QUALITY ASSESSMENT OF DOCKAGE IN RAPESEED

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Douglas Clifford Durnin

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ABSTRACT

Durnin, Douglas C., The University of Manitoba, April, 1983.

QUALITY ASSESSMENT OF DOCKAGE IN RAPESEED.

Major Professor: F.W. Hougen.

Oils extracted from rapeseed fine screenings dockage by the POS Pilot Plant Corporation were examined for detrimental effects on rapeseed oil. Seed materials from the POS fine screenings were compared with inseparable dockage material from rapeseed samples from oilseed crushing plants, and with fine screenings and inseparables from rail carlot samples, to determine the degree of similarity between these dockage fractions, and to determine the extent of contamination of rapeseed by dockage.

Industrially expelled and extracted oils from one sample of rapeseed (variety Tower) and five samples of POS fine screenings were degummed, alkali refined, bleached and deodorized by laboratory techniques. Upon analysis, the oils from the POS fine screenings were higher than the Tower oil in contents of moisture and volatile matter, free fatty acid, chlorophyll, phosphorus and sulfur, and in peroxide value, and in color. The fatty acid compositions of all the samples were similar except for a higher erucic acid content (4.1 to 9.9%) for the POS fine screenings oils than for the Tower oil (0.1%).

The POS fine screenings seed material contained mostly small and broken rapeseed (47%) and weed seeds (24%), primarily stinkweed,

lamb's quarters and green foxtail, and inert matter (29%). The oil content was 28% for the fine screenings compared with 49% for the Tower rapeseed.

Rapeseed samples from six oilseed crushing plants were hand sorted to remove the inseparable material (weed seeds and unsound rapeseed). This inseparable material, comprising 5.7% of the samples, contained less than half as much oil and protein as the rapeseed sample. The inseparables contained greater amounts of linoleic, linolenic plus eicosenoic, eicosadienoic, and erucic acids. The hand sorted individual weed species contained less oil and protein than the rapeseed. The fatty acid compositions were similar to that of rapeseed, except for higher contents of erucic acid (stinkweed, 40.1%; cleavers, 7.9%; lady's thumb, 7.3%), linolenic acid (bluebur, 36%) and arachidic acid (cleavers, 16%). Glucosinolates were detected in stinkweed and cleavers.

Forty-nine rapeseed carlot survey samples were cleaned by a Carter Dockage Tester and then hand sorted for weed species content. The tester removed 6% of the samples as dockage, leaving 1.18% inseparable weed seeds in the cleaned rapeseed. The carlot fine screenings (1.27%) were comprised of stinkweed, lamb's quarters, lady's thumb, green foxtail and rapeseed, similar to the POS fine screenings. The composition of the inseparable weed species was similar to that of the inseparables from the crushing plant samples.

The fine screenings from the two sources examined (POS and carlot samples) and the inseparables from the two sources examined (crushing plant and carlot samples) all showed an overall similarity in botanical composition. It is assumed, therefore, that the chemical and nutritional

qualities of the POS fine screenings, as examined by various laboratories, relfect also the qualities of the POS inseparables (samples that were not available for these studies).

INTRODUCTION

The quality characteristics of rapeseed oil and meal have changed extensively since crushing rapeseed for edible oil in Canada began in the 1950's. The erucic acid and glucosinolate contents of rapeseed cultivars have been reduced to near zero by breeding, and the agronomic properties have been improved. The newer varieties of rapeseed are thus substantially different from earlier varieties. In order to distinguish these newer types of rapeseed, those with low erucic acid and glucosinolate contents have been designated by the name canola.

As improvements were made to the oil and meal, however, the contamination of rapeseed by other seeds became of greater concern. Techniques to remove this material are effective, but some material generally remains in the rapeseed and is processed along with the seed.

Many terms have been used to describe the material removed from rapeseed and other seed crops. The most generally used term, dockage, is defined in the Grain Grading Handbook for Western Canada (Canadian Grain Commission, 1980) for rapeseed as:

> ... all material removed by the round-hole sieve, plus material removed through wire-mesh sieves, plus material removed by aspiration, plus earth pellets up to 2.5%, plus material not in excess of grade tolerance handpicked from the screened sample, plus material removed by cleaning for grade improvement.

This definition encompasses all material that is not rapeseed.

When grading rapeseed samples, however, the Standard of Cleanliness (Canadian Grain Commission, 1980) for grades of rapeseed states that samples:

> May contain not more than 1% of other seeds that are conspicuous and that are not readily separable from Rapeseed, to be assessed as dockage.

This definition of dockage, much narrower than the first, disregards the large and small material and is concerned strictly with material the size of rapeseed, also referred to as inseparables, for the Standard of Cleanliness.

This narrower definition of the inseparable dockage further includes grading factors, which set maximum tolerances for the levels of this dockage permitted in each grade of rapeseed. A distinction is made between foreign material that is easily detected; conspicuous admixture composed of sclerotinia, ergot, stones, and weed seeds, and inconspicuous admixture including wild mustard or brown or oriental mustard seed.

The inseparable dockage and the removable dockage are both included in the assessment of total dockage. The price payable for rapeseed is affected by the amount of dockage in the seed, with reductions in price as the dockage increases.

The contribution of this non-rapeseed material or dockage to the quality of the rapeseed and its products has received little attention. The oil and protein of some weed species have been determined, but the quantities and qualities of weed species in rapeseed have not been closely examined.

In the present study samples of rapeseed and dockage for examination were obtained from different sectors of the Canadian rapeseed industry.

The initial objective of the present work was to examine, by chemical means, the quality of oils extracted from rapeseed dockage material, and thus to be able to assess the effect these oils might have on the quality of rapeseed oil contaminated with such dockage oils. Standards for vegetable

oils established by Canada and other countries are based upon chemical tests which are considered, by agreement, to be indicative of the quality of the oils. These tests include the saponification value, iodine value, acid value, peroxide value, color, and contents of unsaponifiable matter, erucic acid, chlorophyll, phosphorus, and sulfur.

This study was part of a larger study supported by the Canola Council of Canada, where certain other laboratories investigated nutritional and other chemical properties of the same dockage seed and oil. The dockage from the commercial rapeseed samples for this study were collected from different geographical areas in western Canada and further processed by the POS Pilot Plant Corporation, Saskatoon. At the POS Plant the fine screenings fraction of this dockage was extracted for oil. Samples of the fine screenings, the extracted oils, and the residual meal after oil extraction[a] were supplied to the various laboratories for further nutritional and chemical studies.

A second objective of the present work was to examine the dockage in commercial rapeseed from three separate sources, namely,

(i) from the POS Pilot Plant,

(ii) from Canadian oilseed crushing plants, and

(iii) from the yearly rapeseed carlot survey of the Canadian Grain Commission, Winnipeg.

This examination of the various dockage samples was to consist partly of chemical analyses, but mainly of a detailed determination of the botanical composition of the dockage, i.e., the relative amounts of different species of weed seed and other material.

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[a] In this work referred to as the "POS fine screenings" (fine scr.), the "POS fine screenings oils", and the "POS fine screenings meals", respectively.

The POS Pilot Plant samples consisted of the above fine screenings, as well as samples of screen-cleaned Tower rapeseed.

The crushing plant samples consisted of rapeseed that had been cleaned in the plant, ready for crushing. The dockage investigated in our laboratory from this seed thus consisted of the inseparable weed seed and other material[a] that had to be isolated by hand sorting.

The samples from the rapeseed carlot survey originated from country grain elevators. Each year the government Grain Research Laboratory analyses hundreds of samples in the yearly rapeseed carlot survey. Country grain elevators submit to the Canadian Grain Commission samples of rapeseed taken when the seed is loaded into railway cars. These samples are thus representative of the rapeseed that enters the Canadian grain transportation system.

The carlot survey samples, as cleaned in our laboratory, provided all the various dockage fractions, of which the fine screenings and the hand sorted inseparable material[b] were further examined for botanical composition.

The opportunity of including in this thesis an investigation of seed from the latter two sources (crushing plants and carlots) came as a result of earlier having started a project on these two seed sources as a "summer student" under the supervision of Dr. J.K. Daun, at the Grain Research Laboratory of the Canadian Grain Commission, Winnipeg.

A third objective of the present work inadvertently presented itself because of the inclusion in the study of the crushing plant

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[a] In this work referred to as the "crushing plant inseparables".
[b] In this work referred to as the "carlot fine screenings" and the "carlot inseparables", respectively.

samples and the carlot samples. Considering the original objective of examining the chemical quality of the POS fine screenings oils and, by other laboratories, the nutritional quality of the POS fine screenings, it became apparent that no absolute information would be obtained on the chemical and nutritional quality of the POS inseparables - the dockage fraction that for practical reasons generally remains in the commercial rapeseed, even when processed or exported. To provide some information concerning this question, it was decided, as a third objective, to make a careful comparison of the botanical composition of the fine screenings available in this study (i.e., the POS and carlot samples) versus the inseparables available (i.e., the crushing plant and carlot samples). Should the results indicate that the composition of the fine screenings and the inseparables were similar, the conclusions from the chemical and nutritional studies of the POS fine screenings and oils might with some confidence be assumed to be valid also for the inseparable dockage and its extractable oil.

In summary, the total objectives were

(1) To examine the quality of the POS fine screenings oils by chemical analyses.

(2) To examine the botanical composition of the following dockage fractions: POS fine screenings
POS inseparables (Tower rapeseed only)
Crushing plant inseparables
Carlot fine screenings
Carlot inseparables.

(3) To evaluate the degree of similarity of the fine screening samples versus the inseparables samples.

LITERATURE REVIEW

Grading systems in the grain industry were necessitated by the presence of foreign seed material of different species in the grain samples. Each country in the world which trades grain has developed a grading system in which the quantity of non-grain material as well as the quality of the grain is used to assign a grade to the grain.

Rapeseed in Canada is graded according to the quality of the rapeseed and the presence of non-rapeseed material or dockage. Limits have been established for grading rapeseed according to the amount of heated, distinctly green, or damaged rapeseed present, as well as the amount of admixture of foreign material (Canadian Grain Commission, 1980). This admixture of foreign material usually includes sclerotinia, ergot, stones, conspicuous admixtures such as weed seeds, and inconspicuous admixtures such as wild, brown or oriental mustard seed. For the purposes of grading, however, only the quantity is assessed and the chemical quality of the dockage is not taken into account.

The quantities of dockage present in rapeseed exported from Canada have been low. From recorded data (Daun, 1981, personal communication) the amount of dockage not removed from Canadian rapeseed cargoes has averaged 1.9% and 2.0% for the 1980-1981 and 1981-1982 crop years, respectively, for some 1.28 and 0.96 million metric tons of seed. The Canadian Grain Guide allows for 2% dockage in exported rapeseed. This level was established as a trade-off between the degree of cleanliness desirable and the expense involved in cleaning rapeseed to

lower levels of dockage. When dealing with the large quantities of rapeseed such as those exported from Canada, the amount of dockage shipped with the crop becomes very large.

The amount of dockage present in Canadian crops has been the highest for rapeseed (Canadian Grain Commission, 1977). The ten year averages (1966-1976) of dockage on car receipts for all grains arriving at the Thunder Bay, Pacific Coast and Western Division terminal elevators were 2.54, 3.43, and 2.86%, respectively. The same ten year average figures for rapeseed were 11.61, 10.32, and 10.55%, respectively. Rapeseed contains more dockage due to the small size of the seeds. If a combine were set to blow off all the pods and chaff, a considerable amount of the light weight rapeseed would be blown off as well. When the rapeseed was cleaned to a 2% level for export, a large quantity of screenings was thus obtained. These screenings have been used to produce a high-protein chicken feed.

The amount of information on the composition of rapeseed screenings is very limited. Great variability has been reported in the physical composition of rapeseed screenings. Bell and Linton (1961) reported the presence of hull and seed pod fragments, immature or small rapeseed, some weed seeds and other extraneous material in the dockage retained with rapeseed during combine harvesting. Giovanetti and Bell (1972) reported weed seed levels averaging 1.5%, ranging from 0.39 to 4.08%, and inert matter averaging 0.53%, ranging from 0.16 to 1.13%, for rapeseed samples used in an experimental program. A large number of weed species have been identified in rapeseed dockage, the more common ones being wild mustard, stinkweed, lamb's quarters, green foxtail, smart weed and wild buckwheat.

The Canola Council of Canada, formerly the Rapeseed Association of Canada, recently funded a series of projects for examining several aspects of the effects of dockage on the quality of rapeseed oil and meal. Oils were expelled and extracted from fine screenings from rapeseed, as well as from Tower rapeseed, by the POS Pilot Plant Corporation, Saskatoon. These oils and seed materials were distributed to researchers as required for the various projects.

Oils from the fine screenings from rapeseed decreased the stability of canola oil when added in proportions of 1 to 4% (Ismail et al, 1980). Increases in hydroperoxide and peroxide values and thiobarbituric acid numbers, indicating oxidation of the oils, occurred during an accelerated storage test between days 3 and 6; after 6 days the oils were quite rancid. Differences in off-flavor among these poor quality oil mixtures were not detectable by sensory analysis. Erucic acid ranged from 4 to 9% of the fatty acids for the fine screenings oils. The presence of the fine screenings oils was deemed undesirable, and efforts to minimize contamination of rapeseed by dockage materials were recommended.

Studies of the POS fine screenings and fine screenings oils by Ackman and Sebedio (1981) involved the determination of the sterol and fatty acid compositions by gas chromatography. The sterol contents were the highest for the extractor screening oils, intermediate for the expeller screening oils, and the lowest for the Tower oils. The fatty acid compositions for the screening oils were similar to the composition of the Tower oil except for higher proportions of erucic and eicosenoic acids in the screenings oils. The screenings seed materials, composed of 25 to 50% rapeseed and 21 to 31% weed seeds, mostly lamb's quarters and stinkweed, contained 20 to 30% oil. The

fatty acids and sterols of the fine screenings were not sufficiently different from those of canola seed to warrant concern about the nutritional effects if the fine screenings were to be used as animal feed.

The POS fine screenings were examined for their seed composition (Rebolledo et al, 1980). The levels of rapeseed in the samples varied from 24.6 to 54.5%, the proportion of weed seeds ranged from 20.2 to 29.7%, and the proportion of inert material from 16.4 to 31.6%. The protein content was reported to vary from 17.7 to 23.1% and the amino acid distribution was similar to that of Tower rapeseed. The oil content varied from 19.6 to 28.0% in the screenings with 2.7 to 8.7% of the fatty acids being erucic acid. The chemical composition of the rapeseed screenings meals were also determined; the contents of crude protein ranged from 21.3 to 28.2%, fat from 0.4 to 1.7%, phosphorus from 0.74 to 0.98%, and glucosinolates from 0.34 to 2.36 mg/g.

Feeding studies were undertaken to determine effects of the POS fine screenings on the feeding value of canola meal. Bell and Shires (1982) reported more fibre, less protein, less lysine, less gross energy, and lower digestibility for meal from the POS screenings than for Tower rapeseed meal from well cleaned seed. A decline in efficiency of feed utilization for swine was found as the level of screenings in the diet increased, leading to a recommendation that rapeseed be as free from foreign material as possible prior to crushing.

Another feeding trial using broiler chickens showed poorer odor and flavor scores for dark meat from chickens fed diets containing 10% screenings material in the Tower meal diet compared to diets of 100% Tower meal (Hawrysh et al, 1982). The quality differences were small

enough that the meat was still described as acceptable. No differences were found among the white meats from the various diet treatments. Inclusion of screenings as a replacement for canola meal was deemed to have no adverse effects on the eating quality of cooked broiler chicken.

These studies on the oils and meals from the screenings have indicated a reduced quality in products containing these but have not compared the amounts included to the amounts normally occurring in rapeseed samples. Such a comparison has been included in the present work, as it was necessary to clarify the extent of the dockage problem in the rapeseed industry.

In a feeding study using wild mustard and stinkweed as additives to rapeseed in diets for mice, Shires et al (1982) reported no difference in growth rates when the diets included ground raw rapeseed with or without the added weed seeds. However, when cooked meals were employed, the subsequently added weed seeds resulted in lower feed intakes and reduced growth rates. No risk associated with glucosinolates was anticipated if the diets of normally processed commercial rapeseed meal contaminated by stinkweed and wild mustard were rendered free of myrosinase.

A study involving the feeding of pelleted screenings from combine-harvested rapeseed to lambs showed decreasing gains as the amount of screenings exceeded one-third of the hay concentrate fed (Bell and Linton, 1961). The screenings contained only traces of isothiocyanate and thiooxazolidone, two classes of breakdown products of glucosinolates implicated in causing goiter in animals.

A few studies have been conducted to determine the chemical properties of individual weed seed species. Schroeder et al (1974) examined 66 weed and crop species for their contents of fat, protein, nitrogen-free extract, fiber and ash. The species tested were from seven plant families and had been used in herbicide selectivity studies. The fat contents (based on 10% moisture content) for stinkweed, lamb's quarters and green foxtail, three weed seed species commonly found in rapeseed, were 25.8, 4.5 and 4.8%, respectively. The protein contents of the three seed species were 24.2, 20.5 and 13.1%, respectively. The crude fiber contents ranged from 12.4 to 17.1%, the ash contents ranged from 4.6 to 9.6%, and the contents of nitrogen-free extract ranged from 18.3 to 52.3%.

The oil content and fatty acid composition of nine species of Canadian weed seeds were reported by Daun and Tkachuk (1976). Four of these are common in rapeseed, according to Giovanetti and Bell (1972), namely, wild mustard, lamb's quarters, green foxtail and wild buckwheat. The oil contents were 35.2, 9.1, 7.1 and 2.9%, respectively, for these four species; the oils were composed primarily of neutral lipids. From the fatty acid compositions reported by Daun and Tkachuk, erucic acid was found in the oil of wild mustard (6.5% of the total fatty acids) and lamb's quarters (3.6%). Eicosenoic acid (11.9%) and linolenic acid (15.3%) were fatty acids also found in higher amounts than those found in canola rapeseed.

Ten weed seed species were analyzed for amino acid composition and reported to have excellent essential amino acid balance (Tkachuk and Mellish, 1977). Five of the species, commonly found in rapeseed, contained oil and protein, respectively, as follows: wild mustard ,

38.8 and 24.0%; stinkweed, 34.0 and 20.7%; lamb's quarters, 8.4 and 16.8%; green foxtail, 6.2 and 15.2%; and wild buckwheat, 2.1 and 9.1%. Toxic substances in some species such as stinkweed would necessitate processing prior to their use in food or feed preparation. Stinkweed has caused tainting in dairy products from cows grazing on this weed, and feeds containing excessive amounts of stinkweed may be poisonous to horses, cattle, and pigs, and produce off-flavours in meat products (Stevenson, 1976).

