Measurement Instrumentation for Improving Edible Oil Production

Advanced instrumentation supported by a digital environment promotes efficiency, safety, profitability, and sustainability.

EMERSON

The edible oil market continues to experience steady growth, fueled by factors such as the growing global population, evolving cooking style, and an increase in health-conscious consumers. Edible oils remain a fundamental component in food preparation worldwide, but not all edible oil production ends up at the grocery store or as ingredients in prepared food. For instance, edible oils are frequently used as feedstocks for personal care products, pharmaceuticals, and nutritional supplements, with new applications emerging regularly.

Interestingly, the largest increase in edible oil use over the past few decades has been driven by the rising demand for biofuels, particularly renewable diesel and sustainable aviation fuel. While these products can be made from a wide range of possible feedstocks, 15% of all edible oil production worldwide goes to biofuel manufacturing. This trend, combined with other factors, has supported sustained growth that is anticipated to continue.

Regardless of the intended use, the seeds and drupes containing the raw product go through similar manufacturing processes to extract and refine the oil. As the industry expands and its products serve more diverse purposes, advanced measurement instrumentation will be essential to ensure oil quality, operational safety, and process efficiency. This eBook will explore critical processes in edible oil production, and it will examine how Emerson's portfolio of instrumentation can enhance operational efficiency and sustainability.

Edible Oil Types

Oil from vegetable sources is primarily found in seeds and drupes, from which it must be extracted prior to refinement and purification. The amount of processing necessary to create a marketable product depends on the source. There are two main types of edible oils, refined and unrefined.

Refined Oils

Recovering cost-effective yields from a variety of oil sources requires extensive processing. These refined oils provide higher output and longer-term stability, without the potential for rancid flavors and aromas. Refining processes also provide greater opportunities for capturing larger volumes of saleable byproducts, creating additional revenue streams for producers, while improving a facility's sustainability. Byproducts depend on the feedstock being processed, for example: all oil extraction leaves behind solids as a cake, which is suitable for animal feed or fertilizer; cotton seed lint can become yarn or cellulose for fabrics or plastics; coconut meat and milk is used in many applications, from candy to dietary supplements, while the fibrous shell can be used to make mats and rope; and lecithin from soybean processing is a valuable feedstock for animal feed, chocolate, cosmetics, soap, paint, and plastics.

Unrefined Oils

Some unrefined oils can be produced using cold pressing techniques, but most cannot be recovered this way at a commercial scale, except for premium olive oils, and to a lesser extent, peanut and sesame oils. Generally, these are used as food ingredients because they don't work well at high cooking temperatures due to characteristic impurities. Few oil sources are suitable for cold-pressing techniques due to the low yield and trace elements that contribute undesirable aromas and flavors when used for cooking. Moreover, they are harder to store and distribute due to a shorter shelf life.

Challenges for Producers

Edible oil producers must contend with a variety of unique challenges to maximize production, minimize safety risks, maintain product quality, and ensure regulatory compliance.

Maximize Production

Rising production costs—driven by competition for raw materials, energy costs, supply chain disruptions, and basic inflation—cut into margins. Of these factors, the rapidly rising cost of ingredients is perhaps the most important, driving a need for efficient processing.

Minimize Safety Risks

Safety risks are always present where bulk materials are ground and crushed, plus hazardous chemicals are used in multiple processing steps. Bulk material processing can create explosive mixtures of product particulates and air, and chemicals can leak as vapors, liquids, or both.

Maintain Product Quality

Quality control must quantify and compensate for feedstock variabilities to create products with consistent characteristics able to satisfy long-standing customers. Feedstock variability is a perpetual factor with agricultural products due to weather and countless availability issues, resulting in yield changes and inconsistencies of critical attributes. Other leading variables affecting quality include equipment degradation, temperature variations, and discrepancies related to manual operations.

Ensure Regulatory Compliance

Regulatory compliance for food products requires proper sanitation and handling practices, which are regularly inspected. Although specific regulations differ around the world the overall trend is toward stricter rules and more rigorous enforcement.

