Novel Technologies for Food Processing and Shelf Life Extension

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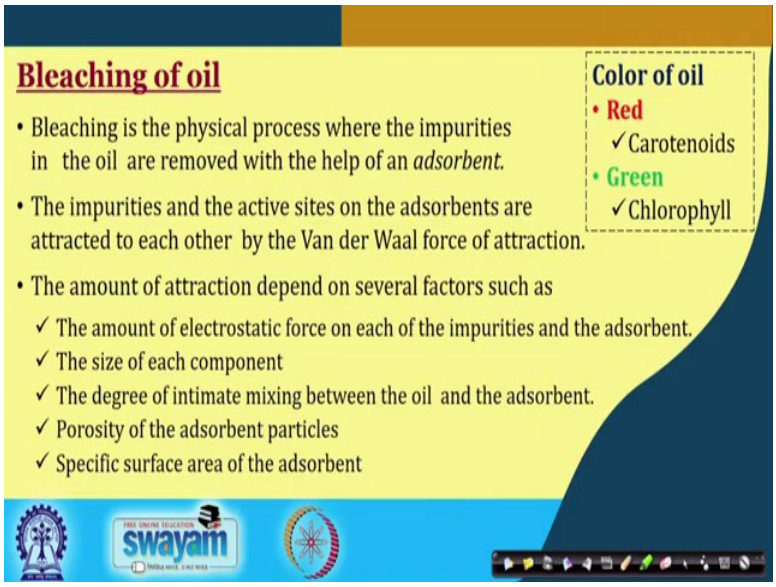
Lecture – 33
Edible Oil Refining (Part 2) Bleaching & Deodourization

Bleaching and deodorization are the major steps of edible oil refining process; this will be studied in this lecture.

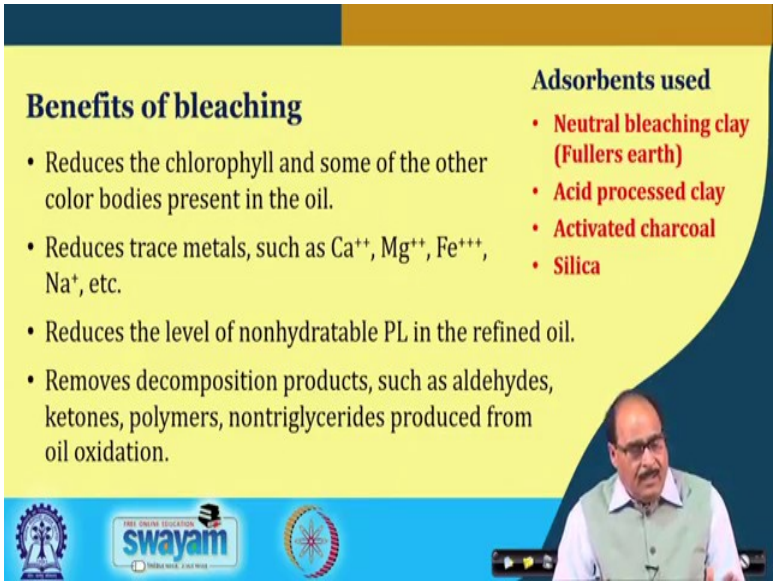


Bleaching of oil

Depending upon the extraction process parameters used along with the triglycerides, there are other components also like chlorophyll which imparts green colour or carotenoids which impart reddish or yellowish colour to the oil. They also get extracted from the oil seed to the oil. So, this becomes necessary that these pigments or those components which contribute to the colour other than those of the triglyceride should be removed.

It is basically a physical process where the impurities in the oil particularly those pigments and other related components are removed with the help of an adsorbent. The impurities and the active sites of the adsorbents are attracted to each other by Van der Waal force of attraction. The amount of attraction accordingly will influence the bleaching efficiency. It depends upon several factors like the amount of electrostatic force on each of the impurities and the adsorbent, the size of each component, the degree

of intimate mixing between the oil and the adsorbent, porosity of the adsorbent particles and specific surface area of the adsorbent.

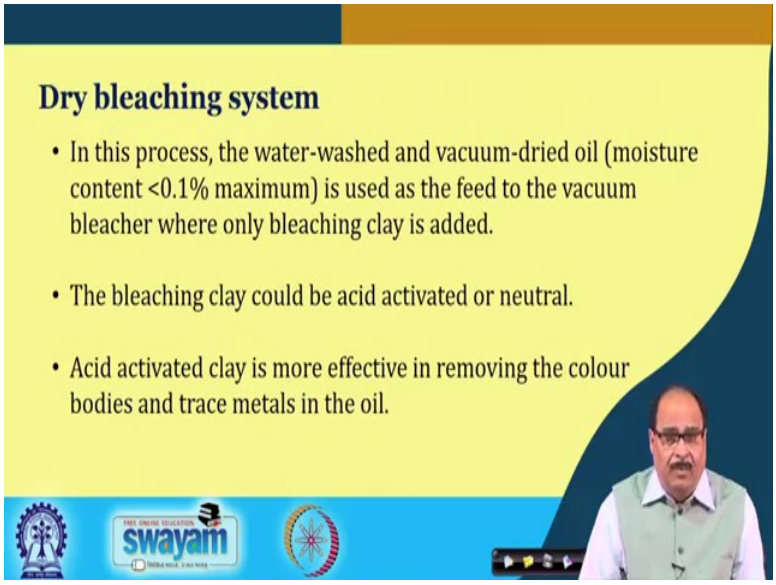


Benefits of bleaching

- Reduces the chlorophyll and some of the other colour bodies present in the oil.
- Reduces the trace metals such as Ca^{++}, Mg^{++}, Fe^{++}, Na^{+}, etc.
- Reduces the level of non-hydratable phospholipids in the refined oil.
- Removes decomposition products, such as aldehydes, ketones, polymers, non-triglycerides produced from oil oxidation.