MATERIALS AND METHODS

Materials

Origin and Processing of the POS Seed Samples

Initially, fine screenings dockage material (1000 kg) removed from commercial rapeseed were received by the POS Pilot Plant Corporation, Saskatoon, from three oilseed crushing plants (CSP Foods, Nipawin, Sask.; NARP, Sexsmith, Alta.; United Oilseed Products Ltd., Lloydminster, Alta.) and two country grain elevators (Cargill Grain Co., Elm Creek, Man.; Cargill Grain Co., North Battleford, Sask.) in western Canada (Canola Council of Canada, Winnipeg, 1982, personal communication). To ensure the confidentiality of the sources of the samples, these were coded "fine screenings A, B, C, D, and E". A sample of Tower rapeseed (1200 kg) was obtained by the POS Plant from CSP Foods Ltd., Saskatoon, and cleaned to less than 0.2% dockage (Bell, J.M., POS Pilot Plant Corp., Saskatoon, 1982, personal communication).

At the POS Plant, the 5 lots of fine screening materials and the Tower seed were each sequentially flaked, cooked, and extracted for oil by the prepress solvent extraction procedure to provide 12 samples of oil (expelled POS fine screenings oils A-E, extracted POS fine screenings oils A-E, expelled Tower oil, and extracted Tower oil) and 6 samples of solvent extracted desolventized (DT) meal (POS fine screenings DT meals A-E, and Tower DT meal).

The target conditions for the processing were as follows: a flake thickness of 0.22-0.25 mm.; in the cooking-prepressing process, a bottom

tray temperature of 90-95°C, flake moisture of 4-6%, retention time of 35 min, residual oil in the cake of 16-22%, and a cake thickness of 70 mm.; in the extraction process, a residual oil in the DT meal of 2-4%, residual solvent in the DT meal of less than 1000 ppm, DT tray temperature of less than 120°C; and in the DT meal, a sizing such that 90% would pass through a 10 mesh screen. These conditions were followed as closely as the various materials would allow. Some necessary modifications were as follows: an increase in flow rate of material for fine screenings A to obtain a good cake; an extended time in the extractor for fine screenings B; and a reduction in the rate of steam injected into the cake for a second run of Tower seed as the meal was overcooked in the first run. The same conditions as for the second Tower run were used for fine screenings E (Bell, POS Pilot Plant Corp., 1982, personal communication).

Oil Samples

Twelve crude oil samples were received from the POS Pilot Plant for the determination of the detrimental effects dockage material might have on rapeseed oil. The samples included the expelled and the extracted oils from each of the 5 lots of POS fine screenings material, labelled A, B, C, D, and E, and from the POS sample of Tower rapeseed. The first shipment of oils included 1 gal of each of the six extractor oils (A-E, and Tower) and of the expeller oils C, D, E, and Tower. Samples of expeller oils A and B were received later, but the quantity was not sufficient to enable these oils to be refined.

Seed Samples

Samples from the POS Pilot Plant. Five 1-kg samples of the POS fine screenings material (labelled Dockage A-E) and a sample of the

Tower rapeseed (1 kg) were received from the POS Pilot Plant.

Samples from the Oilseed Crushing Plants. Rapeseed samples were received from 6 western Canadian oilseed crushing plants located in Lethbridge, Lloydminster, Altona, Sexsmith, Nipawin and Saskatoon. Ten samples were received from each of 5 of the plants and 12 samples from the sixth plant. These samples were taken on different days from the stream of rapeseed being fed to the crushing rolls of these plants. Samples were collected between June 15 and July 14, 1977, for each plant over a period of approximately 2 weeks. The samples from Altona were Brassica napus var. Midas taken from the cleaner-building; the Sexsmith samples were labelled "seed composites"; no information was received about the other four sets of seeds samples.

Samples from the Rapeseed Carlot Survey. Subsamples were taken from samples of the Canadian Grain Commission 1977 rapeseed rail carlot survey in which country elevators submitted to the Grain Research Laboratory, Winnipeg samples of rapeseed which had been loaded into railway grain cars for transport to terminal elevators. Forty-nine subsamples were taken, amounting to 10% of the total received at the Laboratory. The 49 subsamples were chosen in the same proportion (10%) as the number received from each crop district in western Canada.

Methods

In order to determine the quality of the oils, each was subjected to procedures designed to degum, alkali refine, bleach, and deodorize oils on a laboratory scale, simulating factory practice. A subsample of each oil was taken after each step for subsequent analyses.

Refining of the Oil Samples

Degumming. The oils were degummed or deslimed by hydration of the phosphatides according to the method of van Rede (1966). Water (6% by wt) was added to the stirred samples (700 g), and the temperature raised to 80°C in 20 min. When the oils had cooled to 60°C they were placed in a 10°C water bath and rapidly cooled to 30°C. After settling briefly, the gums were separated by centrifugation at 10,000 rpm (16,000 x g) for 30 min and the oil was decanted.

Alkali Refining. The free fatty acids in the oils were neutralized by conversion to their sodium soaps and removed by weak caustic soda and water washings (van Rede, 1966). The oil (500 g) in a beaker was heated slowly to 65°C in a water bath while being stirred by a glass stirrer at 150 rpm. A preheated volume of 0.8N NaOH with 10% NaCl (by wt of NaOH), sufficient to neutralize the free fatty acids plus a 10% excess, was added dropwise. The free fatty acid content of the oil had been previously determined by titration with NaOH according to the American Oil Chemists' Society (A.O.C.S.) Official Method # Ca 5a-40 (1977). The oil was allowed to settle and then centrifuged at 10,000 rpm (16,000 x g). The decanted oil, maintained at 65°C, was washed with 20% (by wt) of preheated 0.1N NaOH with stirring. The water and oil layers were separated in a separatory funnel, and the water layer was drawn off. Hot water washes (20% by wt) were added and drawn off until the water layer became clear and colorless. The oil was then centrifuged (10,000 rpm, 16,000 x g, for 30 min) and decanted from the water.

Bleaching. The bleaching earth obtained (Official Activated Bleaching Earth Lot # Z 1077, American Oil Chemists' Society) was past its official

expiry date; therefore, a bleaching test was done to determine what proportion of earth should be used. Samples of degummed, alkali refined rapeseed (var. Oro) oil were bleached using 4%, 5%, and 6% bleaching earth (by wt). The color of each oil was determined by the A.O.C.S. photometric color method # Cc 13c-50 (1977). The photometric color of a commercial vegetable oil, Crisco, was determined for comparison. The photometric colors obtained for the 4%, 5% and 6% bleaching earth samples were -1.044, -1.237 and -1.125, respectively. As the oil bleached with 5% bleaching earth had a color value closest to that of the commercial oil (-1.601), 5% of bleaching earth was used to bleach the fine screenings oil samples. This was higher than the 4% level recommended for that lot of bleaching earth for determining the bleached color of refined soybean oil.

The neutralized, washed oils were bleached to improve their color characteristics (van Rede, 1966). A glass beaker and plastic lid with holes for the stirrer and thermometer were used as the apparatus. The oil in the apparatus was heated in an ethylene glycol bath to 70°C. The bleaching earth, 5% by weight, was added and stirring resumed as the oil was heated quickly to 110°C and maintained at that temperature for 30 min. The oil was allowed to cool to 90°C and was filtered through Whatman #1 filter paper. Since only a portion of the oil could fit into the funnel at once, the remaining oil was maintained at 70° - 80°C on a hot plate to facilitate filtering.

Deodorization. The oils were deodorized to reduce their odor by steam distillation using a long-necked distillation flask (van Rede, 1966, p. 336). The procedure involved drawing steam through the heated oil by vacuum and collecting the steam and volatile constituents from the

oil in a cool trap. The amount of freshly boiled distilled water generated to steam was 3% of the oil volume. The vacuum pump maintained a vacuum of approximately 5 mm Hg as measured by a U-tube manometer. During the deodorization the oil was maintained at 215°C for two hours. The cool trap consisted of a test tube immersed in a solid carbon dioxide-ethanol bath (-72°C). Laboratory air was admitted when bringing the flask back to room atmosphere.

Analysis of the Oil Samples

Moisture and Volatile Matter Content. The determination of the moisture and volatile matter present in the oils was done using the A.O.C.S. official method # Ca 2c-25 (1977), also referred to as the air oven method. The method involves heating a weighed sample of oil for periods of 30 min at 101°C until the weight loss is less than 0.05%.

Free Fatty Acid Content. The determination of the amounts of free fatty acids present in the oils was done using the A.O.C.S. official method # Ca 5a-40 (1977). The method involves the titration of the oil sample in hot ethanol with sodium hydroxide until the colormetric endpoint with phenolphthalein indicator is reached.

Peroxide Value. The peroxide value of the oils was determined using the A.O.C.S. official method # Cd 8-53 (1977). This method involves reaction of the oil sample with potassium iodide and titration of the excess iodide with sodium thiosulfate using a starch indicator. The test determines the amount of all substances which oxidize potassium iodide under the conditions of the test. These substances are assumed to be peroxides or other similar products of fat oxidation.

Photometric Color. The color of the oils was determined by the A.O.C.S. official method # Cc 13c-50 (1977), also referred to as the

photometric method. The method involves the reading of the spectrophotometric absorbance of the oil sample at wavelengths of 460, 550, 620, and 670 nm and deducting the chlorophyll contribution using the equation:

$$\text{Photometric Color} = 1.29\ A_{460} + 69.7\ A_{550} + 41.2\ A_{620} - 56.4\ A_{670}$$

The test is applicable to cottonseed, soybean and peanut oils and can probably be applied to other fats and oils, as stated in the method. The oils need to be treated with "official diatomaceous earth" prior to analysis.

Chlorophyll Content. The amount of chlorophyll present in the oils was determined using the A.O.C.S. official method # Cc 13d-55 (1977). The method involves the calculation of the chlorophyll content in parts per million from spectrophotometric absorbance measurements at 630, 670 and 710 nm. The method is applicable to refined and bleached oils but not to hydrogenated or deodorized oils because of a shift in the chlorophyll absorption peak for the latter types of oils.

Fatty Acid Composition. Two methods were used for the determination of the fatty acid compositions in the present study: an internal standard method and a rapid method.

i) Internal standard method. This gas chromatographic method was used for seed only. It enabled the oil content of the samples to be determined as well as the fatty acid composition by comparing the total area under the fatty acid peaks to the areas of the internal standard peak. Methyl esters were prepared by weighing the ground dried seed sample (6-15 mg) into a test tube; 1 ml benzene with methyl heptadecanoate (1 mg/ml) as an internal standard was added and the tube shaken; 0.5 ml basic methylation reagent (sodium methoxide, Supelco, Inc.) was added and

the tube shaken; the sample was heated to 50°C for 10 min; 1 drop glacial acetic acid was added; 1 ml hexane was added followed by 3 x 2 ml washes with distilled water; the first two washes were removed by pipet; after the third wash the hexane layer was removed, dried over anhydrous Na_2SO_4 containing 10% $KHCO_3$, and injected into the gas chromatograph. Samples were analyzed on a Hewlett Packard model 5750 gas chromatograph (8 ft x 1/8 in. o.d. DEGS-PS column); peak areas were determined by a Hewlett Packard model 3373B integrator. The column temperature was held for 8 min at 190°C, then increased at 15°C/min to 220°C and held for 5.5 min. Fatty acid compositions were determined by relative peak areas. Oil content was determined by comparing the total fatty acid peak area to the area of the heptadecanoate peak and relating this to the weight of the seed sample.

ii) Rapid method. The fatty acid compositions of oils were determined by conversion of the fatty acids to their methyl esters according to the rapid method of Hougen and Bodo (1973), and subsequent separation by gas chromatography (8 ft x 1/8 in o.d. nickel column, packed with 3% SP 2310 and 2% SP 2300 on 100-120 mesh Chromosorb W AW, from Supelco, Inc.) using a Perkin-Elmer model 3920B gas chromatograph and a Perkin-Elmer Sigma 10 data system. Column, injector, and flame ionization detector temperatures were 190°C, 300°C, and 250°C, respectively. Fatty acid compositions were determined by relative peak areas.

Phosphorus Content. The phosphorus content of the oils was determined according to the method adapted by Daun et al (1981) from the A.O.C.S. official method # Ca 12-55 (1977). The method involves ashing the sample in the presence of zinc oxide followed by colorometric measurement of phosphorus as molybdenum blue.

Sulfur Content. The sulfur content of the oils was determined by the Raney nickel catalyst method (Daun and Hougen, 1976) in which sulfur from the oil forms nickel sulfide; acidification liberates hydrogen sulfide, which is trapped in a receiving base (NaOH) and titrated with mercuric acetate to a colormetric endpoint using dithizone as indicator.

Cleaning of the Seed Samples

Machine Cleaning. Machine cleaning of the rapeseed samples was performed using a Carter Dockage Tester (Simon Day Ltd., Winnipeg). The tester machine allows for the shaking of the seed over and through a series of sieves while material of light weight is blown off by a stream of air. The sieves used were No. 4 (6/64 in.) round-hole and No. 2 (6x21) wire mesh sieves; the air was set midway at 5 on the tester scale. The coarse screenings were the material that did not pass through the round-hole sieve; the fine screenings were the material which passed through the wire mesh sieve; the air blown material was the material removed by the air stream; the cleaned rapeseed was the remaining sample free of the screenings and aspirated material. The removed portions were weighed.

Hand Sorting. Fine screenings samples were hand sorted for individual weed seed species, and rapeseed samples were hand sorted for inseparables, with further separation of the inseparable fraction into individual weed seed species, broken rapeseed, and sprouted rapeseed. Individual seeds were picked up with a seed aspirator. Initial assistance with seed identification was provided by the Grain Inspection Division of the Canadian Grain Commission. Identification of the weed seeds was by visual inspection aided by the use of a magnifying glass and a dissecting microscope. Quantitation of the removed material was done by weighing.

The sample size cleaned by hand sorting was 2.5 g for the fine screenings and Tower rapeseed from the POS Plant, 5 g for the crushing plant rapeseed samples, and 25 g for the cleaned rapeseed from the carlot survey samples.

Sieving. The weighed POS seed samples (approximately 24 g) were separated according to size on wire mesh sieves (U.S. Standard Sieve Series, Endecotts (Filters) Ltd., London, England) numbers 16 (1.19 mm opening), 20 (0.84 mm), 30 (0.59 mm), 40 (0.42 mm), 50 (0.297 mm), and 60 (0.25 mm). The material on each sieve was weighed and the seed species identified by visual recognition.

Washing. The samples of seed material from the POS Plant were washed in water to remove dirt. The dried (105°C air oven overnight), weighed seed sample was wrapped in cheesecloth and immersed in a beaker of room temperature water. The water was stirred for 30 min on a magnetic stirrer. The seed sample was dried as above. The cooled sample was weighed and the loss in weight, assumed to be due to removed dirt and water soluble substances was recorded.

Analysis of the Seed Samples

Oil Content. Two methods were used to determine the oil content of seeds in the present study: the Swedish steel tube method and the Goldfisch extraction method.

i) Swedish steel tube method. The weighed seed sample was shaken (200 rpm) in a stoppered steel tube containing 3 steel balls and 40 ml hexane for 2 hr according to the method of Troeng (1955). After allowing the solids to settle overnight, 20 ml of solution was removed and the solvent evaporated; the residual oil was weighed and the oil content calculated from this weight.

ii) Goldfisch extraction method. The oil content was determined by percolating petroleum ether through the ground dried sample overnight (A.O.C.S. official method # Ba 3-38, 1977) on a Goldfisch extraction apparatus.

Protein Content. The protein content of the seed samples was determined using the Kjeldahl method with titanium dioxide catalyst (Williams, 1973) when sufficient sample was available. When the sample size was less than 1 g the microKjeldahl method of Cocks and van Rede (1966) was used.

Glucosinolate Content. The glucosinolate content of the weed seed species was determined by gas chromatography of the trimethylsilyl (TMS) derivatives of the extracted glucosinolates according to the method of Daun and McGregor (1981) as adapted from Thies (1979) and Heaney and Fenwick (1980).

RESULTS AND DISCUSSION

The study of the dockage material was carried out in three parts, based on the origin of the material, thus representing different segments of the rapeseed or canola industry.

The first part consisted of the fine screenings oils and fine screenings seed samples obtained from the POS Pilot Plant. The oils were refined by laboratory techniques and analyzed for quality characteristics. The fine screenings seed samples, consisting of material removed from rapeseed by screening, were examined for seed composition and oil content.

The second part consisted of rapeseed samples received from six rapeseed crushing plants in western Canada. These samples, taken from the seed being fed into the crushing rolls, were hand-sorted for weed seed composition and some were analyzed for oil and protein contents. The major weed species removed from the samples were analyzed not only for oil and protein contents, but also for fatty acid and glucosinolate compositions.

The third part consisted of samples of rapeseed being moved within the Canadian grain industry and were sub-samples from the rail carlot survey of the Canadian Grain Commission. These samples were examined for seed composition only.

Oil Samples from the POS Pilot Plant

The procedures for refining a vegetable oil on a laboratory scale are designed to provide an estimation of the yield and quality of the oil which would be obtained when the seed is processed by a crushing

plant. The yield of oil or, conversely, the refining losses were of little concern in this project and, hence, were not determined. Emphasis was placed entirely on assessing the quality of the oils obtained at each refining step.

Refining of the Oil Samples

The oils were successively degummed with water, alkali refined with sodium hydroxide, bleached with activated bleaching earth and deodorized by steam distillation under vacuum. The analytical tests for quality were usually performed on the oils from each refining step.

The free fatty acid content of the degummed oils was determined prior to the alkali refining step to estimate the volume of alkali required to neutralize the free fatty acids. The results obtained did not differ substantially from those obtained in later determinations for the degummed oils and are included in the reported means for the free fatty acid analyses (cf. Table 3).

Analysis of the Oil Samples

The quality of the POS oils was assessed by determining several chemical properties of the crude and refined oils. These properties included moisture and volatile matter content, free fatty acid content, peroxide value, photometric color, chlorophyll content, fatty acid composition, and phosphorus and sulfur content. The number of samples analyzed for each chemical property is given in Table 1.

