Optimizing deodorizer distillate tocopherol yields

This article is a guide for vegetable oil refiners to increase the value of their deodorizer distillate. The recommendations in this article are designed to have the optimal effect on increasing the tocopherol value of deodorizer distillate without negatively affecting the quality of the oil being refined.

Deodorization is a steam-stripping process performed under vacuum at high temperature. It is the final step of vegetable oil refining and produces a bland, stable oil. Deodorizer distillate is a by-product of the deodorization process. Deodorizer distillate contains a host of compounds including free fatty acids, mono- and diglycerides, odoriferous compounds, oxidation by-products, tocopherols, sterols, and pesticides.

Historically, deodorizer distillate has been used as an industrial waste oil or burned for its BTU value. In some parts of the world, deodorizer distillate is used as a caloric supplement in animal feed. Deodorizer distillate is not recommended for this use today because of the likelihood of pesticide contamination. Presently, deodorizer distillate which contains a significant percentage of tocopherols is more valuable for its tocopherol content.

Tocopherols are naturally occurring antioxidants in vegetable oils and are a major source of vitamin E in the diet. Natural vitamin E which is optically pure is more active biologically (on a weight basis) than is synthetic vitamin E, which is a mixture of stereoisomers. Tocopherols are concentrated in deodorizer distillate during the deodorization step. As a result, deodorizer distillate is a good source of natural tocopherols that are used to make natural vitamin E.

Deodorizer distillate is also a good source for phytosterols. Historically, phytosterols have been used as precursors for corticosteroids. Today there is increasing interest in phytosterols because of the potential ability of certain phytosterols to inhibit the intestinal absorption of cholesterol. It is important to note that, although there is increasing interest in phytosterols, the commercial value of phytosterols today is still significantly lower than that of tocopherols. The value of deodorizer distillate therefore is based essentially on the tocopherol content.

Figure 1 shows the relationship between the percentage of tocopherol in deodorizer distillate and the current value of distillate. It also shows current alternative values for distillate (BTU value, industrial oil value, etc.). The value of tocopherol has fluctuated over time as a function of supply and demand (Figure 2).

In 1993, several significant human studies were published that indicated the health benefits of ingesting natural vitamin E. As a result, demand for natural vitamin E began rising. During early 1996 there was a temporary shortage of
commercially available distillate as new manufacturers of natural vitamin E began stockpiling their captive distillate. This temporary shortage raised the price of distillate to a record high level. But by late 1996, the supply of distillate exceeded demand as new sources were developed.

Today the demand for natural vitamin E exceeds supply because the increases in production capacity have lagged behind the demand. With new manufacturers of natural vitamin E entering the market, there should be more than enough production capacity to meet future demand. The challenge will be to develop new sources for deodorizer distillate as natural vitamin E demand increases.

**Increasing tocopherol value**

There are three basic requirements for a vegetable oil refiner to capture tocopherol value from deodorizer distillate: the oil being refined must be deodorized; the oil being deodorized must contain tocopherol; and the deodorizer distillate must be condensed and collected.

It would be difficult to justify the purchase of a deodorizer or a change in the type of oil being refined solely on the basis of capturing tocopherol value. A scrubber, a contact condenser that uses a small amount of cooled oil to condense the components volatilized in the deodorizer, is used in vegetable oil refining to condense deodorizer distillate. The purchase of a scrubber normally can be justified on the basis of capturing tocopherol value.

The type of oil being refined has a profound effect on the tocopherol content of the deodorizer distillate. Some crude oils contain significantly higher concentrations of tocopherols than others. Figure 3 shows the relative levels of tocopherol in various crude oils.

Of the major vegetable oils refined in the world, crude soybean oil contains the highest levels of tocopherols, followed by corn, cotton, sunflower, rapeseed, and peanut oils.

Olive oil contains very low levels of tocopherols. Olive oil distillate is not considered to be a good source for tocopherols at this time. However, as the demand for natural vitamin E increases and the availability of tocopherol-containing distillates decreases, olive oil distillate may be sought in the future.

Deodorizer distillate obtained under good conditions can vary solely on the crude oil source. Table 1 shows typical tocopherol levels in deodorizer distillate obtained from crude oils under good operating conditions. Soybean oil distillates historically have contained the highest levels of tocopherols.

Although palm oil contains tocopherols, it also contains high levels of tocotrienols. Tocotrienols cannot be separated economically from tocopherols nor can they be converted economically into racemically pure tocopherols. As a result, palm oil distillate is not a commercial source of tocopherols.

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<tr>
<th>Table 1</th>
<th>Typical tocopherol levels in deodorizer distillate obtained from crude oils</th>
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<tbody>
<tr>
<td>Oil type</td>
<td>Tocopherol (%)</td>
</tr>
<tr>
<td>Soy</td>
<td>10–14</td>
</tr>
<tr>
<td>Corn</td>
<td>7–10</td>
</tr>
<tr>
<td>Cotton</td>
<td>6–10</td>
</tr>
<tr>
<td>Sunflower</td>
<td>5–8</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>4–7</td>
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<tr>
<td>Peanut</td>
<td>2–5</td>
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Oils from animal sources, such as tallow, lard and fish oils, have negligible levels of tocopherols. In addition to being undesirable for their tocopherol content, animal oil distillates and mixtures of animal and vegetable oil distillate are prohibited from kosher certification. Kosher approval for food ingredients, such as antioxidants, is a requirement of most large food manufacturers in the United States.

