Vegetable Oil Deodorizer Distillate: A Rich Source of the Natural Bioactive Components

Syed Tufail Hussain Sherazi* , Sarfaraz Ahmed Mahesar and Sirajuddin
National Centre of Excellence in Analytical Chemistry, University of Sindh, Jamshoro-76080, PAKISTAN

Abstract: Deodorizer distillates are waste products of edible oil processing industries obtained during deodorization process of vegetable oils. It is very cheap source of several health beneficial components such as tocopherols, sterols, squalene as well as free fatty acids which have numerous industrial applications. These valuable components are being used in different foods, pharmaceutical formulations and cosmetics. Traditional sources of these useful components are vegetable oils, fruits, vegetables and nuts. Global need of these important components has been exceeded than their availability. The deodorizer distillates of various vegetable oils are considered to be a rich source of several valuable components. Present review will cover brief introduction of common processing stages involved in all vegetable oil processing, analytical methods for characterization of deodorizer distillates by instrumental techniques, importance and commercial value of deodorizer distillates. Future prospective of current field may leads to cost efficient processes and increased attention on the nutritional quality of deodorized oil and commercial applications of deodorizer distillates as well as their valuable components.

Key words: deodorizer distillates, characterization, analytical techniques, importance, commercial value

1 Introduction

Extracted vegetable oils from the oilseeds are in crude state. Most of the crude oils couldn’t be used directly for edible purpose due to their unacceptable color and odor except olive oil. Crude oils contain undesirable components such as free fatty acids (FFAs), pigments, metals, gums, waxes, phospholipids and odoriferous materials which must be removed to get a stable product with a bland taste. Therefore, through efficient industrial processing these unwanted components are removed with minimum impact on nutrition value of the edible oil. Various processes are involved in the refining of vegetable oils. These processing steps may be chemical or physical. Main difference between these two refining procedures is removal of FFAs which could be achieved either chemically (caustic/alkali neutralization) or physically (steam distillation). Differentiation between physical and chemical refining is very clear through a schematic diagram (Fig. 1). Generally, physical refining includes three processing stages i.e. degumming, bleaching and deodorization while chemical refining includes four processing stages i.e. alkali neutralization in addition to degumming, bleaching and deodorization.

1.1 Degumming

Removal of phospholipids from oil is known as degumming. Gums should be separated from the crude oils in the early refining stage due to two major reasons. Firstly, these are responsible for high refining losses because of their emulsifying nature. Secondly, due to the thermal instability gums are decomposed which leads to darkening the color of oil. There are two types of phospholipids i.e. hydratable phospholipids and non-hydratable phospholipids. Hydratable phospholipids contain polar groups and hence soluble in water. Therefore, hydratable phospholipids are removed with hot water and process is known as water degumming. Non-hydratable phospholipids are removed with acid (usually phosphoric acid) to convert all non-hydrated gums to lyso form (hydratable gums) and easily separated from the oils either in a batch process or centrifugation process. This process is called acid degumming. Proper amount of acid, appropriate time in a retention tank and suitable temperature is necessary to achieve best results of degumming. Small quantity of phosphoric acid (0.1-0.3%) is used...
with 85% solution as surplus amount is not adsorbed on surface of bleaching clay and may cause the problem of hydrolysis or phosphorylation of mono- or diglycerides during physical refining at high temperature. In addition to traditional degumming processes enzymatic degumming technology is now also available for reducing the phosphorus content of vegetable oils below 10 mg/kg. It was first developed by the German Lurgi Company, as the “EnzyMax process” in the 1990s. By using different types of enzymes non-hydratable phospholipids can be changed into a hydratable form, which can easily separated by centrifugation.

1.2 Chemical refining

In chemical refining generally sodium hydroxide (caustic soda) is used. Dilute solution of sodium hydroxide reacts with FFA present in oil to form sodium salts of fatty acids. Saponification leads to formation of soap with FFA and neutralization of oil, soapstock is then removed from the oil with water washes either in a batch process or centrifugation process. There are many disadvantages of chemical refining including loss of oil, high energy requirement, time consuming and production of large amount of byproducts that pollute the environment. Despite above disadvantages, many industries still use this process. Due to these reasons physical refining method is mostly recommended for high FFA contents

1.3 Bleaching

Commonly oils are treated with bleaching clay following neutralization and before deodorization. However, bleaching process can be carried out at different stages according to the type and quality of oil as well per requirement of industry. Bleaching eradicates soluble material from oil. Bleaching is an adsorptive procedure to remove color pigments, metals, residual phosphatides, soaps and oxidation products. On the bases of chemical and physical properties of adsorbed material and the bleaching clay, the nature of adsorption is due to the following mechanisms.