Moisture and Volatile Matter Content. Contents of moisture and volatile matter were determined for the crude oils only, since the first two refining steps of the crude oils involved addition of aqueous solutions to the oils.

Table 1. Number of POS oil samples analyzed.

Analytical Parameter	Stage of Oil Refinement					
	Crude	Degummed	Refined	Bleached	Deodorized	Ref.
Moisture and volatile matter	12	0	0	0	0	a
Free fatty acids	12	10	10	10	10	b
Peroxide value	12	10	10	10	10	c
Photometric color	0	0	0	10	10	d
Chlorophyll	12	10	10	10	0	e
Fatty acid composition	12	10	10	10	10	f
Phosphorus	12	10	10	10	10	g
Sulfur	12	0	0	0	6	h

a A.O.C.S. Ca 2c-25, 1977.
b A.O.C.S. Ca 5a-40, 1977.
c A.O.C.S. Cd 8-53, 1977.
d A.O.C.S. Cc 13c-50, 1977.
e A.O.C.S. Cc 13d-55, 1977.
f Hougen and Bodo, 1973.
g Daun, et al, 1981.
h Daun and Hougen, 1976.

The expeller oils showed little variation in moisture and volatile matter, ranging from 0.11 to 0.30% (Table 2), well within the 0.5% maximum standard allowed for crude rapeseed oil (Canadian Government Specifications Board, 1976). The extractor oils exceeded the allowed standard for moisture and volatile matter and showed considerable variation, ranging from 0.69% to 2.77%. No correlation appeared to exist between the values for the expeller and the extracted oils from the same seed. The values for the Tower oils were low for the expeller oil and intermediate for the extractor oil, compared to the values determined for the fine screenings oils.

The difference between the expeller and extractor oils could relate to their processing. An expelled oil is obtained by crushing the seed sample, heating it to reduce oil viscosity and then pressing the meal cake to force out the oil (Ward, 1976; Norris, 1964). The extracted oil is obtained from the meal by mixing the meal with a solvent such as hexane to dissolve the remaining oil out of the meal, followed by distillation to remove the solvent from the oil (Bernardini, 1976; Stein and Glaser, 1976; Norris, 1964). If there were a small amount of residual solvent in the extracted oil, it might be removed by this test for moisture and volatile matter and thus provide for a higher volatile matter value. The information received from the POS Pilot Plant regarding the procedures used to obtain the oils from the seed material indicated low values for residual solvent but moisture levels of 1% for Extractor oils A and B (Bell, J.M., POS Pilot Plant Corporation, Saskatoon, personal communication).

Free Fatty Acid Content. The free fatty acid content was determined for the crude oils and for the oils after each stage of the refining process (Table 3). The crude and degummed extractor oils had a higher

Table 2. Moisture and volatile matter content of the crude POS oils.

Sample	Moisture and Volatile Matter[a]	
	Expeller Oil	Extractor Oil
	(% by wt)	
Tower rapeseed	0.11	1.27
Fine scr. A	0.30	0.69
Fine scr. B	0.27	2.77
Fine scr. C	0.26	1.40
Fine scr. D	0.18	2.14
Fine scr. E	0.18	2.14

[a] Means of duplicate determinations. The values for the determinations varied by less than ±0.04 except for Tower extractor oil (±0.13).

Table 3. Free fatty acid content of the POS oils before and after refining.[a]

Sample	Stage of Refining				
	Crude	Degummed	Refined	Bleached	Deodorized
	(% as oleic acid)				
Expeller oils					
Tower rapeseed	0.42	0.43	0.14	0.35	0.35
Fine scr. A	11.01	[b]	[b]	[b]	[b]
Fine scr. B	5.47	[b]	[b]	[b]	[b]
Fine scr. C	3.68	3.69	0.18	0.33	0.34
Fine scr. D	2.90	2.92	0.22	0.38	0.39
Fine scr. E	3.18	3.18	0.24	0.34	0.37
Extractor oils					
Tower rapeseed	0.86	0.81	0.12	0.18	0.18
Fine scr. A	11.50	11.94	0.23	0.80	0.68
Fine scr. B	6.72	6.90	0.18	0.60	0.59
Fine scr. C	3.95	4.05	0.16	0.27	0.31
Fine scr. D	4.06	4.07	0.20	0.49	0.47
Fine scr. E	5.72	5.57	0.17	0.26	0.32

[a] Means of duplicate determinations except for the degummed samples which are the means of four determinations. The values for the determinations varied by less than ±0.06.

[b] Not refined.

free fatty acid content than the corresponding expeller oils whereas this was generally reversed for the neutralized, bleached, and deodorized oils with the expeller oils having a higher content.

The crude expeller oils contained somewhat less free fatty acids than the extractor oils from the same source. Values among all the samples ranged from a high of 11.50% (A extractor) to a low of 2.90% (D expeller) for the fine screenings oils. The Tower expeller and extractor oils were much lower than the fine screenings oils in free fatty acids, being the only oils within the 1.0% limit in the specifications for crude rapeseed oil (Canadian Government Specifications Board, 1976).

Only slight changes, if any, occurred at the degumming step of refining; the general trend was a small increase in the free fatty acid content of the oils. The Tower oils remained the only oils below the 1.0% standard limit for the free fatty acid content for crude degummed rapeseed oil. The free fatty acid content of the degummed oils was used to determine the amount of sodium hydroxide required in the alkali refining step to neutralize the fatty acids present.

The main effect on the free fatty acid content of the oils occurred with the alkali refining or neutralization step as expected. This procedure reduced the free fatty acids to less than 0.24% for all the samples. Due to the higher free fatty acid content of the fine screenings oils, relative to the Tower oils, more material was removed from the fine screenings oils by the neutralization step. This was apparent from the amount of oil remaining following this step, even without exact measurement. This is indicative of a high refining loss were these oils to be commercially refined.

The remaining refining steps had slight effects on the free fatty acid content of the oils. Bleaching raised the level slightly while deodorizing had almost no effect on the free fatty acid content. All oils exceeded the 0.05% maximum limit for free fatty acids in salad oils (Canadian Government Specifications Board, 1967a).

Peroxide Value. The peroxide values varied widely between samples at each stage of refining (Table 4). The values for the crude oils ranged from 4.7 to 78 milliequivalents per kilogram of oil. The values for the Tower expeller and extractor oils and the fine screenings A and E expeller oils were in agreement with values reported by Ismail et al (1980); the remaining were lower than the published values. The expeller crude oils were higher in peroxide value than the corresponding extractor oils except for Tower which showed no significant difference between expeller and extractor oil.

The peroxide value increased significantly from the crude to the degummed oils. For most samples the alkali refining step increased the peroxide value whereas all oils showed a decreased value after bleaching and a further reduction after deodorization. Even after deodorizing, however, the oils were high in peroxide value, the highest being 36 meq/kg for deodorized Tower expeller oil. Four of the six extractor oils and one expeller oil had peroxide values lower than the recommended international standard for edible rapeseed oil of not more than 10 meq peroxide oxygen per kg (Appelqvist and Ohlson, 1972). The Canadian Government Specifications Board standards for salad oil (1967a) and shortening (1967b) are 1.0 and 0.3 meq/kg, respectively, considerably lower than the international standard. Expeller and extractor oils from

Table 4. Peroxide value of the POS oils before and after refining.[a]

Sample	Stage of Refining				
	Crude	Degummed	Refined	Bleached	Deodorized
	(meq peroxide oxygen/kg)				
Expeller oils					
Tower rapeseed	5.6	94.4	107.1	64.6	36.0
Fine scr. A	28.7	[b]	[b]	[b]	[b]
Fine scr. B	78.0	[b]	[b]	[b]	[b]
Fine scr. C	38.7	123.7	137.4	75.6	14.3
Fine scr. D	16.8	31.5	69.7	12.8	3.6
Fine scr. E	12.4	178.1	121.2	78.5	31.4
Extractor oils					
Tower rapeseed	5.3	87.8	85.1	60.4	26.6
Fine scr. A	10.1	20.5	73.7	15.5	3.6
Fine scr. B	38.1	50.3	78.3	12.8	3.8
Fine scr. C	17.9	119.9	128.8	84.8	6.4
Fine scr. D	9.5	17.0	55.7	10.9	1.7
Fine scr. E	4.7	166.7	129.9	84.4	23.5

[a] Means of duplicate determinations. The values varied by less than ±0.94.

[b] Not refined.

Tower rapeseed and fine screenings E, and C expeller oil all exceeded the recommended standard.

The immediate history of the oil is important to know when assessing the meaning of the peroxide value (Cocks and van Rede, 1966). In the refining processes employed, Tower was the first oil treated, followed by fine screenings C and E oils. These oils remained at room temperature while the refining was being completed not only for these oils but also for A, B and D oils before analyses were undertaken. The Tower, C and E oils thus had more time during which autoxidation could occur as was indicated in the data where these oils showed a higher peroxide value than the A, B and D oils at each stage of processing. Expeller and extractor oils from the C material appeared to be more resistent to autoxidative processes judging by the lower peroxide value observed for the C oils as compared with the Tower and E oils.

Photometric Color. Before the photometric color test was performed on the oils, visual observations revealed the crude oils all to have a brown color, especially strong for the crude D oils. The Tower oils were the lightest in color as a yellow color could also be seen in them. The bleached and deodorized oils were much lighter, being pale yellow in color and quite clear, nearly transparent.

The photometric color of all oils was determined even though treatment with bleaching earth is required prior to the absorbance readings. Some wavelength readings of the oils exceeded the practical absorbance range of the spectrophotometer due to the brown color of the oils when the photometric color test was first tried. In fact all crude, degummed, and refined oils exceeded the practical range at 460 nm wavelength and most exceeded the limit at the 670 nm wavelength. The D oils exceeded

the limit for all wavelengths except for 710 nm. The oils were diluted with carbon tetrachloride by a factor of ten so that the readings could be made and the resultant color value was multiplied by the dilution factor. Crude, degummed and alkali refined D oils were diluted 100 times as well; the color value determined was slightly greater than with the 10 fold dilution. The ten-fold dilution color values were reported so that all photometric color values would be reported at the same dilution.

The crude, degummed and alkali refined oils were very dark in color but the Tower oils were lighter in color than the dockage oils. Degumming had a mixed effect on the color of the oils; some oils became lighter while others became darker. Alkali refining reduced the color in all the oils but only to a small extent. As expected, the color of all the oils was immensely reduced by the bleaching, with the greatest reduction occurring in the D extractor oil (Table 5). In the bleaching process there is a breaking of the pigment-oil colloid and a deposition of the pigments on the bleaching earth particles (Brimberg, 1982). Deodorization had little effect on the color, causing only slight increases or decreases. However, oils from the same fine screenings followed the same pattern in that both expeller and extractor oils E decreased in color with deodorization whereas both expeller and extractor oils C and D increased.

Chlorophyll Content. The chlorophyll content of the oils was determined for each stage of refining except for the deodorized oils (Table 6); the method is not applicable to deodorized oils (A.O.C.S. Official Method Cc 13d-55, 1977) due to a shift in the peak absorption of the chlorophyll during deodorization. The amount of chlorophyll

Table 5. Photometric color of the bleached and deodorized POS oils.[a]

Sample	Stage of Refining	
	Bleached	Deodorized
Expeller oils		
Tower rapeseed	0	0
Fine scr. A	b	b
Fine scr. B	b	b
Fine scr. C	3	6
Fine scr. D	4	4
Fine scr. E	1	0
Extractor oils		
Tower rapeseed	3	0
Fine scr. A	6	9
Fine scr. B	7	3
Fine scr. C	2	3
Fine scr. D	3	3
Fine scr. E	4	0

[a] All samples diluted by factor of 10 for spectrophotometric reading.
[b] Not refined.

Table 6. Chlorophyll content of the POS oils before and after refining.[a]

Sample	Stage of Refining			
	Crude	Degummed	Refined	Bleached
	(ppm)			
Expeller oils				
Tower rapeseed	14.5	12.2	7.6	0
Fine scr. A	54.1	c	c	c
Fine scr. B	90.6	c	c	c
Fine scr. C	30.3	28.6	13.1	0.20
Fine scr. D	269.7[b]	265.6[b]	224.1[b]	0.30
Fine scr. E	72.0	46.2	39.6	0.20
Extractor oils				
Tower rapeseed	14.3	14.6	9.5	0.20
Fine scr. A	56.3	53.8	36.2	0.20
Fine scr. B	88.8	90.7	72.2	0.10
Fine scr. C	37.7	36.2	26.0	0.04
Fine scr. D	293.6[b]	305.5[b]	263.0[b]	0.10
Fine scr. E	114.1[b]	97.0	76.9	0.50

[a] All samples were diluted by a factor of 10 for spectrophotometric reading, except where noted.
[b] Diluted by a factor of 100 for spectrophotometric reading.
[c] Not refined.

present in the crude samples ranged from 14.3 parts per million (ppm) for the Tower extractor oil to 293.6 ppm for the D extractor oil.

The D oils were the darkest colored oils, needing to be diluted 100 times before the absorbance reading was within the practical range of the spectrophotometer for the crude, degummed, and alkali refined samples. All other values were determined on a 10-fold dilution of the oil sample and the calculated chlorophyll content was multiplied by the appropriate dilution factor.

The expeller and extractor oils from the same source had similar chlorophyll contents, indicating no difference in the extent of chlorophyll removal from the seed effected by the expeller or the extractor method of oil extraction. Judging from the dark brown color of the oils, the chlorophyll measurements probably included pheophytins which have been reported to appear rapidly after oil extraction (Daun, 1982).

The chlorophyll contents showed a slight decrease upon degumming for most of the samples. Alkali refining lowered the content to some extent for every oil but significant amounts still remained. Bleaching reduced the chlorophyll content of every oil to 0.5 ppm or less. The largest reduction occurred in the D extractor oil for which the chlorophyll content dropped from 263 ppm to 0.1 ppm.

The Tower crude oils had a significantly lower chlorophyll content than the oils from the fine screenings. After bleaching, however, the fine screenings oils were comparable in chlorophyll content to the Tower oils, thus showing the effectiveness of the bleaching step.

Fatty Acid Composition. The fatty acid composition was determined for each oil at each stage of refining by gas chromatographic analysis of the methyl esters (Table 7). No significant differences were found

Table 7. Fatty acid composition of the POS oils.[a]

Fatty Acid	Oil Sample					
	Tower Rapeseed	Fine Screenings				
		A[b]	B[b]	C	D	E
			(%)			
Palmitic (16:0)	4.7	4.5	5.6	4.9	5.7	5.0
Stearic (18:0)	1.3	1.6	2.1	1.4	1.8	1.5
Oleic (18:1)	58.9	43.0	46.4	47.5	44.9	46.1
Linoleic (18:2)	21.8	24.1	26.4	23.3	27.9	23.8
Linolenic (18:3)	11.5	11.3	11.6	11.7	11.5	13.5
Eicosenoic (20:1)	1.5	4.3	2.6	3.4	2.8	3.2
Eicosadienoic (20:2)	0.1	0.5	0.3	0.4	0.3	0.2
Behenic (22:0)	0.3	0.5	0.6	0.4	0.5	0.4
Erucic (22:1)	0.1	9.9	4.1	7.1	4.4	6.3

[a] Means for expeller and extractor oil samples, including the samples after each stage of refining; duplicate injections. The standard deviations of the values are less than 0.8.

[b] The expeller crude oil was not refined.

in the fatty acid compositions at the various stages of the refining process. Furthermore, there were no significant differences in the fatty acid composition between the expelled and extracted oils from the same seed sources. The data reported in Table 7, therefore, are given as the means for the expelled and extracted oils, including the samples at all stages of refining.

The fatty acid compositions of the fine screenings oils were similar to that of Tower rapeseed oil except that Tower was higher in oleic acid and lower in the C20 and C22 acids, notably erucic. The Tower values agree with previously published values (Ackman and Sebedio, 1981). Palmitic, stearic, linolenic, eicosadienoic and behenic acids were present in similar amounts in the fine screenings oils and the Tower oils. The fine screenings oils had slightly higher percentages of linoleic and eicosenoic acids than the Tower oils. The greatest difference in the fatty acid composition was in the value for erucic acid. The Tower oil contained less than 0.1% of this fatty acid whereas the fine screenings oils contained from 4.1 to 9.9%. The oils from three fine screenings samples exceeded the 5.0% maximum standard for crude and crude degummed rapeseed oil (Canadian Government Specifications Board, 1976). The elevated erucic acid levels could result from the presence of small and damaged rapeseed (47%, cf. Table 24). Erucic acid containing weed seeds are present in only small amounts (cf. Tables 11 and 19).

Phosphorus Content. The phosphorus content, determined for the oils at all stages of refining, showed considerable variation between samples and for the same samples after the different refining steps (Table 8). The values for the crude oils ranged from 117.4 ppm phosphorus for Tower expeller oil to 1054 ppm for A extractor oil. The crude

Table 8. Phosphorus content of the POS oils before and after refining.[a]

Sample	Stage of Refining				
	Crude	Degummed	Refined	Bleached	Deodorized
			(ppm)		
Expeller oils					
Tower rapeseed	117	135	41.5	1.5	1.5
Fine scr. A	755	b	b	b	b
Fine scr. B	576	b	b	b	b
Fine scr. C	439	331	122	13.2	13.9
Fine scr. D	467	367	102	1.5	1.5
Fine scr. E	350	314	114	30.9	33.1
Extractor oils					
Tower rapeseed	693	104	17.9	1.5	1.5
Fine scr. A	1054	595	289	29.3	25.2
Fine scr. B	871	616	204	6.2	3.2
Fine scr. C	656	369	56.6	17.9	15.1
Fine scr. D	914	416	45.3	1.5	1.5
Fine scr. E	714	431	75.9	30.4	29.4

[a] Means of duplicate determinations. The values for the determinations varied by less than ±4.

[b] Not refined.

expelled oils from each source were much lower in phosphorus than the corresponding extractor oil. This was expected, due to the method of oil removal; expelling removes primarily the triglyceride oil whereas extracting removes nearly all the lipids including the phospholipids.

Degumming decreased the phosphorus content of all the oils except Tower expeller oil which showed an increase. This increase may have been due to the sampling technique for the crude oil. The general decrease in phosphorus upon degumming was expected due to the removal of phospholipids by the hydration procedure. Tower extractor oil showed the largest decrease by the removal of 85% of the phosphorus. The dockage oils all exceeded the 220 ppm maximum phosphorus content for crude degummed rapeseed oil (Canadian Government Specifications Board, 1976).

