Technical

Glucosinolate Levels in Western Canadian Rapeseed and Canola

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Since the introduction of low glucosinolate rapeseed into Canadian production in 1975, the average level of glucosinolates has declined from about 80 μmol/g to 25 μmol/g in the 1985 Canadian new crop. Since 1983, more than 90% of the rapeseed planted in Western Canada has been of canola quality (less than 30 μmol/g glucosinolates). The Northern Alberta/British Columbia growing area is the only area in Western Canada which produced non-canola quality seed in 1984. Export shipments of rapeseed from Western Canada have not contained more than 30 μmol/g glucosinolates since December 1983, and at the end of the 1984/85 shipping year most shipments contained about 20 μmol/g glucosinolates. Western Canadian crushing plants have preferentially selected and crushed canola quality seed since 1979. This preferential selection may have slowed the reduction of glucosinolates in export seed. Crushers have produced canola quality meal from seed containing as much as 50 μmol/g glucosinolates, since between 40 and 60% of the glucosinolates present in the seed were removed during processing. Rapeseed has been introduced recently in Southern Ontario. Although the spring-planted crop is canola quality, the winter crop, which makes up 20% of the production, is still high in glucosinolates.

Canada's changeover to low erucic acid rapeseed (LEAR) in the early 1970's was an example of rapid implementation of a plant breeding achievement. The conversion to LEAR was barely completed, however, when the first low glucosinolate line of rapeseed was licensed in 1975 (1). Glucosinolates are natural antinutritional compounds found in most brassica seeds and plants such as mustard, brussels sprouts, cabbage and califlower. The presence of relatively high levels of certain glucosinolates in traditional types of rapeseed hindered the use of rapeseed meal as a protein supplement, particularly in monogastric animal rations (2). The level of glucosinolates in these new rapeseed types was reduced sufficiently to allow meal from "double zero" rapeseed to completely replace soybean meal in feed formulations (3).

Recognizing the importance and uniqueness of this new crop type, the Canadian rapeseed industry, beginning with the Rapeseed Association of Canada, adopted the name "canola" to signify the difference between the older types of rapeseed and new, higher quality "double zero" Brassica seed varieties. "Canola" was registered as a trademark by the Rapeseed Association of Canada in 1980 (4), and the Rapeseed Association of Canada became the Canola Council of Canada. Many other rapeseed-related organizations also changed their names at that time. They included the Canola Council of Canada, Canola Crushers of Western Canada, Prairie Canola Growers Council, Alberta Canola Growers Association, Saskatchewan Canola Growers Association and Manitoba Canola Growers Association.

The canola trademark also has been registered in other countries, including Algeria, Australia, The Benelux Region, Indonesia, Morocco, Norway, Taiwan, the U.S.S.R. and West Germany. Applications for the canola trademark have been filed in Britain, Columbia, Denmark, Egypt, Hong Kong, India, Japan, Mexico, New Zealand, Pakistan, Poland, South Korea and Venezuela, and applications are being prepared for China and Italy (5).

The Canola Council of Canada has released the trademark to government agencies wishing to incorporate it into their regulations. In 1982, the Canadian Government incorporated canola into the Canada Agricultural Products Standards Act (CAPS Act) (6), allowing the use of Canola on labeled products. This was followed by inclusion of canola specifications in the 1983 Feeds Regulations (7); the revised Seeds Act, due for release in 1986, will include canola specifications.

While the Canadian conversion to low erucic acid cultivars has been well documented (8,9), there is little information available on the commercial adoption of low glucosinolate rapeseed (or canola). Information on the glucosinolate content of rapeseed grown in Canada, processed in Canada or exported from Canada was needed to assist the grain industry in deciding whether it is possible to establish grades for canola within the Grain Act. Since it has not been possible to distinguish visually between traditional types of rapeseed and canola, both seed types have continued to be graded as rapeseed. Canola grade specifications could only be established once the level of glucosinolates in Canadian seed exports fell consistently within the level specified for canola. In November, 1985, the Western Grain Standards Committee recommended the adoption of canola grades beginning in August, 1987.

