# Deodorization of Edible Oil

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## ABSTRACT

Deodorization is a high-temperature, high-vacuum steam-distillation process to remove volatile, odoriferous materials present in edible fats and oils. This paper reviews and discusses the effect of temperature vs time, vacuum vs stripping steam, the importance of air exclusion, heating media, and flavor reversion.

## DEODORIZATION OF EDIBLE OIL

In this short paper, the available deodorization equipment will not be discussed. Brekke (1) made an excellent review of this and other aspects of deodorization. Details of deodorizer design are best obtained from the equipment manufacturer. The purpose of this paper is to review the operating variables of deodorization and their effect on what is removed, what is changed, what is recovered, and what remains.

## THE DEODORIZATION PROCESS (1)

Deodorization is primarily a high-temperature, high-vacuum, steam-distillation process. To produce a high-quality finished product, each deodorizer installation must deaerate the oil, heat the oil, steam strip the oil, and cool the oil – all with zero exposure to air.

Deodorization increases the oil's flavor and oxidative stability by nearly complete removal of free fatty acids (FFA) and other volatile odor and flavor materials, by partial removal of tocopherols, and by thermal destruction of peroxides. The thermal treatment that is a necessary part of the deodorization process also heat bleaches the oil by destruction of the carotenoids that are unstable at deodorization temperature.

Steam deodorization is feasible because the flavor and odor compounds that are to be removed have appreciably greater volatility than do triglycerides. Operation at high temperature increases the volatility of these odoriferous compounds; and the introduction of stripping steam into the deodorizer greatly increases the rate at which these compounds are volatilized. Reduced pressure operation further aids in removal of the odoriferous compounds and protects the oil from atmospheric oxidation.

### Temperature vs Time

Vapor pressures of the volatile constituents in the oil increase rapidly with increase in temperature. For this reason, operation at the highest practical temperature aids in removal of the odoriferous compounds. For example, the vapor pressure of linoleic acid increases from 32 mm Hg at 250 C (482 F) to 67 mm at 270 C (518 F). This would double its rate of removal during deodorization, and if odoriferous compounds were similar, the deodorization time would be halved for each increase in temperature of about 20 C (36 F). Results from operation of commercial deodorizers agree quite well with these predicted values when the comparison is made within a given deodorizer design (2,3).

Operation at elevated temperatures can also promote thermal decomposition of some constituents naturally present in oil, such as peroxides, pigments, and some trace metal-prooxidant complexes. The carotenoid pigments can be decomposed and removed (4) by deodorization at ca. 260 C.

The work of Moser (5) showed that there is a definite relationship between temperature and time of deodorization to produce the most stable oils relative to flavor and peroxide values. The best combinations for refined and bleached soybean oil were found to be 1-2 hr at 210 C (410 F), 30 min to 1 hr at 230 C and 30 min to 1 hr at 250 C, and that 30 min was too long at 270 C. Lineberry (3) established that 15-20 min gave good results at 270 C. He also found that these good results were relatively independent of pressure variations from 2 to 6 mm Hg absolute. Lineberry also found that approximately twice as many tocopherols and sterols are stripped out at 275 C as at 240 C, and that pressure variations of 2-6 mm had only a small influence on tocopherol/sterol stripping.

This time/temperature relationship in the design of a deodorizer can be extrapolated as shown in Table I (where each "O" is from data and each "x" is extrapolation). However, much more knowledge will be needed about the effects of these extended time/temperature relationships on the nutritional values of edible oils.

**TABLE I**

**Deodorization Time vs Temperature**

| | Time (min) | | | | | | |
|---|---|---|---|---|---|---|---|
| Temperature (C) | 120 | 60 | 30 | 15 | 8 | 4 | 2 |
| 210 | O | O | | | | | |
| 230 | | O | O | | | | |
| 250 | | O | O | | | | |
| 270 | | | | O | | | |
| 290 | | | | | x | | |
| 310 | | | | | | x | |
| 330 | | | | | | | x |

Based upon laboratory experiments and analysis of commercial samples, Ackman et al. (6) concluded that the conditions normally used in North America for the steam deodorization of edible vegetable oils convert up to 25% of the linolenic acid from the *cis*-form to the *trans*-form.

Very little is known at this time about the nutritional value of these *trans*-isomers, but if the need should occur for limiting the formation of these *trans*-acids, interest may develop in deodorization methods other than high-temperature stripping.

### Vacuum vs Stripping Steam

Three-stage, steam-jet ejectors routinely maintain an absolute pressure of 4-6 mm in the deodorizer under a commercial stripping steam load. With four-stage ejectors, deodorizers can be operated at 1-3 mm, but an evaluation should be made based on qualitative advantages of the product vs the increased operating costs due to increased motive steam for the ejectors. Also, combinations of ejectors with mechanical pumps should be investigated for energy savings vs investment.

Theoretically, a decrease in absolute pressure and/or an increase in stripping steam will increase the removal rate of the volatile components of the oil. Actually, Lineberry (3) found that within the pressure range of 2-6 mm Hg absolute, the total quantity of distillate was relatively independent of pressure, but directly proportional to the temperature and to the quantity of stripping steam. However, entrainment increased in direct proportion to the volumetric rate of flow of the stripping steam. That is, entrainment increases with an increase in stripping steam flow rate and/or with a decrease in absolute pressure. This can be expressed as the ratio of percentage stripping steam to absolute pressure (%/mm). Most deodorizer designs hold that ratio to between 0.5 and 1.0 in the stripping tray(s). Examples are 3% steam to the stripping tray at 6 mm (ratio = .5) or 2% steam at 2 mm (ratio = 1.0).