Alkali refining brought about a large reduction in the phosphorus content of all the oils, ranging from a 51% reduction in Extractor oil A to 89% in Extractor oil D. This reduction in phosphorus is in agreement with the reported general removal of phospholipids in the alkali refining step (Norris, 1964).

The bleaching step further greatly reduced the phosphorus content of the oils; four of the oils reached a phosphorus level of 1.5 ppm, which is an indication of an acceptable refining efficiency (Norris, 1964). No pattern emerged as reduction of the phosphorus content by the bleaching step ranged from 60% for E extractor oil to 97% for B extractor oil. Both the expeller and extractor oils from fine screenings E retained approximately 30 ppm of phosphorus, a higher value than the other oils, indicating the source of the phosphorus compounds may influence the removal of phosphorus from the oil. The C oils also

retained a high amount of phosphorus after bleaching. Curiously enough the C and E oils were the lowest in phosphorus content of the fine screenings crude oils, suggesting the presence in these samples of phosphorus compounds in close association with the oil throughout the processing. Crude extractor oil A, however, contained the highest phosphorus levels of all the oils but still contained a high level of phosphorus in the deodorized oil, perhaps due to saturation of the bleaching earth.

Deodorization of the oils had a mixed effect on the phosphorus content. The oils with very low phosphorus contents, the Tower and D oils, showed no change, whereas the extractor oils A, B and C decreased. The increase for expeller oils C and E is attributed to analytical error. Following all the processing steps, only the Tower and fine screenings D oils could be considered having been refined with an acceptable overall efficiency with regards to phosphorus.

Sulfur Content. The contents of sulfur were determined for all the crude oils and for six deodorized oils of which enough sample was available for duplicate determinations (Table 9). The extracted oils, both crude and deodorized, generally had a higher sulfur content than the corresponding expelled oils, as earlier reported (Daun and Hougen, 1976; Norris, 1964). The fine screenings oils, both crude and deodorized, had higher contents of sulfur than the Tower oils, indicating the presence of glucosinolate-containing seeds, possibly mustard or stinkweed in the fine screenings. Elevated sulfur contents could also result from the presence of damaged rapeseed, which would undergo more hydrolysis of glucosinolates to produce more oil soluble sulfur compounds.

Table 9. Sulfur content of the POS oils before and after refining.[a]

Sample	Stage of Refining	
	Crude	Deodorized
	(ppm)	
Expeller oils		
Tower rapeseed	2.8	1.7
Fine scr. A	13.2	[b]
Fine scr. B	12.7	[b]
Fine scr. C	11.1	[c]
Fine scr. D	12.6	2.6
Fine scr. E	12.8	[c]
Extractor oils		
Tower rapeseed	8.3	1.7
Fine scr. A	32.0	5.4
Fine scr. B	31.4	6.0
Fine scr. C	23.7	[c]
Fine scr. D	26.1	4.2
Fine scr. E	12.7	[c]

[a] Means of duplicate determinations. The values for the determinations varied by less than ± 1.4.
[b] Not refined.
[c] Not analyzed.

The refining process lowered the sulfur contents as indicated by the deodorized oil samples analyzed. The value for the deodorized Tower oils (1.7 ppm) was slightly higher than for high- and low-glucosinolate seed (Daun and Hougen, 1976), but well within the range reported by other authors (idem, ibid). The deodorized fine screenings oils had higher sulfur contents (2.6 to 6.0 ppm), which might effect a greater degree of catalyst deactivation if hydrogenation of rapeseed oil containing fine screenings oils were undertaken.

Seed Samples from the POS Pilot Plant

Samples of the seed material from the POS Pilot Plant were weighed out for hand-sorting of weed seeds, chaff, and damaged rapeseed. The Tower sample had been cleaned to an exceptionally low level of dockage. It was found to contain 98.4% whole sound rapeseed; the remaining 1.55%, the inseparables, was found to contain 1.4% broken rapeseed, and 0.15% of weed seeds consisting of wild buckwheat (0.1%), bluebur (0.04%) and lamb's quarters (.01%). When the fine screenings A sample was examined it was found to contain a large amount of apparently small broken pieces of rapeseed, and all the material was covered with a fine dirt layer which made seed identification very difficult, if not impossible, without cleaning the seed.

Sieve Cleaning

To circumvent this problem of the dirt covering all the material, the samples were separated according to seed size by shaking the samples through a number of U.S. Standard Sieves having progressively smaller meshes. For the Tower sample all the material remained on the screen having the largest size mesh, number 16, and by visual observation appeared to consist entirely of sound rapeseed. This would be expected since the possibility of finding three weed seeds in approximately 7500 seeds without carefully picking through them was very low. The fine screenings were smaller in size than the Tower rapeseed with only over half the material of the former retained on the number 16 and 20 sieves (Table 10).

The size 16 sieve retained all the larger particles such as small and shrunken rapeseed, large pieces of broken rapeseed, straw pieces, and large seeds of stinkweed, lamb's quarters and lady's thumb. The size

Table 10. Percentage (by weight) of material removed by U.S. Standard Sieves from the POS fine screenings.

Seed Sample	Sieve Number						
	16	20	30	40	50	60	through 60
Fine scr. A	8.5	44.6	21.2	10.7	6.3	1.8	6.9
Fine scr. B	20.5	52.7	15.3	6.4	3.4	0.8	0.9
Fine scr. C	27.8	53.0	11.1	5.1	2.2	0.5	0.4
Fine scr. D	54.5	42.9	2.5	0.1	0.04	0.04	0
Fine scr. E	46.6	36.5	9.9	3.6	1.9	0.5	0.8

20 sieve retained smaller sizes of material similar to the larger mesh as well as green foxtail seeds. Small stones first appeared on the size 30 sieve along with broken and shrunken rapeseed, lamb's quarters and straw. Sieves 40, 50, and 60 retained broken rapeseed, straw pieces and stones, with even smaller pieces of this material passing through the #60 sieve.

Fine screenings A contained a broad range of particle sizes, having 8.5% of the sample retained on the No. 16 sieve and 6.9% passing through the finest sieve. The most noticeable aspect of this sample was the fine dirt which covered all the material, becoming more pronounced with the finer mesh material. Fine screenings B contained much broken and shrunken rapeseed with stinkweed and lamb's quarters the most prevalent weed species. The B sample contained much less fine material with 0.9% passing through the finest sieve and more than 88% being retained by the first three sieves.

Samples C and E contained slightly larger sized material, 92% and 93%, respectively, being retained above sieve No. 30. The C sample was composed of the same type of material as was B. The E sample, in addition to the usual rapeseed, straw, stinkweed, and lamb's quarters, had a considerable amount of flax seed retained by the #16 sieve, and green foxtail retained by the #20 sieve.

Fine screenings D contained larger particle sizes; 54.5% of the material was retained by the #16 sieve, and over 97% was retained by the #16 and 20 sieves. In addition to small, broken and shrunken rapeseed the sample contained stinkweed, lamb's quarters, and lady's thumb.

Oil Content

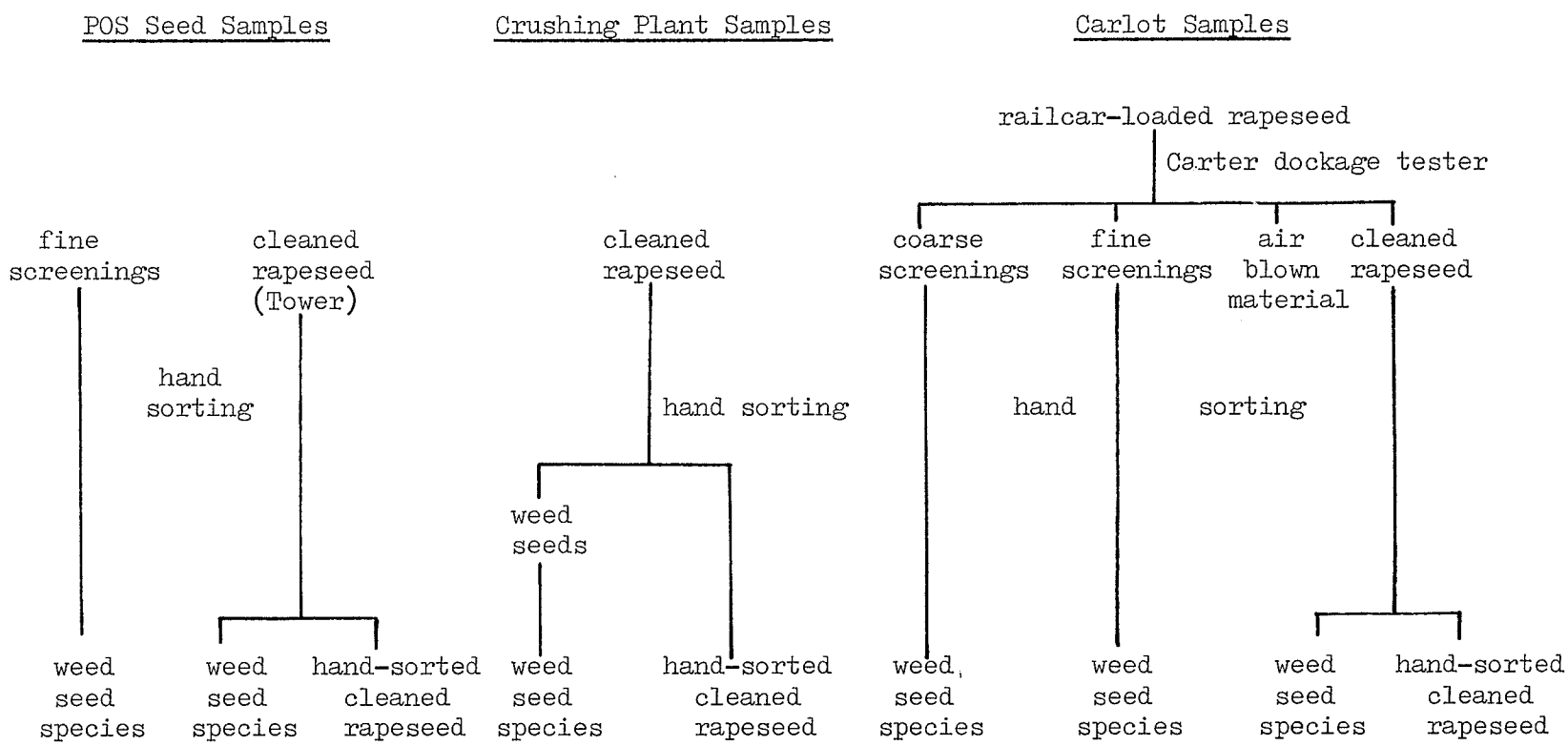
The oil contents of the fine screenings, determined by the Swedish steel tube method, were found to be considerably less than that of the Tower rapeseed. Three samples, C, D and E contained 32.6%, 31.0% and 30.7% oil, respectively. The A and B samples contained only 22.6% and 23.2% oil, respectively, less than half of the 49.2% oil content of the Tower sample. All but the value for the A sample were higher than the fat content in rapeseed screenings reported by Rebolledo et al (1980), and slightly higher than the oil contents reported by Ackman and Sebedio (1981).

Seed Composition

A summary of the cleaning treatments applied to the various seed samples is given in Figure 1. The sorting of the POS seed samples into individual weed species was hampered by the dirt present in the samples. In an attempt to clean the dirt from the fine screenings samples, each sample was soaked in water to wash the dirt from the seed material. However, the water would not only wash the dirt off the seeds but also dissolve water soluble compounds available to it. The amount of material separated by this procedure varied from 9.6% by weight of fine screenings A to 1.1% for the Tower sample. The other fine screenings samples had progressively smaller amounts of material removed by water treatment: 7.8%, 5.1%, 4.5% and 3.3% removed from B, C, D and E fine screenings, respectively.

The water color following the treatment varied with the samples. The Tower sample only made the water faint yellow in color and left it transparent. The water from samples C, D and E turned a darker yellow color but remained transparent. A yellow brown color was obtained from

Figure 1. Summary of the origin and cleaning of the seed samples.



the B seed sample, with the water becoming murky and less transparent. The water from the sample of fine screenings A was murky brown in color with only a tinge of yellow detectable.

The washed seed samples, hand sorted for separation of weed species, were found to be mostly rapeseed but with a considerable content of weed seeds (Table 11). The common and botanical names of the weed seeds identified in this study are given in Table 12. The amounts of weed seeds present varied greatly from 14.4% for dockage D to 32.8% for dockage C, a greater range than was reported by Ackman and Sebedio (1981).

Stinkweed and lamb's quarters were the most abundant weed species found in the POS fine screenings. Stinkweed ranged in composition from 0.1% for the E to 17.6% for the C sample. Lamb's quarters was less variable, ranging from 8.4% for D to 14.8% for fine screenings B. The only other seed species found in any great amount was green foxtail which made up 11.2% of fine screenings E. Other seeds encountered included flax (4.8%) and one kernel of wheat in the fine screenings E sample.

The proportions of the weed species present varied from the values previously reported for the same screenings materials (Ackman and Sebedio, 1981). The reason for the inconsistencies in the total weed seed values could lie in the method of seed sampling and the size of the seed sub-sample separated. In the present study, the sample was taken from the washed seed samples by intermittent removal of seed from the flow as the seed was poured from one vessel to another. The sample size separated by hand was limited to approximately 2.5 g for practical purposes.

Table 11. Percentage (by weight) of total and individual seed species in the washed POS fine screenings.

Seed Species	POS Fine Screenings				
	A	B	C	D	E
Weed species					
Stinkweed	16.2	4.4	17.6	3.8	0.1
Lamb's quarters	8.7	14.8	14.2	8.4	8.6
Lady's thumb	-	-	0.3	1.5	0.9
Green foxtail	-	0.1	0.5	0.2	11.2
Bluebur	-	0.1	-	-	-
Wild buckwheat	-	0.3	-	-	0.8
Canada thistle	-	-	0.2	0.2	0.1
Mustard	-	-	-	0.3	-
Other seeds					
Flax	-	-	-	-	4.8
Wheat	-	-	-	-	1.7
Total seeds	24.9	19.7	32.8	14.4	28.2
Rapeseed, straw, and debris	75.1	80.3	67.2	85.6	71.8

Table 12. Common and botanical names of weed species referred to in the present study.[a]

Common Name	Botanical Name
Stinkweed	Thlaspi arvense L.
Lamb's quarters	Chenopodium album L.
Lady's thumb	Polygonum persicaria L.
Green foxtail	Setaria viridis (L.) Beauv.
Wild buckwheat	Polygonum convolvulus L.
Hemp nettle	Galeopsis tetrahit L.
Cleavers	Galium aparine L.
Bluebur	Lappula echinata Gilib.
Canada thistle	Circium arvense (L.) Scop.

[a] Reference: Canada Weeds Committee, 1975; Frankton and Mulligan, 1970.

Considerable variation was reported not only in the amount of weed species present in the samples, but also in the amount of rapeseed present. Fine screenings A, C, D and E were reported to contain rapeseed of Brassica napus varieties amounting to 46.9, 24.6, 54.5, and 50.7%, respectively, whereas the B material contained 42.4% of Brassica campestris varieties (Ackman and Sebedio, 1981; Rebolledo et al, 1980). Inert material was also reported present in considerable quantity, ranging from 16.4 and 17% for D and E, through 31.6% for A and B, to 46.2% of C, suggesting contamination by soil. From the visual examination of the sieved samples, the fine screenings A appeared to be the most contaminated, probably due to the small size of the dirt. The other samples had small stones rather than powdered dirt as contamination.

Seed Samples from the Oilseed Crushing Plants

The fine screenings material received from the POS Pilot Plant was comprised of material screened out of rapeseed and was not indicative of the amounts present in rapeseed. To assess the amount of contamination of rapeseed by weed seeds, rapeseed samples were examined from six oilseed crushing plants for the weed species content and then the individual weed species were analyzed for their quality.

Seed Composition

The amounts of each weed species, as well as sprouted and broken kernels of rapeseed, hand sorted from the samples from six western Canadian oilseed crushing plants, were averaged for each set of ten or twelve samples to give an estimate of the inseparable components from each crushing plant (Table 13). The data for each sample are provided in Appendix A.

The total amounts of inseparables proved to be similar for the different crushing plant samples ranging from 4.85% for plant Y to 7.31% for plant W. The total amount of weed seeds for these samples ranged from 0.46% for plant Y to 2.57% for plant X.

Of the individual weed species, stinkweed, lamb's quarters, lady's thumb and wild buckwheat were present in significant amounts in most samples; green foxtail, hemp nettle and cleavers were in significant amounts in the samples from only one plant; and bluebur was found only in small amounts throughout. A small amount of mustard was found in all samples except for 0.26% in samples from plant Z. The values for unsound rapeseed ranged from 2.55% to 5.25%. The contents of broken rapeseed were one-half to one-third of the amount of sprouted rapeseed but this ratio could vary a great deal depending on the subjective decision on when to regard a seed to be sprouted.

Table 13. Mean percentage (by weight) of inseparables in the crushing plant samples.[a]

Seed Species	Oilseed Crushing Plant					
	U	V	W	X	Y	Z
Stinkweed	0.33	0.12	0.06	0.91	0.09	0.03
Lamb's quarters	0.20	0.17	0.14	0.84	0.05	0.11
Lady's thumb	0.15	0.16	0.14	0.03	0.02	0.39
Green foxtail	0.04	0.07	0.17	0	0.05	0.04
Hemp nettle	0.11	0.10	0.02	0.21	0	0.02
Bluebur	0.04	0.03	0.10	0.05	0.04	0
Cleavers	0.05	0.11	0.03	0.26	0.02	0.02
Wild buckwheat	0.27	0.06	0.19	0.12	0	0.06
Mustards	0.03	0.06	0.06	0.01	0.07	0.26
Others	0.48	0.26	0.44	0.14	0.12	0.02
Total weed seeds	1.70	1.14	2.06	2.57	0.46	0.95
Sprouted rapeseed	2.72	3.00	3.62	1.66	3.29	3.32
Broken rapeseed	1.78	1.11	1.63	0.89	1.10	0.95
Total unsound rapeseed	4.50	4.11	5.25	2.55	4.39	4.27
Total inseparables (weed seeds plus unsound rapeseed)	6.20	5.25	7.31	5.12	4.85	5.22

[a] Means of 10 samples for each plant (12 for plant V).