1. Physical adsorption: In this process van der Waals forces between molecules hold the adsorbed species on the bleaching clay.
2. Chemisorption: In this process there is a chemical bond between the adsorbate and the adsorbent.
3. Decomposition and dehydration: Pseudoneutralization of peroxides during the oil-bleaching process.

Usually bleaching clays are derived from calcium, magnesium, and aluminum silicates (60–70% SiO₂). Bleaching clays are usually called “bentonites”, composed of calcium montmorillonites (named for a region in France) and mixed sepiolites, hectorites, and smectites. Whereas sodium bentonites are named for Fort Benton, Wyoming. Basically bleaching earths are surface mined, activated, washed, dried, and ground to a powder with a particle size in between 1–100 μm with moisture content of 10–20%. Generally, bleaching clays are classified in two groups i.e. naturally active clays and acid-activated clays. Frequently bleaching is carried out with acid-activated clays.

To reduce the color and oxidative reactants, bleaching is subjected under vacuum (20–30 mm Hg). Mostly, oil is
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heated to 90°C during bleaching. Clay to oil ratio depends on the quality of input oil. The bleaching process is carried out at 80–120°C and takes about 15–30 min. The elevated temperature is necessary to keep a low oil viscosity to improve diffusion and mass transfer rates. But, very high temperature is not suggested since unwanted reactions also become very fast.  

1.4 Physical refining

FFA and other volatile components are removed in deodorization at high temperature and low pressure. If total FFAs are eradicated in deodorizer through steam under high vacuum and temperature without using alkali neutralization then process is called physical refining. Deodorization is a simple process by which saponifiable matter, unsaponifiable substances and other volatile compounds are distilled. Therefore, deodorizer distillates obtained through physical refining contained greater amount of FFA (> 70%) and comparatively less quantity of unsaponifiable matters. Consequently, such deodorizer distillates are marketed as a source of fatty acids. In chemical refining, caustic solution is used to neutralize FFAs either in batch process or continuous process and soap is washed out with water. Thus, deodorizer distillates obtained from chemical refining contain comparatively less quantity of FFA (30-50%) and greater amount of unsaponifiable matters (25-33%) but physical refining is recommended for vegetable oils which contain high amount of FFAs (>3%). Physical refining is recommended for those vegetable oils which have a lower concentration of FFAs (<3%). Initial investment on physical refining is less than chemical refinery and operational cost is also less but recovery of RBD (refined, bleached and deodorized) oil is much better. A step of alkali neutralization is totally avoided in physical refining as compare to chemical refinery which involves costly equipments (such as continuous separators) and greater loss of crude oil. Physical refining is considered to be environment friendly because no wash water is required for physical refinery while a lot of water is needed in alkali neutralization for chemical refinery to clear soap stocks, respectively. Which are environment friendly because no wash water is required for physical refinery while a lot of water is needed in alkali neutralization for chemical refinery to clear soap stocks, respectively. 

1.5 Deodorization process

Deodorization is a simple distillation process in which various volatile components are separated from the oil. Edible oil deodorization is performed industrially in different ways (continuous, semicontinuous or batchwise) with various configurations of deodorizers (horizontal or vertical vessels, tray-type or packed columns). Selection of the most appropriate process technology is mainly determined by the total plant capacity and the number of feedstock changes. Principle of deodorization includes following three processes:

1. Stripping: Stripping of volatile components such as FFA, tocopherols, steroids, odorous compounds, and contaminants (pesticides and light polycyclic aromatic hydrocarbons, etc.),
2. Actual deodorization: Removal of different off-flavor components, and
3. Thermal degradation: Causes destruction of color pigments and unwanted side reactions like polymerization, cis-trans-isomerization and conjugation.

