Improving the Nutritional Properties of Rapeseed

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ABSTRACT

Canadian plant breeders have recently succeeded in producing rapeseed with <1% erucic acid in the oil and with a very low level of glucosinolates in the meal. One such *Brassica napus* cultivar, 'Tower,' is now licensed. The meal from 'Tower' seed has been subjected to extensive chemical and biological testing and has proven to be a markedly superior product as compared with conventional rapeseed meals. This new cultivar is less goitrogenic and more palatable and gives satisfactory productive performance in animals at use levels well in excess of older varieties. The presence of high levels of erucic acid in older varieties made the oils undesirable, particularly because this compound is not well metabolized by cardiac and certain other tissues and results in pathological changes in a number of experimental animals. 'Tower' rapeseed oil is less cardiotoxic than high erucic oils and appears to be no more detrimental when used at the 20% level in animal diets than a number of other oils used in human foods.

Rapeseed is Canada's most important oilseed crop (1). While areas such as the Common Market, China, and the Indian subcontinent may produce as much or more rapeseed, Canada is the major supplier of the world market (Table I). Canadians consumed more rapeseed oil than any other edible oil during the 1972-74 period (2). It is of the utmost importance to Canada that the rapeseed crop continue to receive attention both for the benefit of the export and domestic trade and to ensure that the producer has a crop which will give yields which are competitive with other crops. In addition to giving good yields, an oilseed crop to be successful must have a desirable fatty acid composition, yield a valuable residual meal, have a high oil content, and lend itself to mechanical harvesting and easy transport (2). Plant breeding offers one of the most efficient means of bringing about changes in oil seed quality. The rapeseed crop is a prime example of what can be accomplished through plant breeding to bring about desired changes in a crop.

Rapeseed and other *Cruciferae* oils differ from most other vegetable oils in containing significant amounts of the long chain monoenoic fatty acids with 20 and 22 carbon atoms termed eicosenoic and erucic. Some rapeseeds have been bred specifically for high erucic acid content in the oil and are valuable for many industrial purposes. On the other hand, it has been shown that a high level of erucic acid in the seed oil is undesirable from the nutritional point of view (3). Following the International Rapeseed Conference held in St. Adele, Quebec, in 1970, it was decided that Canadian plant breeders should concentrate on the development of rapeseed cultivars low in erucic acid. This had been started earlier and by 1963 Canadian plant breeders had succeeded in producing both *Brassica napus* and *Brassica campestris* varieties with a low erucic acid content in the seed oil (4,5).

Downey and Harvey (6) found that the fatty acid composition of the seed oil was determined by the genotypic make-up of the developing embryo and not by the maternal parent. The embryonic type of inheritance control is of advantage to the plant breeder since oil extracted from half a seed is sufficient to determine its fatty acid composition, and the remaining half can be grown.

Although there is no evidence that the presence of a high amount of erucic acid in the diet constitutes a human health hazard (3), on the basis of animal experiments, it was considered prudent by various countries to limit the erucic acid intake of humans through issuing guidelines to industry. In Canada it was suggested that 22:1 fatty acids should not constitute more than 5% of the total fatty acids of fatty foods intended for human consumption (2); this is now a gazetted regulation. The Canadian conversion to low erucic acid varieties was essentially complete by 1974 with some 4 million acres seeded to the new cultivars (Table II).

The *B. napus* cultivar called 'Tower' is now grown fairly extensively and produces oil with less than 1% of the fatty acids as erucic acid; many samples will contain only 0.2-0.3% erucic acid. The predominant fatty acid is oleic with ca. 60%, followed by linoleic and a substantial amount of linolenic, for a total of ca. 95% of fatty acids with an 18 carbon chain length. A high total of triglycerides having the same chain length results in crystallization problems after hydrogenation and as a consequence the physical properties of margarines and shortenings are adversely affected. The greater the degree of hydrogenation the greater the problem. This difficulty can be eliminated by blending with hydrogenated oils of dissimilar fatty acid composition such as soybean oil (7).