In order to assess the sampling error in the determination of seed compositions, ten sub-samples of sample V-2 were examined. The relative standard deviations from the mean ranged from 30% to 130% for the amounts present of the eight most prevalent weed species. This may seem excessive until it is taken into account that only one or two seeds of a weed species may have been found in a five-gram sub-sample; a variation in this amount of one or two seeds would be sufficient to cause this high standard deviation. The standard deviation could have been reduced if the sample had been larger, but this would not have been practical.

Analysis of the Inseparables

Two rapeseed samples tested showed a noticeable increase in oil content when the inseparables were removed. The samples from plants Y and Z showed increases of 1.08% and 1.43% in oil content, respectively, after removal of the weed seeds. This increase was statistically significant as can be seen in Tables 14 and 15.

The inseparables removed from the samples from crushing plants Y and Z had much lower oil and protein contents than the rapeseed samples (Table 16). Only one sample contained more than 30% oil and one sample contained only 11.2%. If this material of low oil content were mixed with sound rapeseed at levels exceeding 5%, the reduction in oil content of the entire sample would be readily apparent. The relatively low protein contents of the inseparables would tend to lower the nutritive value for an uncleaned rapeseed sample.

The fatty acid composition of the inseparables removed from the samples from plants Y and Z differed from that of Tower rapeseed (Table 17). Oleic acid was much lower in the inseparables, ranging

Table 14. Comparison of the oil content of the rapeseed samples from crushing plant Y before and after the removal of the inseparables by hand sorting.

Sample	Oil Content[a]		
	Before cleaning[b]	After cleaning[c]	Difference[d]
	(%)	(%)	
Y-1	45.45	45.86	0.41
Y-2	45.46	45.29	-0.17
Y-3	45.44	46.16	0.72
Y-4	44.63	46.76	2.13
Y-5	44.80	46.22	1.43
Y-6	44.26	45.61	1.35
Y-7	44.56	45.73	1.18
Y-8	44.23	45.71	1.48
Y-9	43.72	44.81	1.10
Y-10	44.19	45.33	1.15
Mean	44.67	45.75	1.08[e]
Std. dev.	0.61	0.55	0.63

[a] Dry basis.
[b] Mean of two determinations; range of variation: 0.01-0.11, mean range: 0.055.
[c] Single determination.
[d] After cleaning minus before cleaning.
[e] The difference is significant at a 99.9% confidence level. The t-variable of $t = \frac{\bar{d}}{s/\sqrt{n}} = 5.42$.

Table 15. Comparison of the oil content of the rapeseed samples from crushing plant Z before and after the removal of the inseparables by hand sorting.

Sample	Oil Content[a]		
	Before cleaning[b]	After cleaning[c]	Difference[d]
	(%)	(%)	
Z-1	45.13	46.93	1.80
Z-2	44.86	45.88	1.03
Z-3	45.38	45.84	0.46
Z-4	45.28	46.87	1.60
Z-5	45.04	46.89	1.86
Z-6	45.10	47.07	1.98
Z-7	45.29	46.71	1.42
Z-8	45.09	46.63	1.54
Z-9	45.12	46.28	1.16
Z-10	45.18	46.69	1.52
Mean	45.14	46.58	1.43[e]
Std. dev.	0.05	0.43	0.45

[a] Dry basis.
[b] Mean of two determinations; range of variation: 0.01-0.23, mean range: 0.097.
[c] Single determination.
[d] After cleaning minus before cleaning.
[e] The difference is significant at a 99.9% confidence level. The t-variable of $t = \frac{\bar{d}}{s/\sqrt{n}} = 10.05$.

Table 16. Oil and protein contents of the inseparables removed from rapeseed samples of crushing plants Y and Z.

Sample	Oil Content	Protein Content
	(% dry weight)	(%)[a]
Inseparables Y		
Y-1	23.7	[b]
Y-2	16.9	[b]
Y-3	29.4	[b]
Y-4	23.0	20.1
Y-5	21.4	[b]
Y-6	17.4	18.8
Y-7	19.5	[b]
Y-8	28.8	[b]
Y-9	34.9	[b]
Y-10	11.2	17.4
Rapeseed Y	45.8[c]	40.6[d]
Inseparables Z		
Z-1	12.7	17.9
Z-2	17.6	[b]
Z-3	12.6	20.1
Z-4	20.0	21.1
Z-5	22.2	18.5
Z-6	16.6	17.9
Z-7	15.4	18.0
Z-8	22.9	21.1
Z-9	20.0	19.0
Z-10	16.8	18.2
Rapeseed Z	46.6[c]	39.6[d]

[a] N x 6.25, % of oil free meal, dry weight.
[b] Not analyzed due to lack of sample.
[c] Mean of 10 cleaned samples.
[d] Mean of 10 samples, as received, no cleaning, N x 5.7.

Table 17. Fatty acid composition for the inseparables removed from the samples of crushing plants Y and Z and for Tower rapeseed oil.[a]

Sample	Fatty Acids						
	16:0	18:0	18:1	18:2	18:3+20:1	20:2	22:1
			(%)				
Inseparables							
Y-1	4.6	1.8	32.2	24.4	30.2	0	4.2
Y-2	3.1	0.3	13.8	25.3	22.3	1.9	24.9
Y-3	3.1	0.7	26.2	22.7	21.2	2.5	18.8
Y-4	4.6	1.0	17.5	19.7	24.4	8.4	13.3
Y-5	3.8	1.0	27.8	23.2	19.8	3.9	12.2
Y-6	4.4	0.8	17.9	31.6	13.3	2.1	23.5
Y-7	3.8	1.6	40.9	30.8	12.7	0.7	6.0
Y-8	3.4	1.1	31.3	23.7	19.7	2.0	14.6
Y-9	3.8	1.8	20.8	20.5	36.3	1.7	11.5
Y-10	5.4	1.2	29.0	26.3	19.3	5.5	4.4
Z-1	4.4	1.3	41.1	27.9	18.0	0.6	3.0
Z-2	3.1	0.9	21.0	20.0	16.3	20.2	6.6
Z-3	4.0	1.0	29.5	29.4	19.0	1.2	9.1
Z-4	3.6	1.0	30.3	28.3	22.0	0.7	10.6
Z-5	3.7	1.1	35.8	27.2	20.8	1.2	6.2
Z-6	4.2	1.1	38.7	26.8	17.2	0.5	8.6
Z-7	5.0	1.1	40.2	27.4	15.1	0.6	6.8
Z-8	4.0	1.4	44.2	25.2	17.9	0.4	4.0
Z-9	3.8	1.2	40.1	23.8	20.1	0.5	6.1
Z-10	3.8	1.0	29.8	32.4	22.4	0.7	5.9
Tower rapeseed oil[b]	4.7	1.3	58.9	21.8	13.0	0.1	0.1

[a] Means of duplicate determinations.
[b] From Table 7.

from 13.8% for sample Y-2 to 44.2% for sample Z-8 as compared to 58.9% for Tower rapeseed. Linolenic and eicosenoic acids, not separated by the DEGS column, were present in larger proportions than in Tower (13.0%). The inseparables removed from the plant Y samples averaged 21.9% for the content of linolenic and eicosenoic acids combined, ranging from 12.7% (Y-7) to 36.3% (Y-9). The inseparables from the Z plant samples averaged 18.9% for the two fatty acids and ranged from 15.1% (Z-7) to 22.4% (Z-10). A large difference also occurred between Tower rapeseed and the inseparables in the amount of erucic acid. The content in the Tower oil was negligible, less than 0.1% erucic acid, but the plant Y and Z samples averaged 13.3 and 6.7%, respectively. The plant Y samples ranged from 4.2 to 24.9% erucic acid whereas the plant Z samples had a narrower range of 3.0 to 10.6%. One sample, Z-2, contained 20.2% eicosadienoic acid while the remainder were much lower in this fatty acid. Sufficient sample was not available to later verify this unusually high value by repeated analysis.

Analysis of the Weed Species

The eight most prevalent weed species encountered in the crushing plant samples were analyzed for oil and protein contents to determine their contribution to the composition of the inseparables. The crushing plant samples, used as a source of weed seeds, were hand sorted to obtain the individual weed species samples. The oil content revealed high levels of oil in stinkweed, hemp nettle and bluebur (Table 18). Cleavers had a moderate level of 21.6%, while the remaining four species contained less than 10% oil. The values reported were in agreement with previously reported values for lamb's quarters, green foxtail, and wild buckwheat (Daun and Tkachuk, 1976; Schroeder et al, 1974; Tkachuk and Mellish, 1977).

Table 18. Oil and protein content of the major weed seed species.[a]

Weed Species	Oil Content[b]	Protein Content[c]
	(%)	(%)
Stinkweed	35.5	20.8
Lamb's quarters	9.0	14.6
Lady's thumb	4.1	10.4
Green foxtail	5.9	16.3
Hemp nettle	36.1	18.8
Bluebur	31.1	17.2
Cleavers	21.6	13.2
Wild buckwheat	2.0	12.1

[a] Dry weight basis.
[b] Mean of duplicate determinations.
[c] Protein as N x 6.25; single determination.

The value for stinkweed, 35.5%, was in agreement with Tkachuk and Mellish, but was considerably higher than the value reported by Schroeder et al. During industrial oil extraction, the weeds with higher oil contents would have little effect, but the species of low oil content would tend to absorb oil from the rapeseed during the expelling stage and release it during solvent extraction.

The protein content, determined by the Kjeldahl procedure showed less variation than the oil content, and ranged from 10.4 to 20.8% (Table 18). The value for green foxtail, 16.3%, is in agreement with reported values corrected for moisture and nitrogen factor (Schroeder et al, 1974; Tkachuk and Mellish, 1977). The values for stinkweed and lamb's quarters were lower than reported by Tkachuk and Mellish, whose values again were considerably lower than the values reported by Schroeder et al. Wild buckwheat was found to have a higher protein content than previously reported. Stinkweed, lamb's quarters, and wild buckwheat have been reported to show excellent essential amino acid balance and, except for the presence of toxic substances in stinkweed, to hold possibilities of serving as nutritious food or feed material (Tkachuk and Mellish, 1977). Green foxtail was reported to have the poorest balance of essential amino acids.

The eight major weed seed species differed widely in their fatty acid compositions (Table 19). The ranges for the various fatty acids were palmitic, 3.2 to 9.7%; stearic, 0.1 to 1.7%; oleic, 9.8 to 43.6%; linoleic, 17.1 to 57.5%; linolenic, 6.5 to 36.9%; arachidic, trace amounts to 17.2%; eicosenoic, 0.2 to 9.6%; and erucic, trace amounts to 40.1%. The high linolenic acid content of hemp nettle (22.9%), bluebur (34.9%) and cleavers (36.9%) may lead to oxidative products in

Table 19. Fatty acid composition for the major weed seed species and Tower rapeseed oil.[a]

Sample	Fatty Acid Composition							
	16:0	18:0	18:1	18:2	18:3	20:0	20:1	22:1
				(%)				
Stinkweed	3.2	0.1	9.8	21.1	13.4	[b]	9.6	40.1
Lamb's quarters	8.8	1.0	25.4	49.3	11.0	[b]	0.8	2.4
Lady's thumb	6.7	1.7	25.4	41.3	6.5	[b]	2.6	7.3
Green foxtail	4.5	1.3	18.0	57.5	15.3	[b]	0.7	[b]
Hemp nettle	4.4	0.6	18.5	53.1	22.9	[b]	0.2	[b]
Bluebur	7.3	1.5	15.5	17.1	34.9	17.2	0.6	[b]
Cleavers	3.7	0.8	14.2	17.6	36.9	14.9	2.2	7.9
Wild buckwheat	9.7	0.9	43.6	36.2	6.8	[b]	1.4	0.8
Tower rapeseed oil	4.7	1.3	58.9	21.8	11.5	[b]	1.5	[b]

[a] Mean values of duplicate determinations.
[b] Trace amount.

the fatty acids and poor stability in the oils. The erucic acid found in several weed species, stinkweed (40.1%), cleavers (7.9%), and lady's thumb (7.3%), would cause an elevated erucic acid level in the rapeseed oil. Bluebur and cleavers contained arachidic acid at levels of 17.2 and 14.9%, respectively, in marked contrast to the trace levels of the other weed species and Tower rapeseed.

The results of the fatty acid analyses compared favorably with previously reported values (Daun and Tkachuk, 1976), although some variation was seen in the oleic, linoleic and linolenic values for lamb's quarters and green foxtail.

The presence in the rapeseed samples of weed seeds with appreciable contents of erucic acid would nevertheless not greatly influence the total erucic acid content of the rapeseed sample. Thus, the maximum contamination of the rapeseed samples observed in this study, with 0.91% stinkweed of 40.1% erucic acid content, plus 0.39% lady's thumb of 7.3% erucic acid (cf. Tables 13 and 19), would contribute an extra erucic acid content to the sample of merely (0.91 x 40.1 x 0.01 + 0.39 x 7.3 x 0.01)% = 0.39% erucic acid. Similarly, the presence in the rapeseed samples of weed seeds with appreciable contents of linolenic acid would not greatly influence the total linolenic acid content of the rapeseed sample, and thus will not *per se* contribute appreciably to the oxidative instability of the sample. Thus, the maximum contamination of the rapeseed with weed seeds observed in this study would contribute an extra content of linolenic acid to the sample as follows:

stinkweed	(13.4 x 0.91) x 0.01 = 0.1219
lamb's quarters	(11.0 x 0.84) x 0.01 = 0.0924
lady's thumb	(6.5 x 0.39) x 0.01 = 0.0254

green foxtail	(15.3 x 0.17) x 0.01 = 0.0260
hemp nettle	(22.9 x 0.21) x 0.01 = 0.0481
bluebur	(34.9 x 0.10) x 0.01 = 0.0349
cleavers	(36.9 x 0.26) x 0.01 = 0.0959
wild buckwheat	(6.8 x 0.27) x 0.01 = 0.0184
Total contamination:	0.4630% linolenic acid

The presence of glucosinolate compounds, the major hindrance to the more abundant use of rapeseed meal as a protein supplement source in animal feeds, was detected in only two of the weed species (Table 20). Lamb's quarters, lady's thumb, green foxtail, hemp nettle, bluebur and wild buckwheat all contained no detectable amounts of any sulfur compound of this nature. Stinkweed contained a large amount of allyl glucosinolate or sinigrin, determined to be 200 µmoles per gram using benzyl glucosinolate as the internal standard (Daun, personal communication). Differences in the glucosinolate content of the two Tower rapeseed samples were found. One sample, obtained from the POS Pilot Plant along with the fine screenings material contained 33 µmoles per gram, nearly 9 µmoles more than the Tower sample usually included as a check sample in the analyses. This would imply that the homogeneity of the Tower rapeseed with regards to glucosinolate content was not as good as would be desired. The major difference in quantities of glucosinolates in the two Tower samples was in the 2-hydroxy-3-butenyl glucosinolate.

The identification of glucosinolate compounds in cleavers is unusual, suggesting contamination of the seed sample. Analysis of a cleavers sample picked by Plant Products Division of the Canadian Department of Agriculture revealed no glucosinolate compounds (Daun, 1982, personal communication).

Table 20. Glucosinolate contents for the major weed seed species and Tower rapeseed.[a]

Glucosinolate	Sample			
	Stinkweed	Cleavers	Tower[b]	Tower[c]
		(μm/g)		
3-Butenyl-	0	0.1	5.7	5.4
4-Pentenyl-	0	0.2	1.1	0.3
2-Hydroxy-3-Butenyl-	0	0.3	17.6	9.5
2-Hydroxy-4-Pentenyl-	0	0	0.7	0.1
Subtotal	0	0.6	25.1	15.3
3-Indolymethyl-	0	0	0.6	0.7
1-Methoxy-3-Indolylmethyl-	0	0	7.3	8.3
Allyl-	200[d]	0	0	0
Total	200	0.6	33.0	24.3

[a] Defatted, moisture-free meal.
[b] Sample received from the POS Pilot Plant.
[c] Check sample normally included with analyses.
[d] Daun, J.K., personal communication.

Seed Samples from the Rapeseed Carlot Survey

The seed samples discussed so far, the POS fine screenings and the crushing plant samples, were not representative of the rapeseed crop as customarily encountered. The POS fine screenings consisted of small seeds, chiefly broken rapeseed, stinkweed and lamb's quarters. The crushing plant samples on the other hand were cleaned rapeseed consisting mostly of rapeseed with little extraneous material. To fill in the gap between these two extremes, samples of rapeseed transported by the grain handling system were cleaned using sieves and then hand sorted to assess the amount of total dockage present including the amounts removed in each fraction.

Dockage Fractions of the Rapeseed Carlot Survey Samples

The samples were first separated by a Carter Dockage Tester into four categories. Material that would not pass through the round hole sieve, the course screenings, was separated as was material which could be removed by a stream of air. The cleaned rapeseed was collected after passing over the wire mesh sieve, the material small enough to fall through this screen, the fine screenings, was also collected. A sub-sample of the cleaned rapeseed was then hand sorted to remove the remaining inseparable weed seeds.