Therefore, during deodorization volatile components are evaporated from liquid to gas and subsequently back to liquid via condensation. Generally, during processing the temperature of deodorizer is maintained at 180–260°C using high pressure steam boiler. High vacuum between 2–8 mmHg is retained in the deodorizer to avert the oil from oxidative damage. Optimized stripping parameters such temperature, time, vacuum, and amount of stripping steam or nitrogen gas are control the specifications of the outgoing deodorized oil and deodorization cost. The volatile odoriferous compounds are stripped off by direct injection of high temperature steam. These unwanted volatile compounds include FFAs, peroxides, aldehydes, ketones, alcohols, and carbohydrates are removed during deodorization. However, some bioactive components like tocopherols, sterols and squalene are also distilled during deodorization.

1.6 Deodorizer distillate (DD)

The deodorizer distillates are complex mixture of many health beneficial constituents. Volatile compounds present in a very small concentration in the vegetable oils are responsible for the unacceptable odor, color, taste and flavor of the oil. Commonly, vegetable fats and oils are subjected to industrial treatments before being consumed for edible application. Industrial processing such as neutralization, bleaching and deodorization produces significant amount of waste materials like soapstocks, spent bleaching clays and deodorizer distillates, respectively. Which are often wasted without being proper utilization and many valuable components are lost. Deodorizer distillate is an important by-product obtained from the deodorization process of vegetable oils. The unwanted volatile com-
pounds include aldehydes, ketones, alcohols, and peroxides which must be removed for edible applications of the oil. Volatile compounds are stripped off by direct injection of superheated steam or nitrogen at a temperature between 220 and 260°C depending upon the types of deodorizers and quality of input oils. From deodorizer, volatile fraction is distilled and collected through condensers as deodorizer distillate. Deodorizer distillates are a natural source of valuable components such as tocopherols, tocotrienols, phytosterols, hydrocarbons, and squalene as well as mono and di-acylglycerols and FFAs9, 12, 22, 23. Tocopherols are very important natural antioxidants that prevent the rancidity of oils during storage and improve the shelf life of edible oils31. Assessment of the each component present in the deodorizer distillate is very important to evaluate the value of deodorizer distillate1, 25.

2 Analytical techniques used for the characterization of deodorizer distillate

In the literature, few analytical methods are reported for comprehensive analysis of deodorizer distillates. Liquid-liquid extraction, esterification/transesterification, molecular distillation, and crystallization techniques are applied for extraction, separation and purification of different constituents of deodorizer distillates. Supercritical fluid fractionation (SFF) technology has been also applied for the recovery of valuable compounds from deodorizer distillates. Main focus of these techniques was on the determination and recovery of tocopherols and sterols which are most important constituents of deodorizer distillates. Some investigators have also studied the phase equilibria and separation behavior of deodorizer distillates. Simple and accurate approaches were used for chemical characterization and evaluation of different components present in the deodorizer distillates1, 2, 12, 22.

Capillary gas chromatography (GC) is a modest and quicker technique for classification of all constituents in deodorizer distillates. There is no need of saponification when using this method. Resolution of the peaks of eluted components is much better than the GC analysis utilizing a packed column. Therefore, capillary GC is considered to be best choice for the separation of the most important components present in the deodorizer distillate in one single run. Multicomponent analyses of deodorizer distillates present were carried by some scientists via in situ silylation. After silylation, the components were separated by GC with mass spectrometry (MS) for final identification. The compounds separated were tocopherols, sterols, fatty acids and glycerol esters1. For the determination of bioactive components in deodorizer distillates, use of costly procedure like capillary supercritical fluid chromatography–mass spectroscopy is not appropriate technique and considered to be one of the less popular methods due to high price and time consumption. Although, Snyder et al. used this method for the separation and characterization of tocopherol, squalene and sterol of deodorizer distillate samples but authors suggested that if in any lab facility of capillary supercritical fluid chromatography–mass spectroscopy is available then this technique could be successfully used for the characterization of tocopherol, squalene and sterols20. It may be possible to entirely characterize the deodorizer distillate by this method, but further research involving temperature and pressure must be carried out to evaluate their effects on the separation of all the components of the distillate. Another costly technique was reported by Ramamurthi and McCurdy, which includes lipase-catalyzed modification of fatty acids27. This technique was applied on canola and soybean oil deodorizer distillates. The volatile fractions were separated by vacuum distillation to concentrate the fraction containing bioactive components such as tocopherols, sterols and squalene. For the characterization, GC technique was applied. But, high temperature was not so suitable and resolution of peaks was also not so good. Therefore, separation of individual component for accurate quantification is not an easy task.