Breeding for a reduced level of glucosinolates has had high priority in Canadian rapeseed breeding programs ever since rapid accurate methods for their determination were developed in 1968 (8). The presence of glucosinolates in the oilseed meal has been known for many years to have detrimental effects on animal growth and reproduction and is considered by most nutritionists to be the major limiting factor in the use of rapeseed meal in diets for animals. The glucosinolates per se are nontoxic, but rapeseed also contains the enzyme myrosinase which hydrolyzes the glucosinolates to produce toxic isothiocyanates, 5-vinyl-2-oxazolidinethione (goitrin), and organic nitriles. Although the myrosinase may be inactivated by heat, it is known to be present in other plants and in certain intestinal microorganisms, and thus the logical method of dealing with the problem is to breed for "zero" glucosinolate varieties of rapeseed.

TABLE I

Average Rapeseed Production and Net Exports of Major Producing Areas 1970-73

Producing area	'000 metric tons Production	Exports
Canada	1,575	1,066
Indian Subcontinent	2,812	0
China	1,202	160
Western Europe	1,285	552
Eastern Europe	1,102	332
All others	468	47

TABLE II

Erucic Acid Content (%) in the Total Canadian Rapeseed Crop by Year and Province

Province	1972	1973	1974	1975[a]
Alberta	10.1	8.9	5.6	4.5
Saskatchewan	4.6	6.4	3.8	3.5
Manitoba	4.0	3.4	3.2	2.0
Canada	6.6	6.9	4.3	3.8

[a]Predicted

TABLE III

Effect of Fats on Heart Lesions

Fat	No. Rats	No. Affected	Foc. Myoc.[a] Necr. (fresh)	Foc. Myoc.[a] Necr. (old)	Microv.[b] alter.
			Percent of maximum[c]		
Corn oil	16	8	14.6	12.5	4.2
'Target' rapeseed oil	17	16	56.9	64.9	49.0
'Tower' rapeseed oil	17	12	29.4	33.3	11.8
'Tower' IV 97.1	17	11	29.4	35.3	23.5
'Tower' IV 76.6	17	7	13.7	11.8	2.0
12 'Tower' + 8 ACF[d]	17	5	13.7	9.8	5.9
12 'Tower' IV 97.1 + 8 ACF	17	10	17.7	15.7	2.0
12 'Tower' IV 76.6 + 8 ACF	17	10	13.7	15.7	11.8
'1788' rapeseed oil	17	7	45.1	41.2	21.6
'1788' IV 69.9	17	11	11.8	21.6	17.7

[a]Focal myocardial necrosis.

[b]Microvascular alteration including severe changes at the small and minute blood vessel walls characterized by oedematous loosening and swelling of the walls. Some walls showed severe vacuolization and deposition of lipid droplets in H and E sections; partial fragmentation of the inner elastic membrane was demonstrated in the vessels.

[c]Severity rating. Each heart scored from 0-3 according to severity for each trait. Percent of maximum = $\frac{\text{actual score}}{\text{potential score}} \times 100$.

[d]Average Canadian fat with rapeseed oil and hydrogenated rapeseed oil replaced by soybean oil and hydrogenated soybean oil, respectively.

While the glucosinolates are not fat soluble, the hydrolytic products are, and if enzyme hydrolysis occurs before oil extraction, the hydrolytic products will contaminate the oil. It is well known that these S-compounds poison the nickel which is used as a catalyst in most commercial hydrogenation procedures. Thus, rapeseed oil requires greater catalyst usage than does, for example, soybean oil. It is expected that oils from the low-glucosinolate varieties of rapeseed will overcome this problem (7).

The identification of very low levels of glucosinolates in the 'Bronowski' cultivar of rape from Poland immediately led to its use in the breeding programs throughout the world (9). As a result, summer rape cultivars, which are low in erucic acid and low in glucosinolate content, are now in commercial production in Canada and Germany (8).