There are three areas where vegetable oil refiners can focus their efforts to have the greatest effect on increasing the value of deodorizer distillate. The three areas are: (a) optimizing the deodorizer and scrubber conditions to recover tocopherols, (b) preserving the tocopherols once they have been recovered, and (c) minimizing the dilution of tocopherols during processing and storage.

**Optimizing deodorizer and scrubber conditions**

The operating conditions that have the greatest effect on tocopherol levels in deodorizer distillate are deodorization time (flow rate, metering rate, residence time), deodorization temperature, scrubber temperature, steam (rate, weight, and volume), and vacuum. Figure 4 is a schematic representation of a deodorization system.

It is unlikely that a vegetable oil refiner would make significant changes in the rate or residence time of the oil in the deodorizer for the sole purpose of capturing tocopherol value. A vegetable oil refiner with limited capacity is more concerned with maximizing the throughput of oil. However, in situations where there is clearly an excess capacity, deodorization times can be increased to the point where oil loss, oil quality, and energy cost are balanced with the additional value obtained from increasing tocopherol levels.

The conditions that can be optimized with a minimal effect on oil production and minimal effect on the finished oil quality are deodorization temperature, scrubber temperature, and steam rate.

Some general rules of thumb:
- The typical amount of deodorizer distillate recovered from refined oils is between 0.2–0.3% based on the weight of oil being deodorized. Values as high as 0.45% have been recovered.
- The most important variable in deodorization and tocopherol recovery is deodorization temperature. Temperature is important because of its effect on the vapor pressure of volatile components. Deodorization temperatures
typically range between 240–275°C (460–530°F). For optimal tocopherol recovery, temperatures should be above 260°C (502°F). At these temperatures the quality of the finished oil is not significantly affected.

Recently, vegetable oil refiners have become concerned with the formation of trans fatty acids. Although there is some formation of trans fatty acids during deodorization, it is minor compared to the formation of trans fatty acids during the hydrogenation process.

- Scrubber temperatures are best maintained as low as possible while maintaining the handling characteristics of the recycled material. Typically, scrubber temperatures are related to the iodine value (IV) of the oil. A scrubber can be maintained at lower temperatures when the stock oil has a high IV. Vegetable oil distillates with high levels of phytosterols may plug the heat exchanger of the scrubber if the circulating temperature is too low. In general, temperatures between 57 and 63°C are used for normal oil stocks and product blends in the United States. Temperatures as low as 45°C can be used for distillates from oils having high IVs or where there are no plugging problems due to phytosterols.

- Steam acts as a carrier to remove volatile components from the oil being deodorized. Steam also is used to create turbulence which intimately mixes the steam with the oil. Excessive steam can cause misting, which can lead to neutral oil carry-over, or splashing, increasing neutral oil loss as shell-drain. Ideally the steam rate should cause as much turbulence as possible to create maximum mixing but should be low enough to prevent significant splashing and carry-over. In general, a good steam rate is between 0.5% and 4.0% based on the weight of oil being processed.

Most vegetable oil refiners do not have the ability to control the level of vacuum. With a properly designed and operating system, vacuums are typically 5 mm Hg or less. Air leaks, faulty equipment, or excessive amounts of steam can lead to insufficient vacuum. If a system is being operated as designed and pressures are significantly higher than 5 mm Hg, an additional vacuum stage may be justified by both reduced steam costs and increased tocopherol production.

**Preserving tocopherols**

Tocopherols collected under the best conditions can be lost if the distillate is not stored properly. Tocopherols are antioxidants. They can degrade or be destroyed by exposure to oxygen, heat, and the by-products of metal corrosion. Storing deodorizer distillate properly becomes more important the longer the distillate is being stored.

Proper storage tanks usually can be justified based on the value captured from distillate sales.

The best conditions for storing distillate include storage at ambient temperatures, storage under a nitrogen blanket, temporary gentle heating for handling purposes, and use of a storage tank constructed of a noncorroding material such as stainless steel.

The worst conditions for storing deodorizer distillate would include storage in an area where the tank is exposed to heat or direct sunlight, storage without an inert gas blanket, storage in a tank constructed of carbon steel, storage of distillate for periods longer than three months, and storage of distillate with moisture levels greater than 3%. Moisture in a storage tank should be minimized. One way to limit moisture is to use nitrogen instead of steam to blow out inlet lines (Figure 5).
Monitoring the ratio of tocopherols to total sterols (after saponification) is a good way to determine if degradation is occurring during processing or storage (Table 2). Tocopherols will degrade under conditions that sterols will not. If the percentage of total sterols relative to tocopherols is large, or if it is increasing, degradation is occurring.