In the literature some methods have been reported for the separation of the components of deodorizer distillates. Notable methods include solvent extraction and crystallization26, 25, supercritical carbon dioxide extraction (SC-CO2)30–31, enzymatic reaction34 and molecular distillation35, 36. Some other separation methods have been also described in the literature such as permeation of tocopherol from deodorizer distillates using a non-porous denser polymeric membrane37 and concentration of tocopherol and sterols by addition of melted deodorizer distillates to a solution of urea and alcohol to separate fatty acids from the mixture38. But these methods were rarely used as these have no any advantages over the distinguished methods.

3 Composition of deodorizer distillates

Deodorizer distillate obtained from palm oil refining is known as palm fatty acid distillate (PFAD). Variation in composition of deodorizer distillate is basically depends on the quality of input oil, type of deodorizer and processing parameters such as volume of stripping steam, vacuum, temperature and time of deodorization. Amount of DD is independent on the types of oil but it depends on the FFAs level of input oil to deodorization process. For example, amount of PFAD obtained from processing of palm oil has been reported about 4%29. Top (2010) reported that PFAD is composed of FFAs (81.7%), glycerides (14.4%), squalene (0.8%), vitamin E (0.5%), sterols (0.4%) and other substances (2.2%)40. According to Saba Naz et al., concentration of phytoster-
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ols in unsaponified part of deodorizer distillates was the most abundant (21.27–25.53%) in different samples of canola deodorizer distillate and PFAD samples, whereas squalene and tocopherol were present in concentration ranges between 2.89–13.21% and 1.29–5.81%, respectively.

Bondioli et al. reported the typical compositions (wt %) of olive oil deodorizer distillate (OODD) obtained from chemical refining. Amount of FFA and squalene were found to be dominant with the levels of 34% and 28%, respectively whereas phytosterols were reported 4.6%.

Winter provided main components of deodorizer distillates and concentration of unsaponifiable matter expressed as % (w/w). Value of deodorizer distillate depends on the amount of unsaponifiables matter. In sunflower oil deodorizer distillates, mean percentages of unsaponifiable matter, tocopherols, \( \alpha \)-tocopherol, sterols, stigmasterol were found to be around 39.0, 9.30, 5.70, 18.0 and 2.90%, respectively. While in cotton seed oil deodorizer distillates concentrations of unsaponifiables, tocopherols, \( \alpha \)-tocopherol, sterols, stigmasterol were estimated to be 42.0, 11.40, 6.30, 20.0 and <1%, accordingly. Similarly, in soybean oil deodorizer distillates percentages of unsaponifiables, tocopherols, \( \alpha \)-tocopherols, sterols, stigmasterol were detected to be 33.0, 11.1, 0.90, 18 and 4.40%, respectively. In rapeseed oil deodorizer distillates percentages of unsaponifiables, tocopherols, \( \alpha \)-tocopherols, sterols, stigmasterol were found to be around 35.0, 8.20, 1.40, 14.60 and 1.80%, respectively as shown in Table 1.

Table 2 represents composition of unsaponified deodorizer distillates analyzed by quantitative GC obtained during chemical and physical refining of different soft oils. The distillate from physical refining is a suitable source of fatty acids, whereas chemical refining provides a better deodorizer distillate for the recovery of sterols and tocopherols from the unsaponifiable fraction.