The fiber content of rapeseed meal is relatively high and is one of the limiting factors in its use in poultry feeds. A significant reduction (4%) in fiber can be achieved through introduction of yellow-seeded cultivars since the yellow seed coat is thinner and lower in fiber (10).

Goals for future quality improvement in rapeseed have been set by Canada's plant breeders and include such advances as (a) oil content at least 44% of dry seed weight, (b) less than 0.2 mg/g glucosinolate in meal, (c) yellow seed coat, (d) protein content of at least 48% of meal, (e) lower fiber content, (f) erucic acid <1% and >50%, (g) linoleic acid >40%, (h) linolenic acid <3%, (i) palmitic acid up to 10%, and (j) increased methionine and cystine. Considering these quality improvements, (a), (b), and (c) are already in sight and a zero glucosinolate meal is in the offing. As to raising the protein in the meal from the present 36-38% to 48%, this would have to be done by a combination of breeding and processing to lower the hull content. As stated above, the change to yellow seed coated varieties will lower the fiber content by ca. 4 percent; a greater reduction than this should be possible by dehulling the meal by air classification or other processing techniques. A low erucic, low glucosinolate *B. campestris* cultivar will be field tested in Canada in 1976 and should be available for quantity planting in 1977. This will greatly extend the area in which the "double zero" strains of rapeseed can be grown since *B. campestris* is earlier maturing than the *B. napus* 'Tower' variety and can beat the frost hazard of more northerly areas. Altering the levels of linoleic and linolenic acid appears feasible but will probably require a few years to incorporate into commercial varieties. Evidence indicates that the relatively low level of palmitic acid in rapeseed oil is partially responsible for its poor digestibility and utilization; this subject has been reviewed (3). This author would agree with the goal of increasing the levels of methionine and cystine in rapeseed, but equal importance should be given to raising the level of lysine which is presently considerably below that in soybean meal, as a percentage of the protein.

Evidence on the nutritional value of the products from the first licensed low erucic acid and low glucosinolate variety 'Tower,' a *Brassica napus* type, is now becoming available. Other low erucic acid oils have also been studied. It is well established that high-erucic acid rapeseed oils cause cardiac lesions in rats, characterized by early lipid accumulation follwed by focal necrosis of the muscle fibers and infiltration by mononucleocytes (3). Rocquelin and Cluzan (12) found that rapeseed varieties containing relatively low levels (1-2%) of erucic acid also resulted in cardiac lesions in the rat when included in the diet. These findings have subsequently been confirmed by several groups of workers. Up to the present the pathogenic agent present in low erucic acid oil has not been identified. Kramer et al. (13) studied the cardiotoxicity of a number of fractions obtained by absorption chromatography or molecular distillation of a low erucic acid rapeseed oil. All fractions, including a highly purified triglyceride fraction, proved to be toxic. It was concluded that the cardiopathogenic properties appear to be associated with the triglycerides of the oil and not with the nontriglyceride minor components, such as brassicasterol, present in the fully refined oil.

Beare-Rogers et al. (14) reported that partial hydrogenation of high or low erucic acid rapeseed oils reduced the incidence of cardiac lesions. In their work, hydrogenation resulted in a marked decrease in the linolenic acid content of the oils whereas the docosenoic acid content was only slightly affected. They postulated the presence in rapeseed oils of a pathogenic factor, other than erucic acid, which is removed or destroyed by hydrogenation.

McCutcheon et al. (15), on the basis of an experiment involving ten different oils or oil blends, including rapeseed oils, simulated rapeseed-type oils and modified rapeseed type-oils have postulated that linolenic acid plays a role in the etiology of cardiac necrosis observed when rats are fed diets containing low erucic acid rapeseed oils.

