Environmental, Health, and Safety Guidelines for Vegetable Oil Processing

Introduction

The Environmental, Health, and Safety (EHS) Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP)[1]. When one or more members of the World Bank Group are involved in a project, these EHS Guidelines are applied as required by their respective policies and standards. These industry sector EHS guidelines are designed to be used together with the **General EHS Guidelines** document, which provides guidance to users on common EHS issues potentially applicable to all industry sectors. For complex projects, use of multiple industry-sector guidelines may be necessary. A complete list of industry-sector guidelines can be found at: www.ifc.org/ifcext/enviro.nsf/Content/EnvironmentalGuidelines

The EHS Guidelines contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs. Application of the EHS Guidelines to existing facilities may involve the establishment of site-specific targets, with an appropriate timetable for achieving them. The applicability of the EHS Guidelines should be tailored to the hazards and risks established for each project on the basis of the results of an environmental assessment in which site-specific variables, such as host country context, assimilative capacity of the environment, and other project factors, are taken into account. The applicability of specific technical recommendations should be based on the professional opinion of qualified and experienced persons. When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels or measures than those provided in these EHS Guidelines are appropriate, in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment.

[1] Defined as the exercise of professional skill, diligence, prudence and foresight that would be reasonably expected from skilled and experienced professionals engaged in the same type of undertaking under the same or similar circumstances globally. The circumstances that skilled and experienced professionals may find when evaluating the range of pollution prevention and control techniques available to a project may include, but are not limited to, varying levels of environmental degradation and environmental assimilative capacity as well as varying levels of financial and technical feasibility.

Applicability

The EHS Guidelines for Vegetable Oil Processing are applicable to facilities that extract and process oils and fats from vegetable sources. It covers crude oil production and refining processes, from the preparation of raw materials to the bottling and packaging of final products for human or animal consumption, among other uses. Annex A contains a full description of industry activities for this sector. The production of oilseeds, beans, and palm oil fresh fruit bunches at the plantations is covered by the EHS Guidelines for Annual Crop Production and the EHS Guidelines for Plantation Crop Production. This document is organized according to the following sections:

1.0 Industry-Specific Impacts and Management

The following section provides a summary of EHS issues associated with vegetable oil processing that occur during the operations phase, along with recommendations for their management. Recommendations for the management of EHS issues common to most large industrial facilities during the construction and decommissioning phases are provided in the **General EHS Guidelines**.

1.1 Environmental

Environmental issues associated with the operational phase of vegetable oil processing primarily include the following:

- Solid waste and by-products
- Wastewater
- Emissions to air
- Water and energy consumption
- Hazardous materials

Solid Waste and By-Products

Vegetable oil processing activities generate significant quantities of organic solid waste and by-products, such as empty fruit bunches (EFBs) and waste palm kernels. The amount of waste generated depends on the quality of the raw materials and the use or reprocessing of the discarded materials into commercially viable by-products. Other solid wastes from the vegetable oil manufacturing process include soap stock and spent acids from chemical refining of crude oil; spent bleaching earth containing gums, metals, and pigments; deodorizer distillate from the steam distillation of refined edible oils; mucilage from degumming; and spent catalysts and filtering aid from the hardening process.

Recommended techniques for prevention and control of solid wastes and by-products include the following:

- EFBs from oil palm plantations should not be incinerated. EFBs should be returned to the plantations where, together with the trimmings from trees, they are valuable as soil amendment and a source of carbon;
- Collect waste palm kernels for fuel for steam and power generation at refineries. The waste kernel cannot be burned by typical crude palm oil (CPO) mills because, unlike refineries, their boilers are not designed to manage the high silica content of the kernel;
- Use uncontaminated sludge and effluent from on-site wastewater treatment as fertilizer in agricultural applications;
- Dispose of contaminated sludge from wastewater treatment at a sanitary landfill or by incineration. Incineration should only be conducted in permitted facilities operating under international recognized standards for pollution prevention and control;[2]
- Reduce product losses through better production control (e.g. monitor and adjust air humidity to prevent product losses caused by the formation of molds on edible materials);
- Recycle autoclave condensate to remove vegetable oil;
- Optimize the design of packaging material to reduce its volume (e.g. by reducing the thickness or number of layers) but without compromising food safety, transport safety, or other quality requirements;
- Investigate the following options for the responsible disposal of spent bleaching earth:
    - Use as a feedstock for brick, block, and cement manufacturing

[2] Examples of key environmental issues associated with incinerations facilities are available in the IFC EHS Guidelines for Waste Management Facilities.

