Physical Refining of Edible Oils

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ABSTRACT: Physical refining of edible oils offers several advantages over alkali refining. The method described for physical refining of rapeseed oil involves several novel factors, including the availability of cold-pressed rapeseed oil low in phosphatide content and deacidification/deodorization in a film molecular evaporator. Parameters are presented from a pilot plant unit with an output of 500 metric tons per year. Further applications of the technology are proposed, including the processing of oils to pharmaceutical-grade products.
JAOCS 72, 1193–1196 (1995).

KEY WORDS: Cold-pressed rapeseed oil, cold-pressed sunflower oil, molecular distillation, physical refining of edible oils.

There has been interest in physical refining of vegetable oils for some time (1–4). The procedure is attractive because of its simplicity, lack of environmental impact, low oil losses, and good-quality products. Some experts nevertheless remain skeptical, and the refining system with caustic soda is the technology of choice.

Classic processing, also called chemical or wet processing, includes degumming, neutralization, bleaching, and deodorization. Physical refining, also known as dry or steam refining, has been known for years and is based on the higher volatility of free fatty acids (FFA) compared to triacylglycerols. In physical refining, removal of FFA by chemical neutralization is replaced by simultaneous deacidification/deodorization.

In principle, physical refining involves three operations, the first two (degumming and bleaching) being virtually identical. The principal difference concerns the removal of acidity. Physical refining uses steam stripping in a vacuum, a procedure that removes FFA, unsaponifiable substances, and pungent compounds, thus circumventing chemical neutralization with its environmentally objectionable soapstocks. As a consequence, oil losses are reduced, the quality of FFA is increased, and the operation is simplified. It consumes less steam, water, and power and, hence, requires less capital investment. This procedure is also suitable for the processing of oils with higher acidity (palm oil). On the other hand, practical experience with physical refining has shown that it only leads to acceptable results when good quality starting oils are used. Incomplete removal of undesirable components during the pretreatment of oil has to be compensated for by an increased use of bleaching earth (5). Lower oil losses attained by steam refining, compared to oil losses involved in caustic refining, do not offset the oil losses due to the increased volumes of bleaching earth needed (6). In any case, the quality of the final product is always determined by the quality of the crude oil. Even caustic refining will not provide high yields of stable, high-quality oil if it starts from a crude oil with a high acidity number, a high peroxide number, and high metal and chlorophyll contents. The major emphasis is being placed on preliminary processing of crude oil prior to steam refining, which is aimed at removal of any components that might, during subsequent high-temperature steam refining, darken in color or undergo other adverse alterations and thus decrease the quality of the final product (6). This preliminary processing, which includes degumming and bleaching, can be relatively simple, provided the crude oil does not contain high amounts of peptides and iron (3). Soybean oil, sunflower oil, rapeseed oil, and corn germ oil have been mentioned in this context; under European climatic conditions, mainly rapeseed oil and sunflower oil can be considered.

The importance of rapeseed oil has rapidly increased with development of its double-low variety canola, a species that contains only minor quantities of erucic acid and glucosinolates (5), both considered antinutritional factors for humans and animals.

We have introduced two new factors (7) into the physical refining of edible oils: (i) The new technology uses cold-pressed rapeseed oil. Compared to extracted oils, cold-pressed oil contains minimum levels of phospholipids and other components that have to be removed during pretreatment. (ii) For deacidification/deodorization, molecular distillation in a short-path evaporator with wiped film is being used rather than vacuum steam distillation.

