Canola Seed and Oil Processing

by Ted Mag

Canola is one of the most important oilseed crops in the world. The oil from the seed has gained an excellent reputation for its nutritional qualities in the human diet and is the most important component of the seed in terms of market value. The meal is an important source of protein in animal feeding.

The processing methods used to extract the oil from the seed to produce a high quality raw oil for further processing and a high quality protein meal as an animal feed have been developed over the years. These methods are continually being improved. Processing of the oil after extraction to obtain a large variety of oil products for human consumption also has a long history, and is continually being improved. This brochure gives an overview of these processes and methods as used in the industry.

Extraction of Seed for Oil and Meal

Seed Grading and Cleaning

Seed delivered to the extraction plant from the farm is graded according to a strict grading standard for canola established by the Canadian Grain Commission. Payment is based on grade. It is the first step to help ensure that a quality oil and meal are obtained. The graded seed is then cleaned to remove plant stalks, grain seeds and other materials from the bulk of the seed. Aspiration, indent cleaning, sieving, or some combination of these are used in the cleaning process. Dehulling of the seed is, at present, not a commercial process.

Seed Preparation for Extraction

In many extraction plants, the cleaned seed is first heated to about 30-40ºC to prevent shattering. This is especially important with very cold seed. Some moisture adjustment may also be required. The preheated seed is then flaked on roller mills, set to very tight clearance. Usually, two sets of roller mills are used, with the second set adjusted to a tighter clearance than the first. The flaked seed is then heated to about 75-100ºC in cookers. These may be either vertical tanks with agitated, steam-heated trays or, in more modern plants, horizontal, rotary kilns equipped with steam coils.

This heating, also called cooking or conditioning, serves several very important functions: it ruptures remaining intact cells to release oil, coalesces small oil droplets to larger ones, coagulates protein for better diffusion during solvent extraction, and adjusts the moisture content of the seed prior to solvent extraction.

Another very important function of the cooking operation is to control enzymatic activity in the flaked seed, which depends on temperature and moisture content. Two enzyme systems are of importance: myrosinase, which hydrolyzes glucosinolates; and lipases, which hydrolyze triglycerides and phosphatides. These hydrolysis processes must be suppressed to produce quality oil and meal. Glucosinolate breakdown products impair the quality of the oil and the meal; triglyceride and, especially, phosphatide breakdown products make the oil more difficult to refine. A small concentration of breakdown products is usually unavoidable.

Prepressing

The heat-conditioned seed is passed into continuous screw-presses or expellers. The function of this equipment is to reduce the oil content of the seed from about 42% (8% moisture basis) to 16-20% mechanically. Subsequent solvent extraction of the remaining oil is then much more efficient and economical. Expellers consist of a rotating screw shaft in a cylindrical barrel. The barrel has flat steel bars mounted edgewise around the inside and spaced to allow oil to flow from between the bars while retaining the solid material within. Pressure and heat are developed within the barrel by the rotating screw shaft working against an adjustable choke at the solids (presscake) discharge end of the barrel. Some discharge of very fine solids with the oil draining from the expeller is unavoidable. These fines are separated from the oil by gravity and filtration, and recycled to the conditioning stage. The presscake, which may be put through a mechanical breaker to produce uniform sized particles, is now ready for solvent extraction.

In some plants, the presscake is subjected to mechanical extrusion to improve its solvent extraction properties. Extruders used for this purpose consist of a barrel with a rotating shaft fitted with flights. Steam is added and heating and mixing take place along the length of the barrel. Pressure is developed. The material is then discharged through the small openings of a die plate at the end of the barrel. The pressure release on discharge “expands” the extruded material, making it very porous. These small diameter, porous pieces of presscake (collets) have excellent solvent extraction properties. Capacity of solvent extraction equipment is significantly enhanced.