- Use as fertilizer, if not contaminated with heavy metals such as nickel, pesticide residues, and other contaminants
- Dispose of by anaerobic digestion and then use it for land spreading
- If contaminated, manage according to the waste management guidance presented in the **General EHS Guidelines**

- Investigate the following options for the use of distillates (e.g. free fatty acids and volatile organic compounds [VOCs]), depending on the level of pollutants (pesticides and / or residues):
  - Use as animal feed if uncontaminated
  - Apply as a feedstock for chemical industry processes (e.g. antioxidants)
  - Use as fuel for energy production
- The nickel catalyst from hydrogenation should be either:
  - Recycled and recovered for reuse as a nickel catalyst or as nickel metal, salt, or other use
  - Stored and disposed of according to the waste management guidance presented in the **General EHS Guidelines**
- Manage filtering aid mixed with nickel in accordance with the recommendations for nickel catalyst;
- Collect residues from the raw-material preparation phase for conditioning (drying) and reprocessing (grinding) to yield by-products (e.g. animal feed).

Wastewater

Industrial Process Wastewater

Vegetable oil processing wastewater generated during oil washing and neutralization may have a high content of organic material and, subsequently, a high biochemical oxygen demand (BOD) and chemical oxygen demand (COD). Wastewater may also have a high content of suspended solids, organic nitrogen, and oil and fat, and may contain pesticide residues from the treatment of the raw materials. Recommended measures for the prevention of process wastewater include the following:

- Use emulsion breaking techniques, (e.g. dissolved air flotation [DAF]), to segregate high BOD and COD oils from wastewater;
- Recycle condensates;
- Use grids to cover drains in the production area and to prevent solid wastes and concentrated liquids from entering the wastewater stream;
- Select disinfection chemicals to match the cleaning operation being applied on the process equipment to the type of problem. Caustics (e.g. lye) are typically used for polymerized fat, and acids are used for lime deposit acids;
- Apply cleaning chemicals using the correct dose and application;
- Apply Cleaning-in-Place (CIP) procedures to help reduce chemical, water, and energy consumption in cleaning operations;
- Properly treat and discharge cleaning solutions (e.g. through a soap-splitting process) to separate oil and fatty acids from the water phase and then through a fat trap;
- When feasible, replace phosphoric acid with citric acid in degumming operations (this reduces the phosphorus load in the wastewater and also brings about a slight reduction in sludge quantities).

Process Wastewater Treatment

Techniques for treating industrial process wastewater in this sector include grease traps, skimmers or oil water separators for separation of floatable solids; flow and load equalization; sedimentation for suspended solids reduction using clarifiers; biological treatment, typically anaerobic followed by aerobic treatment, for reduction of soluble organic matter (BOD);

biological nutrient removal for reduction in nitrogen and phosphorus; chlorination of effluent when disinfection is required; dewatering and disposal of residuals; in some instances composting or land application of wastewater treatment residuals of acceptable quality may be possible. Additional engineering controls may be required to contain and neutralize nuisance odors.

Management of industrial wastewater and examples of treatment approaches are discussed in the **General EHS Guidelines**. Through use of these technologies and good practice techniques for wastewater management, facilities should meet the Guideline Values for wastewater discharge as indicated in the relevant table of Section 2 of this industry sector document.