Results from our laboratory [Slinger et al. (16)] are similar to the findings of Beare-Rogers (14). Our results indicated (Table III) that the high erucic acid (38.9%)

TABLE IV

Percentage Fatty Acid Composition of Oils Used[a]

Fatty acid	Corn[a] oil	'Target' RSO	'Tower' RSO	'Tower' IV 97.1	'Tower' IV 76.6	'1788' RSO	'1788' IV 69.9	Average Canadian fat
12:0	---	---	---	---	---	---	---	1.7
14:0	---	---	---	---	---	---	---	3.7
14:1	---	---	---	---	---	---	---	0.4
15:1	---	---	---	---	---	---	---	0.2
16:0	11.2	3.3	4.3	4.9	5.0	4.2	4.1	21.7
16:1	---	0.2	0.3	---	---	0.3	0.4	2.4
17:0	---	---	0.1	---	---	0.1	Trace	---
17:1	---	0.1	0.1	---	---	---	---	---
18:0	2.0	1.5	1.7	3.2	11.3	1.8	13.9	12.4
18:1	27.8	21.4	59.1	72.7	76.0	55.2	65.8	42.8
18:2 (n-6)[b]	58.7	14.2	22.8	16.6	5.5	20.9	5.8	13.4
18:3 (n-3)[b]	0.3	7.0	8.2	0.7	---	8.7	0.3	0.5
20:0	---	0.7	0.5	0.5	0.6	0.5	1.3	0.2
20:1	---	12.3	2.0	1.3	1.3	4.7	4.5	0.2
20:2	---	0.3	---	---	---	---	---	---
22:0	---	0.2	Trace	---	---	---	---	---
22:1 (n-9)[b]	---	38.9	0.9	Trace	Trace	3.6	2.7	---

[a]Average of duplicate determinations.

[b]x:y (n-z) Abbreviation for fatty acid with x carbon atoms, y double bonds, and the terminal double bond z carbon atoms from the terminal methyl group.

TABLE V

Incidence of Histopathological Changes in Hearts of Rats Fed Various Dietary Oils at the 20% Level

Treatment	Incidence of histopathological changes		
	6 days[a]	8 weeks[b]	16 weeks[b]
High erucic acid RSO	5/6	3/11	6/10
Low erucic acid RSO (Canbra)	1/6	3/12	7/11
Herring oil	2/6	4/12	5/11
Soybean oil	0/6	1/12	5/11

[a]Indicates fat vacuoles in myocardial fibers.

[b]Indicates focal myocardial degeneration.

'Target' variety gave the highest toxicity rating of a number of oils fed at the 20% level of the diet to Wistar rats for an 18 wk period. 'Tower' oil with 0.9% 22:1 (n-9, Table IV) gave only a slightly higher severity rating than corn oil and when the former was hydrogenated to an iodine value (IV) of 76.6 there was no difference between the severity rating of corn oil and the hydrogenated 'Tower' oil. Mixing 'Tower' oil or this oil hydrogenated to an IV of 97.1 or 76.6 with an average Canadian fat (ACF) mixture, in the proportions of 12:8, gave severity ratings which were no different from that with corn oil at the 20% level. Hydrogenation of a new cultivar, '1788,' to give an IV of 69.9, markedly reduced the myocardial lesion score. Fatty acid analysis of these oils and fats (Table IV) showed that the hydrogenation markedly reduced the levels of 18:2 (n-6) and 18:3 (n-3). In the case of the '1788' cultivar, 22:1 (n-9) was reduced by hydrogenation from only 3.6 to 2.7% while accompanied by a marked reduction in heart lesions severity. These data lend support to the hypothesis of McCutheon et al. (15) that 18:3 (n-3) may be a factor in the etiology of the cardiopathology. It is also apparent that blends of fats containing high levels of 'Tower' oil are no more detrimental than corn oil.

