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Fundamental Quality Control in Vegetable Oil Refining

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Introduction

Quality assurance is an important and necessary function in any manufacturing company. It provides the necessary know-how to the plants so they can deliver finished products within the highest standards. The quality control department in a plant provides important services by maintaining a high standard of product quality and by providing proper training to the plant personnel in process and quality control. The technology of oil processing has changed considerably during the past two decades. During the same period, there has been a shift in the industry. The traditional companies, which pioneered the development of oil technology in the United States, have essentially disappeared. The United States Department of Agriculture–Agricultural Research Service (USDA–ARS) group, which pioneered oil refining and related technology for over half a century, is beginning to focus its research work on value-added, high-margin, and low-volume products.

On the other hand, the equipment manufacturers and processing aid manufacturers are more engaged in doing applied work in oil processing in order to improve oil quality and plant productivity. This has created a void in the oil processing plants, where the new personnel do not have an in-house knowledge base available to them. They are depending more and more on outside resources such as equipment or ingredient manufacturers. Interaction with equipment manufacturers or ingredient suppliers and the oil plant is very specific. In most cases the equipment manufacturers or the ingredient suppliers have limited contact with an oil plant, depending on the need at the plant. Some universities and organizations offer short courses on oil-related topics. However, these do not always provide the necessary in-depth knowledge that is often necessary in an oil plant.

During the same time period, many corporations have cut back on quality-control activity in order to reduce costs. This practice is very shortsighted. In reality, the cost to a company is far greater when it has to deal with customer refusals brought about by noncompliance with product-quality standards. It means double processing and packaging. A far more serious impact is created when a customer loses trust in the vendor and switches its supply source.

Today's market is highly competitive. Any company is likely to lose business if it does not possess the capability of supplying customers with high-quality product at a competitive price. Therefore, more than ever before, it is important that the personnel in an oil-processing plant be well-informed of the techniques of oil processing, manufacturing, quality, and cost management.

Discussion

Key Elements for Good Quality-Control Management

As in all other areas of management, quality management requires a well-defined set of objectives. Examples of such objectives are as follows:

- quality standards
- product standards
- process-operation standards
- training program for process personnel to understand the principles behind process operation and quality management and
- training program for the maintenance personnel on routine and preventive maintenance.

Quality Objectives

Some examples of quality objectives for an oil-processing plant are listed below:

1. 100% compliance with the finished-product standards,
2. total compliance with the process-operating standards,
3. zero defects on all products shipped,
4. zero customer refusal for noncompliance with quality, and
5. in-process or finished-product reprocessing less than 2% of total plant production.

One Hundred Percent Compliance with the Finished-Product Standards. The company should take a corporate position that no product can be shipped unless all finished-product specifications are met. This will not only improve the company's image, but it also will reduce the manufacturing costs at the plant.

To manufacture finished products with zero defects, the incoming raw materials must meet all specifications. Poor-quality crude oil prevents production of the best-quality finished product at a low cost. Poor-quality crude oil not only increases refining losses but also increases the use of bleaching clay and catalyst. It also reduces the deodorizer throughput and produces a less than desirable product at an added cost of processing. Similarly, poor-quality process material, such as bleaching clay or hydrogenation catalyst, does not allow the plant to meet the desired oil-quality standards.

Sometimes the finished-product standards can be met but at a high cost of processing. In addition, the products made in this manner may not meet the shelf life.

Total Compliance with the Process Standards. Process-operating standards are critical in order to obtain in-process oils with the proper functional properties and stability. Process-operating standards are established on the basis of the desired functional properties of the finished products. Some of this information may be available in the public domain; some may be developed by individual companies and retained as proprietary information within the company. In any case, the process conditions are typically related to the following:

- operating temperature,
- operating pressure (vacuum in deodorizing),
- batch size,
- oil-flow rate in a continuous process,
- caustic-addition parameters,
- water-washing parameters,
- bleaching clay and catalyst dosage, and
- reaction time in hydrogenation.