Solvent Extraction

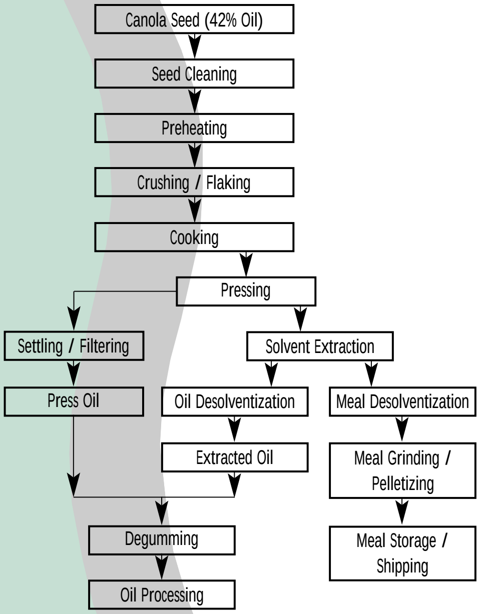
The presscake from the expellers, as is, or as collets from extruders, is conveyed to the solvent extractor. Some cooling during conveying is done to minimize vaporization of hexane in the extractor. A variety of extractor designs are in use. The solvent is hexane, specifically refined for this application. In the extractor, the solids are solvent-washed in stages, first with hexane already high in oil content (miscella) and then with progressively leaner miscella and, finally with pure hexane. This leaches the oil content in the solid material (meal) down to about 1%, depending somewhat on equipment design and throughput rate.

The meal and the miscella are now "stripped" of the solvent to recover solvent-free meal and oil. The solvent-saturated meal is conveyed to a desolventizer, which is a vertical tank equipped with heated trays and agitators. Reduced pressure and sometimes live steam are used to evaporate the hexane and to dry the meal. The hexane and moisture vapours are condensed, the water and hexane are separated, and the hexane is reused. Several stages of heating and drying are applied to reduce the hexane content to negligible levels and moisture to 8-11 %. Some removal of glucosinolates and their break-down products and some protein denaturing occurs.

To achieve the best meal quality, the process must be well controlled with respect to temperature (110ºC max.) and time. Usually, the final treatment in desolventizing is a cooling stage. Cooled meal may be ground to a uniform particle size, or pelleted, ready for storage and marketing. Dehulling of the meal for non-ruminant feed may, in future, become commercial practice.

The miscella containing the oil is desolventized in three-stage evaporator equipment. The hexane vapour from this operation is, also, condensed for reuse. A properly operated extraction plant loses no more than about 2-3 litres of hexane/mt of seed processed. Beach (1), Unger (2), Buhr (4), Dahlen (6), and Williams (7) have written on details of various aspects of canola seed extraction.

Canola Seed Extraction & Degumming of Oil



Degumming

The "crude" oil from the two extraction stages is usually blended and then degummed before being stored for sale or further processing. Degumming removes phosphatides coextracted with the oil, which tend to separate from the oil as a sludge during storage. The phosphatide content of crude oil varies, but is usually in the order of 1.25%, or measured as phosphorus, 500 ppm.

Two degumming methods are in use: (a) using water to precipitate phosphatides and; (b) using an acid such as citric, malic, or phosphoric and water (superdegumming). After contacting the oil with these reagents, the oil is centrifuged to separate the precipitated material. Degumming with water only, leaves from 100-250 ppm of phosphorus, depending on the extent of hydrolysis of phosphatides in the course of seed preparation, as discussed earlier. In degumming with an acid and water, the hydrolyzed, non-hydratable phosphatides (NHP) are also removed. Residual concentrations are about 25 ppm of phosphorus. The separated phosphatides are added to the meal in the desolventizer. This raises the residual oil content of the meal to about 2-3% and raises its energy content. Typical concentrations of the various minor constituents found in crude and in degummed canola oil are given in Table 1.