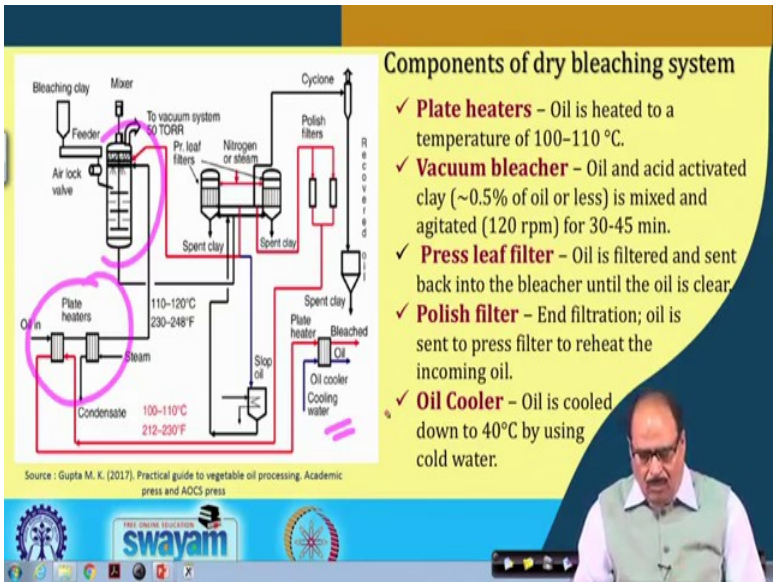
If these components are not removed, they may act as pro oxidant and this actually reduces the shelf life of the oil.

The different adsorbents which are used include neutral bleaching clay or commonly known as fullers earth, acid processed clay, activated charcoal and silica.



Dry bleaching system

- In this process, the water-washed and vacuum-dried oil (moisture content <0.1% maximum) is used as the feed to the vacuum bleacher where only bleaching clay is added.
- The bleaching clay could be acid activated or neutral.
- Acid activated clay is more effective in removing the colour bodies and trace metals in the oil.



Components of dry bleaching system

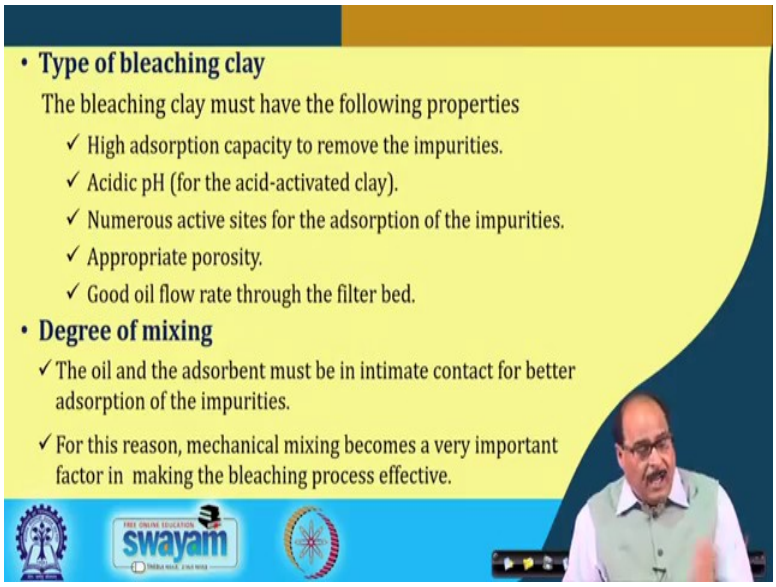
- ✓ **Plate heaters** – Oil is heated to a temperature of 100–110 °C.
- ✓ **Vacuum bleacher** – Heated oil is sent to the vacuum bleacher. Oil and acid activated clay (~0.5% of oil or less) is mixed and agitated (120 rpm) for 30-45 min.
- ✓ **Press leaf filter** – Oil is filtered and sent back into the bleacher until the oil is clear.
- ✓ **Polish filter** – End filtration; oil is sent to press filter to reheat the incoming oil.
- ✓ **Oil Cooler** – Oil is cooled down to 40°C by using cold water.

Critical control points in dry bleaching

- **Incoming oil quality**

- ✓ When the bleached oil is high in phosphorous, soap, and moisture contents more amount of bleaching clay is required.
- ✓ Soap, phosphorus & moisture have a tendency to plug up the porosity of the filter bed, decreasing the filtration rate.
- ✓ Increased bleaching clay usage also builds up the cake faster in the filter, reducing the filtration cycle time.
- ✓ Higher soap in the oil produces high FFA.

✓ Higher amount of bleaching clay reduces the level of tocopherols and other natural antioxidants.



- **Types of bleaching clay**

The bleaching clay must have the following properties:

✓ High adsorption capacity to remove the impurities.

✓ Acidic pH (for the acid-activated clay).

✓ Numerous active sites for the adsorption of the impurities.