It is clear from the provided literature that composition of deodorizer distillates depends on the nature of the vegetable oil and processing parameters. Therefore, composition of different deodorizer distillates is dissimilar. Important factors which strongly influence on quantity and value of deodorizer distillate include variety of the seeds and type of extraction (mechanical or chemical) of oil and processing conditions of the deodorizer. High temperature, elevated vacuum, increased steam pressure and extended time of deodorization are responsible to increase the rate of volatilization and amount of deodorizer distillate. Deodorizer distillates obtained from chemically refined oil contain greater concentration of tocopherols (3.5-18.2%), and phytosterols (10-21%) while lesser amount of FFAs (9-42%). However, the distillates resulting from physically refined vegetable oils contain a greater amount of FFAs (70-81%) and lower concentration of tocopherols (1.3-7.5%) and phytosterols (3.3-10.8%) . Overall PFAD was reported to be contained highest amount of FFA (~82% w/w of total distillate) and could be used for biodiesel or animal feed manufacturing. However, appreciable concentrations of phytosterols, squalene and tocopherol were also detected in PFAD. Highest level of squalene was reported in olive oil deodorizer distillate and found to be excellent source of squalene which is used in many cosmetics and medicines. Due to greater amount of FFA (>3%) palm and corn oils are recommended for physical refining while sunflower, soyabean, cotton seed, canola and rapeseed oils are recommended for chemical refining due low concentration of FFA (<3%) in their crude oils. Soybean deodorizer distillate contains greater concentration of \( \gamma \)-tocopherol (11%) and \( \beta \)-sitosterol (8%) but considered to be a good source of stigmasterol (~4%) as stigmasterol is comparatively low in other deodorizer distillates. In the same way cotton seed and sunflower deodorizer distillates contain greater level of \( \alpha \)-tocopherols (~4%) .

4 Importance of bioactive compounds

Unsaponified portion of deodorizer distillates contain greater concentration of valuable components such as tocopherols, sterols and squalene whereas saponified part contains significant amount of FFAs and acylglycerols.

Increasing interest in nutraceuticals and functional foods has promoted food-derived phytochemicals as bioactive in-

<table>
<thead>
<tr>
<th>Bioactive compounds</th>
<th>Deodorizer Distillates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sunflower</td>
</tr>
<tr>
<td>Unsaponifiables matter</td>
<td>39.0</td>
</tr>
<tr>
<td>Tocopherols</td>
<td>9.30</td>
</tr>
<tr>
<td>( \alpha )-Tocopherols</td>
<td>5.70</td>
</tr>
<tr>
<td>Sterols</td>
<td>18.0</td>
</tr>
<tr>
<td>Stigmasterol</td>
<td>2.90</td>
</tr>
</tbody>
</table>

Mean values of replicate samples
Tocopherols are fat-soluble vitamins which are nutritionally very important components and exhibit high antioxidant activity. Commercially vitamin E is available as food supplement in the form of α-tocopheryl acetate. The synthetic and natural forms of vitamin E are labeled as D,L and D, respectively. But activity of synthetic form is approximately half as compared to natural form. It has been reported that α-tocopherol has highest vitamin E activity and prevents cardiovascular disease, cancer, infection, and inflammation as well as decreases the risk of degenerative diseases. Higher bioactivity of tocopherol isomers is in the order of α’ > β’ > γ’ > δ. Each form of tocopherol has its particular biological activity which is directly related with potency or functional use in the body. Such action is directly related with platelet aggregation and antioxidant functions. In each refining stage especially during deodorization, these valuable compounds are reduced. FDA recommended daily vitamin E allowances for humans are: infants, 6.7 mg; adults, children, and lactating and pregnant women, 20.1 mg while daily intake of α-tocopherol is about 5–9 mg.

Phytosterols are important members of the natural products family known as triterpene and these could be converted to phytostanols through chemical hydrogenation. Therefore, phytostanols are a fully hydrogenated subgroup of phytosterols. Both, phytostanols and phytosterols are considered to be very effective in lowering low density lipoprotein serum cholesterol. Vitamin E and sterols are also considered to be good candidates for corticoid drug and hormone synthesis. Similarly use of stigmasterol has been reported in the preparation of corticoids and progesterone while sitosterol is used for the production of estrogens, contraceptives, diuretics, and male hormones. Due to effective physiological activity of phyotosterols, these are used in many functional foods like margarine blended with steryl esters and salad oils and dressings with added sterols. Yang et al. reported that phytosterols possess anti-inflammatory, anti-atherogenic, anti-cancer and antioxidative activities. Moreover, phytosterols can be used in pharmaceuticals (production of therapeutic steroids), nutrition (anti-cholesterol additives in foods, anti-cancer properties), and cosmetics (creams, lipstick).