Table 1: Minor Constituents of Crude and of Degummed Canola Oil

Free fatty acids	0.4 – 1.0%
Phospholipids	1 – 1.5%
Water degummed (as P)	100 – 250 ppm
Acid – water deg. (as P)	10 – 50 ppm
Unsaponifiables	
(Tocopherols, Sterols)	0.5 – 1.2%
Chlorophylls	10 – 35 ppm
Sulphur compounds (as S)	3 – 15 ppm
Iron, Crude/Acid-Wat. Deg.	<2/<0.2 ppm
Copper	<det. limit

The most recent development in degumming uses acid and aqueous sodium hydroxide, rather than acid and water, especially with lower quality oils. This represents an intermediate between acid-water degumming and alkali refining. Phosphatides as well as some of the other impurities are removed and, if sufficient alkali is applied to saponify the free fatty acids, fully refined oil is obtainable.

Oil Processing and Products

Alkali and Physical Refining

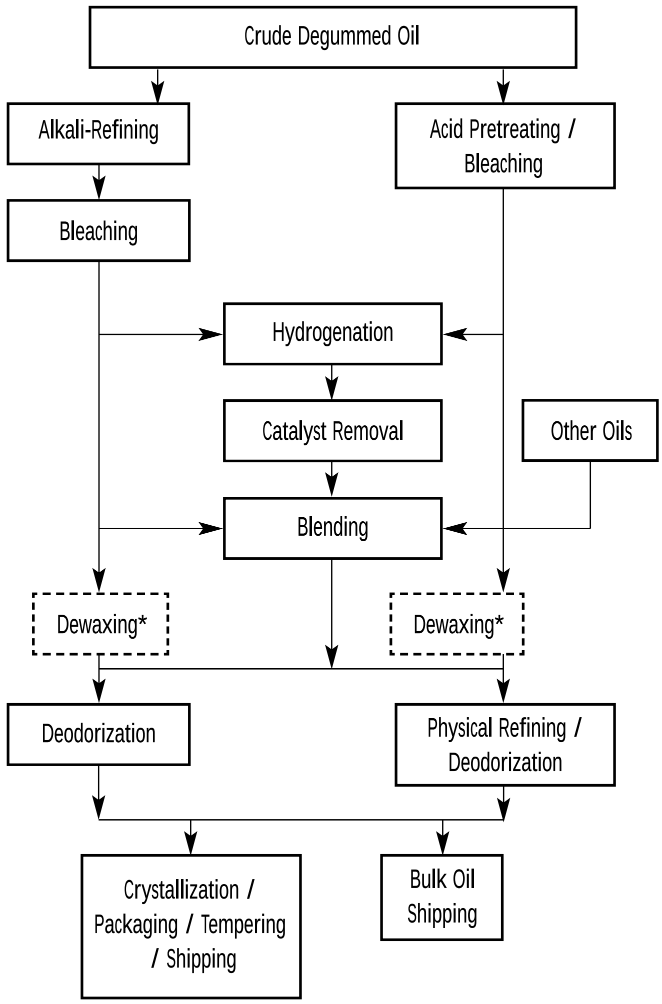
Degummed oil is further purified in a process of refining. One of two methods are used, namely, alkali refining, especially with water degummed oil, and physical refining with acid-water degummed oil. Alkali refining is the most common process used, even with acid-water degummed oil. Physical refining is a relatively new development. It requires well-degummed oil of moderate chlorophyll and free fatty acid content, but it is then very economical.