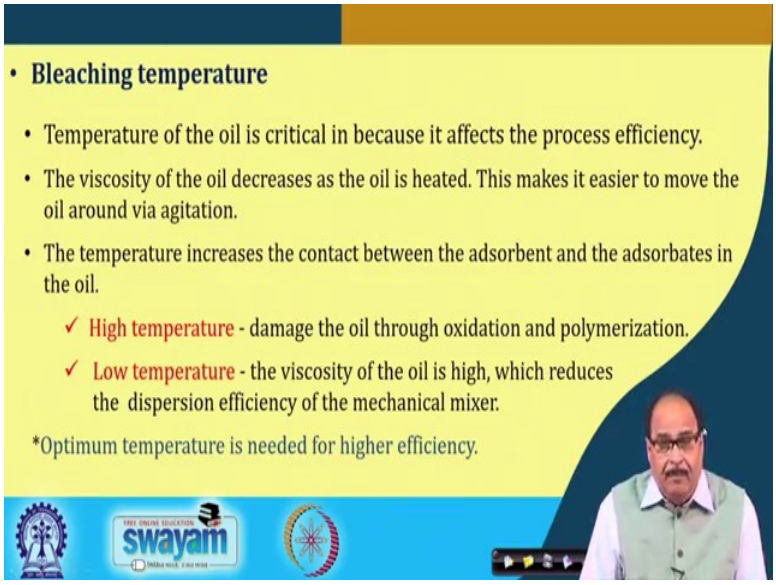
✓ Appropriate porosity.

✓ Good oil flow rate through the filter bed.

- **Degree of mixing**

✓ The oil and the adsorbent must be in intimate contact for better adsorption of the impurities.

✓ For this reason, mechanical mixing becomes a very important factor in making the bleaching process effective.



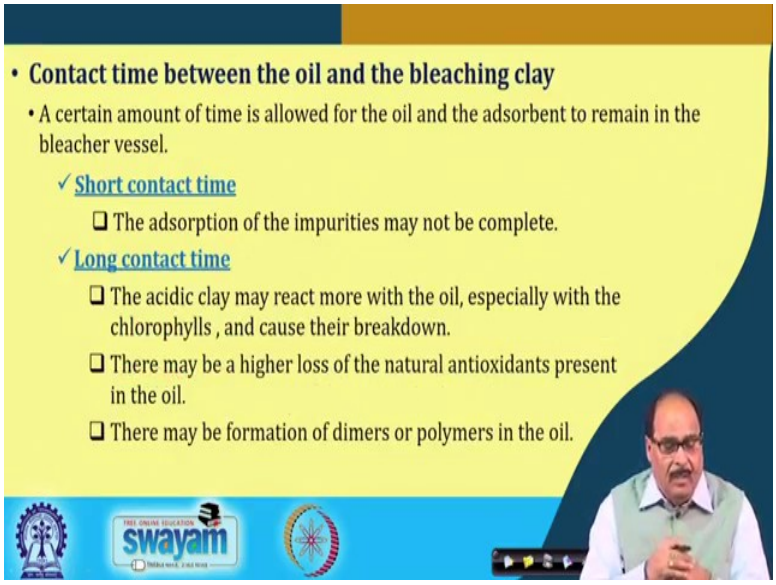
Bleaching temperature

- Temperature of the oil is critical in because it affects the process efficiency.
- The viscosity of the oil decreases as the oil is heated. This makes it easier to move the oil around via agitation.
- The temperature increases the contact between the adsorbent and the adsorbates in the oil.

✓ High temperature - damage the oil through oxidation and polymerization.

✓ Low temperature - the viscosity of the oil is high, which reduces the dispersion efficiency of the mechanical mixer.

*Optimum temperature is needed for higher efficiency.

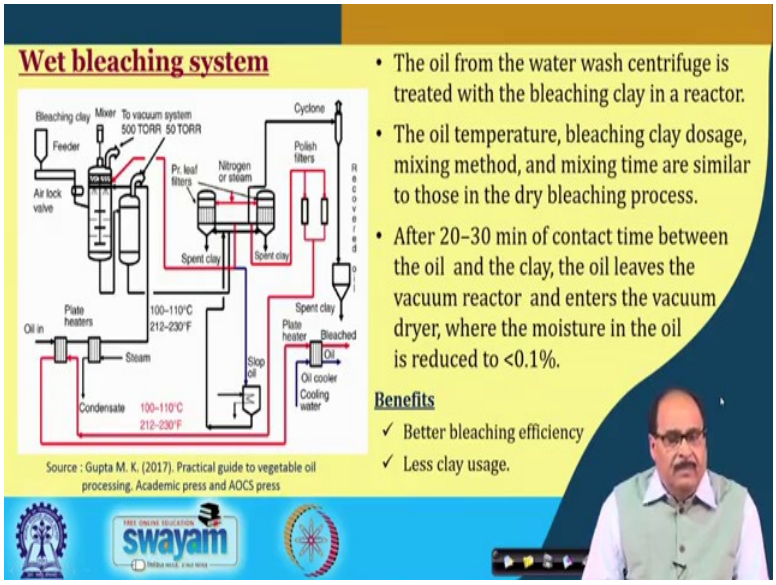


Contact time between the oil and the bleaching clay

- A certain amount of time is allowed for the oil and the adsorbent to remain in the bleacher vessel.
  - ✓ **Short contact time**
  - ✓ The adsorption of the impurities may not be complete.
  - ✓ **Long contact time**
  - ✓ The acidic clay may react more with the oil, especially with the chlorophylls, and cause their breakdown.

❑ There may be a higher loss of the natural antioxidants present in the oil.

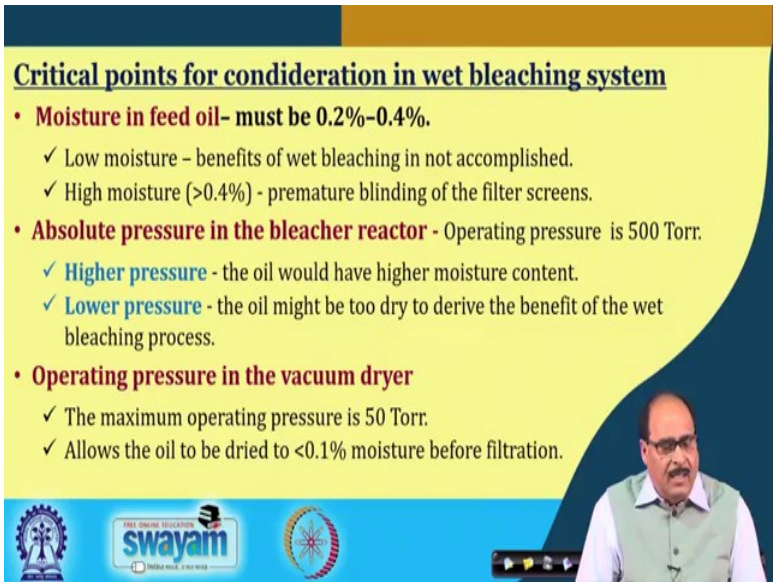
❑ There may be formation of dimers or polymers in the oil.