Other Wastewater Streams & Water Consumption

Guidance on the management of non-contaminated wastewater from utility operations, non-contaminated stormwater, and sanitary sewage is provided in the **General EHS Guidelines**. Contaminated streams should be routed to the treatment system for industrial process wastewater. Vegetable oil facilities require significant amounts of water for crude oil production (cooling water), chemical neutralization processes, and subsequent washing and deodorization. Recommendations to reduce water consumption, especially where it may be a limited natural resource, are provided in the **General EHS Guidelines**. Sector-specific recommendations to reduce water consumption include the following:

- Use emulsion breaking techniques (e.g.DAF), to segregate high BOD and COD oils from wastewater;
- When economically viable, consider the use of physical refining instead of chemical refining to reduce water consumption;
- Recover condensate from heating processes and reuse;
- Use heat recovery (e.g. heat from oil processes) to heat incoming oil with the outgoing oil. Up to 75 percent of the heat of the oil can be recovered in this way, reducing the water demand in the steam system;
- Close the cooling water circuit and recirculate cooling waters.

Emissions to Air

Volatile Organic Compounds

Particulate matter (dust) and VOCs are the principal emissions from vegetable oil processing. Dust results from the processing of raw materials, including cleaning, screening, and crushing, whereas VOC emissions are caused by the use of oil-extraction solvents, normally hexane.[3] Solvent emissions arise from several sources within vegetable oil processing plants, including the solvent-recovery unit, the meal dryer and cooler, and leaks in piping and vents. Small quantities of solvent may be present in the crude vegetable oil if the oil has been extracted by a solvent and will volatilize during the oil-refining process, particularly during deodorization. Odor emissions arise from multiple sources (e.g. cookers, soap splitting, and vacuum generation).

The recommended management techniques to prevent and control VOCs include the following:

- Ensure the efficient recovery of solvent by distillation of the oil from the extractor;
- Recover solvent vapors where feasible, primarily through the use of countercurrent flow desolventizer–toaster in vegetable oil extraction;
- Use a reboiler and a gravity separator to treat condensates with high solvent content, to reduce solvent emissions and reduce the risk of explosions in the sewer.

[3] Hexane is classified as a hazardous air pollutant in some jurisdictions.

- Additional recommendations for the prevention and control of VOC emissions are presented in the **General EHS Guidelines**.

The recommended management techniques to prevent and control dust and odors include the following:

- Ensure proper maintenance of cleaning, screening, and crushing equipment, including any ventilation and air handling systems, to reduce emissions of fugitive dust;
- Install cyclones and / or fabric filters or electrostatic precipitators on selected vents, including meal dryers, coolers, and grinders, to remove odor emissions;
- Reduce odor emissions (e.g. from soap splitting, cookers in the extraction process, vacuum systems, and pressurized systems) with a caustic, alkaline, or ozone scrubber system or incinerate the gas in a boiler plant or in separate incinerator systems.

Exhaust Gases

Vegetable oil processing plants are large energy and steam consumers making use of auxiliary boilers for the generation of steam energy. Emissions related to the operation of these steam energy sources typically consists of combustion by-products such as NOx, SOx, PM , volatile organic compounds (VOCs), and greenhouse gases (namely CO and CO2). Recommended management strategies include adoption of a combined strategy which includes a reduction in energy demand, use of cleaner fuels, and application of emissions controls where required. Recommendations on energy efficiency are addressed in the **General EHS Guidelines**.

Guidance for the management of small combustion source emissions with a capacity of up to 50 megawatt thermal (MWth), including exhaust emission guidelines, is provided in the **General EHS Guidelines**. Guidance applicable to combustion sources greater than 50 MWth is presented in the **EHS Guidelines for Thermal Power**.

Energy Consumption and Management

Vegetable oil facilities use energy to heat water and produce steam for process applications (especially for soap splitting and deodorization) and cleaning processes. Other common energy consumption systems include refrigeration and compressed air. Detailed recommendations for energy conservation are presented in the **General EHS Guidelines**.