In alkali refining, the oil is first contacted with about 0.05-0.1% of concentrated phosphoric acid in a high intensity mixer to help precipitate phosphatides. It is then contacted with an approximately 12% aqueous solution of sodium hydroxide to neutralize the free fatty acids and any excess phosphoric acid present, and to precipitate phosphatides. This requires about 2-3% of the solution. Very intensive mixing is used. Temperatures and contact times may vary from about 90ºC and only seconds for both acid and caustic in the so called "short-mix" process to about 40ºC and 15 minutes each in the "long-mix" process. The oil/soap mixture is then heated to about 90ºC, if required, and centrifuged to separate the aqueous soap phase. This phase also contains the precipitated phosphatides and some triglyceride oil. The centrifuged oil must be further contacted with about 5-10% hot water to reduce soap levels from about 400 ppm to <50 ppm. Free fatty acids are reduced to <0.05% and phosphorus to <2 ppm. Iron and copper concentrations are reduced to below detection. Coloured compounds (chlorophylloids, carotenoids) are not affected significantly. The concentration of sulfur compounds is reduced slightly. This oil is now ready for bleaching. The soap phase from this operation can be added to the meal, similar to the disposal of the phosphatides from degumming, or it can be acidulated and used as a feed ingredient. The wash water must be treated to reduce the oil content to acceptable levels for discharge. Mag, 1990 (3) has reviewed industrial refining practice in some detail. Carlson, 1993 (8) reviewed refining methods and costs.

In physical refining, acid-water degummed oil with a phosphorus content below 50 ppm is first subject to a phosphoric acid pretreatment, as in the short-mix alkali refining process. It is then contacted with acid-activated bleaching clay in a standard bleaching process at 95-105ºC. The clay, along with precipitated phosphatides and adsorbed chlorophylloid and some carotenoid compounds, is then removed by filtration. This is the first and most important stage of physical refining. It delivers bleached oil ready for deodorizing. Except for the free fatty acids in the oil, all other minor constituents are reduced to the same concentrations as in alkali refining and in addition, chlorophyll is reduced to the concentration required of bleached oil, namely <25 ppb. Usually, from 1-3% acid-activated bleaching clay is used, depending primarily on the concentration and type of chlorophylloid compounds present in the oil.

The removal of the free fatty acids in the oil is done by steam distillation in a deodorizer. This simultaneously deodorizes the oil. Because deodorization is the last process normally carried out on edible oils, this step may be delayed until other processes, such as hydrogenation of the oil, have been done. Little authoritative industrial experience with physical refining and the pretreatment of canola oil for physical refining has been published so far.

Canola Oil Processing



* Dotted box indicates this process is optional

Adsorptive Bleaching

Alkali refined oil, which still contains most of the chlorophylloid compounds present in the crude oil, requires bleaching. These compounds must be removed. They catalyze oil oxidation and give an undesirable green colour to the oil. It has become recognized that chlorophyll removal is the most important aspect of canola oil bleaching. Acid-activated clays are used. Their adsorptive properties are especially effective for the removal of these compounds. Other coloured compounds, some of the oxidation breakdown products and traces of iron are also removed in this process.

The process itself is carried out under vacuum with the oil at about 100ºC. Many process versions are in use. About 5-30 minutes of contact time is given, while the oil/clay slurry is progressively dried to about 0.1% moisture content. This gives the best adsorption efficiency. As indicated earlier, about 1-3% clay (10% moisture content) may be required to achieve chlorophyll removal to <25 ppb. This level is innocuous in respect to oxidation and colour of the oil. Mag, 1989 (5) has given an overview of edible oil bleaching practice, with particular attention to canola oil. Brimberg, 1981 (9) and Henderson, 1993 (10) have investigated aspects of chlorophyll adsorption important to the process.

Hydrogenation

This process, which was first introduced in the edible oils industry in connection with cottonseed and marine oil around 1900, changes the melting behaviour of oils and improves the oxidative stability. Today, it is also applied to such oils as soybean and canola. Hydrogen is added to the double bonds of unsaturated fatty acids at temperatures of 160-200ºC and pressures of 100-300 kPa in the presence of a nickel catalyst to facilitate the reaction. Chlorophyll, phosphatides, soaps, and especially sulfur compounds “poison” the catalyst, raising process costs. The former are removed in refining and bleaching. Sulfur compounds are only reduced somewhat in these treatments; deMan, 1983 (11) has investigated the role of sulfur compounds in catalyst poisoning in canola oil hydrogenation.