This report examines the level of glucosinolates in rapeseed samples collected through the Canadian Grain Commission's routine monitoring programs as well as samples collected from Western Canadian crushing plants.

MATERIALS AND METHODS

Line elevator companies, grain cooperatives and crushing plants supplied samples of rapeseed of the new fall crop in their area. These samples were composited for analysis as described in Canadian Grain Commission Crop Bulletins (10–14). Samples of process seed and meal also were obtained from Western Canadian crushing plants as part of a project to evaluate seed and oil chlorophyll. Three crushing plants continued in the project throughout the period 1979 to 1985. Samples representing rail car unloads at terminals and export cargo shipments were obtained from the Canadian Grain Commission's Inspection Division as part of the Grain Research Laboratory's regular surveys. Rail car unloads were sampled on a 20% basis and composited by grade for analysis on a quarterly basis. Subsamples from the official loading sample from export cargo shipments were analyzed individually. All seed arriving at terminals and exported from Canada, graded No. 3 Canada Rapeseed or better, was sampled in the rail car and export cargo surveys.

Glucosinolate analysis was conducted according to the gas liquid chromatographic method of the Canadian Grain Commission's Grain Research Laboratory (15), as specified in the canola definition. This method is based on procedures published by Thies (16) and modified by Heaney and Fenwick (17) and involves extraction and purification of intact glucosinolates by ion exchange chromatography, isolation as desulfoglucosinolates and pertrimethylsilylation prior to programmed temperature gas liquid chromatographic separation and detection. This procedure has been found to be more accurate for analyzing low levels of glucosinolates than methods involving glucosinolate hydrolysis (18). The relatively low throughput and high expense of this method, however, has limited its use in analyzing large numbers of samples. Some samples analyzed prior to January, 1982, were analyzed by a glucosinolate hydrolysis procedure (19). Results from these analyses may be low.

Total glucosinolate results reported in this study include only the glucosinolates from the canola definition, that is 3-butenyl-, 4-pentenyl-, 2-hydroxy-3-butenyl- and 2-hydroxy-4-pentenyl glucosinolates.

RESULTS AND DISCUSSION

Definition of canola. Breeders, who began attempting to introduce low glucosinolate quality into rapeseed in the late 1960's, concentrated on removing what were then thought to be the major glucosinolates in rapeseed (3-butenyl-, 4-pentenyl- and combined 2-hydroxy-3-butenyl- and 2-hydroxy-4 pentenyl-glucosinolates). The hydrolysis products of these glucosinolates were used as a basis for relatively easy analytical procedures for determination of total glucosinolates.

Based on nutritional studies carried out on meals produced from low glucosinolate lines developed using these procedures, a maximum level of 30 μmol/g of oil-free meal of any combination of the above glucosinolates was established for canola.

The definition of glucosinolate levels in canola was complicated by the discovery, in 1978, of a further major group of glucosinolates in rapeseed (20). These glucosinolates, known as indolyl glucosinolates, have been found in approximately the same quantity in both high- and low glucosinolate rapeseed. Because the level of indolyl glucosinolates appeared to be the same in both canola and traditional rapeseed (21), and because until recently it has not been possible to analyze these components accurately, indolyl glucosinolates have not been included in the canola definition.

Canola varieties. Since the first "double zero" rapeseed variety Tower was released in 1975, a total of 10 *B. napus* and two *B. campestris* low glucosinolate varieties have been released for production in Canada, including the currently most popular varieties *B. napus* c. Westar (licensed in 1982) and *B. campestris* cv. Tobin (1981). These varieties replaced the lower yielding *B. napus* cv. Regent (1977) and *B. campestris* cv. Candle (1977). *B. napus* cv. Altex (1978) and Andor (1980) were earlier maturing *B. napus* strains developed for growth in the Central Alberta region, while *B. napus* cv. Pivot (1985) was developed for irrigated areas. Two *B. napus* varieties, Triton (1984) and Tribute (1985), were developed to be resistant to triazine herbicides and, although they have been found to be substantially lower yielding than Westar, they are suitable in regions where contamination with wild mustard (*Sinapis arvensis* L.) or stinkweed (*Thlaspi arvense* L.) pose serious problems. *B. napus* cv. Reston (1982) was developed with low levels of glucosinolates and high levels of erucic acid to satisfy the limited demand for industrial rapeseed oil. Both *B. campestris* lines, Candle and Tobin, were selected to have a partially yellow seed coat, this characteristic being associated with lower fiber and high oil and protein.