Overcoming these challenges calls for sophisticated instrumentation deployed in a digital environment. This strategy helps address the above and other challenges daily, improving performance measurably on all fronts, so a facility can reap the benefits of digital transformation. The rest of this eBook will discuss how to overcome these challenges in critical applications throughout the edible oil production process for safety, quality, and profitability.

Edible Oil Production

Edible Oil Production

While production details vary according to the seed or drupe being processed, all follow similar production steps, and all require advanced measurement instrumentation to maintain quality and maximize efficiency while helping companies meet industry standards and adapt to the evolving demands of the market (Figure 1).

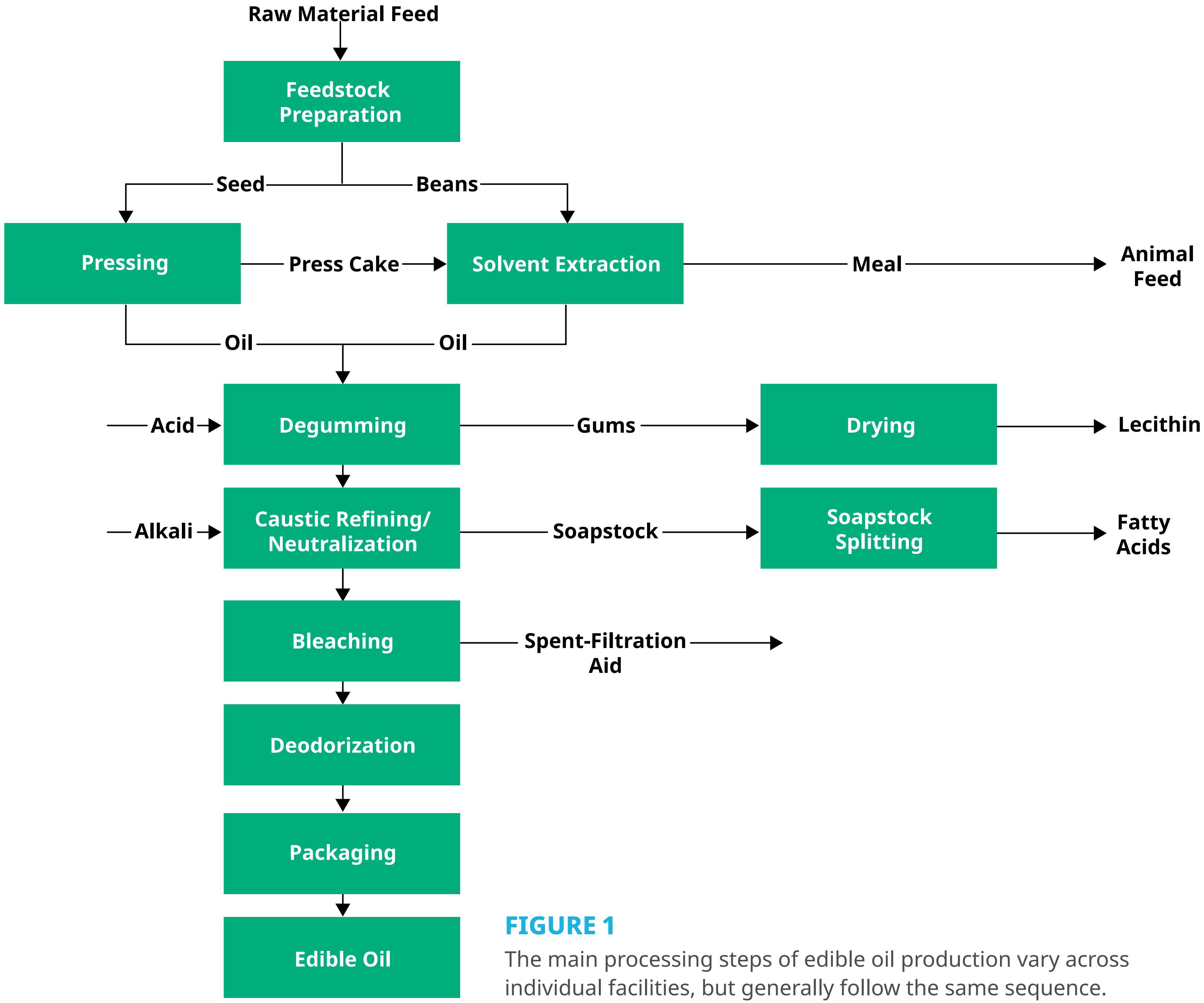

FIGURE 1
The main processing steps of edible oil production vary across individual facilities, but generally follow the same sequence.