Minimizing dilution
The value of deodorizer distillate sold for its tocopherol content is based primarily on the amount of tocopherol in the distillate. Any components that dilute the tocopherol content in the distillate also lower the value of the distillate.

Tocopherols can be diluted during processing in a number of ways. Physical refining carries free fatty acids into deodorizer distillate. These fatty acids would otherwise be removed as soapstock in a chemical refining process. Hydrogenation generates free fatty acids in vegetable oils. These free fatty acids are also carried over into the distillate.

It is unlikely that a vegetable oil refiner would decide to change from physical refining to chemical refining based solely on a desire to capture the value of tocopherol. It is also unlikely that a refiner would stop hydrogenating for that reason. However, there are other factors that contribute to the dilution of tocopherols that can be avoided. Neutral oil carry-over, the addition of shell-drain to distillate, and the addition of hot-well skimmings to distillate all contribute to the dilution of tocopherols. All can be avoided.

Minimizing neutral oil loss to deodorizer distillate not only increases the value of the distillate but also improves the yield of refined oil. Neutral oil can be carried over into distillate when fine droplets of atomized oil are carried into the scrubber. Oil atomization can occur with excessive steam. It also can occur when the demister pad in the deodorizer is improperly aligned above the tray.

Monitoring the ratio of acid value to saponification value is a good way to determine whether there is excessive neutral oil carry-over in deodorizer distillate. Typically, the ratio of acid value to saponification value should be 0.67 or greater. If this ratio is sig-

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Table 2
Ratio of tocopherols to total sterols (after saponification)

<table>
<thead>
<tr>
<th>Distillate sterol:tocopherol ratio</th>
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<tbody>
<tr>
<td>Soy</td>
<td>1.3:1</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>1.6:1</td>
</tr>
<tr>
<td>Sunflower</td>
<td>2.4:1</td>
</tr>
<tr>
<td>Corn</td>
<td>2.7:1</td>
</tr>
<tr>
<td>Cottonseed</td>
<td>3.1:1</td>
</tr>
<tr>
<td>Peanut</td>
<td>4.0:1</td>
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significantly less than 0.67, steps should be taken to identify the origin of the excess neutral oil.

Excessive amounts of oil in the shell-drain can occur when steam splashes oil out of a tray and into the shell of the deodorizer. It also can occur when a tray or demister pad is misaligned. Shell-drain is almost always neutral oil, which is very low in tocopherols. For this reason shell-drain will dilute the tocopherol concentration and should not be added to the deodorizer distillate.

Shell-drain also can form when vapors condense on cold spots in the deodorizer. A tocopherol analysis of the shell-drain will indicate if this is occurring. If the analysis shows significantly more than 1% tocopherol, there is more than likely a cold spot in the deodorizer condensing vapors.

Excessive amounts of hot-well skimmings indicate that the scrubber is not operating properly. This can occur when the demister pad in the scrubber is misaligned or when the cooling system or contact system of the scrubber is not working properly. Tocopherols in hot-well skimmings usually degrade due to the exposure to oxygen and water. Because of this degradation, hot-well skimmings have a very low percentage of tocopherols. In addition to low tocopherols, hot-well skimmings usually contain emulsified water. As a result, not only can hot-well skimmings dilute the tocopherol content of the deodorizer distillate, but the water in the skimmings can also contribute to the degradation of the tocopherols. For this reason, hot-well skimmings should not be added to deodorizer distillate.

**Shipping costs**

This article has outlined ways of obtaining optimal levels of tocopherols in deodorizer distillate. Some manufacturers of natural vitamin E have paid more for deodorizer distillate containing high concentrations of tocopherols. This is another reason why it makes economic sense for vegetable oil manufacturers to optimize their tocopherol yields. Some vegetable oil manufacturers and entrepreneurs have considered purchasing equipment to further concentrate tocopherols after the distillate has been collected. Before investing in these technologies, it is important to understand the economic constraints of concentration.

When distillate is shipped internationally, the ocean freight costs can be significantly higher than typical domestic freight costs. It costs more per pound (of tocopherol) to ship distillate with 5% tocopherol than it does to ship an equivalent weight with 10% tocopherol. Manufacturers of natural vitamin E realize this and pay a percentage of the freight savings as a premium to motivate vegetable oil manufacturers to obtain higher concentrations.

This means that the maximum value that can be extracted from concentration is the cost difference between shipping distillate at the starting concentration and shipping distillate at the final concentration, which means that more of a premium will be paid for concentrating from 4% to 15% than for concentrating from 15% to 30%.

In most cases, if a vegetable oil manufacturer wants to increase its tocopherol levels from 4% to 15%, it makes more economic sense to optimize the deodorization process than to invest in concentration equipment.

Yield is another economic constraint of concentrating that is of particular interest to natural vitamin E manufacturers. The value of the tocopherol lost during concentrating will be greater than the premium paid for concentrating unless the tocopherol yield is in the high nineties. In most cases having more tocopherol is more important than having concentrated tocopherol.

Careful operation of a deodorizer with proper scrubbing and careful handling of distillate will result in recovery of a valuable by-product.

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