Early varietal acceptance was hampered in the northwest growing region by the lack of a low glucosinolate *B. campestris* line. Even the first low glucosinolate *B. campestris* variety, Candle, was not well accepted as its yield was only 90% of the then predominant *B. campestris* LEAR variety Torch. The *B. campestris* variety Tobin had an acceptable yield and, coupled with the high yielding *B. napus* variety Westar, made up the predominance of varieties grown in 1984 and 1985 (22). Since 1982, more than 90% of growers surveyed planted varieties with canola quality (Fig. 1).

Breeder's seed from canola varieties released in Canada has contained very low levels of glucosinolates, usually between 10 and 20 μmol/g. The level of glucosinolates in pure varieties, however, has been shown to be affected strongly by environment with variations between planted seed and harvested seed of as much as $\pm$100% (23). This variation, coupled with the difficulties associated with analysis, has made impossible the implementation of certified seed glucosinolate levels, similar to the certified seed erucic acid levels used during the conversion to LEAR (24). As a partial solution, foundation seed levels have been restricted to 28 μmol/g.

New crop surveys. The Canadian Grain Commission's new crop surveys have been designed to provide an estimate of the quality of the annually harvested new crop. In the case of rapeseed, recent surveys have included approximately 1500 samples which have been composited by grade and crop district prior to analysis. Average glucosinolate values for new crop Western Canadian rapeseed first fell below 30 μmol/g in 1982 (Fig. 2), the same year that all three Prairie Provinces had average levels less than 30 μmol/g. As with erucic acid, reduction

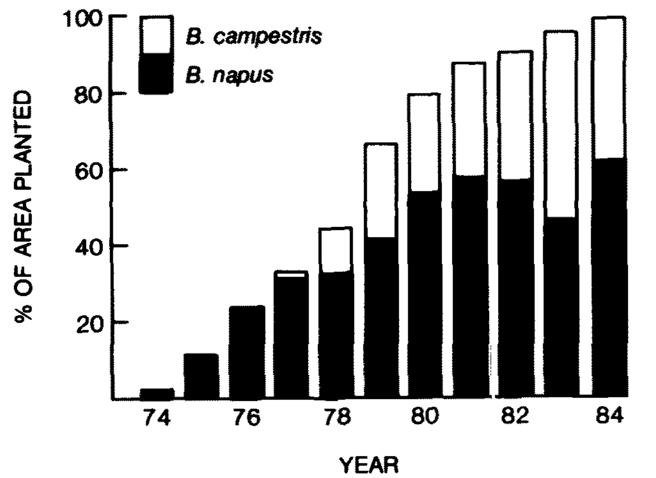

FIG. 1. Plantings of low glucosinolate rapeseed varieties in Western Canada.

of glucosinolates was slower in the western and northern growing regions (Table 1). By 1985, however, Alberta was the only area of Western Canada which was not producing seed with less than 30 μmol/g (Table 2).

The glucosinolate levels in varietal composites prepared from new crop survey samples has reflected the pattern in the regional crop (Table 3). *B. napus* varieties had consistently low levels of glucosinolates reflecting their somewhat lower level in certified seed and their predominant use in the Eastern Prairies where contamination with old *B. campestris* seed is minimal. Commercially produced seed from both *B. campestris* lines has averaged close to 30 μmol/g glucosinolates. This was due to the *B. campestris* canola varieties' relatively high level of glucosinolates and to their contamination with old high glucosinolate *B. campestris* lines which also were grown predominantly in the Western Prairies. Plant breeders have given a high priority to reducing the glucosinolate levels in *B. campestris* varieties.