Feedstock Preparation and Pressing

Feedstock Preparation and Pressing

The initial processing step begins with the raw material from the field or orchard, and it concludes with two streams: an oil flow, and solids in the form of cake or meal. Raw materials are stored in a silo or vessel suited to the specific product.

For example, olives and soybeans need different types of storage. Whatever the case, it is critical to monitor the contents for inventory control and to ensure the process doesn't simply run out of raw material. Two measurement technologies (Figure 2) work well for this purpose: Non-Contacting Radar Level Technology (Rosemount™ 5408 Level Transmitter or Rosemount 1208 Level Transmitter) and Point Level Detection Technology (Rosemount 2500 Level Switches). A continuous level reading indicates how much is in the vessel at any moment, and it can also indicate rates of material consumption over time. On the other hand, level switches show when the contents are above or below strategic points.

FIGURE 2

Where continuous measurements are necessary, non-contacting radar (left) can provide a precise measurement even in dusty environments, and level switches (right) can indicate strategic points in the vessel, such as maximum and minimum fill points.

Solvent Extraction

Solvent Extraction

While olives give up their oil fairly easily, other seeds require a solvent to extract oil from the solids and complete recovery. Soybeans, for example, require this solvent extraction processing step, while other feedstocks release most oil in the pressing step leaving recoverable amounts in the solids cake.

This process requires a volatile hydrocarbon, typically hexane, to dissolve oil out of the solids and produce miscella, a mix of oil and solvent. The miscella passes through a two-stage evaporation process, similar to distillation, to recover most of the hexane so it can be reused. Extracting the last hexane from the oil requires additional treatment via a steam stripping column. While almost all the hexane is recovered, some is invariably lost in the process, so more must be added. Additionally, hexane is highly flammable, especially when heated, so this process is hazardous and subject to strict safety and environmental regulations.

An efficient and safe solvent extraction process calls for three critical instrumentation applications: solvent versus solids flow, pressure and temperature throughout, and flow and density.

Solvent Versus Solids Flow

The flow of hexane must match the solids input to maintain optimal recovery without wasting solvent. A small sampling slip stream is typically measured to determine how well the extraction process is working, and if more solvent needs to be added. For this application, Emerson's Micro Motion™ ELITE Flow and Density Meters (Figure 3) provide an accurate reading of percent solids, even in these difficult conditions with flow and temperature variability.

FIGURE 3

Coriolis flow meters provide reliable two-phase flow measurement for the most challenging applications.

Pressure and Temperature Throughout

Each stage of the process must happen at a specific temperature and pressure. This includes the solvent, miscella, and oil processing within each vessel, and in between steps. Since evaporation, condensation, and steam stripping are hazardous operations, only instruments approved for use in those environments are permitted. Two appropriate choices for these critical processes are Emerson's Rosemount 2051 Pressure Transmitter and Rosemount 644 Temperature Transmitter families (Figure 4).

FIGURE 4

Emerson's Rosemount 2051 Pressure Transmitter (left) is safety-certified and an industry-standard for differential and gage measurements, while the Rosemount 644 Temperature Transmitter family (right) provides exceptional versatility, with options for head and rail mounting.

Flow and Density

At each step of the separation process, it is critical to measure flow and density to determine the proportion of solvent to crude oil to ensure that all steps are working properly. If solvent is not being captured as expected, it will affect the final product. Emerson's Micro Motion ELITE Coriolis Flow and Density Meters (Figure 3) measure mass natively, and they can measure density, allowing them to determine when residual solvent is in the oil.

