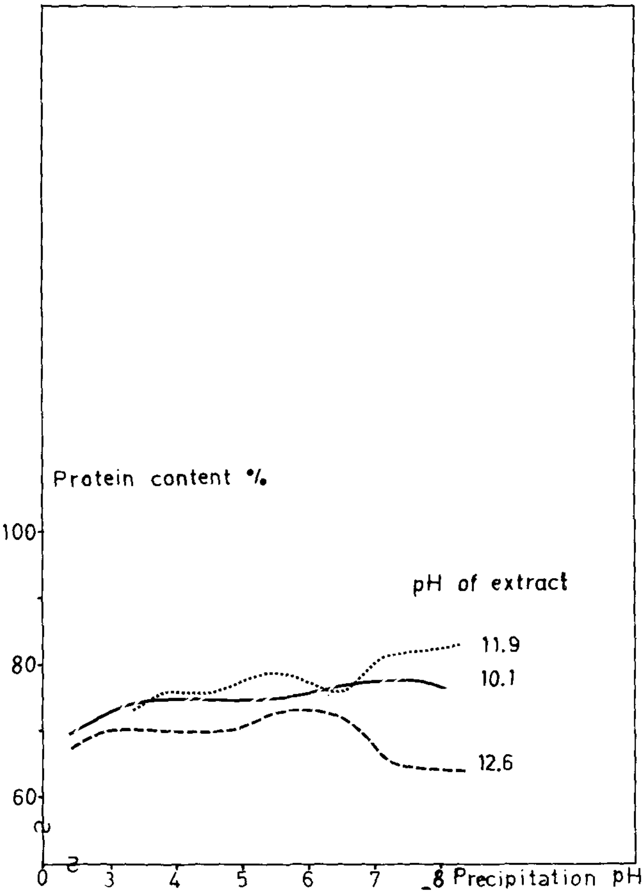

FIG. 4. Protein content of rapeseed protein isolates as function of the pH during extraction and precipitation.

The basic proteins accounted for ca. 20% of the total and had molecular weights in the range of 15-20,000. Only ca. 5% of the total soluble proteins had molecular weights of 50-75,000, and the major portion had molecular weights from ca. 120,000 to ca. 150,000.

The overall amino acid composition of a rapeseed protein concentrate is compared to that of soybean meal in Table VI. As can be seen from the table, lysine is about as

TABLE VIII

Yield Per Hectare for *Brassica napus*

Winter type	Yield	Summer type	Yield
Average crop	2.800 kg	Average crop	1.800 kg
Local test	3.200 kg	Contracted growers	2.300 kg
Tests made by the seed Association	4.500 kg	Chocied grower	3.000 kg

TABLE IX

Comparison of Production Results

Production	Rapeseed, winter type	Wheat, winter type	Milk
Seeds, kg	2.600	3.680	
Milk, kg	---	---	4.000
Meltable protein, kg	475	330	130
Meltable fat, kg	1.100	45	160
Meltable carbohydrate, kg	380	2.320	200

high in rapeseed protein concentrate as in soybean meal, and methionine is considerably higher.

PRODUCTION OF RAPESEED PROTEIN CONCENTRATE

Some years ago research work on a process to produce rapeseed protein concentrate for human consumption started in Canada and now also in Sweden.

In order to produce a rapeseed protein concentrate for human consumption, there are some processes that must be given special consideration. (a) dehulling; (b) inactivation of myrosinase; (c) removal of glucosinolates; (d) heat treatment; and (e) oil extraction. These different steps can be applied in different sequences. An example of the nutritional evaluation of the product obtained is given in Figure 3. As can be seen, the rapeseed protein has a much higher PER than caseine.

Spinning of Rapeseed Protein

To produce spun protein fibers, a solution of molecule-dissolved, partially denatured protein is prepared. This solution is squirted through fine holes in spinning nozzle in a coagulation bath that is slightly acidic. It is essential that the protein content of the isolate be as high as possible and the content of fibers very low. The protein isolate should be easy to dissolve and easy to precipitate.

Figure 4 shows the nitrogen solubility as a function of the pH of the solvent. There are large differences in solubility of the proteins from rapeseed meal that has been exposed to different temperatures. The yield of protein for different pH's of the solvent has been studied as a function of the pH of the precipitation (B. Törnell, personal communication).

PROSPECTS

In the FAO's "Prospects for Oilseeds and Oilseed Products in 1980," the greatest annual rate of increase on a commodity basis is projected for rapeseed oil as 4.7%. This should give an increase from 1970-80 of ca. 1.3 million tons of rapeseed oil or an increase of more than 5 million tons of rapeseed. This would give a total of 12 million tons of rapeseed.

These estimates are rather traditional, and the actual situation in 1980 might be that the production and use of rapeseed is much higher. A reason for this is that the fatty acid composition will change during the next 10 years, so that erucic acid will be practically removed and substituted by linoleic acid and oleic acid. Even a decrease in linoleic acid may be foreseen. In this way rapeseed oil will have a much stronger position for use in, e.g., margarines high in polyunsaturated fatty acids.

Another perhaps more important reason is the possibility that the content of glucosinolates could be dramatically reduced in rapeseed, and consequently the meal will be much more readily accepted as feedstuff for chickens, pigs and other animals, where at present it can only be used in very small portion.

That rapeseed has great possibilities can also be seen from Tables VIII and IX. The first one compares production results for different crops in Sweden. The yield per hectare is compared from different localities. The use of better seed, more fertilizers and irrigation would greatly increase the output of rapeseed in, e.g., India. With these projections, by 1980 rapeseed oil shall have passed cottonseed oil and even sunflower seed oil and have become number three among vegetable oils in the world after soybean oil and peanut oil.

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