Nutritional importance of phytosterols is due to their ability of lowering serum cholesterol and thereby reducing risk of cardiovascular diseases. Analysis of unsaponifiable extracts of deodorizer distillates reveals the presence of the following phytosterols: β-sitosterol, brassicasterol, stigmasterol, and campesterol.

Table 2 Composition of unsaponified deodorizer distillates (%) obtained from chemical or physical refining of different soft oils.

<table>
<thead>
<tr>
<th>Bioactive compounds</th>
<th>Soybean Chemical</th>
<th>Corn Physical</th>
<th>Sunflower Chemical</th>
<th>Rapeseed Chemical</th>
</tr>
</thead>
<tbody>
<tr>
<td>δ-Tocopherol</td>
<td>4.4–5.6</td>
<td>2.0</td>
<td>0.1</td>
<td>n.d.*</td>
</tr>
<tr>
<td>β-Tocopherol</td>
<td>0.4–0.5</td>
<td>n.d.</td>
<td>0.1</td>
<td>n.d.</td>
</tr>
<tr>
<td>γ-Tocopherol</td>
<td>10.7–11.3</td>
<td>5.0</td>
<td>1.1–2.8</td>
<td>0.3</td>
</tr>
<tr>
<td>α-Tocopherol</td>
<td>0.8</td>
<td>0.5</td>
<td>0.2–0.4</td>
<td>4.8</td>
</tr>
<tr>
<td><strong>Total Tocopherols</strong></td>
<td><strong>16.3–18.2</strong></td>
<td><strong>7.5</strong></td>
<td><strong>1.5–3.4</strong></td>
<td><strong>5.1</strong></td>
</tr>
<tr>
<td>Campesterol</td>
<td>5.1–5.7</td>
<td>1.9</td>
<td>0.8–1.7</td>
<td>1.6</td>
</tr>
<tr>
<td>Stigmasterol</td>
<td>4.1–4.8</td>
<td>1.4</td>
<td>0.2–0.4</td>
<td>2.0</td>
</tr>
<tr>
<td>β-Sitosterol</td>
<td>7.9–8.3</td>
<td>3.0</td>
<td>1.7–3.4</td>
<td>8.6</td>
</tr>
<tr>
<td><strong>Total sterols</strong></td>
<td><strong>19.4–21.4</strong></td>
<td><strong>10.8</strong></td>
<td><strong>3.3–6.1</strong></td>
<td><strong>14.2</strong></td>
</tr>
<tr>
<td>Mono-acylglycerols</td>
<td>1.2–1.9</td>
<td>1.9</td>
<td>0.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Diacylglycerols</td>
<td>2.7–3.8</td>
<td>8.1</td>
<td>0.5–1.3</td>
<td>1.9</td>
</tr>
<tr>
<td>Triacylglycerols</td>
<td>5.1–5.9</td>
<td>3.8</td>
<td>0.1–0.8</td>
<td>2.6</td>
</tr>
<tr>
<td>FFA (as C18:1)</td>
<td>33</td>
<td>73.8</td>
<td>77–81</td>
<td>9.2</td>
</tr>
<tr>
<td>Squalene</td>
<td>1.3–2.1</td>
<td>0.6</td>
<td>0.2–1.0</td>
<td>0.7</td>
</tr>
</tbody>
</table>

n.d.*, Not detected
**Δ5 avenasterol, Δ7 avenasterol and Δ5 stigmasterol**
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Deodorizer distillates obtained from vegetable oil processing have effective anticancer and antipyretic properties. The National Institutes of Health has issued guidelines regarding treatment of high blood cholesterol through its National Cholesterol Education Program. The guidelines recommend that plant sterols could be used as therapeutic dietary options to enhance lowering of LDL (low-density lipoprotein) cholesterol. Per day 2 g of phytosterols along with 10–25 g of soluble fiber has been recommended for significant reduction of cholesterol \( \text{LDL} \) [64–67]. The addition of phytosterols esters to foods is regulated by the European Union Regulation (EC) No. 258/97 of the European Parliament and of the Council of 27 January 1997 concerning novel foods and novel food ingredients [68].