Hazardous Materials

Vegetable oil processing involves the transport, storage, and use of bulk quantities of acids, alkalis, solvents, and hydrogen during extraction and refining. Their transport, storage, and handling provide opportunities for spills or other types of releases with potentially negative impacts to soil and water resources. Their flammability and other potentially hazardous characteristics also present a risk of fire and explosions. Hazardous materials should be managed according to the guidance presented in the **General EHS Guidelines.**

1.2 Occupational Health and Safety

Occupational health and safety impacts during the construction and decommissioning of vegetable oil processing plants are common to those of most large industrial facilities and their prevention and control is discussed in the **General EHS Guidelines**.

Occupational health and safety issues during the operational phase include the following:

- Chemical hazards
- Physical hazards
- Noise

Chemical Hazards

Vegetable oil processing activities may present a risk of exposure to hazardous chemicals by inhalation or other exposure routes, as well as a risk of explosions resulting from volatization of solvent dissolved in the oil (e.g. hexane), and fire, from spent bleaching earth with a high iodine value oil, high ambient temperature, and high circulation–draft of air.

Operators in vegetable oil facilities may be exposed to hazardous substances including inhalation of hexane or other solvents used for extraction; inhalation of toxic chemicals (e.g. sodium methylate can cause burns on the skin and lung tissues if inhaled); eye or skin exposure to acids or bases; inhalation of dust from transportation of raw materials (e.g. seeds and beans to the crushing plant); inhalation of dust from meal treatment and shipment; inhalation of dust from bleaching earth, filter aid, and nickel catalyst; and inhalation of aflatoxins present in raw materials. Guidance on the management of chemical hazards in the workplace is presented in the **General EHS Guidelines**.

Additional industry-related recommendations include the following:

- Train employees in chemical handling (e.g. the correct interpretation of material safety data sheets, international chemical safety cards, and first aid procedures). Seasonal and other temporary workers should be fully trained before they work with chemicals;
- Provide employees with the necessary personal protective clothing and equipment, when specified as part of the job safety analysis and safety data information;
- In oil extraction areas, ensure that there is adequate air circulation to reduce the concentration of solvents;
- Provide ventilation, especially at workstations related to raw-material handling, milling, handling of bleaching earth, and use of solvents;
- Maintain air concentrations of VOCs below 10 percent of lower explosive limits. For hexane, the lower explosive limit is 1.1 percent (volume per volume [v/v]) and the upper explosive limit is 7.5 percent [v/v]);
- Ensure proper distillation of oil after extraction for effective solvent removal;
- Prevent leaks and spills of oils in the extraction plant;
- Control the flash-point temperature of the incoming extracted oils and use temperature control for all facilities receiving solvent extracted oils;
- Apply preventive maintenance (e.g. regular inspections) to reduce the risk of burns from all pipes carrying steam and all hot surfaces;
- When feasible, use hot water, rather than solvents, to facilitate cleaning.

Physical Hazards

Physical hazards in vegetable oil processing facilities are similar to those present in other industry sectors and include the potential for falls caused by slippery floors and stairs, potential collisions with internal transport such as trucks, and accidental contact with conveyor systems, such as those used in the crushing plants and for the removal of spent earth. Guidance on the prevention and control of physical hazards is presented in the **General EHS Guidelines**.

Noise

Operators in vegetable oil plants are also exposed to noise from internal transport, conveyors, boilers, pumps, fans, and various steam and air leaks. Guidance on prevention and control of noise impacts are presented in the **General EHS Guidelines**.

1.3 Community Health and Safety

Community health and safety impacts during the operation phase of vegetable oil processing are common to most industry sectors, including those related to traffic safety during transport of raw materials and finished products, and are discussed in the **General EHS Guidelines**. Industry-specific issues that could affect the community or the public at large may include the potential presence of pathogens and contaminants in processed oil (e.g. pesticide residues).

A product recall caused by contaminated or adulterated products found in commerce that is attributable to a specific company can damage a viable business. If a company can trace its products back to specific lot numbers, then a recall is a matter of removing all products associated with the specific lot numbers.