Rail car unloads. Analysis of quarterly composite samples of railway shipments of rapeseed arriving at terminals has provided information on the overall quality of seed shipped during that quarter. This seed may have been quite different in composition and quality from the seed tested in new crop surveys depending on the carryover of old stocks, the activity of crushing plants, and the use of Atlantic or Pacific terminals. The average level of glucosinolates in rail car unloads (Fig. 3) did not fall below 30 μmol/g until midway through the 1982/83 shipping season, mainly due to the carryover of old stocks and the preferential use of low glucosinolate seed by

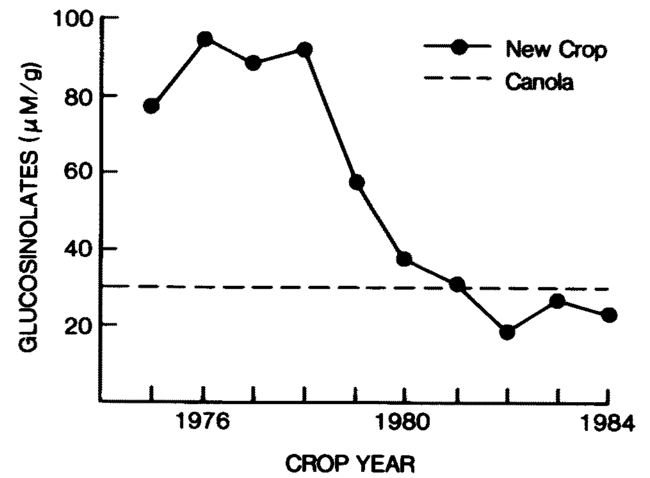

FIG. 2. Average level of glucosinolates in Western Canadian rapeseed.

TABLE 1

Glucosinolate Content (μmol/g) of Western Canadian Rapeseed from New Crop Surveys

Year	Manitoba	Saskatchewan	Alberta	Western Canada
1980	35	37	63	38
1981	21	31	32	29
1982	17	23	28	24
1983	25	25	30	27
1984	18	20	31	24
1985	14	24	35	28

TABLE 2

Glucosinolate Content (μmol/g) of Rapeseed Produced in Alberta[a] from New Crop Surveys

Year	South	Central	North[a]	Alberta[a]
1980	41	33	81	63
1981	30	30	38	32
1982	27	25	37	28
1983	33	29	34	30
1984	29	29	42	31
1985	35	36	41	35

[a]Includes Peace River Region of British Columbia.

TABLE 3

Glucosinolate Content (μmol/g) of Western Canadian Rapeseed Varieties from New Crop Surveys

Variety	1984	1983	1982	1981	As licensed[a]
Brassica napus L.					
Westar	16	11			14
Regent	14	14	21	21	12
Altex	17	21	27	17	10
Andor		12			10
Tower		18	23	23	10
Triton	14	15			12
Brassica campestris L.					
Tobin	32	30	35		10
Candle	30	31	29	34	9
Torch	46	69	60	81	80 (est'd.)

[a]From information on the license description supplied by Food Production and Inspection Branch of Agriculture Canada.

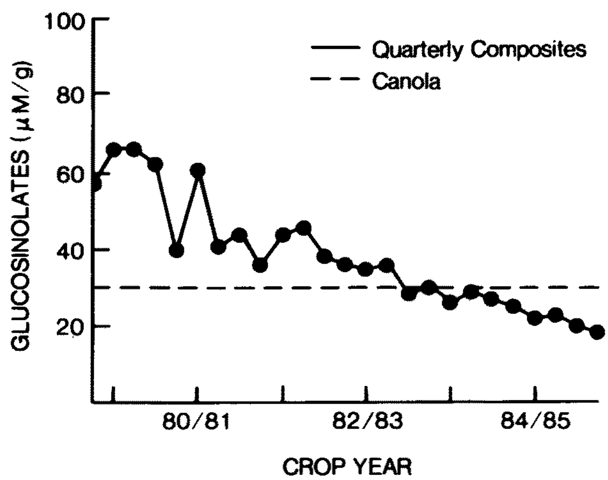

FIG. 3. Glucosinolate content of rapeseed unloaded at terminal elevators.