Cold-pressed rapeseed oil. Cold-pressed rapeseed oil has been introduced as a new raw material along with the development of alternative fuels from renewable sources. When transesterified with methanol, using a relatively unsophisticated process (the implementation of which is feasible even under simple conditions, such as a farm), this oil yields methyl esters of higher fatty acids. These methyl esters may be used as diesel fuel that requires no engine adjustments and does not lower an engine's power. Naturally, the use of hydrocarbon extraction of rapeseed in a farm environment is out of the question for smaller units with a capacity of

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500–10,000 metric tons of methyl esters per year. In this case, rapeseed oil is obtained by cold pressing in low-capacity presses without previous seed conditioning, at temperatures not exceeding 75–80°C. Reliable filter presses also have been developed to filter such oils. The crude oil obtained this way contains only low levels of phosphatides and other components, and can be worked up by physical refining to an edible oil. Although cold pressing gives lower yields, the differences are not great. Prepressing–solvent extraction of rapeseed has an oil yield of approximately 97%, prepressing–final pressing gives approximately 86%, whereas cold pressing yields approximately 82% of total oil content. The by-product, cake, represents a valuable component of animal fodder mixtures, either with or without further processing.

Molecular distillation. The removal of FFA and other unwanted components by steam refining uses low pressure (approximately 400–700 Pa) at temperatures of 220–270°C, depending on the oil (3). However, oil residence times within the distillation equipment are long, up to 30–60 min, and are temperature-dependent as well (8,9). As expected, some oil components undergo chemical changes under these conditions. This drawback has been addressed by applying high-vacuum distillation in a short-path evaporator with wiped film. At the pressure of residual gasses of 0.1–100 Pa, the distillation temperature drops by 200–250°C, and when the oil passes the evaporator in the form of a wiped film 0.1–1 mm thick, the substance exposure to higher temperatures is brought down to a few seconds. Both these factors, together with the negligible partial oxygen pressure in the evaporator, provide for the distillatory processing of both thermolabile substances and those with low volatility without engendering their thermal decomposition. In addition, a special mechanism of mass transfer in the distillation space between the evaporator and the condenser with a distance of 20–70 mm allows one to achieve a high evaporation capacity of 20–40 g m^{-2} s^{-1}.

Therefore, of all the distillation procedures available, molecular distillation uses the lowest working temperature possible. An expedient setting of working parameters helps to efficiently separate FFA from oil with the simultaneous preservation of valuable natural substances, such as phytosterols and mainly tocopherols, leaving them chemically unchanged. As compared to steam distillation, deacidification in a vacuum evaporator with wiped film is both simpler and economically more feasible.

Process description. The semi-continual process of physical refining by short-path wiped-film distillation is being run on a pilot production unit with an output of 500 metric tons of rapeseed oil per year. Figure 1 shows the equipment for refining by film vacuum distillation.

Rapeseed oil pressing has been designed as a continual process because operation breaks and restarts present some operational risks. The cold-pressed and force-filtrated oil is