Wet bleaching system

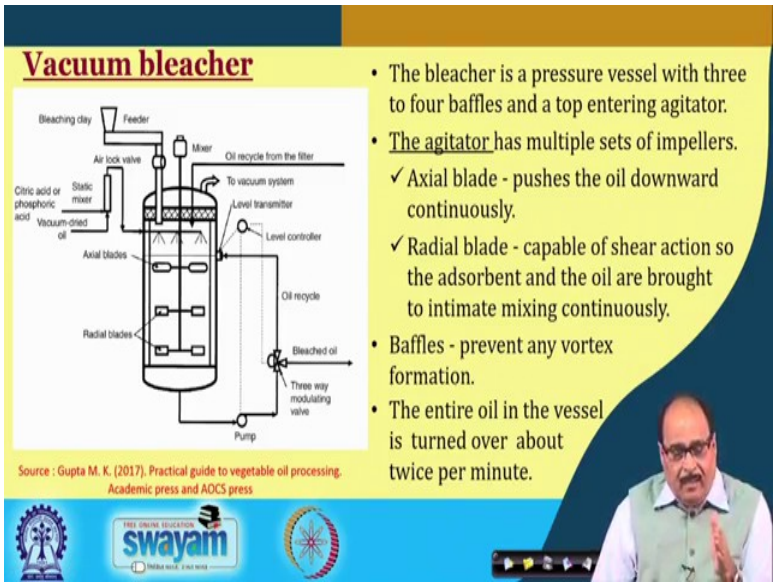
- The oil from the water wash centrifuge is treated with the bleaching clay in a reactor.
- The oil temperature, bleaching clay dosage, mixing method, and mixing time are similar to those in the dry bleaching process.
- After 20–30 min of contact time between the oil and the clay, the oil leaves the vacuum reactor and enters the vacuum dryer, where the moisture in the oil is reduced to <0.1%.

In fact, the wet bleaching system is better and more efficient than that of the dry bleaching process and it results in less clay usage.



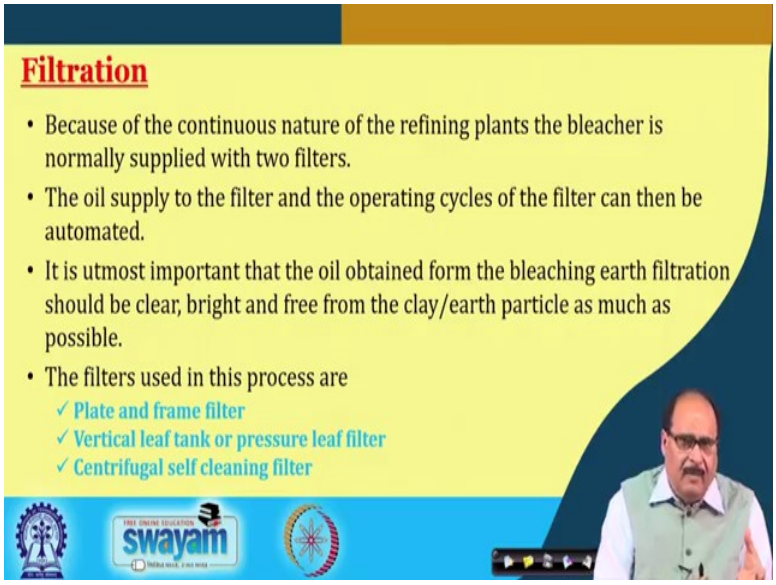
Critical points for consideration in wet bleaching system

- **Moisture in feed oil – must be 0.2%–0.4%.**
  - ✓ Low moisture – benefits of wet bleaching in not accomplished.
  - ✓ High moisture (>0.4%) - premature blinding of the filter screens.
- **Absolute pressure in the bleacher reactor -** Operating pressure is 500 Torr.
  - ✓ **Higher pressure** - the oil would have higher moisture content.
  - ✓ **Lower pressure** - the oil might be too dry to derive the benefit of the wet bleaching process.
- **Operating pressure in the vacuum dryer**
  - ✓ The maximum operating pressure is 50 Torr.
  - ✓ Allows the oil to be dried to <0.1% moisture before filtration.



Vacuum bleacher

The schematic of the vacuum bleaching system has been shown in the figure. It is basically a pressure vessel with three to four baffles provided and a top entering agitator. The agitator is provided with the multiple sets of impellers. These are of axial blade that pushes the oil down continuously and radial blade capable of shear action so, the adsorbent and the oil are brought to intimate mixing continuously. Baffles which are provided prevent any vortex formation and the entire oil in the vessel is turned over about twice per minute so as to ensure thorough mixing and intimate contact between the bleacher clay and the oil in the equipment.