With a product safety program in place, the company can protect itself against product adulteration, contamination, and the impacts of product recalls. Vegetable oil processing should therefore be performed according to internationally recognized food safety standards consistent with the principles of hazard analysis critical control points (HACCP)[4] and FAO/WHO *Codex Alimentarius*. Recommended product safety principles include the following:

- Facilitate tracing of product for easy removal of product from commerce;
- Fully institutionalize HACCP prerequisites, including the following:
    - Good management practices
    - Chemical control
    - Customer complaints mechanism

[4] ISO (2005).

2.0 Performance Indicators and Monitoring

2.1 Environment

Emissions and Effluent Guidelines

Tables 1 and 2 present emission and effluent guidelines for this sector. Guideline values for process emissions and effluents in this sector are indicative of good international industry practice as reflected in relevant standards of countries with recognized regulatory frameworks.

Table 1. Effluent levels for vegetable oil processing

Pollutants	Units	Guideline Value
pH	pH	6 – 9
BOD_5	mg/l	50
COD	mg/l	250
Total nitrogen	mg/l	10
Total phosphorus	mg/l	2
Oil and grease	mg/l	10
Total suspended solids	mg/l	50
Temperature increase	°C	<3[b]
Total coliform bacteria	MPN[a] / 100 ml	400
Active Ingredients / Antibiotics	To be determined on a case specific basis	

Notes:
[a] MPN = Most Probable Number
[b] At the edge of a scientifically established mixing zone which takes into account ambient water quality, receiving water use, potential receptors and assimilative capacity

These guidelines are achievable under normal operating conditions in appropriately designed and operated facilities through the application of pollution prevention and control techniques discussed in the preceding sections of this document. These levels should be achieved, without dilution, at least 95 percent of the time that the plant or unit is operating, to be calculated as a proportion of annual operating hours. Deviation from these levels in consideration of specific, local project conditions should be justified in the environmental assessment. Effluent guidelines are applicable for direct discharges of treated effluents to surface waters for general use. Site-specific discharge levels may be established based on the availability and conditions in use of publicly operated sewage collection and treatment systems or, if discharged directly to surface waters, on the receiving water use classification as described in the **General EHS Guidelines**.

Emissions guidelines are applicable to process emissions. Combustion source emissions guidelines associated with steam- and power-generation activities from sources with a capacity equal to or lower than 50 MWth are addressed in the **General EHS Guidelines** with larger power source emissions addressed in the **EHS Guidelines for Thermal Power**. Guidance on ambient considerations based on the total load of emissions is provided in the **General EHS Guidelines**.

Table 2. Air emission levels for vegetable oil processing.

Pollutants	Units	Guideline Value
Dust	mg/Nm³	10 (dry dust) 40 (wet dust)
Hexane / VOCs	mg/Nm³	100

NOTE:
Dust level of 10 mg/Nm3 for dry dust can be achieved by applying cyclones and bag filters on selected vents, e.g. from meal dryers, coolers, and grinders. A dust level of 40 mg/Nm3 for wet dust can be achieved by applying cyclones and or multicyclones. Hexane: A value of 100 mg/normal m³ will be obtainable with most available abatement techniques, such as distillation recovery of all exhaust from extraction process.

Resource Use and Waste

Tables 3 and 4 present information on resource-use waste generation in the vegetable oil processing sector that can be considered as indicators of this sector's efficiency and may be used to track performance changes over time. Note that the volume of wastewater produced depends highly on the raw material processed and the technology applied. For production of oil based on palm fruit, wastewater volumes can often be limited to 3–5 m³/t of feedstock.[5]

Table 3. Resource and energy consumption.

Inputs per unit of product	Unit	Benchmark
Water[a]		
Crude oil production	m³/t raw material	0.2–14
Chemical neutralization	m³/t product	1–1.5
Deodorization	m³/t product	10–30
Hardening	m³/t product	2.2–7
Energy use in deodorization[b*]		Steam
Continuous	kJ/kg feedstock	95
SemiContinuous	kJ/kg feedstock	220
Batch	kJ/kg feedstock	440
Per 1% FFA[c] removal	kJ/kg feedstock	3.5

NOTES: [a] EC (2005) ; [b] Hui (1996) ; [c] FFA: free fatty acid.