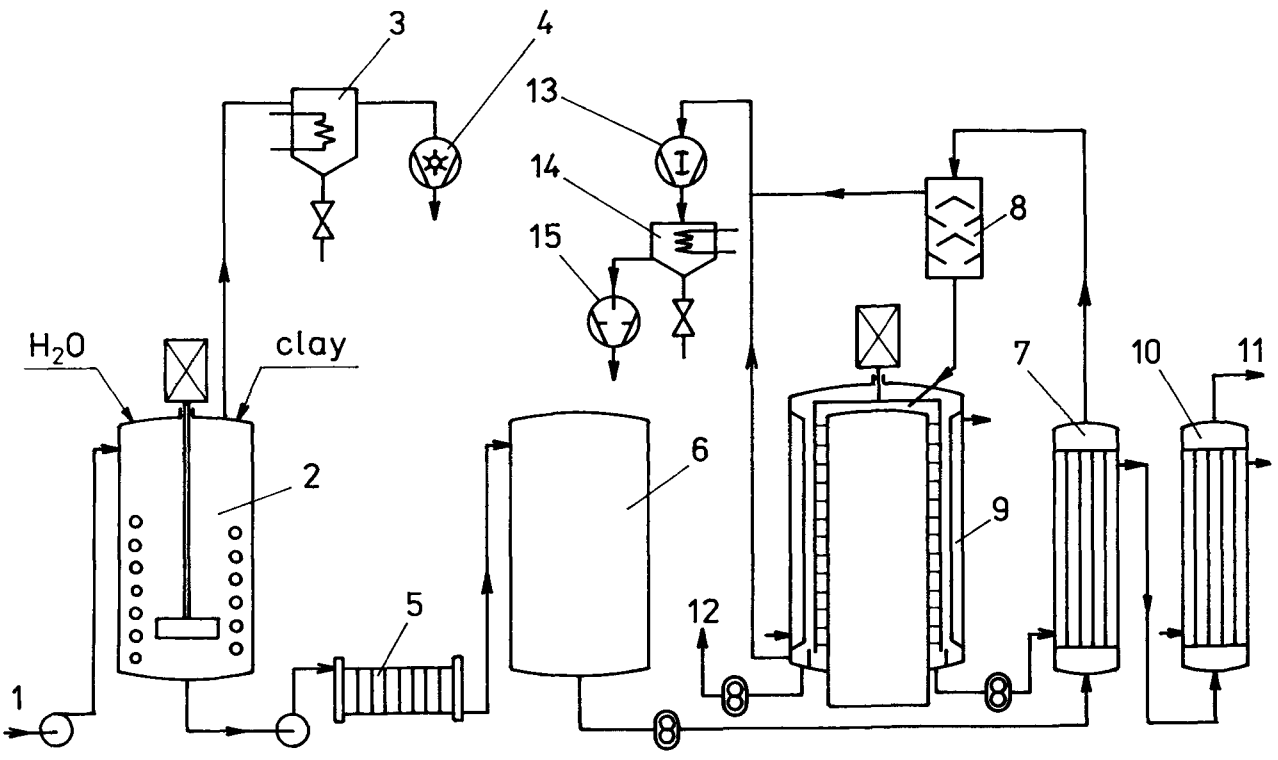

FIG. 1. Equipment for physical refining of cold-pressed oil with deacidification–deodorization of oil in molecular evaporator with wiped film. 1, Crude oil inlet; 2, reactor; 3, low-temperature condenser; 4, water ring pump; 5, filter press; 6, storage tank; 7, recuperative cooler; 8, defoamer; 9, molecular evaporator; 10, cooler; 11, refined oil outlet; 12, deodorizing condensate; 13, Roots pump (Leybold AG, Köln, Germany); 14, freezing trap; and 15, rotary pump.

then pumped from the crude oil tank into a stirred reactor (Figs. 1,2), which is equipped with a heating and a cooling coil. This is where oil degumming takes place at higher temperatures in the presence of water. Because cold-pressed oil contains few resins and little slime, no special step is needed to remove them after the separation, as they will be removed from the oil together with the bleaching clay by filtration after bleaching. If, however, deep degumming is required, as evidenced by low (several ppm) phosphorus content, some of the procedures described elsewhere (2–6,10) can be used for the degumming. The same applies for physical refining with the molecular distillation of extracted oil; higher levels of phospholipids and other admixtures present in this oil make simple degumming by hydration insufficient.