Process-operating standards are critical for obtaining the appropriate product quality. All in-process oil must meet the standards at each and every stage of operation before the oil is moved to the next processing step. Any deviation from this procedure causes difficulty in the subsequent operating steps and can produce off-quality product.

Zero Defects on All Products Shipped. Occasionally in an oil-manufacturing plant, the freshly made product is found to meet the finished product standards, but it fails to do so at the time of shipping. There are various reasons for such occurrences. Usually, poor-storage conditions for the finished product, lack of inventory rotation, and marginal quality of the raw materials and finished products are responsible for such failures. Therefore, a company must have a monitoring system in place to have periodic checks on the finished products in storage. There must be a maximum limit on storage time between production and shipping of the product to ensure adequate safeguards against deterioration of the product.

Zero Customer Refusal for Noncompliance of Product. It always hurts the manufacturer when a customer returns a shipment of product because it failed to meet the standards or because it did not perform satisfactorily. Customer refusal due to quality has several implications:

- It increases the cost of the product because most returned products need reprocessing.
- The plant incurs additional costs because of the loss of packaging costs, transportation, loss of product due to additional handling, and reprocessing of the material. Sometimes the product is degraded to a lower-cost commodity or is sold as distressed merchandise, depending on the state of the product as received at the plant.
- An industrial end user may lose confidence in the supplier and may even switch to another manufacturer. It is difficult to regain the confidence of a dissatisfied customer, and it may mean a permanent loss to the business.

Reprocessing of Finished Product or In-Process Oil. Combined reprocessing of in-process oil and finished product must be less than 2% of plant production. Any reprocessing at the plant means double processing costs and loss of product, packaging, and processing materials. Reprocessing may indicate that the process is lacking in several areas:

- control of incoming raw materials,
- inadequate control of the operating procedures,
- poor condition of the processing equipment due to inadequate maintenance,
- lack of understanding of proper processing conditions,
- insufficient training for process, quality, and maintenance personnel,
- production personnel not being held accountable for quality deviations, and
- lack of manufacturing experience of the management.

The author has observed a scenario in one plant where nearly 25% of the packaged product was reprocessed due to poor quality. Although this was an extreme case, there are many plants where 5 to 10% of reprocessing of the in-process oil is common. This amount is still too high and should be brought back to less than 2%.

Quality Standards for Finished Products

Quality standards on any product are established on the basis of the following:

- the specific product and its application,
- the quality requirement of specific customers,
- the shelf-life stability of the product, and
- the competitive edge of the product over its competition.

It is clear that not all products manufactured at the plant would have the same end use. For example, shortening for baking would have very different product specifications than margarine or liquid shortening. Certain products are manufactured to meet the specifications of an end user, where the product is used to manufacture a finished product with certain specifications.

Shelf life of the finished product is important for both domestic and industrial uses. Not all products are sold directly to the stores or supermarkets. All products go through a distribution channel and that requires time. Therefore, the finished product must be robust enough to retain its high quality throughout the time normally required for the distribution and sales. In addition, the product must last for a certain period of time after it has been purchased. This is true whether an individual consumer buys the product from the grocery store or whether an industrial user purchases the same product in a large quantity from the distributor.

Finally, a product enjoys high demand if it has a competitive edge over other manufacturers' products of the same category.

Process Standards

A manufacturing operation needs to have well-defined process standards. These must include clear instructions on temperature, pressure, starting conditions, finishing conditions, sampling frequency and procedure, troubleshooting, and so on.

Process conditions are predetermined and are based on the types of finished products needed by the company. For the purpose of this article, all quality standards will refer only to the process from crude oil to finished product. Crushing of oilseeds is not included.

Therefore, process conditions start from the receiving and storage of crude oils. After the incoming crude oil has been certified acceptable by quality control, clear standards must be in place for oil unloading, inventory check after unloading, storage temperature, and agitation, where needed. From this point, the oil is refined, bleached, and possibly hydrogenated; product blends are made; and the liquid oil or the blended products are deodorized, stored in tanks, packaged, and stored in the warehouse or shipped directly to wholesale customers. It is very important that the process and quality personnel fully understand the significance of each operating condition in order to make products that have the desired quality traits.