The name squalene for the \( \text{C}_{30}\text{H}_{48} \) hydrocarbon is related with its occurrence in shark liver oil (Squalus spp.). Significant amount of squalene is found in rice bran oil, olive, palm and wheat germ. Squalene is an important linear hydrocarbon and abundantly found in almost all types of deodorizer distillates. It is widely used in cosmetics and in the biosynthesis of cholesterol [69]. Hydrogenation of squalene provides another important product known as squalane and not subjected to autoxidation. Squalane and squalene can be metabolized and have a great potential to be used in toxicology studies [70]. Squalene in addition to other lipids such as hexadecane with mycobacterium cell wall enhances non-specific immunity against tumors. Due to free flowing oil ability, squalane has been used in skin lubricant, pharmaceuticals, and as a transporter for lipophilic drugs. Squalene and squalane emulsions are used in human cancer vaccines due to their effective immune response and antitumor activity. In the United States, average daily intake of squalene is about 30 mg per day per person. Squalene has been considered to be vital dietary cancer chemopreventive agent and powerful antioxidant [70, 71].

FFAs are product of lipid hydrolysis and are directly related to unpleasant flavor and taste of the edible oils. Therefore, for edible applications, FFAs should be removed through refining process. Generally, FFAs are significant contributors in the composition of deodorizer distillates. At present, deodorizer distillate obtained from processing of vegetable oils during deodorization has gained much attention for the production of biodiesel as a green approach [40, 72]. FFAs could be used in the formulation of animal feed and soap industries as well as in the oleochemicals industries. Monoglycerides, diglycerides and triglycerides are known as acylglycerols. Triacylglycerols are the significant components in vegetable oil deodorizer distillate. Monoglycerides and diglycerides have detergent properties as these are easily form miscelles in water solutions [1, 16, 17, 21].

5 Commercial value of deodorizer distillate

Specifications of DD obtained from various studies as well as national and international standards provide helpful data about quality and commercial importance. However, these specifications are intended to be advisory and not to be implied in any contract. The commercial value of deodorizer distillates depends on the level of unsaponifiable matters. Commonly, price of DD is based on tocopherol and stigmasterol contents. However, tocopherol market has a great impact in determining the price of deodorizer distillates than sterol market. Commonly, distillate obtained through physical refining is lower in value than distillate from caustic refined oil. Because deodorizer distillates acquired through physical refining are less in concentration of tocopherols and sterols while greater in concentration of FFAs. Furthermore, the oxidative stability of the physically refinery distillate is lower as measured by carbonyl and peroxide values [1, 21, 45]. Therefore, price of deodorizer distillates is reduced and this affects the total sale of distillate. Tocopherols and phytosterols are used as active ingredients in many types of functional foods. Therefore, deodorizer distillates with a high concentration of these components should have good market value. When market of tocopherol and steroid is strong then disposal of deodorizer distillate is profitable. Otherwise it is sold as soap stock or can be disposal issue. In some countries deodorizer distillates are used in animal and poultry feeds.

6 Conclusions

On the one hand deodorization process removes odorous components from the vegetable oil to make it acceptable to the consumers for edible purpose on the other hand bioactive components are achieved in concentrated form through deodorizer distillates. However, use of optimized parameters is necessary to control loss of nutritionally useful components from final deodorized oil during deodorization process. Deodorizer distillates are rich and cheap sources of many valuable and health beneficial components such as tocopherols, phytosterols and squalenes. Deodorizer distillates have a great potential to meet the increasing demand of consumers for these natural bioactive components and may find new approaches of characterization and applications in pharmaceuticals, foods and cosmetics industries in future.

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Author Contributions
Conceived and designed the experiments: Sherazi, STH
Analysed the data: Sherazi, STH, Sirajuddin, Mahesar, SA
Wrote the first draft of the manuscript: Mahesar, SA
Contributed to the writing of the manuscript: Sherazi, STH; Mahesar, SA; Sirajuddin
Agree with manuscript results and conclusions: Sherazi, STH; Mahesar, SA; Sirajuddin
Jointly developed the structure and arguments for the paper: Sherazi, STH; Mahesar, SA; Sirajuddin
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References
25) Newkirk, D.R. Studies on Vegetable Oil Deodorization.
Deodorizer distillates obtained from vegetable oil processing

Distillates with Respect to Lipid and Pesticide Content; The American University: Washington, DC. (1982).