No other food oil has come under such extensive experimental scrutiny as rapeseed oil. It is now becoming apparent that a number of other oils, used at relatively high deitary levels, will cause the same cardiopathogenicity as low erucic acid rapeseed oils. Vogtman et al. (17) found no differences in the toxicity of soybean oil and low erucic acid rapeseed oils. Lall et al. (18) found higher levels of fat in the early stages of growth in rats fed high erucic rapeseed oil but no significant difference in the incidence of myocardial degeneration between high erucic rapeseed oil, low erucic rapeseed oil, herring oil, or soybean oil after feeding the oils at the 20% level for a period of 16 wk (Table V). While the lesions in the high erucic acid group were more severe, there appeared to be no differences among the three remaining oils. Vles (19) stated that low erucic acid rapeseed oils in the nutrition of man and animals are as satisfactory as other vegetable oils. He concluded that the cardiac lesions induced in male weanling rats fed rapeseed oils were due to 22:1 (n-9) only and not to other factors. He found no statistically significant difference between the

TABLE VI

Weight gain, Feed Efficiency, and Chilled Weights of Broiler Chickens at 8 Weeks of Age

Treatments	Av. wt. gain (g)	Feed/gain	Chilled carcass wt. (g)
1) Control diet	1631[ab]	1.99[abc]	1180[ab]
2) 10% 'T-Alt.' RSM[d]	1695[a]	1.97[bc]	1248[a]
3) 20% 'T-Alt.' RSM	1699[a]	1.93[c]	1233[a]
4) 40% 'T-Alt.' RSM	1620[abc]	2.06[ab]	1175[ab]
5) 10% 'T-Sas.' RSM[e]	1695[a]	1.96[bc]	1252[a]
6) 20% 'T-Sas.' RSM	1684[a]	1.93[c]	1183[ab]
7) 10% 'Tower' RS (UH)[f]	1604[bc]	2.06[ab]	1145[ab]
8) 20% 'Tower' RS (UH)	1552[bc]	2.10[a]	1122[b]

[abc]In each column mean values having same superscript are not significantly different ($P<0.05$).

[d]'T-Alt.' RSM = 'Tower Altona' rapeseed meal, prepress solvent process.

[e]'T-Sas.' RSM = 'Tower Saskatchewan' wheat pool rapeseed meal, solvent process.

[f]'Tower' RS (UH) = Full-fat 'Tower' rapeseed, unheated.

TABLE VII

Effect of 'Tower' RSM on Performance of Laying Hens[a]

Criteria	Corn, soy Control	Control + 10% 'Tower' RSM	Control + 15% 'Tower' RSM
Egg production (% hen day basis)	75.1	73.5	78.8
Av. feed intake/day	106	104	103
Av. egg wt. (g)	57.4	55.5	55.4
G feed/g egg	2.51	2.57	2.38
Mortality	6/36	3/36	4/36

[a]Results after six 28 day periods.

TABLE VIII

Turkey Performance Data[a]

Diet no.	Dietary treatment	Weight gain (g)	Feed consumption (kg)	Feed/gain
1	Corn-soy control	8679[b]	23.43[b]	2.70[b]
2	25% 'Tower,' prepress solvent, RSM	8883[b]	22.47[b]	2.53[c]
3	25% 'Tower,' solvent, RSM	8879[b]	22.32[b]	2.52[c]
4	25% 'Target' prepress solvent, RSM	8183[c]	20.87[c]	2.55[c]
5	Unground, autoclaved, full-fat rapeseed	8954[c]	23.20[b]	2.59[bc]

[a]Results from hatching through 16 wk of age.

[bc]Column values with the same superscript letters are not significantly different ($P<0.05$).

TABLE IX

Effect of Different Fats on Performance of Turkeys[a]

Diet no.	Dietary treatment	Weight gain (g)	Feed consumption (kg)	Feed/gain
1	10% soybean oil	9307[b]	21.50[b]	2.31[b]
2	10% 'Tower' RSO	9423[b]	21.90[b]	2.32[b]
3	10% 'Target' RSO	8808[c]	20.30[c]	2.31[b]

[a]Results from hatching through 16 wk of age.