The coarse and fine screenings and the air blown material varied in quantity ranging from 0.17 to 23.5%. Data for each carlot sample are given in Appendix B. A summary of the data for the three prairie provinces was prepared (Table 21). Manitoba contained the least amount of separable material (total screenings) followed by Saskatchewan and Alberta, in that order. Prior to being loaded, some of the carlot samples, judging by the amount of screenings removed, had been cleaned which was

Table 21. Mean percentages (by weight) of all dockage fractions removed from the rapeseed carlot survey samples.[a]

Dockage Components	Carlot Samples		
	Manitoba	Saskatchewan	Alberta
		(% (std. dev.))	
Coarse screenings	1.10 (1.80)	2.40 (2.50)	3.90 (3.10)
Air blown material	1.50 (1.80)	1.80 (1.10)	3.60 (1.40)
Fine screenings	0.80 (1.20)	0.80 (0.60)	2.20 (1.10)
Total screenings	3.40	5.00	9.70
Inseparables	1.63	0.88	1.08
Total dockage[b]	5.03 (5.40)	5.88 (3.60)	10.78 (4.90)
Weed seeds[c]			
Stinkweed	0.01 (0.01)	0.15 (0.18)	0.79 (0.88)
Lamb's quarters	0.26 (0.43)	0.35 (0.38)	1.16 (1.02)
Lady's thumb	0.63 (1.10)	0.07 (0.20)	0.10 (0.14)
Green foxtail	0.34 (0.23)	0.09 (0.21)	0.07 (0.16)
Hemp nettle	0.01 (0.02)	0.02 (0.05)	0.06 (0.09)
Bluebur	0.01 (0.01)	0.02 (0.02)	0.03 (0.04)
Cleavers	0.01 (0.01)	0.02 (0.03)	0.10 (0.12)
Wild buckwheat	0.07 (0.10)	0.11 (0.14)	0.22 (0.18)
Mustards	0.99 (0.91)	0.60 (0.70)	0.21 (0.38)
Wild oats	0.30 (0.48)	1.04 (1.30)	0.96 (1.15)
Total weed species	2.63	2.38	3.70
Other seeds			
Rapeseed and chaff[d]	0.44 (0.75)	0.71 (0.50)	1.07 (0.31)
Wheat[c]	0.38 (0.60)	0.84 (1.30)	2.22 (2.21)
Flax[c]	0.01 (0.02)	0.02 (0.04)	0.02 (0.04)
Total other seeds	0.83	1.57	3.31

[a] Means, by province, of 6 samples for Manitoba, 22 samples for Saskatchewan, and 21 samples for Alberta.
[b] Coarse screenings and fine screenings and air blown material and inseparables.
[c] From coarse screenings, fine screenings, and inseparable material hand sorted from the cleaned rapeseed (not air blown material).
[d] From coarse and fine screenings.

not considered in the table. Omitting these presumably precleaned samples from the means, the total screenings removed was raised to 9.4% for Manitoba, 7.1% for Saskatchewan, and 10.1% for Alberta rapeseed. Considering the range of values within each provincial grouping, reflected in the large standard deviations, the amounts of total screenings were similar according to geographical location.

The weed species, sorted from the coarse and fine screenings as well as from a subsample of cleaned rapeseed, were combined for the total content of each species (Table 21). Other seeds (cf. Table 21) were similarly sorted from all the dockage fractions and combined. Stinkweed was most evident in the samples from Alberta (0.79%) while Manitoba had almost none. Lamb's quarters was found in all the areas but Alberta had the highest mean value. Lady's thumb and green foxtail were most abundant in the Manitoba samples. Mustards were found in most of the samples, the highest amount from the Manitoba samples. Wild oats were also found in samples from all three provinces. The other weed species found were usually present in small amounts only. Again the high standard deviations reflect the variability among the samples.

Seed Composition of the Fine Screenings

The variability among samples was also seen among the fine screenings from the carlot samples (Table 22). Fine screening samples from Alberta tended to contain more weed material (63.8%) than the more eastern provinces. The Alberta total was comprised of stinkweed (29.9%) and lamb's quarters (30.2%) as well as small amounts of lady's thumb and green foxtail. Manitoba contained the highest percentage of lady's thumb (12.6%) and green foxtail (16.4%), while the Saskatchewan mean percentages were between the Alberta and Manitoba values. The other

Table 22. Mean percentage of the seed species in the rapeseed carlot fine screenings.[a]

Seed Species	Carlot Samples		
	Manitoba	Saskatchewan	Alberta
		(% (std. dev.))	
Weed seeds			
Stinkweed	2.7 (3.1)	14.4 (16.1)	29.9 (18.7)
Lamb's quarters	12.7 (15.2)	20.8 (18.1)	30.2 (17.9)
Lady's thumb	12.6 (16.3)	4.8 (14.5)	1.5 (2.1)
Green foxtail	16.4 (14.3)	4.7 (7.2)	2.2 (4.5)
Hemp nettle	0.0	0.0	0.0
Bluebur	0.0	0.0	0.0
Cleavers	0.0	0.0	0.0
Wild buckwheat	0.0	0.0	0.0
Total weed seeds	44.4	44.7	63.8
Other seeds			
Rapeseed and chaff	50.8 (23.1)	55.1 (25.0)	35.3 (18.5)
Flax	3.2 (7.6)	0.1 (0.6)	0.0

[a] Means, by province, of 6 samples for Manitoba, 22 samples for Saskatchewan, and 21 samples for Alberta.

four weed species occurred only in minute amounts in all three provinces. Despite the variability, however, the amount of stinkweed found in the Alberta samples was significantly higher than that for the Manitoba samples.

Seed Composition of the Inseparables

Great variability was also found in the percentages of inseparables hand sorted from the cleaned rapeseed of the carlot samples (Table 23). In most cases the standard deviation was in excess of the mean percentage. The total inseparables were highest for the samples from Manitoba followed by the Alberta and Saskatchewan samples in that order. The inseparables of the Manitoba total were comprised mainly of mustard seeds (1.04%), green foxtail (0.30%), and lady's thumb (0.20%); the Saskatchewan total was comprised mainly of mustard seeds (0.61%) and lamb's quarters (0.11%); and the Alberta total was comprised mainly of lamb's quarters (0.46%), stinkweed (0.12%), and cleavers (0.11%).

Table 23. Mean percentage of the inseparable seed species hand sorted from the cleaned rapeseed of the rapeseed carlot survey samples.[a]

Seed Species	Carlot Samples		
	Manitoba	Saskatchewan	Alberta
		(% (std. dev.))	
Weed seeds			
Stinkweed	0	0	0.12 (0.19)
Lamb's quarters	0.05 (0.07)	0.11 (0.12)	0.46 (0.54)
Lady's thumb	0.20 (0.30)	0.03 (0.09)	0.06 (0.08)
Green foxtail	0.30 (0.21)	0.06 (0.13)	0.03 (0.07)
Hemp nettle	0.01 (0.02)	0.01 (0.04)	0.04 (0.06)
Bluebur	0	0.01 (0.02)	0.01 (0.03)
Cleavers	0.01 (0.01)	0.01 (0.03)	0.11 (0.13)
Wild buckwheat	0.01 (0.01)	0.01 (0.01)	0
Mustards	1.04 (0.96)	0.61 (0.71)	0.23 (0.44)
Total weed seeds	1.62	0.85	1.06
Other seeds			
Flax	0.01 (0.02)	0.01 (0.02)	0.01 (0.02)
Wheat	0	0.02 (0.04)	0.01 (0.03)

[a] Means, by province, of 6 samples for Manitoba, 22 samples for Saskatchewan, and 21 samples for Alberta.

GENERAL DISCUSSION

Of the three main objectives outlined in the introduction, all completed, the first two have been discussed in the previous chapter: the quality properties of the POS fine screenings oils have been assessed by chemical and physical analyses. As well, the botanical compositions of the various fine screenings and inseparable fractions from the POS Pilot Plant, crushing plants and carlot samples have been determined. The third objective, remaining to be discussed in the present chapter, is the evaluation of the degree of similarity between the fine screenings samples and the inseparable samples. This comparison should establish if the conclusions from the nutritional and chemical studies of the POS fine screenings and oils may be assumed to be valid also for the (POS) inseparable dockage and its extractable oil (i.e., the samples that were unavailable for examination). It is the inseparable dockage, not the fine screenings, that inadvertantly and invariably is included in the rapeseed processed for food and feed.

The degree of similarity will be examined by first comparing the POS and carlot fine screenings, then comparing the crushing plant and carlot inseparables, and finally comparing the fine screenings with the inseparables.

Similarities between the Fine Screenings

The POS fine screenings were composed of material smaller than the Tower rapeseed sample, chiefly broken rapeseed as well as high amounts of weed species (cf. Table 11). Unfortunately, the POS dockage samples

were limited to the fine screenings material; no samples or other information were available concerning the inseparable dockage remaining in the cleaned rapeseed.

The rapeseed carlot survey samples, cleaned by the dockage tester, were separated into classifications of fine screenings and inseparable dockage, which could subsequently be compared with the POS fine screenings and the crushing plant inseparables, with respect to composition and total amounts.

The fine screenings from the carlot samples (1.27%) contained an average of 51% weed seeds, the remaining 49% being mainly small and broken rapeseed which had also passed through the fine screen used (cf. Table 22 and 24). The POS fine screenings contained, on the average, 24% weed seeds, 29% inert material (Ackman and Sebedio, 1981), and 47% rapeseed material (cf. Table 11 and 24), close to the value for rapeseed in the carlot fine screenings. Comparing only the weed species and not including the inert material and rapeseed present in the samples, the composition of the four most abundant weed species was found to be similar for the POS and the carlot fine screenings (Table 25). From these resemblances, with respect to weed seeds composition as well as total fine screenings composition, it may be concluded that the fine screenings from the carlot samples and the POS samples show a fair degree of similarity.

Similarities between the Inseparables

A comparison of the total content of inseparables in the rapeseed from the crushing plant and carlot samples was not feasible, as the rapeseed component of the carlot inseparables was not sorted from the cleaned rapeseed samples; thus, there is no estimate of the amount of

Table 24. Summary of approximate mean dockage quantities.

Dockage fraction	Samples		
	POS	Crushing plants	Carlots
Fine screenings			
Content in rapeseed (%)	NS[a]	NS	1.27[b]
Gross composition (%)		NS	
Weed seed[c]	24[d]		51[e]
Rapeseed	47[d]		49[e]
Inert material	29[d]		
Inseparables			
Content in rapeseed (%)	NS	5.66[f]	1.18[g]
Gross composition (%)	NS		NS[a,g]
Weed seed[c]		25[h]	
Rapeseed		71[h]	
Other		5[h]	

[a] No sample available.
[b] cf. Table 21.
[c] For detailed composition of weed seed fractions, see Tables 25 and 26.
[d] cf. Table 11.
[e] cf. Table 22.
[f] i.e., 1.48% weed seeds and 4.18% rapeseed, cf. Table 13.
[g] Weed seeds only (cf. Table 23); the rapeseed component of the inseparables was not measured.
[h] cf. Table 13.

Table 25. Mean composition of the weed seed fraction of the POS fine screenings and the rapeseed carlot fine screenings.[a]

Weed Species	POS Fine Screenings[b]			Rapeseed Carlot Fine Screenings[c]		
	Mean	(std.dev.)	Range	Mean	(std.dev.)	Range
Stinkweed	33.6	(29.9)	0.4-65.1	28.4	(20.7)	6.1-46.9
Lamb's quarters	48.4	(18.3)	30.5-75.1	40.8	(10.6)	28.6-47.3
Lady's thumb	2.9	(4.4)	0 -10.4	13.8	(13.3)	2.4-28.4
Green foxtail	8.6	(17.4)	0 -39.7	16.9	(17.7)	3.4-36.9

[a] Percent of total weed species in the fraction, excluding the rapeseed and other material present.
[b] Mean for samples A-E, cf. Table 11.
[c] Mean for Manitoba, Saskatchewan, and Alberta samples, cf. Table 22.

rapeseed in the carlot inseparables. A comparison can be made, however, of the weed seed component of the inseparables from the same two sources (Table 24). The amount of weed seed inseparables was 1.48% for the crushing plant samples and 1.18% for the carlot samples. Similarly, a comparison of the gross composition of the inseparables was not feasible (cf. Table 24), as the rapeseed component for the carlot inseparables was not determined.

The weed species compositions of the crushing plant inseparables (cf. Table 13) and the rapeseed carlot inseparables (cf. Table 23) were similar (Table 26). Although the mean total weed seeds was somewhat greater for the crushing plants, the mean amounts of individual weed seed species were very similar for the two sets of samples, with two exceptions. The crushing plant samples contained 0.3% of stinkweed whereas the carlot samples contained only 0.04% of this weed. A larger difference occurred in the mustard contents of the samples. The carlot samples contained 0.6% mustard seeds whereas the crushing plant samples contained only 0.08%. This difference could partly be due to greater experience when the carlot samples were hand sorted. The species of weed seeds identified in the two sets of rapeseed inseparables were the same. From the above comparisons, it may be concluded that the inseparables from the crushing plant and carlot samples show a fair degree of similarity.

Similarities between the Fine Screenings and Inseparables

In comparing the fine screenings fractions with the inseparable fractions, it can be seen (Table 24) that the content of these fractions in rapeseed differed, mainly in that the weed seed component of the inseparables was present in about twice the amount (1.48% and 1.18%) of

Table 26. Mean percentages of the inseparable weed species hand sorted from the crushing plant samples and the carlot cleaned rapeseed samples.[a]

Weed Seed Species	Crushing Plant Inseparables[b]			Rapeseed Carlot Inseparables[c]		
	Mean	(std.dev.)	Range	Mean	(std.dev.)	Range
Stinkweed	0.26	(0.34)	0.03-0.91	0.04	(0.07)	0 -0.12
Lamb's quarters	0.25	(0.29)	0.05-0.84	0.21	(0.20)	0.05-0.46
Lady's thumb	0.15	(0.13)	0.02-0.39	0.10	(0.09)	0.03-0.20
Green foxtail	0.06	(0.06)	0 -0.17	0.13	(0.15)	0.03-0.30
Hemp nettle	0.08	(0.08)	0 -0.21	0.02	(0.02)	0.01-0.04
Bluebur	0.04	(0.03)	0 -0.10	0.01	(0.01)	0 -0.01
Cleavers	0.08	(0.09)	0.02-0.26	0.04	(0.06)	0.01-0.11
Wild buckwheat	0.11	(0.10)	0 -0.27	0.01	(0.01)	0 -0.01
Mustards	0.08	(0.09)	0.01-0.26	0.63	(0.41)	0.23-1.04
Total weed seeds	1.48	(0.78)	0.46-2.57	1.18	(0.40)	0.85-1.62

[a] Excluding unsound rapeseed and other material of the inseparables.
[b] Mean for the six crushing plants, cf. Table 13.
[c] Mean for Manitoba, Saskatchewan and Alberta samples, cf. Table 23.

the weed seed component of the fine screenings (1.27% x $\frac{1}{2}$ = 0.64%). Also, the rapeseed of the inseparables constituted a larger proportion (4.18%) of the crushing plant rapeseed than the rapeseed of the fine screenings in the carlot samples (1.27% x $\frac{1}{2}$ = 0.64%).

The gross compositions of the fine screenings and inseparables fractions showed general similarity (Table 24), however, with somewhat similar percentages of weed seeds (24%, 51%, 25%) in the different fractions, as well as similar percentages of rapeseed (47%, 49%, 71%) in the different fractions.

To compare the composition of the weed seed components of the fine screenings and the inseparables, the mean percentages of the four major weed seed species were calculated for the inseparable samples in Table 26 and compared with the percentages for the fine screenings samples in Table 25. The percentages of the weed seed species for the crushing plant and carlot samples, respectively, were for stinkweed, 24.2 and 3.6%; lamb's quarters, 24.2 and 17.9%; lady's thumb, 16.1 and 8.9%; and green foxtail, 4.8 and 8.9%. Considering the large variation in composition between "replicate" samples in this study, as indicated by the calculated standard deviations, the above figures may be interpreted to demonstrate a general resemblance in weed species compositions between the inseparable dockages and the fine screenings dockages.

In summary it may be concluded that the compositions were similar for all four dockage fractions studied, i.e., the fine screenings from the POS and carlot samples, and the inseparables from the crushing plant and carlot samples. The amounts of these fractions in rapeseed differed, however, with generally larger amounts of the inseparables than the fine screenings being present.

Based on the above comparisons of the figures presented in Table 24, it may be concluded as highly probable that the unknown composition of the POS inseparables were similar to the composition of the POS fine screenings. Therefore, the experimental results by different laboratories from testing the chemical and the nutritional quality of the POS fine screenings might, with some reservations, be considered valid also for the POS inseparables - the dockage fraction that was not available for study.

Influence of Inseparable Dockage on Rapeseed Quality

The extent of rapeseed contamination by the weed seed inseparables (not including unsound rapeseed) was found to be in the 0.88% to 1.63% range according to the total weed species hand sorted from the cleaned rapeseed samples from the rapeseed carlot survey which had been cleaned using sieves of similar sizing as those normally used by government inspectors (cf. Tables 23 and 24). The corresponding levels of inseparables contamination in the crushing plant samples was found to be 0.46% to 2.57% weed seeds plus 2.55% to 5.25% unsound rapeseed, totalling 4.85% to 7.31% inseparable dockage (cf. Tables 13 and 24). The level of inseparables in the examined rapeseed samples thus showed some variation.

Nutritional studies incorporating the POS fine screenings into diets of swine and chickens (Bell and Shires, 1982, and Hawrysh et al, 1982) resulted in the recommendation of very different courses of action. Total removal of fine screenings from the diets of swine was suggested, apparently implying total removal also of the inseparables, as this study has shown the fine screenings and the inseparables to be of similar

quality. Up to 10% incorporation of fine screenings into the diets of broiler chickens was allowable.

A 1% to 1.5% level of inseparable contamination of the rapeseed would imply a 0.8% to 1.1% contamination of the rapeseed oil with the oil from the inseparable dockage, assuming a 30% oil content for this fraction. Assuming furthermore, in accordance with the above discussion, that the composition and quality of this inseparables oil and the POS fine screenings oil are similar, the contribution of the contaminating inseparables oil to the composition and quality of the rapeseed oil should be small, except that it might lead to a lower oxidative stability and an increased color of the oil. The suggestion (Ismail et al, 1980) that the content of dockage oils such as the POS fine screenings oils be limited to 1% would in many cases be achieved by just using cleaned rapeseed, as long as no screenings were added back to the seed.

SUMMARY AND CONCLUSIONS

Oils derived from fine screenings of rapeseed were received from the POS Pilot Plant and were degummed, alkali refined, bleached and deodorized according to laboratory techniques. The chemical properties of these fine screenings oils determined at the various stages of processing were found to be inferior to those of Tower rapeseed oil. Higher free fatty acid levels occurred in the crude fine screenings oils. Higher peroxide values for the fine screenings oils at most stages of refining indicated a lower stability for these oils. The higher color and chlorophyll content of the fine screenings oils tended to cause darker colored oils which could lead to reduced consumer acceptability. The erucic acid contents of the fine screenings oils were 4.1 to 9.9%, much higher than the 0.1% in the Tower rapeseed oil, but would contribute little to the final rapeseed oil erucic acid content due to the low amounts of fine screenings oils normally found in rapeseed oils. Higher phosphorus and sulfur contents in the fine screenings oils persisted throughout the refining procedure, which could result in increased refining costs in the crushing of rapeseed contaminated with fine screenings.