Western Canadian crushing plants. The level of glucosinolates in rail shipments continued to decline through the 1984/85 shipping season.

Export cargo shipments. Export cargo shipments, analyzed individually on a monthly basis, have given an up-to-date estimate of the quality of rapeseed export shipments. In conjunction with new crop survey information, data from export cargo surveys has allowed exporters and importers to form a good estimate of the quality of future shipments. The monthly average glucosinolate level of Canadian rapeseed has not exceeded 30 μmol/g since September 1983, and no export shipment has contained more than 30 μmol/g since December 1983 (Figs. 4 and 5). The level of glucosinolates in export shipments has continued to decline, paralleling the level in rail car shipments. It would seem very unlikely that any rapeseed shipped from Canada would contain more than 30 μmol/g glucosinolates unless it were made up completely of seed from Alberta.

Crushing plants. Prior to 1982, the glucosinolate level of seed entering Western Canadian crushing plants was lower than the overall average level for Western Canadian rapeseed because the crushers contracted for and selected low glucosinolate rapeseed where possible. A survey of 24 process samples from 1979 to 1981 and 30 process samples from after 1983 to 1984 showed equal medians (28 μmol/g and 25 μmol/g) and equal dispersions. The pre-1982 crushing plant median of 28 μmol/g is well below the 1979/1981 new crop average glucosinolate level of 42 μmol/g while the 1983/84 median is not different from the 1983 and 1984 average new crop glucosinolate level (Fig. 6). By siphoning off the low glucosinolate seed in the late 1970's and early 1980's, Western Canadian crushing plants hindered the conversion of Canada's export rapeseed to canola quality.

According to the canola definition, the maximum allowable glucosinolate level in canola meal is the same as for canola seed. This gives crushing plants an edge because between 40 and 60% of the glucosinolates present in the seed are destroyed during processing (Fig. 7).

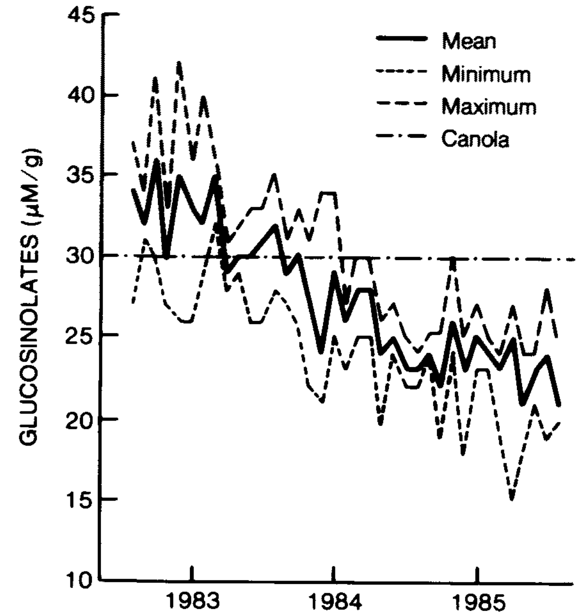

FIG. 4. Glucosinolate content of rapeseed exported from Canada.

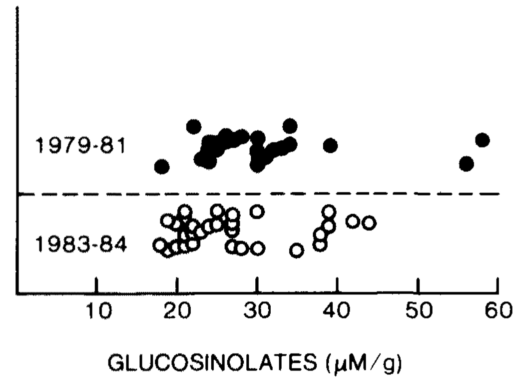

FIG. 6. Glucosinolate content of seed processed in Western Canadian crushing plants. Data has been randomly jittered on the nondimensional y-axis to minimize overlap.