[bc]Column values with the same superscript letters are not significantly different.

cardiotoxicity of rats fed 'Tower' oil (1.4% erucic acid) and sunflower oil while there was a much higher incidence with rapeseed oil (45% erucic acid). In addition, Beare-Rogers (personal communication, 1976) found that feeding 'Tower' rapeseed oil to Wistar strain rats at a level of 15% of the diet, by weight, or 30% of the calories, with 5%, by weight, of other fat gave a negligible incidence of cardiopathology and no more than from a 3:1 mixture of lard and corn oil, or sunflowerseed oil, fed at the same level.

Lall and Slinger (20) found that with laying hens the inclusion in the diet of 10 and 20% high erucic acid *B. napus* or *B. campestris* rapeseed oil exerted a depressing effect on egg production, egg weight, yolk weight, and egg hatchability as compared to the performance of hens on tallow or corn oil. In contrast, the use of low erucic acid *B. napus*, 'Canbra,' rapeseed oil exerted no detrimental effects on reproductive performance thus suggesting that erucic acid was the main factor responsible for the deleterious effects.

'Tower' rapeseed meal (RSM) has been used in numerous experiments in our laboratories in work with chicken broilers, laying hens, turkeys and pigs (21,22). In Table VI are presented the results of a portion of a broiler experiment in which four replicate groups of 10 White Plymouth Rock male chicks were fed equicaloric, equinitrogenous diets for an 8 wk period. The control group was fed a conventional corn-soybean meal diet. Inclusion of 10, 20, or 40% 'Tower,' Altona RSM (prepress, solvent), 10 or 20% 'Tower,' Saskatchewan Wheat Pool RSM (solvent), or 10 or 20% unheated full-fat 'Tower' rapeseed gave weight, feed efficiency, and carcass weight results which were not significantly different from the controls.

A portion of the results from a laying hen experiment are shown in Table VII. Triplicate groups of 12 hens, housed two per cage, were fed a conventional corn-soy control diet or this same diet with 10% or 15% 'Tower' RSM replacing soybean meal on an equicaloric, equinitrogenous basis. While the differences in performance were not statistically significant there was a somewhat lower feed intake and lower egg weight in the RSM-fed groups.

In a further experiment, Nicholas Large White turkey poults were fed from hatching through 16 wk of age on diets containing 25% of 'Tower' RSM, both prepress solvent and solvent, and the conventional high glucosinolate 'Target' RSM. A further treatment involved the use of 21.5% of 'Tower' full-fat whole seed which was autoclaved at 121 C for 20 min. Each treatment consisted of four groups of 22 poults at the start. The results (Table VIII) indicate that only the high glucosinolate 'Target' RSM gave results which were inferior to the control. A high incidence of the hock abnormality "perosis" was found in the 'Target'-fed birds at four weeks of age while no other group showed this condition. 'Target' rapeseed oil, which is high in erucic acid, proved inferior to soybean oil or 'Tower' RS oil based on the weight gain of turkeys in a further segment of the above experiment (Table IX).

Bowland (23) found that with a wheat-barley-soybean meal diet, 'Tower' RSM may completely replace the soy-

TABLE X

Productive Performance of Yorkshire Pigs on Experimental Diets[a]

Treatments	Av. daily weight gain (kg)	Feed/gain	Av. final body wt. (kg)	Carcass index
1. Corn-soy control	0.79	2.82	101.5	92.0
2. 'Tower' prepress solvent, RSM (17.5)	0.74	2.72	97.4	95.0
3. 'Tower,' solvent, RSM (17.5%)	0.70	2.79	92.2	98.0

[a]Based on unweighted means of two replicate groups of four boars and two replicate groups of four gilts after a 15 wk feeding period.