Table 4. Example of semicontinuous deodorization

Parameter	Unit	Industry benchmark
Latent heat steam	kJ/g	2000
Amount of feedstock	Kg	1000
FFA removal	kg (steam)	0.35
Stripping steam	kg (steam)	5
Motive steam	kg (steam)	35
Total	kg (steam)	65
Heating	kg (steam)	24.2
Electricity	KWh	5

Note: Semicontinuous deodorization, 0.2% FFA, 0.5% stripping steam, and average electricity consumption; FFA, free fatty acid.
Source: Hui (1996).

[5] EC (2005) and World Bank (1998).

2.2 Occupational Health and Safety

Occupational Health and Safety Guidelines

Occupational health and safety performance should be evaluated against internationally published exposure guidelines, of which examples include the Threshold Limit Value (TLV®) occupational exposure guidelines and Biological Exposure Indices (BEIs®) published by American Conference of Governmental Industrial Hygienists (ACGIH),[6] the Pocket Guide to Chemical Hazards published by the United States National Institute for Occupational Health and Safety (NIOSH),[7] Permissible Exposure Limits (PELs) published by the Occupational Safety and Health Administration of the United States (OSHA),[8] Indicative Occupational Exposure Limit Values published by European Union member states,[9] or other similar sources.

Accident and Fatality Rates

Projects should try to reduce the number of accidents among project workers (whether directly employed or subcontracted) to a rate of zero, especially accidents that could result in lost work time, different levels of disability, or even fatalities. Facility rates may be benchmarked against the performance of facilities in this sector in developed countries through consultation with published sources (e.g. US Bureau of Labor Statistics and UK Health and Safety Executive)[10].

Occupational Health and Safety Monitoring

The working environment should be monitored for occupational hazards relevant to the specific project. Monitoring should be designed and implemented by accredited professionals,[11] as part of an occupational health and safety monitoring program. Facilities should also maintain a record of occupational accidents, diseases, and dangerous occurrences and other accidents. Additional guidance on occupational health and safety monitoring programs is provided in the **General EHS Guidelines**.

[6] Available at: http://www.acgih.org/TLV/ and http://www.acgih.org/store/
[7] Available at: http://www.cdc.gov/niosh/npg/
[8] Available at: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9992
[9] Available at: http://europe.osha.eu.int/good_practice/risks/ds/oel/
[10] Available at: http://www.bls.gov/iif/ and http://www.hse.gov.uk/statistics/index.htm

[11] Accredited professionals may include certified industrial hygienists, registered occupational hygienists, or certified safety professionals or their equivalent.

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Annex A: General Description of Industry Activities

The vegetable oil processing industry extracts and processes oils and fats from vegetable sources. Vegetable oils and fats are principally used for human consumption, but they are also used in animal feed, for medicinal purposes, and for certain technical applications. In developing countries, the production of crude palm oil (CPO) is typically carried out in CPO mills associated with the plantations. CPO is then transported to refineries all around the world. A significant part of the CPO, however, is processed locally and exported as refined, bleached, and deodorized (rbd) quality oil.

Figure A-1 presents a simplified flow diagram of vegetable oil production. The main steps in vegetable oil processing are extraction, refinement, other modification, and deodorization.

Extraction

Oil is extracted from beans, grains, seeds, nuts, and fruits. The raw materials are received at the facility and stored before initial processing. The type of storage depends on the raw material, (e.g. soybeans are stored in grain elevators). The raw materials are prepared using a variety of processes, including cleaning, drying, crushing, conditioning, and pressing. Beans are processed into flakes so that the oil cells are exposed, facilitating oil extraction, and fruits are pressed to extract oil. Environmental, health and safety issues from the raw material preparation phase include particulate emissions (e.g. from cleaning and drying), and solid waste (e.g. empty fruit bunches [EFB]) resulting from threshing operations as well as sticks, stems, pods, sand, and dirt.