The POS fine screenings samples were examined for their seed composition. This material, smaller than rapeseed in size, had approximately half the oil content of Tower rapeseed. The main components of the fine screenings were small and broken rapeseed (47%), and weed seeds (24%), primarily stinkweed and lamb's quarters, although one sample contained a large amount of green foxtail. There was also a considerable amount of dirt and stones in the samples.

Samples of cleaned rapeseed from oilseed crushing plants, hand sorted for inseparable dockage, were found to contain 1.48% weed seeds on the average, and 4.18% unsound rapeseed. These total inseparables contained lower amounts of oil and protein and more erucic acid than the Tower rapeseed. The main weed species separated contained less oil than Tower rapeseed, some below 10% oil. The protein content of the total inseparables and the individual weed species, ranging from 10 to 21%, was also lower than for rapeseed. Significant amounts of erucic acid were found in the oils from four of the eight weed species tested; stinkweed was the highest (40.1%) followed by cleavers (7.9%), lady's thumb (7.3%) and lamb's quarters (2.4%). The oils from bluebur and cleavers contained 35% and 37% linolenic acid, respectively, much more than the other weed species and rapeseed. Two weed species were found to contain glucosinolate compounds: cleavers had 0.6 µmoles per gram of meal and stinkweed had 200 µmoles of allyl-glucosinolate per gram of meal. Taking into consideration the small amount of inseparable dockage found in the rapeseed crushing plant samples, the effect of this dockage on the quality of rapeseed oil would be negligible.

Samples from the rapeseed carlot survey were cleaned in a dockage tester and then hand sorted for weed species content. The mean amount of total dockage for the 49 samples was 7.1% of the total weight of which 6.0% was removed by the tester. The fine screenings removed by the tester were comprised of stinkweed, lamb's quarters, lady's thumb, green foxtail and rapeseed. The inseparables hand sorted from the cleaned rapeseed amounted to 1.2% of the carlot samples and showed a similar composition to the crushing plant inseparables.

The comparison of the inseparable dockage from the crushing plants

and carlot samples with the fine screenings from the POS and carlot samples revealed a general similarity between the inseparables and the fine screenings as far as weed species content and composition was concerned. The amounts of unsound rapeseed present showed more variation. It was concluded that the results of the various chemical and nutritional studies carried out on the POS fine screenings material could with reasonable probability be assumed to be valid also for the POS inseparable dockage material that had not been made available for this study.

If the POS fine screenings oils were present in rapeseed oil at a level of around 1%, they would not be readily evident from any noticeable elevation in the erucic acid content, phosphorus content or sulfur content of the rapeseed oil. The stability of the oil against oxidative deterioration might be reduced, however, and the color of the oil might increase.

The level of fine screenings material permissible in the seed would appear to be dependent upon the end use of the meal. The digestibility has been shown to vary with the animal being fed the fine screenings meal. If the meal was being prepared for a particular animal diet, care should be taken that the rapeseed was cleaned to a level acceptable for that particular animal.

There was considerable similarity between the gross composition of the dockage (i.e., the fine screenings and inseparables examined) and the composition of rapeseed, partly as a result of variable amounts of rapeseed being present in the dockage. The presence of small percentages of dockage in rapeseed would not markedly influence the gross composition of the rapeseed and oil, such as its protein content and fatty acid composition. It could, however, result in more subtle effects, caused by increased enzyme activity stemming from the unsound rapeseed component of the dockage.

The sulfur content of the oil might increase, due to an increased enzymatic hydrolysis of the glucosinolates in the rapeseed. The amount of partially hydrolysed phospholipids (lysophospholipids) in the oil might increase, due to an increased phospholipase activity. The lysophospholipids are particularly difficult to remove in the degumming process. The amount of free fatty acids in the oil might increase, due to an increased lipase activity. These effects would further have a detrimental effect on the color and oxidative stability of the oils.

BIBLIOGRAPHY

ACKMAN, R.G. and SEBEDIO, J. - L. 1981. Fatty acids and sterols in oils from Canola screenings. J. Amer. Oil Chem. Soc. 58:594-598.

AMERICAN OIL CHEMISTS' SOCIETY, 1977. Official and Tentative Methods of the American Oil Chemists' Society, 3rd ed, including additions and revisions. American Oil Chemists' Society, Champaign, Illinois.

APPELQVIST, L. - A. and OHLSON, R., ed. 1972. Rapeseed Cultivation, Composition, Processing and Utilization. Elsevier Publishing Company, Amsterdam. 382.

BELL, J.M. and LINTON, J.H. 1961. Digestibility and feedlot studies on rapeseed screenings for feeder lambs. Can. J. Anim. Sci. 41:230-235.

BELL, J.M. and SHIRES, A. 1982. Effects of canola dockage content on the feeding value of canola meal for swine. in Research on Canola Seed, Oil, Meal, and Meal Fractions, Seventh Progress Report, Canola Council of Canada. (in print).

BERNARDINI, E. 1976. Batch and continuous solvent extraction. J. Amer. Oil Chem. Soc. 53:275-278.

BRIMBERG, U.I. 1982. Kinetics of bleaching of vegetable oils. J. Amer. Oil Chem. Soc. 59:74-78.

CANADA WEED COMMITTEE. 1975. Common and Botanical Names of Weeds in Canada. Canada Department of Agriculture, publication 1397:67.

CANADIAN GOVERNMENT SPECIFICATIONS BOARD. 1976. Standard for Rapeseed Oil, Low Erucic Acid, Crude and Crude Degummed. Canadian Government Publication Can2-32.300M-76. Canadian Government Specifications Board, Ottawa.

CANADIAN GOVERNMENT SPECIFICATIONS BOARD. 1967a. Standard for Salad Oil. Canadian Government Publication 32-GP -76. Canadian Government Specifications Board, Ottawa.

CANADIAN GOVERNMENT SPECIFICATIONS BOARD. 1967b. Standard for Shortening. Canadian Government Publication 32-GP-75b. Canadian Government Specifications Board, Ottawa.

CANADIAN GRAIN COMMISSION. 1977. Dockage on car receipts of grain at terminal elevators, Western Division. Appendix III in Market Specifications for Canadian Grains. Canada Grains Council, Winnipeg.

CANADIAN GRAIN COMMISSION. 1980. Grain Grading Handbook for Western Canada. effective August 1, 1980. Agriculture Canada. 57-61.

COCKS, L.V. and van REDE, C. 1966. Handbook for Oil and Fat Analysts. Academic Press Inc., New York. 32-33, 129-130.

DAUN, J.K. 1982. The relationship between rapeseed chlorophyll, rapeseed oil chlorophyll and percentage green seeds. J. Amer. Oil Chem. Soc. 59:15-18.

DAUN, J.K., DAVIDSON, L.D., BLAKE, J.A. and YUEN, Wo. 1981. Comparison of methods for the analysis of phosphorus in canola oil. J. Amer. Oil Chem. Soc. 58:914-916.

DAUN, J. and HOUGEN, F. 1976. Sulfur content of rapeseed oils. J. Amer. Oil Chem. Soc. 53:169-171.

DAUN, J.K. and McGREGOR, D.L. 1981. Glucosinolate analysis of canola (rapeseed). Approved method by the Canadian Grain Commission.

DAUN, J.K. and TKACHUK, R. 1976. Fatty acid composition of oils extracted from Canadian wild seeds. J. Amer. Oil Chem. Soc. 53:661-662.

FRANKTON, C. and MULLIGAN, G.A. 1970. Weeds in Canada. Canada Department of Agriculture, publication 948, 217 pp.

GIOVANNETTI, P. and BELL, J.M. 1972. Research on rapeseed meal. 1st Progress Report. Rapeseed Association of Canada, Winnipeg. 12-13.

HAWRYSH, Z.T., SAM, R.M., ROBBLEE, A.R. and HARDIN, R.T. 1982. Influence of canola screenings meal on the eating quality of broiler chickens. in Research on Canola Seed, Oil, Meal, and Meal Fractions, Seventh Progress Report, Canola Council of Canada. (in print).

HEANEY, R.K. and FENWICK, G.A. 1980. The analysis of glucosinolates in Brassica species using gas chromatography. Direct determination of the thiocyanate ion precursers, glucobrassicin and neuglucobrassicin. J. Sci. Food Agric. 31:593-599.

HOUGEN, F.W. and BODO, V. 1973. Extraction and methanalysis of oil from whole or crushed rapeseed for fatty acid analysis. J. Amer. Oil Chem. Soc. 50:230-234.

ISMAIL, F., ESKIN, N.A.M. and VAISEY-GENSER, M. 1980. The effect of dockage oil on the stability of canola oil. in Research on Canola Seed, Oil, Meal, and Meal Fractions, Sixth Progress Report, Canola Council of Canada publication 57:234-239.

LESNIAK, J. 1980. Commercial analysis of rapeseed and its products. I Canada. in Analytical Chemistry of Rapeseed and its Products. ed. J.K. Daun, D.I. McGregor, and E.E. McGregor. The Canola Council of Canada, Winnipeg. 49-51.

NORRIS, F.A. 1964. Extraction of fats and oils. in Bailey's Industrial Oil and Fat Products. Swern, D., ed. Interscience Publishers, New York. 637-710.

NORRIS, F.A. 1964. Refining and bleaching. in Bailey's Industrial Oil and Fat Products. Swern, D., ed. Interscience Publishers, Yew York. 719-792.

REBOLLEDO, M., ROBBLEE, A.R. and CLANDININ, D.R. 1980. Composition of rapeseed screenings and rapeseed screenings meal. Submitted to Can. J. of Anim. Sci. for consideration for publication.

SCHROEDER, M., DELI, J., SCHALL, E.D. and WARREN, G.F. 1974. Seed composition of 66 weed and crop species. Weed Science 22:345-348.

SHIRES, A., BELL, J.M., KEITH, M.O. and McGREGOR, D.I. 1982. Rapeseed dockage. Effects of feeding raw and processed wild mustard and stinkweed seed on growth and feed utilization in mice. Can. J. Anim. Sci. 62:275-285.

STEIN, W. and GLASER, F.W. 1976. Continuous solvent extraction of sunflower seed, groundnuts, palmkernels, rapeseed, and copra. J. Amer. Oil Chem. Soc. 53:283-285.

STEVENSON, C.L. 1976. Letter regarding injurious class of weed seeds. Appendix VII in Market Specifications for Canadian Grains. Canada Grains Council, Winnipeg.

THIES, W. 1979. Detection and utilization of a glucosinolate sulphohydrolase in the edible snail Helix pomatia. Naturwissenschaften 66:364-365.

TKACHUK, R. and MELLISH, V.J. 1977. Amino acid and proximate analyses of weed seeds. Can. J. Pl. Sci. 57:243-249.

TROENG, S. 1955. Oil determination of oilseeds. Gravimetric routine method. J. Amer. Oil Chem. Soc. 32:124-126.

VAISEY-GENSER, M. and ESKIN, N.A.M. 1979. Canola oil: properties, processes and food quality. publication 55. Rapeseed Association of Canada (Winnipeg). 38pp.

van REDE, C. 1966. Quality assessment of raw materials for their suitability for refining, bleaching, and deodorizing. in Laboratory Handbook for Oil and Fat Analysts. Cocks, L.V. and van Rede, C., ed., Academic Press Inc., New York. 328-339.

WARD, J.A. 1976. Processing high oil content seeds in continuous screw presses. J. Amer. Oil Chem. Soc. 53:261-264.

WILLIAMS, P.C. 1973. The employment of titanium dioxide as a catalyst for large scle Kjeldahl determination of the protein content of cereal grains. J. Sci. Food Agric. 24:343-348.

APPENDIX A

Percentage (by Weight) of Total Weed Seeds and Unsound Rapeseed including Breakdown by Major Weed Species Removed from Samples from the Oilseed Crushing Plants.

Appendix A. Percentage (by weight) of total weed seeds and unsound rapeseed including the breakdown by major weed species removed from the samples from the oilseed crushing plant at Lethbridge.

	Sample Number									
	U-1	U-2	U-3	U-4	U-5	U-6	U-7	U-8	U-9	U-10
Stinkweed	0.46	0.24	0.24	0.08	0.34	0.60	0.40	0.42	0.28	0.24
Lamb's quarters	0.32	0.26	0.30	0.12	0.18	0.24	0.18	0.34	0.04	0.02
Lady's thumb	0.42	0.00	0.10	0.38	0.12	0.12	0.22	0.06	0.10	0.00
Green foxtail	0.22	0.00	0.06	0.14	0.00	0.00	0.00	0.00	0.02	0.00
Hemp nettle	0.02	0.12	0.22	0.00	0.00	0.08	0.08	0.08	0.06	0.48
Bluebur	0.02	0.00	0.00	0.00	0.00	0.00	0.20	0.18	0.02	0.00
Cleavers	0.00	0.20	0.14	0.00	0.02	0.00	0.08	0.00	0.08	0.00
Wild buckwheat	0.24	0.16	0.58	0.60	0.08	0.28	0.38	0.02	0.32	0.08
Mustards	0.00	0.08	0.04	0.00	0.00	0.04	0.12	0.00	0.00	0.00
Others	0.72	0.10	0.50	0.28	1.52	0.42	0.30	0.34	0.60	0.00
Total weed species	2.42	1.16	2.18	1.60	2.26	1.78	1.96	1.44	1.52	0.82
Unsound rapeseed										
Sprouted	2.08	3.44	3.38	3.28	1.90	1.96	2.44	2.64	1.88	4.24
Broken	2.02	2.70	2.46	1.70	1.92	1.48	1.52	1.48	1.08	1.42
Total unsound rapeseed	2.10	6.14	5.84	4.98	3.82	3.44	3.96	4.12	2.96	5.66
Total dockage (weed species and unsound rapeseed)	6.52	7.30	8.02	6.58	6.08	5.22	5.92	5.56	4.48	6.48

Appendix A. Percentage (by weight) of total weed seeds and unsound rapeseed including the breakdown by major weed species removed from the samples from the oilseed crushing plant at Lloydminster.

	Sample Number											
	V-1	V-2	V-3	V-4	V-5	V-6	V-7	V-8	V-9	V-10	V-11	V-12
Stinkweed	0.10	0.08	0.14	0.12	0.08	0.12	0.04	0.20	0.02	0.18	0.12	0.26
Lamb's quarters	0.30	0.18	0.12	0.18	0.16	0.22	0.16	0.20	0.08	0.14	0.14	0.20
Lady's thumb	0.14	0.08	0.14	0.38	0.04	0.28	0.20	0.22	0.00	0.08	0.28	0.06
Green foxtail	0.04	0.16	0.16	0.14	0.00	0.08	0.06	0.04	0.08	0.00	0.06	0.02
Hemp nettle	0.04	0.14	0.12	0.04	0.00	0.08	0.00	0.06	0.10	0.20	0.26	0.20
Bluebur	0.00	0.04	0.00	0.16	0.04	0.00	0.02	0.00	0.02	0.04	0.04	0.04
Cleavers	0.00	0.16	0.10	0.02	0.12	0.08	0.00	0.18	0.24	0.22	0.04	0.20
Wild buckwheat	0.00	0.08	0.04	0.00	0.18	0.04	0.00	0.00	0.00	0.10	0.04	0.20
Mustards	0.00	0.00	0.12	0.16	0.04	0.24	0.04	0.14	0.00	0.00	0.00	0.00
Others	0.00	0.48	0.44	0.26	0.10	0.00	0.00	0.22	0.60	0.40	0.10	0.56
Total weed species	0.62	1.40	1.38	1.46	0.76	1.14	0.52	1.26	1.14	1.36	1.08	1.74
Unsound rapeseed												
Sprouted	2.34	2.58	2.96	2.72	3.16	3.16	3.28	3.18	2.60	4.06	1.54	4.42
Broken	0.54	1.00	1.12	1.24	0.94	0.94	0.92	1.22	0.78	1.00	1.54	2.12
Total unsound rapeseed	2.88	3.58	4.08	3.96	4.10	4.10	4.20	4.40	3.38	5.06	3.08	6.54
Total dockage (weed species and unsound rapeseed)	3.50	4.98	5.46	5.42	4.86	5.24	4.72	5.66	4.52	6.42	4.16	8.28

Appendix A. Percentage (by weight) of total weed seeds and unsound rapeseed including the breakdown by major weed species removed from the samples from the oilseed crushing plant at Altona.

	Sample Number									
	W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8	W-9	W-10
Stinkweed	0.02	0.00	0.04	0.18	0.18	0.00	0.06	0.02	0.06	0.00
Lamb's quarters	0.02	0.16	0.16	0.22	0.18	0.02	0.04	0.04	0.56	0.02
Lady's thumb	0.08	0.06	0.12	0.00	0.18	0.08	0.08	0.06	0.56	0.16
Green foxtail	0.24	0.04	0.02	0.06	0.12	0.16	0.06	0.72	0.12	0.20
Hemp nettle	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.08	0.00	0.00
Bluebur	0.04	0.14	0.12	0.16	0.22	0.04	0.08	0.08	0.08	0.06
Cleavers	0.04	0.00	0.10	0.00	0.00	0.00	0.06	0.00	0.00	0.06
Wild buckwheat	0.08	0.32	0.10	0.08	0.00	0.00	0.10	0.30	0.44	0.48
Mustards	0.12	0.04	0.10	0.00	0.10	0.04	0.04	0.00	0.08	0.12
Others	0.08	1.46	0.26	0.32	0.34	0.00	0.00	0.74	0.34	0.88
Total weed species	0.72	2.22	1.02	1.02	1.32	0.70	0.62	2.04	2.24	1.98
Unsound rapeseed										
Sprouted	3.92	5.90	4.12	2.72	3.22	3.54	2.84	3.14	2.98	3.78
Broken	1.88	1.86	1.50	1.32	1.90	1.70	1.08	1.90	1.04	2.12
Total unsound rapeseed	5.80	7.76	5.62	4.04	5.12	5.24	3.92	5.04	4.02	5.90
Total dockage (weed species and unsound rapeseed)	6.52	9.98	6.64	5.06	6.44	5.94	4.54	7.08	6.26	7.88

Appendix A. Percentage (by weight) of total weed seeds and unsound rapeseed including the breakdown by major weed species removed from the samples from the oilseed crushing plant at Sexsmith.