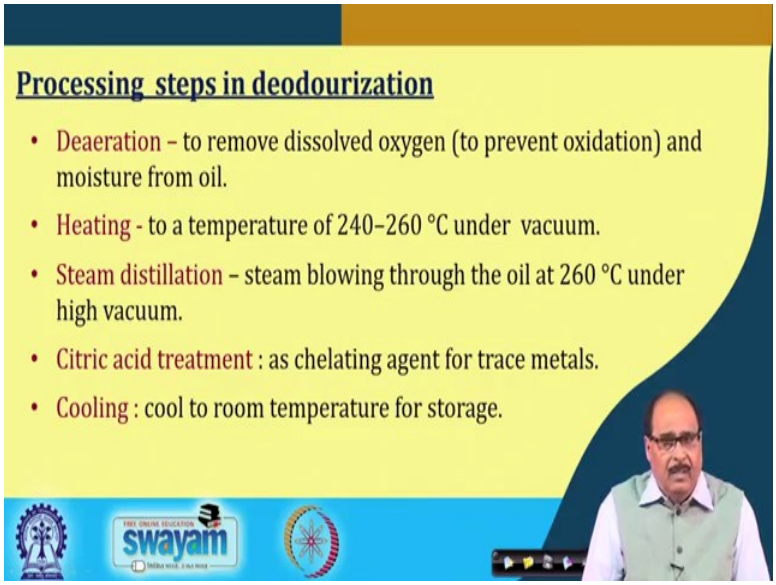
So, after the bleaching, the earth or clay or adsorbent which has been added into the oil must be separated because the pigments may get adsorbed by the product. These earth or clay particles are removed using appropriate filtration steps.

- Because of the continuous nature of the refining plants, the bleacher is normally supplied with two filters.
- The oil supply to the filter and the operating cycles of the filter can then be automated.
- It is utmost important that the oil obtained from the bleaching earth filtration should be clear, bright and free from the clay/earth particle as much as possible.

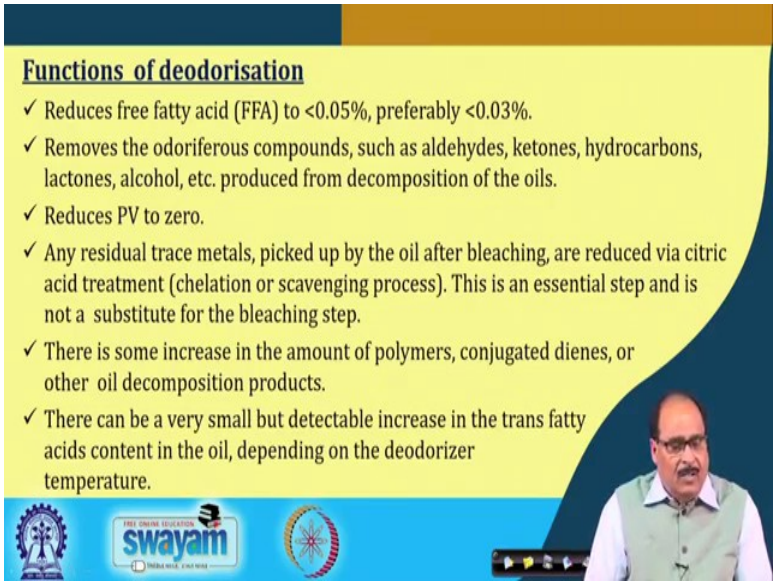
- Accordingly, the filtration system should be efficient i.e. screens should be of appropriate size so that it can remove even the finest particle possible. They generally use filters in oil refining plants.

- The filters used in this process are
  - ✓ Plate and frame filter
  - ✓ Vertical leaf tank or pressure leaf filter
  - ✓ Centrifugal self-cleaning filter

The filtered oil may be diverted to the product manufacturing for hydrogenation, winterization, and if it is to be used for frying and cooking purpose, it is normally sent to the deodorizer where the impurities or even the free fatty acid which are not separated in the earlier processes, those are separated here. Thus, the deodorization is the last stage of the refining process of edible oils. In this process the odours and flavours of fats and oils are totally removed resulting in a bland finished product. Deodorization of the refined and bleached oil is carried out under vacuum and at an absolute pressure of 1 to 6 mm of Hg. In fact, experienced tasters sometimes are not able to identify the source of the oil if the oil is gone through deodorization.



The processing steps in the deodorization are deaeration to remove dissolved oxygen (particularly to prevent oxidation) and moisture from the oil, heating of the oil to a temperature of around 240 to 260 °C under vacuum. Steam distillation is the blowing of steam through the oil maintain at around 255 to 260 °C under high vacuum and, it is during this process, the fatty acids etc. are removed. They are evaporated and are distilled to remove. In fact, since high temperature normally is used and the fatty acid vapours are corrosive in nature. Accordingly, the equipment and the construction material for the equipment should be of such nature that it can withstand the highly corrosive fatty acids vapour. And, in fact, it might so happen by the nature of the process conditions or processing steps used in the deodorization plant that the deodorized oil may contain certain metal ions, carbon or even the earth particles etc. which has been used in the process and cannot be separated in the filtration process. In the last step of the deodorization process, citric acid is added which acts as a chelating agent. Otherwise if the citric acid is not added, the deodorized oil would revert or oxidise rapidly and whole purpose of the process may get deviated. Then, finally, the deodorized oil is cooled to room temperature, properly packaged and is stored under appropriate conditions.