The process is carried out batchwise. There are various reactor designs in use. Depending on temperature, pressure, and to some extent the specific catalyst properties, different melting behaviour in the hydrogenated fat can be obtained. The oxidative stability improvement, also, is modified somewhat by choice of process conditions. It is possible to hydrogenate fatty acids with multiple double bonds preferentially. These are the most easily oxidized and their concentration must, therefore, be reduced or eliminated for best effect on stability. Usually, conditions are chosen which provide this selectivity. In canola oil, very low concentrations of these fatty acids can be achieved with very little hardening of the oil taking place. Melting behaviour is most usually evaluated by determining the proportion of solid fat in a sample over the temperature range of interest, usually 10-40ºC.

Another consequence of hydrogenation is the formation of isomeric fatty acids. Positional isomers as well as geometric, or trans isomers are formed. These compounds are important contributors to the melting properties and the functional utility of the hydrogenated fat. Recently, nutrition science has again focused on the role of trans isomer fatty acids in the diet. This will probably continue to be controversial for some time.

Hydrogenated Canola Oil in Shortenings and Margarines

Hydrogenated fats from canola oil play an important role in the production of the wide range of fat products used in Canada and other countries. They often appear in blends with other oils to combine the advantages of canola oil with those of other oils. They are especially important as lightly hydrogenated oils for their exceptional stability. This is due, in part, to the high content of monounsaturated fatty acids in canola oil. These products are becoming very popular because of their good stability and pourability and the low saturated fatty acid content. Table 2 gives typical data from industry experience.

Table 2: Composition and Stability of Lightly Hydrogenated Canola

	Canola	
	non-hydrogenated	lightly hydrogenated
Fatty acid composition		
C16:0 palmitic	4	4
C18:0 stearic	2	4
C18:1 oleic	60	80
C18:2 linoleic	22	8
C18:3 linolenic	10	2
Iodine Value	115	90
Stability		
Frying	--	good
AOM hours	15	75
Pourability	Yes	Yes

Table 3 shows some typical margarine oil blends using canola oil hydrogenated to different melting ranges and non-hydrogenated, and also hydrogenated soybean oils.

Table 3: Margarine with Canola Oil

Oil Stock	Hard Margarine		Soft Margarine		No-Trans
%	1	2	1	2	3
Canola					
Hard	46	--	25	--	--
Medium	8	--	10	--	--
Soft	46	60	12	--	--
Non - Hydrogenated	--	--	53	75	90
Palm/Palm Kernel Interesterified	--	--	--	--	10
Soy Bean					
Very Hard	--	--	--	25	--
Hard	--	40	--	--	--

The above hydrogenated canola oil stocks that are used in margarines, are also used extensively in shortenings and as stable frying fats. Industry makes a wide variety of canola based hydrogenated oil stocks for tailor-made shortenings.

Very highly hydrogenated canola oils are rarely used in margarine and baking shortenings, because of the tendency to form large (beta) crystals over time. This impairs eating properties and baking performance. The crystallization behaviour of hydrogenated canola oil for margarine and shortening products has been studied extensively by deMan (12) and Naguib-Mostafa (13). With the increasing demand for trans-free margarines, canola oil with its favourable nutritional profile is used as the liquid, non-hydrogenated component, preferably alone, but also in combination with other non-hydrogenated oils such as sunflower, soybean, linola and olive.

Interesterification

Interesterification is another process for changing the melting properties of fats and oils. The position of fatty acids in the triglyceride is changed randomly. When the process is applied to blends of different oils, triglycerides with fatty acid compositions are formed that can be sufficiently different from the original oils to change the melting characteristics of the resulting fat in a way not achievable by mere blending. The process represents an alternative to the use of partially hydrogenated fats to manufacture products of a variety of melting properties.

Thomas (14) and Desrosier (15) have investigated interesterification of non-hydrogenated canola oil with fully hydrogenated vegetable oils. If trans isomers in fat and oil products must be decreased in the future, interesterification will assume greater performance. Interesterification has also been proposed for use in controlling the problem with beta crystallization of hydrogenated canola oil, however, it has not found significant use for this purpose because of cost.