Oil extraction can be performed mechanically (e.g. by boiling fruits and pressing seeds and nuts) or in combination with the use of solvents. During solvent extraction, hexane is used to wash the processed raw materials, typically in a countercurrent extractor. The extraction is normally followed by skimming (boiled oils) or filtration (pressed fats) and separation of the crude oil from the solvent-oil mixture (micella). Hexane is removed from the oil through distillation, and from the flakes through steam vapor in a desolventizer, and recovered for reuse after condensation and separation from water. The recovery processes for flakes that are intended for animal consumption typically use conventional distillation to remove hexane in a desolventizer-toaster. The desolventized flakes are then ground for use as meal (e.g. soybean meal). The process for flakes that are intended for human consumption uses specialty or “flash” distillation, in which superheated hexane is used in a vacuum followed by steam stripping. Flash distillation removes more residual hexane from the flakes, but it uses more energy and generates more emissions than the conventional process.[12]

Example of Palm Oil Extraction[13]

Palm fruit is processed to produce crude palm fruit oil and crude palm kernel oil. The fruit grows in clusters on a central, branched stalk rather similar to grapes and consists of oily pulp surrounded by a tough outer skin containing seeds (or kernels) in the pulp. Palm fruit oil is extracted from the pulp and palm kernel oil is extracted from the seed. During harvest, the bunches are loaded into lorries or railway cars and taken to the extraction facility. The sterilizing cars are rolled into cylindrical sterilizing chambers and steam is sparged into the chamber. The heat sterilizes the fruit to prevent bacterial or enzymatic activity from attacking the oil. The length of time in the sterilization chamber depends on the size and maturity of the fruit.

After sterilization, the fruits are removed from the stems in threshing equipment and then washed before being transported

[12] MOEA.
[13] Hui (1996).

to a twin-screw press that squeezes out the palm fruit oil. When possible, EFBs should be returned to the plantations where, together with the trimmings from trees, they should be spread on the ground to biodegrade. The extracted palm fruit oil is clarified in a continuous decanter or settling tank to remove water and solid matter. The cake from the screw press consists of moist pulp solids, kernels (or seeds), and the outer skin of the fruit. The kernels are separated from the fiber and cellular debris and conditioned by lowering their moisture level so that the meat shrinks loose from the shell. The kernels are then cracked and the meats are separated from the shells either by mixing them into an aqueous slurry of clay or salt so that the kernels float and the shells sink; or mixing them with water and passing the mixture through a liquid cyclone (the heavier shells pass out of the bottom and the lighter meat floats to the top). The meats are then dried and sent for storage before being pressed in screw presses to produce palm kernel oil.

Refinement

The crude oil is refined to remove undesired impurities such as gums, free fatty acids (FFA), traces of metals, coloring components, and volatile components. During refining, the FFA are removed to the level of less than 0.1 percent in the refined oil either by chemical or physical refining. Where appropriate, preference should be given to physical rather than chemical refining of crude oil as the bleaching earth used in this process has a lower environmental impact. Conversely, chemical refining results in a better product quality in terms of lower FFA levels, longer shelf life, and a more reliable process.[14]

Before refining occurs, degumming may be applied to the crude oil. Degumming is an essential step of the physical refining process because the oil entering the final deodorization has to have a low content of phosphatide. Degumming is also used in conjunction with chemical refining. Degumming methods can either be acidic or enzymatic. In acidic degumming, phosphoric acid is added to remove phosphatides, phospholipids, and lecithins. Degummed oil has a phosphorus content of less than 30 parts per million (ppm). Citric acid may be used instead of phosphoric acid, which brings a range of advantages, including reduced phosphorus load in the wastewater and a slight reduction in the amount of sludge. Enzymatic degumming uses enzymatic hydrolysis of the phosphatides. Environmental benefits from this approach include reduced consumption of phosphoric and sulfuric acid, as well as caustic soda, water, and energy.

Chemical Refining

Conventional chemical refining involves degumming for the removal of phospholipids, neutralization for the removal of FFA, and bleaching for decolorization and deodorization. Water is added during degumming to hydrate any gums present and the mixture is then centrifuged for separation. Non-hydratable gums are removed using phosphoric or citric acid before water is added and separation takes place in a centrifuge.