	Sample Number									
	X-1	X-2	X-3	X-4	X-5	X-6	X-7	X-8	X-9	X-10
Stinkweed	1.10	1.02	0.62	0.60	0.92	1.38	0.76	0.90	0.80	1.00
Lamb's quarters	0.56	0.24	0.74	0.88	0.94	1.36	1.24	1.36	1.00	0.09
Lady's thumb	0.00	0.04	0.18	0.00	0.04	0.00	0.00	0.00	0.02	0.04
Green foxtail	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hemp nettle	0.04	0.00	0.58	0.06	0.22	0.02	0.12	0.40	0.52	0.14
Bluebur	0.10	0.00	0.02	0.04	0.00	0.00	0.08	0.12	0.08	0.02
Cleavers	0.24	0.12	0.14	0.34	0.00	0.14	0.66	0.32	0.34	0.28
Wild buckwheat	0.18	0.00	0.16	0.10	0.00	0.26	0.34	0.04	0.00	0.14
Mustards	0.02	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Others	0.16	0.00	0.00	0.00	0.00	0.12	0.52	0.02	0.20	0.36
Total weed species	2.42	1.42	2.48	2.02	2.12	3.28	3.72	3.16	2.96	2.07
Unsound rapeseed										
Sprouted	1.76	0.96	1.68	2.48	1.28	1.84	1.84	1.86	1.68	1.18
Broken	0.82	0.82	0.58	1.18	0.92	1.14	0.68	1.10	0.76	0.90
Total unsound rapeseed	2.58	1.78	2.26	3.66	2.20	2.98	2.52	2.96	2.44	2.08
Total dockage (weed species and unsound rapeseed)	5.00	3.20	4.74	5.68	4.32	6.26	6.24	6.12	5.40	4.15

Appendix A. Percentage (by weight) of total weed seeds and unsound rapeseed including the breakdown by major weed species removed from the samples from the oilseed crushing plant at Nipawin.

	Sample Number									
	Y-1	Y-2	Y-3	Y-4	Y-5	Y-6	Y-7	Y-8	Y-9	Y-10
Stinkweed	0.01	0.06	0.10	0.20	0.05	0.22	0.01	0.10	0.11	0.02
Lamb's quarters	0.05	0.04	0.05	0.02	0.10	0.08	0.00	0.09	0.00	0.04
Lady's thumb	0.03	0.05	0.00	0.04	0.07	0.00	0.00	0.03	0.00	0.00
Green foxtail	0.03	0.00	0.00	0.08	0.04	0.21	0.11	0.00	0.00	0.01
Hemp nettle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bluebur	0.00	0.00	0.00	0.23	0.05	0.00	0.00	0.00	0.00	0.09
Cleavers	0.05	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00
Wild buckwheat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mustards	0.12	0.00	0.07	0.04	0.07	0.04	0.04	0.13	0.14	0.09
Others	0.08	0.00	0.00	0.29	0.00	0.09	0.02	0.00	0.14	0.53
Total weed species	0.37	0.15	0.22	0.90	0.38	0.83	0.18	0.35	0.39	0.78
Unsound rapeseed										
Sprouted	2.91	2.65	3.57	3.74	3.39	2.79	3.15	3.98	2.71	4.00
Broken	1.03	0.96	0.52	1.82	0.94	1.18	0.90	1.14	1.37	1.10
Total unsound rapeseed	3.94	3.61	4.09	5.56	4.33	3.97	4.05	5.12	4.08	5.10
Total dockage (weed species and unsound rapeseed)	4.31	3.76	4.31	6.46	4.71	4.80	4.23	5.47	4.47	5.88

Appendix A. Percentage (by weight) of total weed seeds and unsound rapeseed including the breakdown by major weed species removed from the samples from the oilseed crushing plant at Saskatoon.

	Sample Number									
	Z-1	Z-2	Z-3	Z-4	Z-5	Z-6	Z-7	Z-8	Z-9	Z-10
Stinkweed	0.02	0.02	0.05	0.09	0.02	0.04	0.06	0.00	0.00	0.02
Lamb's quarters	0.06	0.06	0.27	0.12	0.18	0.04	0.04	0.04	0.19	0.05
Lady's thumb	0.89	0.33	0.23	0.45	0.36	0.39	0.29	0.21	0.31	0.39
Green foxtail	0.00	0.00	0.04	0.03	0.05	0.02	0.12	0.08	0.03	0.00
Hemp nettle	0.00	0.00	0.00	0.07	0.06	0.00	0.00	0.00	0.00	0.06
Bluebur	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Cleavers	0.05	0.00	0.12	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Wild buckwheat	0.08	0.08	0.00	0.00	0.12	0.11	0.09	0.00	0.09	0.00
Mustards	0.28	0.21	0.20	0.32	0.34	0.16	0.20	0.40	0.44	0.08
Others	0.00	0.00	0.00	0.04	0.00	0.00	0.07	0.04	0.00	0.00
Total weed species	1.38	0.70	0.91	1.12	1.20	0.76	0.87	0.77	1.06	0.60
Unsound rapeseed										
Sprouted	4.14	3.14	3.06	3.96	3.82	3.93	3.62	2.95	2.60	1.99
Broken	0.86	0.82	1.30	0.92	0.97	0.83	1.19	0.57	1.22	0.79
Total unsound rapeseed	5.00	3.96	4.36	4.88	4.79	4.76	4.81	3.52	3.82	2.88
Total dockage (weed species and unsound rapeseed)	6.38	4.66	5.27	6.00	5.99	5.52	5.68	4.29	4.88	3.38

APPENDIX B

Percentages (by weight) of the screenings and weed species removed from the rapeseed carlot survey samples.

Appendix B. Percentages (by weight) of the screenings and weed species removed from the rapeseed carlot survey samples from Manitoba.

	Carlot Sample No.					
	1872	1932	1942	2075	2144	2267
Coarse screenings	2.90	0.00	0.03	0.01	0.00	3.90
Fine screenings	2.40	0.02	0.01	0.01	0.01	2.11
Air blown material	4.00	0.37	0.27	0.45	0.32	3.45
Total screenings	9.30	0.39	0.31	0.47	0.33	9.46
Weed species[a]						
Stinkweed	0.01	0.01	0.00	0.01	0.01	0.00
Lamb's quarters	0.44	0.01	0.01	0.01	0.01	1.06
Lady's thumb	1.03	0.00	0.00	0.01	0.01	2.72
Green foxtail	0.52	0.13	0.01	0.29	0.53	0.56
Hemp nettle	0.05	0.00	0.00	0.02	0.00	0.00
Bluebur	0.01	0.00	0.00	0.00	0.00	0.01
Cleavers	0.00	0.02	0.02	0.00	0.02	0.00
Wild buckwheat	0.23	0.02	0.00	0.00	0.00	0.16
Mustards	0.44	0.17	1.06	2.23	0.12	1.94
Wild oats	0.73	0.00	0.00	0.01	0.00	1.08
Total weed species	3.46	0.36	1.09	2.58	0.70	7.53
Other seeds						
Rapeseed and chaff	1.85	0.01	0.01	0.01	0.01	0.76
Wheat	1.40	0.00	0.02	0.00	0.01	0.85
Flax	0.01	0.00	0.05	0.00	0.00	0.01
Total other seeds	3.26	0.01	0.08	0.01	0.02	1.62
Total dockage[b]	10.70	0.70	1.40	3.00	1.00	12.80

a Does not include air screenings.
b Screenings plus inseparable seeds calculated by the formula
Total dockage = wt (6/64 screen + air + No. 2 wire screen + weeds in cleaned sample) x 100/total wt.

Appendix B. Percentages (by weight) of the screenings and weed species removed from the rapeseed carlot survey samples from Saskatchewan.

	Carlot Sample No.										
	1880	1903	1916	1941	1946	1971	1981	1982	2005	2011	2024
Coarse screenings	5.11	1.01	2.65	0.00	7.87	1.20	2.17	1.37	4.35	0.04	0.00
Fine screenings	1.03	1.29	0.42	0.02	1.55	0.58	2.03	0.74	0.72	0.38	0.04
Air blown material	2.09	2.87	1.89	0.15	2.52	2.34	2.85	2.45	2.14	1.25	0.61
Total screenings	8.23	5.17	4.96	0.17	11.94	4.12	7.05	4.56	7.21	1.67	0.65
Weed species[a]											
Stinkweed	0.23	0.05	0.02	0.01	0.38	0.10	0.07	0.06	0.34	0.01	0.01
Lamb's quarters	0.63	0.87	0.14	0.01	0.56	0.05	1.31	0.05	0.03	0.13	0.37
Lady's thumb	0.00	0.00	0.13	0.01	0.93	0.02	0.01	0.09	0.00	0.01	0.00
Green foxtail	0.05	0.02	0.01	0.06	0.01	0.01	0.02	0.01	0.30	0.01	0.01
Hemp nettle	0.01	0.01	0.01	0.00	0.09	0.01	0.21	0.01	0.00	0.00	0.00
Bluebur	0.02	0.01	0.00	0.00	0.02	0.01	0.01	0.00	0.00	0.00	0.02
Cleavers	0.04	0.02	0.00	0.00	0.00	0.01	0.15	0.02	0.00	0.00	0.01
Wild buckwheat	0.58	0.03	0.03	0.01	0.16	0.03	0.08	0.04	0.10	0.00	0.00
Mustards	0.17	0.08	0.46	1.58	0.41	2.09	0.48	1.32	0.06	0.00	0.79
Wild oats	1.81	0.20	0.91	0.00	1.16	0.67	1.07	0.41	1.92	0.00	0.00
Total weed species	3.54	1.29	1.71	1.68	3.72	2.99	3.41	2.01	2.75	0.16	1.21
Other seeds											
Rapeseed and chaff	0.98	1.10	0.62	0.01	0.55	0.84	1.21	1.04	0.82	0.33	0.03
Wheat	2.11	0.20	1.30	0.00	6.16	0.10	0.63	0.41	1.63	0.12	0.00
Flax	0.00	0.00	0.01	0.00	0.05	0.00	0.00	0.06	0.12	0.00	0.00
Total other seeds	3.09	1.30	1.93	0.01	6.76	0.94	1.84	1.51	2.57	0.45	0.03
Total dockage[b]	8.70	5.40	5.50	1.80	13.00	6.20	8.10	6.00	7.50	1.90	1.80

a Does not include air screenings.
b Screenings plus inseparable seeds calculated by the formula
Total dockage = wt (6/64 screen + air + No. 2 wire screen + weeds in cleaned sample) x 100/total wt.

Appendix B. Percentages (by weight) of the screenings and weed species removed from the rapeseed carlot survey samples from Saskatchewan (continued).

	Carlot Sample No.										
	2050	2096	2100	2128	2147	2171	2193	2228	2288	2295	2340
Coarse screenings	0.04	0.01	2.46	0.00	0.00	6.69	4.62	6.74	2.93	1.13	1.71
Fine screenings	0.07	0.01	1.40	0.03	0.01	0.73	0.82	1.11	2.01	1.23	0.78
Air blown material	0.37	0.24	2.29	0.26	0.20	2.23	2.49	3.58	3.47	2.78	1.48
Total screenings	0.48	0.26	6.15	0.29	0.21	9.65	7.93	11.43	8.41	5.14	3.97
Weed species[a]											
Stinkweed	0.01	0.01	0.73	0.01	0.01	0.31	0.01	0.30	0.15	0.15	0.27
Lamb's quarters	0.07	0.02	0.11	0.01	0.02	0.22	0.62	0.18	1.17	0.37	0.40
Lady's thumb	0.24	0.00	0.02	0.00	0.00	0.01	0.00	0.01	0.01	0.03	0.00
Green foxtail	0.01	0.01	0.02	0.01	0.03	0.03	0.25	0.19	0.95	0.01	0.04
Hemp nettle	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00
Bluebur	0.01	0.01	0.01	0.00	0.00	0.10	0.01	0.01	0.01	0.07	0.01
Cleavers	0.04	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.01
Wild buckwheat	0.00	0.00	0.16	0.00	0.00	0.27	0.30	0.18	0.23	0.10	0.01
Mustards	0.87	0.72	0.08	0.75	2.45	0.05	0.48	0.15	0.07	0.00	0.07
Wild oats	0.00	0.00	1.26	0.00	0.00	3.31	3.33	4.79	1.01	0.51	0.42
Total weed species	1.31	0.77	2.39	0.80	2.51	4.30	5.00	5.83	3.61	1.25	1.23
Other seeds											
Rapeseed and chaff	0.00	0.03	1.25	0.02	0.18	1.52	0.84	1.34	1.13	1.15	0.64
Wheat	0.02	0.03	0.40	0.00	0.00	1.72	0.44	0.99	1.13	0.16	0.80
Flax	0.04	0.00	0.01	0.04	0.00	0.01	0.00	0.00	0.11	0.00	0.00
Total other seeds	0.06	0.06	1.66	0.06	0.18	3.25	1.28	2.33	2.37	1.31	1.44
Total dockage[b]	1.70	1.00	6.40	1.10	2.70	9.80	8.80	11.80	9.50	5.40	4.20

a Does not include air screenings.
b Screenings plus inseparable seeds calculated by the formula
Total dockage = wt (6/64 screen + air + No. 2 wire screen + weeds in cleaned sample) x 100/total wt.

Appendix B. Percentages (by weight) of the screenings and weed species removed from the rapeseed carlot survey samples from Alberta.

	Carlot Sample No.										
	1875	1887	1888	1893	1906	1913	1919	1923	1925	1966	1980
Coarse screenings	4.47	1.46	3.94	3.46	2.86	2.47	4.25	3.40	15.38	4.25	3.71
Fine screenings	3.60	1.42	3.92	1.90	1.86	3.05	2.66	4.42	3.82	2.16	0.79
Air blown material	3.86	4.50	5.39	3.28	4.75	6.10	3.93	5.46	4.25	3.59	1.56
Total screenings	11.93	7.38	13.25	8.64	9.47	11.62	10.84	13.28	23.45	10.00	6.06
Weed species[a]											
Stinkweed	1.41	0.46	3.34	0.32	1.09	0.34	0.86	3.03	0.33	0.31	0.39
Lamb's quarters	2.53	0.35	1.31	1.29	1.49	3.28	1.98	1.99	3.03	0.78	0.18
Lady's thumb	0.00	0.01	0.00	0.04	0.01	0.25	0.05	0.01	0.06	0.46	0.04
Green foxtail	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.64	0.23	0.01
Hemp nettle	0.02	0.37	0.03	0.09	0.04	0.11	0.03	0.00	0.21	0.01	0.11
Bluebur	0.14	0.00	0.02	0.01	0.02	0.06	0.01	0.10	0.02	0.04	0.00
Cleavers	0.20	0.04	0.11	0.20	0.16	0.08	0.24	0.50	0.01	0.04	0.02
Wild buckwheat	0.51	0.07	0.21	0.26	0.65	0.55	0.29	0.28	0.31	0.57	0.21
Mustards	0.15	0.05	0.24	0.31	0.14	0.05	0.12	0.09	0.07	0.07	0.08
Wild oats	1.58	0.20	0.88	1.20	0.51	0.38	0.46	1.83	5.34	1.88	1.12
Total weed species	6.55	1.55	6.14	3.73	4.12	5.10	4.05	7.83	10.02	4.39	2.16
Other seeds											
Rapeseed and chaff	0.90	1.15	0.97	1.14	1.03	1.76	0.86	0.84	1.26	1.12	0.98
Wheat	2.15	0.75	2.59	1.58	0.98	0.86	3.06	0.82	9.02	1.44	1.59
Flax	0.03	0.00	0.01	0.01	0.00	0.11	0.02	0.10	0.00	0.01	0.10
Total other seeds	3.08	1.90	3.57	2.73	2.01	2.73	3.94	1.76	10.28	2.57	2.67
Total dockage[b]	13.40	8.00	15.10	9.70	10.90	14.00	12.00	15.10	24.60	10.60	8.50

a Does not include air screenings.
b Screenings plus inseparable seeds calculated by the formula
Total dockage = wt (6/64 screen + air + No. 2 wire screen + weeds in cleaned sample) x 100/total wt.

Appendix B. Percentages (by weight) of the screenings and weed species removed from the rapeseed carlot survey samples from Alberta (continued).

	Carlot Sample No.									
	1994	2176	2195	2205	2276	2282	2289	2322	2341	2357
Coarse screenings	1.14	3.24	0.07	3.40	4.43	8.61	4.58	2.32	1.70	2.60
Fine screenings	1.98	2.28	0.46	1.20	1.47	1.96	3.29	1.25	1.11	1.51
Air blown material	3.09	3.09	0.60	2.10	2.59	3.62	5.56	3.57	2.72	2.20
Total screenings	6.21	8.61	1.13	6.70	8.49	14.19	13.43	7.14	5.53	6.31
Weed species[a]										
Stinkweed	0.02	0.51	0.15	0.38	0.77	1.49	0.58	0.36	0.27	0.28
Lamb's quarters	0.22	1.36	0.24	0.02	0.24	0.26	2.37	0.33	0.36	0.66
Lady's thumb	0.12	0.22	0.07	0.24	0.05	0.02	0.00	0.00	0.01	0.46
Green foxtail	0.01	0.08	0.04	0.02	0.01	0.01	0.00	0.02	0.42	0.01
Hemp nettle	0.02	0.06	0.04	0.02	0.02	0.01	0.02	0.00	0.00	0.14
Bluebur	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.04	0.01
Cleavers	0.00	0.10	0.18	0.06	0.00	0.13	0.00	0.00	0.01	0.12
Wild buckwheat	0.02	0.13	0.00	0.02	0.20	0.03	0.14	0.39	0.16	0.05
Mustards	0.08	0.01	0.35	0.06	0.33	1.80	0.06	0.08	0.00	0.21
Wild oats	0.05	0.33	0.05	1.07	0.67	0.63	0.65	0.05	0.30	0.88
Total weed species	0.54	2.81	1.12	1.90	2.30	4.39	3.83	1.24	1.57	2.82
Other seeds										
Rapeseed and chaff	2.28	0.82	0.17	1.58	1.03	0.98	0.98	0.85	0.92	0.76
Wheat	0.50	2.48	0.05	1.39	2.93	7.48	3.37	1.56	0.64	1.34
Flax	0.00	0.00	0.04	0.00	0.01	0.00	0.00	0.02	0.00	0.00
Total other seeds	2.78	3.30	0.26	2.97	3.97	8.46	4.35	2.43	1.56	2.10
Total dockage[b]	6.40	9.20	2.00	7.00	8.90	16.50	13.80	7.30	5.70	7.20

a Does not include air screenings.
b Screenings plus inseparable seeds calculated by the formula
Total dockage = wt (6/64 screen + air + No. 2 wire screen + weeds in cleaned sample) x 100/total wt.