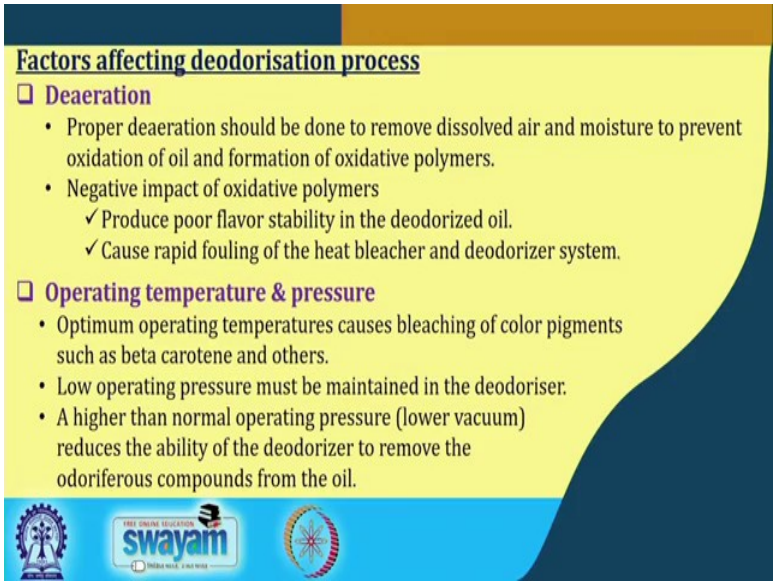


Functions of deodorisation

- ✓ Reduces free fatty acid (FFA) to <0.05%, preferably <0.03%.
- ✓ Removes the odoriferous compounds, such as aldehydes, ketones, hydrocarbons, lactones, alcohol, etc. produced from decomposition of the oils.
- ✓ Reduces PV to zero.

- ✓ Any residual trace metals, picked up by the oil after bleaching, are reduced via citric acid treatment (chelation or scavenging process). This is an essential step and is not a substitute for the bleaching step.
- ✓ There is some increase in the amount of polymers, conjugated dienes, or other oil decomposition products.
- ✓ There can be a very small but detectable increase in the trans fatty acids content in the oil, depending on the deodorizer temperature.

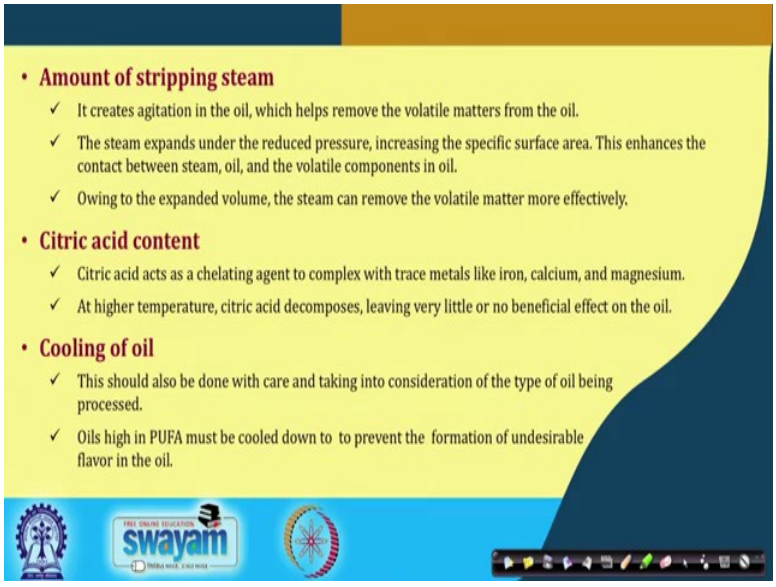
It becomes very important during the deodorization step that the condition particularly the temperature and pressure etc. should be maintained in such a way that it results in the amount of polymers or conjugated diene etc., at the same time it should not convert the cis to trans form of the fatty acids.



Factors affecting deodorisation process

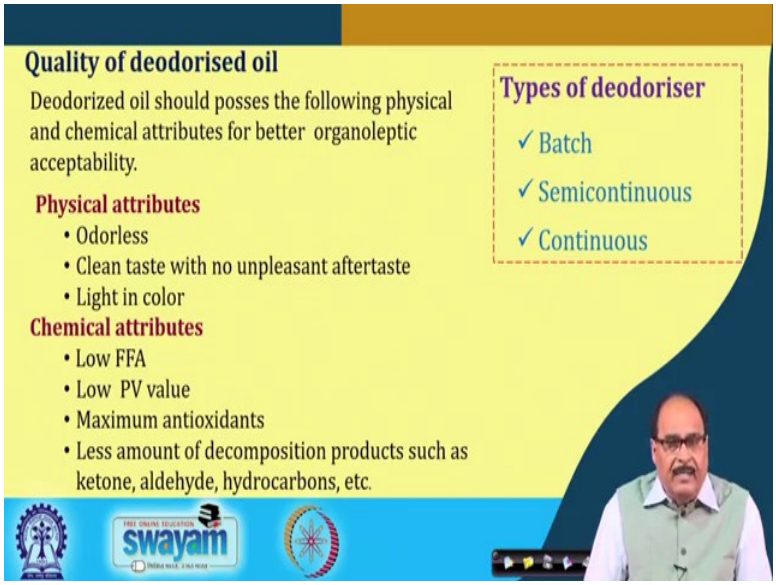
- ❑ **Deaeration**
  - Proper deaeration should be done to remove dissolved air and moisture to prevent oxidation of oil and formation of oxidative polymers.
  - Negative impact of oxidative polymers.
  - Produce poor flavor stability in the deodorized oil.
  - Cause rapid fouling of the heat bleacher and deodorizer system.
- ❑ **Operating temperature and pressure**

- Optimum operating temperatures causes balancing of color pigments such as beta carotene and others.
- Low operating pressure must be maintained in the deodoriser.
- A higher than the normal operating pressure reduces the ability of the deodorizer to remove the odoriferous compounds from the oil.



- **Amount of stripping steam**
  - It creates agitation in the oil, which helps remove the volatile matters from the oil.
  - The steam expands under the reduced pressure, increasing the specific surface area. This enhances the contact between steam, oil, and the volatile components in oil.
  - Owing to the expanded volume, the steam can remove the volatile matter more effectively.
- **Citric acid content**
  - Citric acid acts as a chelating agent to complex with trace metals like iron, calcium, and magnesium.
  - At higher temperature, citric acid decomposes, leaving very little or no beneficial effect on the oil.
- **Cooling of oil**
  - This should also be done with care and taking into consideration of the type of oil being processed.