In-Process Standards

These standards are truly the heart of quality management in an oil-processing plant. The process personnel need to know the in-process standards for each type of oil and finished product produced in the plant. Some of the in-process oil-quality standards are similar for most oils in refining, bleaching, hydrogenation, and deodorization. Process-operating standards do vary according to the type of product made.

It is not possible to cover in-process standards for all types of products in this article. However, some guidelines are provided here to give the reader a general idea of the type of standards that are needed to obtain good oil quality in the process.

Crude-Oil Handling and Storage. Although process standards for the crushing operation are not included, it is important to mention that the procedure for proper handling of the crude oil is essentially the same for both the crusher and the refiner. The following guidelines are suggested for crude oil:

- Filter the crude oil after solvent removal.
- Cool the oil to less than 400°C before storage.
- Keep the oil cool and avoid exposure to oxygen.
- Maintain a peroxide value of less than 4 and an anisidine value of less than 2 in the crude oil during storage.
- Agitate the crude oil with mechanical agitator to keep the gums and meals in suspension.

Refined Oil. The purpose of refining crude oil is to reduce the free fatty acids (FFA) and the trace impurities that are present in the oil. In chemical refining, it is important to maintain certain in-process standards, which are measured in terms of trace impurities and the soap produced during caustic treatment of the crude oil. Some guidelines for good-quality refined oil are outlined in Table 1.

Table 1. Guidelines for Good-Quality Refined Oil

Refined oil	In-process standard
Free fatty acids	0.01–0.02%
Soap	<500 ppm; Never >1000 ppm
Phosphorus	<3 ppm

Water-Washed Oil. The purpose of water wash is primarily to reduce the amount of residual soap in the oil. Following are the in-process standards for water-washed oil:

Free fatty acids	0.02–0.05%
Soap	<100 ppm

Prebleached Oil. The purpose of this processing step is to do the following:

- remove the residual soap,
- reduce chlorophyll and reduce the red color pigments,
- reduce phosphorus (phospholipids) and trace metals to very low levels, and
- remove products of oil oxidation.

Prebleached oil should meet the in-process standards shown in Table 2 in order to obtain good-quality oil.

Table 2. Guidelines for Good-Quality Prebleached Oil

Prebleached oil	In-process standard
Soap	0 ppm
Phosphorus	<1 ppm
Iron	<0.3 ppm
Calcium	0.2 ppm
Magnesium	<0.2 ppm
Chlorophyll (soybean and canola)	<30 ppb
Lovibond red color	Varies with oil type
Peroxide value	0 meq/kg
Anisidine value	<4
Moisture	<0.1%

Peroxide value in freshly prebleached oil from a vacuum-bleaching process must be zero. If the peroxide value is high, one needs to look into the source of oxygen in the system. A peroxide value of zero does not always define the state of oxidation of the oil; this is why anisidine value must be determined in the prebleached oil along with the peroxide value. The peroxide value shows the primary state of oxidation in the oil. These compounds are quite unstable and break down to a number of aldehydes and ketones. The anisidine value determines the concentration of one group of aldehydes (2-alkenals). Generally, the state of oxidation in the oil is better defined as the Totox value:

Totox value = anisidine value + 2 x peroxide value

It should be mentioned here that hydrogenation becomes very difficult if the prebleached oil does not meet the in-process standards. High phosphorus, positive soap, high peroxide value, high FFA, and high moisture cause catalyst poisoning. This can lead to several quality issues:

- The reaction time is increased.
- *Trans* isomers of oleic and linoleic acids in the hydrogenated oil are increased.
- Additional catalyst is required to complete the reaction.
- The hydrogenated oil does not have the desired solid content at the specific reaction end point, as determined by the iodine value or reaction time.
- The hydrogenated oil may contain a higher level of colloidal nickel under this reaction condition. This requires postbleaching to reduce the colloidal nickel in the oil.

Postbleaching increases FFA in the oil, reduces natural antioxidant tocopherols, and also slows down the deodorization rate, which means lower productivity and increased oil losses at the plant and added costs of processing.