TABLE XI

Effect of Dietary Treatment on Swine Organ Weights[a]

Diet	Dietary treatment	Thyroid wt. (mg/kg body wt.)	Liver wt. (g/kg body wt.)	Heart wt. (g/kg body wt.)	Spleen wt. (g/kg body wt.)
1	Corn-soy control	84	15.3	3.3	1.5
2	'Tower' RSM[b]	123	15,1	3.5	1.5
3	'Target' RSM[c]	295	20.8	3.6	1.5

[a]Av. based on 8 males + 8 females per dietary treatment.

[b]'Tower' RSM contained 0.15 mg/gm of glucosinolates as butenyl isothiocyanate equivalent.

[c]'Target' RSM contained 9.50 mg/gm of glucosinolates as butenyl isothiocyanate equivalent.

bean meal in diets of starting-growing pigs with no depression in performance. Moody et al. (22) using a corn soybean meal diet, found some depression in weight gain when 17.5% of either 'Altona' (prepress, solvent) or 'Sas. Pool' (solvent) RSM replaced soybean meal on an equicaloric, equinitrogenous basis (Table X). The solvent RSM gave somewhat inferior results as compared with the prepress solvent meal. This may have been related to the fact that the former meal contained 1.89 mg/g of glucosinolates as compared with 0.15 mg/g for the latter meal when expressed as butenyl isothiocyanate.

In all animal species worked with we have found 'Tower' RSM to be much less goitrogenic than the high glucosinolate RSM varities. This is illustrated by the results of one pig experiment (Table XI) in which both thyroid and liver weights of pigs were considerably higher from animals fed 'Target' RSM with 9.5 mg/gm glucosinolates as compared with those from pigs fed 'Tower' RSM containing 0.15 mg/gm glucosinolates. However, even the 'Tower' RSM was still somewhat goitrogenic as compared with the corn, soybean meal control animals.

Srivastava and Hill (24), using rats, have confirmed the need for heat treatment of 'Tower' and '1788' rapeseed meals even though the amounts of glucosinolates present in these meals were too low to be held responsible for the heat effect recorded. This has been confirmed by Slinger et al. using the chick (21); in this work, autoclaving proved more effective than dry heating in reducing goitrogenicity.

Clandinin and Robblee (25) have reviewed evidence with poultry and swine indicating that meal from low glucosinolate, low erucic acid varieties of rapeseed can be used at considerably higher levels than the unimproved varieties. They point out that while there was no major problem in the use of older varieties with ruminants, the improved palatability of the low glucosinolate RSM for ruminants is extremely important in obtaining wide acceptance of the product by feeders of dairy and beef cattle.

Considerable work has been done on the development of rapeseed meal concentrates and protein isolates for human consumption. Sarwar et al. (26) found that while rapeseed meals were inferior to other oilseed meals as the sole source of protein in the diets of laboratory mice, the protein isolates from rapeseed meal were better sources of dietary protein than were soybean, sunflower, flax, and safflower isolates. The extraction of glucosinolates [Kozlowska et al. (27)] and air-classification of hulls from the meals [Tape et al. (28] have been successfully achieved. One problem with rapeseed flours and protein isolates is the brown colors exhibited when aqueous slimes are adjusted to alkaline pH. This appears to be due to the presence of phenolic compounds, a number of which have been identified and found to be removable by diffusion extraction methods (29).

Most of the feeding trials using the new varieties of rapeseed meal have tended to be relatively short-term. To more fully assess the nutritional value of these meals, experiments should be conducted in which the meal is fed for more than one generation.

While plant breeders have come a long way in improving the nutritional value of rapeseed oil and meal there are still numerous alterations which are required before maximum utilization of these products is possible. Not only should work be continued in the breeding area but more research should be done on methods of processing, particularly with the meal, as a means of improving nutritional value. However, rapeseed oils responded quite differently to refining than did corn oil, soybean oil, or herring oil and more research in this area would also be desirable (30).

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