The degummed oil is then cooled down, and acid-activated bleaching clay is gradually introduced, under intense stirring, into the cooled oil (approximately 1.5 wt%). The pressure in the reactor is lowered to 7–8 kPa and the oil is heated to 80–90°C. The evaporating water keeps the reactor content well stirred. When bleaching is completed, the oil is cooled to below 45°C and air is let into the reactor. The suspension is then filtered on a filter press (Figs. 1,5), and the bleached oil is collected in a tank (Figs. 1,6). The oil is fed from the tank by a pump through the preheater and defoamer onto the evaporating surface of the short-path evaporator (Figs. 1,7,8, and 9, respectively), where deacidification and deodorization take place in a thin, wiped-film at a pressure of uncondensable gases of 10–40 Pa and at a heating fluid temperature of 190–210°C. The oil temperature within the film is lower by 20–40°C. The peripheral liquid load of the evaporating cylinder is 8 L dm^{-1} h^{-1}, and the evaporator liquid load is 45 L m^{-2} h^{-1}. The cooling jacket of the molecular evaporator is heated to 50–55°C, and the condensate (1.5–2% of the feed) is pumped into an acid oil tank. The acid number of the condensate is 90–110 mg KOH/g. The distillation residue from the evaporator represents a deacidified and deodorized oil which is then pumped from the evaporator through a recuperatory heat exchanger (Figs. 1,7), where it serves to preheat the oil pumped into the evaporator. Prior to coming into contact with air, the refined oil is cooled in a cooler (Figs. 1,10) to below 50°C. The vacuum circuit of the reactor (Figs. 1,2) includes a water ring vacuum pump with a low-temperature cooler on its input. The vacuum system of the molecular evaporator (Figs. 1,9) contains a Roots vacuum pump (Leybold AG, Köln, Germany) coupled with a rotary vacuum pump, and a cold trap mounted before the rotary pump.

The computer-controlled production unit described here has been in operation for 15 mon and has produced high-quality oil without any technological problems.

Table 1 presents typical data that characterize samples of crude cold-pressed rapeseed oil and of the physically refined rapeseed oil taken from the unit. According to organoleptic flavor assessments, the refined oil has both a satisfactory neutral taste and flavor, as assessed by an authorized agency, the State Agriculture and Food Inspection of the Slovak Republic. Color and flavor stability of the oil were also satisfactory.

TABLE 1
Properties of Cold-Pressed Crude and Physically Refined Rapeseed and Sunflower Oils

	Rapeseed oil		Sunflower oil	
Parameter	Crude	Refined	Crude	Refined
Acid number[a]	1.98	0.09	0.98	0.08
Peroxide number[b]	2.93	0.35	1.56	0.17
Phosphorus content (ppm)	31	8	41	12
Color[c]	—	7	—	6

[a]mg KOH/g. [b]mmol/kg. [c]CS standard 58 01 01 (Ref. 13).

Cold-pressed sunflower oil from dehulled sunflower seed has been refined on a pilot-plant scale by this procedure. Selected parameters of this oil are shown in Table 1. The oil has been characterized by sensorial assessment as possessing a mild residual flavor of the starting material, but nevertheless complied with the Czechoslovak standard (11).

Compared with classical wet refining, the physical refining of vegetable oils for human nutrition is substantially more simple. It presents no environmental problems and is economically more feasible. From the technological point of view, the previously mentioned modified procedure simplifies matters even further. Thus, the combination of technological simplicity and economical feasibility makes this procedure attractive even for small operators and enables them to enter the market with novel high-quality products. Deacidification and deodorization in a vacuum evaporator with wiped film are also applicable to adequately pretreated solvent-extracted oils.

Pharmaceutical grade oils. After physical refining at pilot-plant scale by the procedure described here, cold-pressed sunflower oil also was tested as a pharmaceutical-grade sunflower oil *(Oleum helianthi)*. The oil complies to the 1993 British Pharmacopoeia specification (12). The oil was dewaxed by winterization after bleaching and prior to deacidification/deodorization on an evaporator. Tests were performed by the State Institute for Drug Control of the Slovak Republic. The oil has been cleared for the preparation of injection solutions.

Castor oil *(Oleum ricini)* is one of a group of oils that presents significant problems in refining. With classical refining, soapstock sedimentation is difficult because the ricinoleic acid hydroxyl group increases solubility and dispersability of soaps; moreover, the oil is dense and viscous. In contrast, physical refining on a pilot-plant scale by these procedures was easy. The pharmaceutical-grade castor oil's acid number, 0.21 mg KOH/g, obtained from crude oil with an acid number of 1.26 mg KOH/g, compares well with the usual maximum allowable value of 0.30 mg KOH/g. This oil also has been used to prepare injection solutions.

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[Received February 8, 1995; accepted July 26, 1995]