- Oils high in PUFA must be cooled down to prevent the formation of undesirable flavor in the oil.



Quality of deodorised oil

Deodorized oil should possess the following physical and chemical attributes for better organoleptic acceptability.

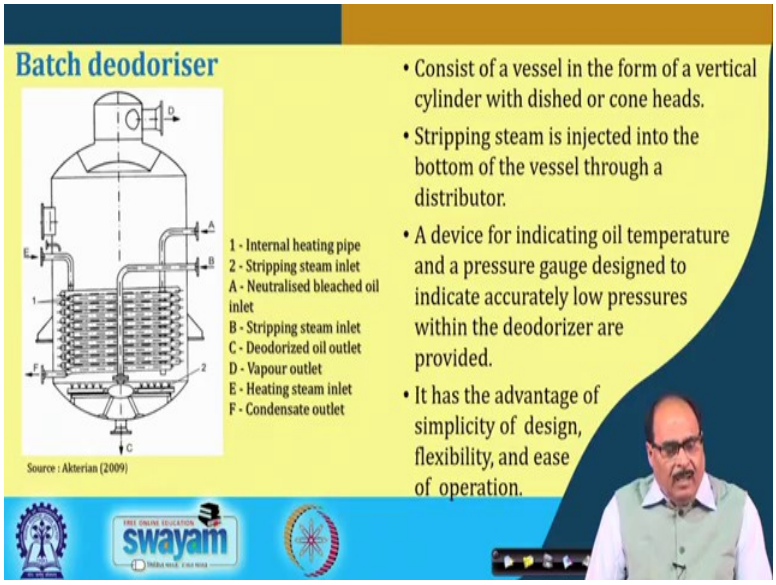
Physical attributes

- Odorless
- Clean taste with no unpleasant aftertaste
- Light in color

Chemical attributes

- Low FFA
- Low PV value
- Maximum antioxidants
- Less amount of decomposition products such as ketone, aldehyde, hydrocarbons, etc.

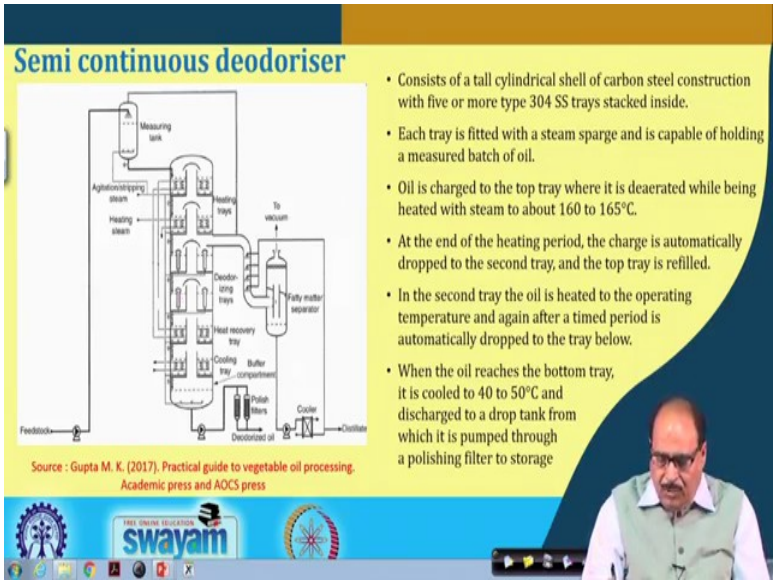
The types of the deodorizer are batch, semi continuous and continuous method. Accordingly, the deodorization step should be carried out and parameter should be controlled.



Batch deodoriser

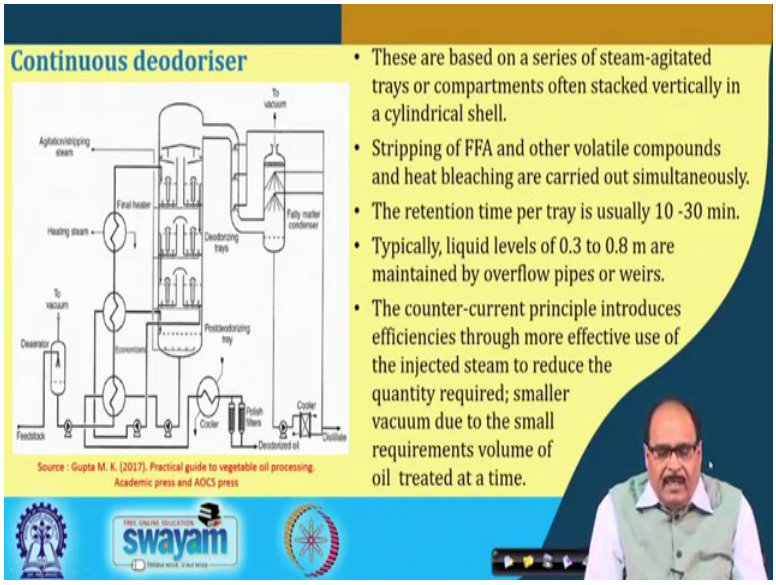
- Consist of a vessel in the form of a vertical cylinder with dished or cone heads.
- Stripping steam is injected into the bottom of the vessel through a distributor.
- A device for indicating oil temperature and a pressure gauge designed to indicate accurately low pressure within the deodorizer are provided.
- It has the advantage of simplicity of design, flexibility, and ease of operation.