The oil losses encountered in deodorization are attributed to three factors: compounds distilled from the oil, oil droplets entrained in the exit vapors, and losses due to hydrolysis of the oil to fatty acids by reaction with the stripping steam. Information obtained from industrial processors indicate total average losses of 0.60, 0.56, and 0.50% for batch, semicontinuous and continuous deodorizers, respectively. The deodorizers operated on feedstocks with initial FFA contents of 0.10, 0.11, and 0.13%, respectively, and each lowered the final FFA content to 0.03% (14).

Distillation losses include FFA, the fatty acids formed by hydrolysis of the oil, small amounts of the triglyceride itself, plus sterols, tocopherols, and other unsaponfiable matter. In deodorization of cottonseed oil at 6 mm and 283 C, each pound of stripping steam is calculated to split out 0.024-0.049 lb of fatty acid (2).

*Contact with air.* Oil must be scrupulously protected from air throughout the entire deodorizing operation. Deaeration of the feedstock as a first step is absolutely essential, because the oil may contain an appreciable amount of dissolved oxygen due to previous exposure to the atmosphere.

At deodorization temperature, the oil reacts very rapidly with oxygen with a decidedly bad effect on the oil's flavor and oxidative stability. All metallic parts in contact with the hot oil should be made of type 304 stainless steel or better (316 SS or nickel). Periodic preventive maintenance is needed to prevent air leaks from occurring in deodorizer fittings below the oil level and in external pumps, heaters, and coolers. Welded construction of the deodorizer shell and connections greatly reduces the possibility of leakage. The double shell feature of some designs of deodorizers eliminates the possibility of the hot oil being exposed to air entering through leaks in the outer shell.

The stripping steam also must be oxygen-free and, therefore, should be generated from deaerated water. Many stripping steam lines are operating at pressures below atmospheric before they enter the deodorizer and all such lines should be carefully fabricated and maintained so as to exclude the in-leakage of any air which would in turn be sparged into the hot oil.

## Heating the Oil (Table II)

When steam is to be used as the heat-transfer medium, a boiler operating at about 1,000 psig (70 bar) and 285 C is required.

Because of the capital investment and operating expense for such a boiler, US edible oil processors for a number of years have used a vapor-phase heat-transfer medium sold under the tradenames of Dowtherm A and Therminol VP-1. This mixture of diphenyl and diphenyloxide develops a pressure of less than two bar (30 psig) for heating the oil to a deodorization temperature of 270 C. These Dowtherm vaporizers should be operated at a tube wall temperature of less than 395 C to prevent formation of high boiling compounds (7).

Oil allegedly contaminated by Dowtherm A caused sickness and death in Japan in 1973, and the Japanese government now prohibits the installation of new deodorizers using Dowtherm as the heating medium. The deodorizer tray (8) was found to have a leaky heat-transfer coil but the deodorizer conditions employed removed both Dowtherm A and KSK-60 from the oil. However, the components causing the illnesses and death were not identified.

The use of chlorinated biphenyl compounds as liquid-phase heat-transfer media for the processing of edible products is prohibited in the USA.

*Additives.* A common practice is to add citric acid (0.005 to .01% based on weight of the oil), to protect the oil against oxidation. The acid inactivates traces of metal (10, 11), particularly iron and copper, which appear both in the native oil and as a result of processing (12). Citric acid decomposes rapidly at temperatures above 150 C, and the usual practice is to add the acid during the cooling stage in the deodorizer.

## Flavor Reversion (13)

After undergoing refining and being rendered flavorless and odorless by steam deodorization, certain oils may develop objectionable flavors through oxidation far short of that required to produce rancidity. The flavor and odor changes occurring in such fats are commonly termed "flavor reversion." Oils with linoleic or linolenic acid components are subjects to this change. These include linseed, soybean, rapeseed, and all marine animal oils.

No data are available as to the exact amount of oxygen required to cause flavor reversion in any particular fat. It is certain, however, that it is extremely small, in some cases

**TABLE II**

**Deodorizer Steam and Energy Consumption per 1,000 kg (9)**

| | Semicontinuous | | Continuous | |
|---|---|---|---|---|
| | No heat exchange | Internal heat exchange | Internal heat exchange | External heat exchange |
| Stripping steam (kg) | 20-30 | 20-30 | 15-20 | 15-20 |
| Jet steam (4 torr) (kg) | 70-100 | 70-100 | 50-70 | 50-70 |
| Heating (kcal)[a] (80-240 C) | 100,000 | 43-57,000 | 60,000 | 40,000 |

[a] Actual fuel input to boiler(s) might be 60% more than these figures.

probably not more than a fraction of 1%.

Although linolenic acid appears to be involved in the development of flavor reversion, when attempts to remove it by selective hydrogenation are made, no appreciable reduction in the tendency to revert is apparent. The reverted flavor of hydrogenated oil, however, usually bears little resemblance to that of the same oil before hydrogenation.

The following practices will reduce the possibility of flavor reversion after deodorization:

- store the oil in the crude state rather than after caustic refining,
- thorough caustic refining (complete phosphatide removal) at minimum temperature and air exposure,
- vacuum bleaching is a critical step because of the exposure to large surface areas at elevated temperatures in the possible presence of air (15),
- minimize heavy metal contact,
- use chelating agents (citric acid) before and after deodorization,
- replace the antioxidants removed by processing,
- limit the deodorizing temperature/time combination,
- nitrogen blanketing of processed oils,
- reduced exposure to light, and
- blend stocks before rather than after deodorization.

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