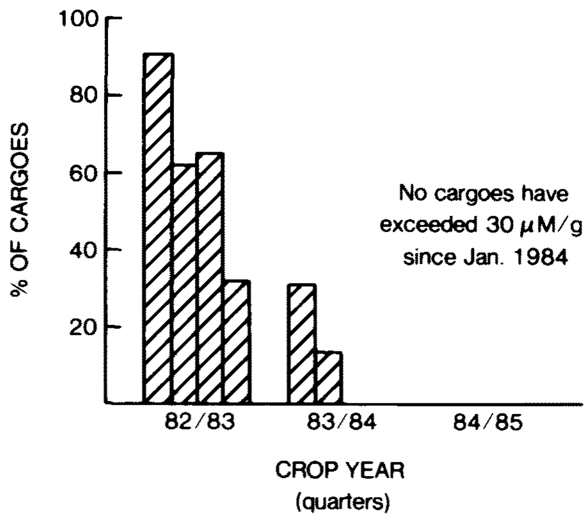

FIG. 5. Percentage of Canadian rapeseed export shipments containing more than 30 μmol/g glucosinolates.

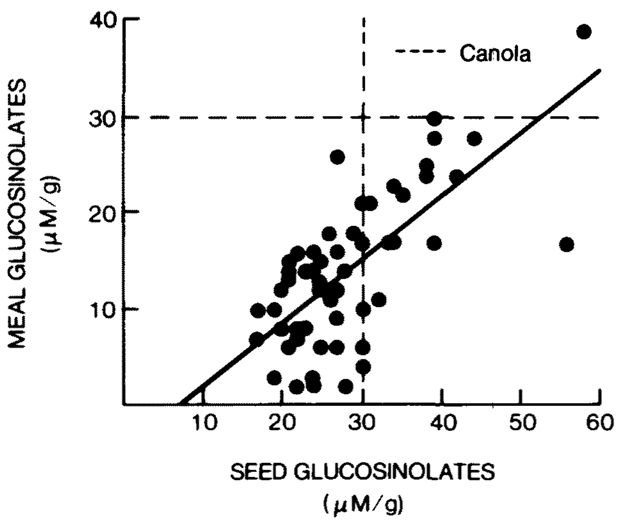

FIG. 7. Effect of processing on glucosinolates.

Crushing plants have made canola meal from seed containing as much as 50 μmol/g glucosinolates.

Eastern Canada. Rapeseed has been introduced recently as an oil crop in Eastern Canada. The glucosinolate problem is more difficult in Eastern Canada, however, since in addition to summer types of seed, winter types of rapeseed also have been grown. As yet there is no winter rapeseed variety licensed in Canada which meets canola specifications for glucosinolates.

In 1984/85, approximately 25,000 acres of rapeseed were planted in Eastern Ontario. Of this, 20,000 acres were planted to summer rapeseed which averaged approximately 20 μmol/g glucosinolates; 4000 acres were planted to the winter variety Tandem averaging approximately 45 μmol/g; and 1000 acres were planted to other winter rapeseed types averaging approximately 150 μmol/g. Assuming the yield from winter rapeseed to be approximately 1.3 times the yield of summer types, the overall average level of glucosinolates in Eastern Canadian rapeseed would be about 31 μmol/g, or just over the canola limit. Unfortunately, the early harvest time for the winter type seed makes it difficult to blend into the eastern summer harvest, and eastern crushers must rely on western seed for blending the eastern high glucosinolate winter seed. The growing popularity of winter rapeseed will make blending even more difficult in the future. Hopefully, the development of canola quality winter varieties eventually will make it possible to guarantee canola quality in Ontario.

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