Thus, one can appreciate the importance of meeting the in-process standards and of not transferring the oil to the next processing step unless all in-process standards have been met.

Hydrogenation. Oil quality in hydrogenation can be adversely affected even if the prebleached oil quality is satisfactory. Adverse effects are caused by factors such as these:

- poor-quality hydrogen gas,
- poor-quality catalyst,
- poor mechanical condition of the reactor, and
- improper operation of the reactor.

The above factors affect the hydrogenation process the same as poor-quality prebleached oil.

The solids content and melting characteristics of the finished products are achieved through the hydrogenation process. Therefore, improper hydrogenation, whether it is due to poor-quality prebleached oil or poor process, will prevent the plant from producing finished product with consistency. Guidelines for good-quality hydrogenated oil are listed in Table 3.

Table 3. Guidelines for Good-Quality Hydrogenated Oil

Hydrogenation	In-process standard
Iodine value (IV)	Must meet the specifications
Solids (SFI or SFC)	Must meet specifications
Nickel	<0.5 ppm

Free fatty acid in hydrogenated oil must not exceed that of prebleached oil by more than 0.1%.
SFI, solid fat index; SFC, solid fat content.

Deodorization. This is the final step in oil processing. Here the oil is steam-distilled under high vacuum. The deodorizer removes volatile impurities such as FFA, aldehydes, ketones, and so on. It also reduces the red color. It cannot, however, reduce the chlorophyll in the oil, nor can it reduce the trace impurities such as phosphorus and trace metals. Deodorization cannot undo any processing mistakes from the prior steps. Therefore, the oil must be properly refined, bleached, and hydrogenated in order for the deodorizer to produce good-quality finished oil.

Deodorized oil is very prone to oxidation and develops oxidized flavor in storage. The oil should be cooled and saturated with nitrogen as it leaves the deodorizer. Nitrogen protection is also recommended for the final storage tanks. A set of guidelines is outlined below for obtaining good-quality deodorized oil.

Quality Control Is Corporate Accountability

Quality control is a vital need for a company, and it should be viewed as a corporate responsibility. A high-level manager (i.e., a vice president or a director) should be in-charge of quality assurance (QA). The quality control (QC) manager should report directly to the plant manager. This gives the QC manager some clout. The plant manager reviews plant-quality results with the corporate QA manager on a predetermined schedule, receives feedback, and communicates this feedback with the QC and production managers.

In summary, quality control in a corporation must be regarded as a contributor to a company's profit. It should receive corporate recognition by having a high-level corporate manager appointed as the head of the QA function and provided adequate funding in order to have the staff to support the manufacturing plants.

At the plant level, quality control must not be just a policing function. It should take proactive steps to do the following:

- serve as a resource for technical information regarding process and quality control,
- periodically update quality standards and training materials as needed,
- promote product, process, packaging, and quality standards,
- lead the company in setting the quality goals,
- provide personnel training on product and process,
- conduct an audit at the plants in compliance with the standards,
- review results of the audit with plant management, and
- set goals and dates for future reviews on compliance with quality.

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Table 4. Guidelines for Good-Quality Deodorized Oil

Deodorizer	In-process standard	Deodorizer	In-process standard
Free fatty acids	<0.05%	Magnesium	<0.2 ppm
Peroxide value	Freshly deodorized = 0 meq/kg	Nickel	<0.5 ppm
	In storage = 0.5 meq/kg, max	Lovibond red color	Meet standards
	As shipped = <1 meq/kg	Active oxygen method (AOM)	Meet standards
	As received = <1 meq/kg for frying	Oxidative stability index (OSI)	Meet standards
	As received = <2 meq/kg for other applications	Storage temperature	Liquid oil <30°C
Anisidine value	<4		Hydrogenated product is not over 5°C above the melting point
Flavor	Bland, sweet, buttery, nutty	Mechanical agitation	Recommended
Phosphorus	<1 ppm	Nitrogen protection	Recommended
Iron	<0.3 ppm		
Calcium	<0.2 ppm		