In modern plants, the process is carried out in a heated, agitated tank, equipped with a vacuum system and a water spray. The oil must be very dry and low in free fatty acids. Sodium methoxide (a strong base, 0.05%) is added to the heated (150ºC) oil as a powder under agitation and contacted for about 30 minutes to catalyse the reaction. The oil is then cooled to about 90ºC, phosphoric acid is added to neutralize the base. The oil is then washed, or alternatively, bleached.

Dewaxing

Canola oil is a natural salad oil. This means that it remains clear and liquid at refrigerator temperatures. However, the oil does occasionally contain a small concentration of waxes (about 100 – 200 ppm). These compounds are related to triglycerides in composition, but are usually crystalline at room temperature, or lower. In some cases, it is desirable, therefore, to dewax the oil to avoid a hazy appearance. The process is carried out by chilling in a continuous heat exchanger to about 5ºC and metering about 0.1% of a filter aid into the chilled oil stream on the way to a filter. This reduces the wax content to <50 ppm, which no longer produces a visible haze. Przybylski (16), and Ackman (17) have studied waxes in canola oil.

Deodorization

In edible oil processing, deodorization is the final "refining" step. Its primary function is to remove compounds from the oil which impart odour and taste typical of the seed from which it is derived. In addition, such processes as bleaching and hydrogenation form traces of compounds, which also impart typical odour and taste and must be removed. Further, at the temperatures required, heat-bleaching of the yellow-red carotenoid compounds is an important aspect of the process. As mentioned earlier, deodorizing serves to physically refine the oil as an alternative to alkali refining.

The treatment is essentially a steam distillation of the odour and flavour compounds from the oil, as well as other relatively volatile compounds from the oil such as free fatty acids. Steam distillation is used extensively in industries with heat sensitive materials. The oil, which must be thoroughly purified in the previous process steps, is heated to 260-265ºC under very high vacuum (2-4mm Hg pressure) to exclude air. This increases the volatility of the compounds to be removed. Steam is blown through the oil (2-4%), which increases the volatility further and allows efficient removal of the volatiles to very low levels. Many different process versions are in use. In recent years there has been much emphasis on improving the energy efficiency of the process and eliminating air and water pollution, which are associated with vacuum generation and volatiles.

Margarine and Shortening Packaging and Tempering

With the exception of bulk frying fats, margarine and shortening oils are converted into semi-solid form for final use. Margarine oils are emulsified with an appropriate water phase first. Shortenings, which do not usually involve a water phase, are crystallized directly. The crystallization is carried out in systems consisting of ammonia cooled, scraped-surface heat exchangers (A-units), followed by resting units (B-units) in which further crystallization with or without agitation takes place. The now partially crystalline, but still pumpable fat product is then transferred to fillers where it is packaged in a variety of packages and sizes. In the case of shortenings, about 10% by volume of nitrogen gas is added ahead of the B-units. This gives the product its white, even-textured appearance. Essential process conditions are chilling in the A-unit to about 25ºC and resting to allow most of the crystallization to take place before the product enters the package. When done properly, there should be no more than about a 1ºC temperature rise in the package. Products high in hydrogenated canola oil require special care to ensure that crystallization to the very small beta prime type crystals is achieved. Essentially this means very rapid and complete crystallization before the product enters the package.

Tempering of crystallized fat products refers to the process of allowing certain equilibrium processes in the crystalline/liquid fat mixture to reach completion. The properly crystallized, packaged products is held for two to four days at 25-27ºC to improve plasticity, creaming, and baking performance. It is a poorly understood process, but it is very important for optimum shortening properties. Margarines are usually tempered for a shorter time and then refrigerated. The effect of commercial crystallization conditions and product tempering has been studied by deMan (12) in connection with his studies on the crystallization behaviour of margarines and shortenings made from hydrogenated canola oil.

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