During degumming, caustic soda is added to the oil, which has been preheated to between 75ºC and 110ºC to saponify the FFA. This process gives rise to two main outputs, namely semirefined oil and soap stock. The soap stock is removed by precipitation followed by sedimentation or centrifugation and may be further processed into acid oils by splitting. The soap stock is heated to between 70ºC and 100ºC and reacts with sulfuric acid to reform the fatty acids. The resulting by-products can be sold to the paints and cosmetics sector, as well as to the animal feed industry. The neutralized oil is bleached to remove coloring matter and other minor constituents.

[14] EC (2006).

Physical Refining

Physical refining is a more simple process in which the crude oil is degummed and bleached, and then steam stripped to remove FFA, odor, and VOCs all in one step. A physical pretreatment can be used to achieve a low phospholipid content by degumming and using bleaching earth. Following this, FFA can be stripped from the physically pretreated oil using steam in a vacuum at temperatures of around 250°C and refined by the oil flowing over a series of trays countercurrent to the flow of the stripping steam. Previous neutralization stages are not necessary because the neutralization and deodorization are combined. A scrubber is then used to condense the greater part of the fat from the vapors as a water-free product.[15]

Other Modification

Hydrogenation

Most installations carry out hydrogenation to produce fats with superior retention qualities and higher melting points. Hydrogenation is usually carried out by dispersing hydrogen gas in the oil in the presence of a finely divided nickel catalyst supported on diatomaceous earth. The resultant hydrogenated fats are filtered to remove the hydrogenation catalyst, subjected to a light earth bleach, and deodorized before they can be used for edible purposes. After hardening, the oil is mixed with an aqueous solution to produce an emulsion. The emulsified mixture is then pasteurized, cooled, and crystallized to obtain the final product.[16]

Interestification

Interestification involves the separation of triglycerides into fatty acids and glycerol followed by recombination. The reaction is carried out using phosphoric or citric acid with a catalyst, typically sodium methoxide. Interestification modifies the functional properties of the treated oil and may be carried out after neutralization or deodorization.

Deodorization

During deodorization, the bleached oil is steam-distilled at low pressure to remove volatile impurities, including undesirable odors and flavors. Volatile components are removed from the feedstock using steam in a process that may last from 15 minutes to 5 hours. The vapors from the deodorizer contain air, water vapor, fatty acids, and other variables. Before entering the vessel, the vapors pass through a scrubber and a scrubbing liquid is sprayed in the vapor stream. Fatty acids and volatiles partly condense on the scrubbing droplets or alternatively on the packing material. This process produces the fully refined, edible oils and fats.[17]

Resource Consumption

Vegetable oil processing facilities use energy to heat water and produce steam for process applications (especially for soap splitting and deodorization) and for cleaning processes. Energy consumption will vary according to oil type (e.g. the energy needed for cold-pressing unconditioned olive oil is twice as high as the energy needed for pressing heat-conditioned oilseeds).

Water is mainly used for neutralization and deodorization, and both processes produce wastewater with a high organic load. Typically used chemicals include alkalis such as caustic soda and sodium carbonate; acids including phosphoric acid, citric acid, and sulfuric acid; Ni-catalysts; and methylates. Solvents such as acetone, ethanol, and methanol are sometimes used instead of, or to supplement, hexane in the extraction process. Hexane can cause health problems in relatively low

[15] EC (2006).

[16] EC (2006).

[17] EC (2006).

concentrations and other dangerous chemicals, including strong acids and bases, present significant health and safety hazards.

In parallel with the primary production of vegetable oil, some by-products, such as oils for animal feed or pharmaceutical products, are often produced by further processing of residues. This processing can reduce solid waste production, including fractions like spent bleaching earth that can be reused for energy production through direct incineration or biogas production either on-site or at another location. Citric acid and phosphoric acid can generally be used interchangeably in degumming operations.

Figure A-1 Production of Vegetable Oil