(See Figure) A is the neutralised and bleach oil inlet; B is the stripping steam inlet, C is deodorized oil outlet. Point D is where the vapours are removed from top of the vessel; E and F are heating system inlet and condensate outlet.



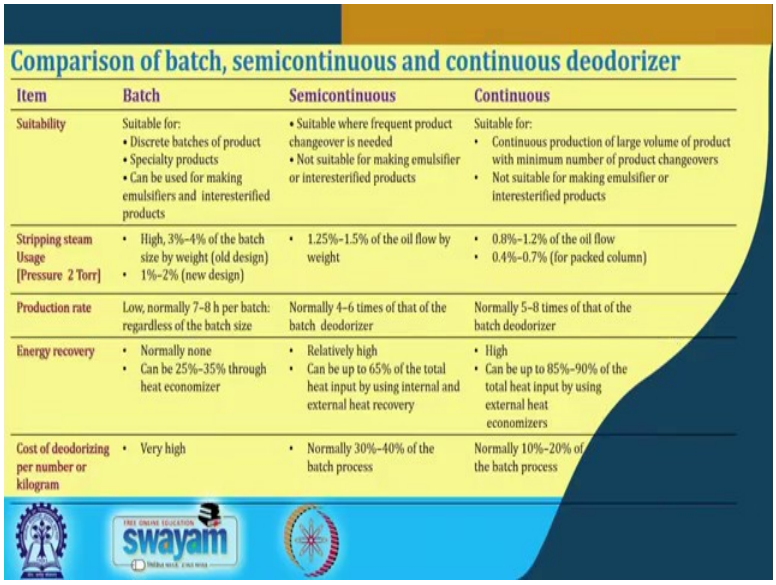
Semi continuous deodoriser

- Consists of a tall cylindrical shell of carbon steel construction with five or more type 304 SS trays stacked inside.
- There are different trays stacked inside the cylindrical vessel. Each tray is fitted with a steam sparge and is capable of holding a measured batch of oil.
- Oil is charged to the top tray where it is deaerated while being heated with steam to about 160 to 165°C.
- At the end of the heating period, the charge is automatically dropped to the second tray, and the top tray is refilled.
- In the second tray the oil is heated to the operating temperature and again after a timed period is automatically dropped to the tray below.
- When the oil reaches the bottom tray, it is cooled to 40-50 °C and discharged to a drop tank from which it is pumped through a polishing filter to storage.



Continuous deodoriser

- These are based on a series of steam-agitated trays or compartments often stacked vertically in a cylindrical shell.
- Stripping of FFA and other volatile compounds and heat bleaching are carried out simultaneously.
- The retention time per tray is usually 10 -30 min.
- Typically, liquid levels of 0.3 to 0.8 m are maintained by overflow pipes or weirs.
- The counter current principle introduces efficiencies through more effective use of the injected steam to reduce the quantity required; smaller vacuum due to the smaller requirements of the volume of the oil treated at particular moment of time.



Comparison of batch, semicontinuous and continuous deodorizer

Item	Batch	Semicontinuous	Continuous
Suitability	Suitable for: • Discrete batches of product • Specialty products • Can be used for making emulsifiers and interesterified products	• Suitable where frequent product changeover is needed • Not suitable for making emulsifier or interesterified products	Suitable for: • Continuous production of large volume of product with minimum number of product changeovers • Not suitable for making emulsifier or interesterified products
Stripping steam Usage [Pressure 2 Torr]	• High, 3%–4% of the batch size by weight (old design) • 1%–2% (new design)	• 1.25%–1.5% of the oil flow by weight	• 0.8%–1.2% of the oil flow • 0.4%–0.7% (for packed column)
Production rate	Low, normally 7–8 h per batch: regardless of the batch size	Normally 4–6 times of that of the batch deodorizer	Normally 5–8 times of that of the batch deodorizer
Energy recovery	• Normally none • Can be 25%–35% through heat economizer	• Relatively high • Can be up to 65% of the total heat input by using internal and external heat recovery	• High • Can be up to 85%–90% of the total heat input by using external heat economizers
Cost of deodorizing per number or kilogram	• Very high	• Normally 30%–40% of the batch process	Normally 10%–20% of the batch process

A comparison between the batch, semi continuous and continuous deodorizers is shown regarding the suitability, stripping steam usage, production rate, energy recovery and cost of deodorizing per unit volume or per kg of the oil. Like for example, the batch deodorizers are comparatively costlier processes whereas, about 30 to 40 percent lesser cost in the semi continuous than that of the batch process and even the continuous processes are normally 10 to 20 percent of the batch process.

The batch process deodorized oil can be used for making emulsifiers and interesterified products etc. The deodorized oil with semi continuous process is suitable where the frequent product change over is needed. However, they are not very good for making emulsifier or interesterified product. The oil deodorized using continuous process is suitable for continuous production of large volume of product with minimum number of product changeovers, they are however, not suitable for making emulsifier or interesterified product etc.

The production rate is normally low in the case of batch process; in the semi continuous process it is 4 to 6 times more than that of the batch process and the continuous process has 5 to 8 times higher production efficiency than the batch process. So, depending upon the resources available, the end use, extended use, storage, level of impurities etc. that should be removed in the deodorization process, the efficiency of the earlier processes like bleaching, neutralization, etc. varies.

Depending upon the appropriate method of deodorization, process parameter used, the purpose here is that after the deodorization process, a good quality oil is obtained which can be used for edible purposes for cooking, frying and for other purposes and it should not contain any component other than the triglyceride as far as possible.

After the refining, these oils are used for convergence into different products like solid fats for recovery of various components; even that the waste steams which are obtained in different stages like degumming that they are used for lecithin production. Similarly from the other steams also they can be used for extraction of the free fatty acids, alcohol and others. So, various valuable products or by-products can be derived from the oil refining plants.