Degumming

Degumming

Refining begins by extracting the gums, phospholipids, proteins, and other trace components that are insoluble in oil when hydrated. Degumming must be completed before storing the oil to prevent the formation of gum deposits. There are three approaches depending on the type of production: water degumming, acid degumming, and enzymatic degumming.

Water Degumming

For oils with high phosphatide content, water degumming is frequently used. This requires heating the oil and mixing in water with constant agitation to keep it in suspension. Hydrated gums can then be removed and the oil dried.

Acid Degumming

This approach has two variations, dry and wet. Dry is best where gum content is relatively low, such as with palm and coconut oils. Those with higher gum content, such as corn oil, use wet degumming. Similar to water degumming, acid is added to heated oil and agitated, allowing hydrated gums to be removed. Overall, acid degumming is not as effective where high degrees of removal are necessary.

Enzymatic Degumming

This process requires the selection of specific enzymes to match the gum content and provide a chemical environment (correct pH, temperature, etc.) to optimize enzyme activity. The enzymes are able to change non-hydratable phospholipids into hydratable phospholipids so they can be removed more easily. This requires mixing in the solution and extracting the hydrated gums via centrifugal separation.

Effective degumming depends on critical instrumentation to ensure efficient and safe operation.

Hot Water and Acid Solution Flow

Adding hot water, acid, and enzymes requires careful monitoring of dosing rates. Since all these solutions are conductive, Emerson's Rosemount Magnetic Flow Meter Sensors and Transmitters (Figure 5) provide high accuracy flow measurement across a wide turn-down range. They also withstand corrosive additives since wetted parts are protected with advanced plastic coatings. Emerson's Flexim FLUXUS® F721 Non-Intrusive Ultrasonic Liquid Flow Measurement flow meters can be customized to work well in these flow applications, and most of these meters are available as a portable flow solution, making them ideal for applications where temporary measurements are needed.

FIGURE 5

Emerson's Rosemount Magnetic Flow Meter family includes the 8705 Flanged Magnetic Flow Meter (left) and the 8711 Wafer Magnetic Flow Meter (center), and these can be fitted with the 8732 Field Mountable Transmitter (right) to provide sophisticated diagnostics. Emerson's Flexim FLUXUS F721 Non-Intrusive Ultrasonic Liquid Flow Measurement flow meter (bottom) provides readings without a process penetration.

Steam Flow Measurement

A degumming unit can have multiple heat exchangers supplied with steam. Evaluating heat exchanger performance depends on an accurate steam flow measurement, calling for Emerson's Rosemount 8800 Vortex Flow Meter (Figure 6). This family excels in steam applications with its sealed all-cast, gasket-free design that eliminates leaks and allows for online sensor replacement, reducing steam safety concerns and maintenance issues. Pressure and temperature compensation capability provides accurate and reliable calculated mass flow measurement for saturated and superheated steam applications. Flexim FLUXUS G721 ST-LT Non-Intrusive Steam Flow Measurement meter is an alternative to a vortex meter in many applications due to its wider flow measurement range. All sensors mount non-intrusively, eliminating the need for process shutdowns.

FIGURE 6

Emerson's Rosemount 8800 Vortex flow meter (left) can measure liquids and gases, and it is especially suited to steam applications, and Emerson's Flexim FLUXUS G721 ST-LT Non-Intrusive Steam Flow Measurement flow meter (right) also works well in this application.

Heat Exchanger Pressure and Temperature

As already mentioned, steam flow measurement is critical, but so is measuring differential pressure and temperature across a heat exchanger since these variables help calculate efficiency and are reliable indicators of fouling. Two appropriate choices are Emerson's Rosemount 2051 Pressure Transmitter and Rosemount 644 Temperature Transmitter families (Figure 4).

Caustic Refining/ Neutralization

Caustic Refining/ Neutralization

Even after degumming, oil can still retain undesirable color, odor, and bitterness caused by free fatty acids. The second stage of refining neutralizes these by mixing in a caustic solution, usually sodium hydroxide or sodium carbonate, to react with fatty acids, thereby creating soap. This process also neutralizes any remaining acid from the degumming stage. Caustic refining usually happens at a temperature between 40° to 85° C. The soap thus created is insoluble in oil so it can be removed easily via a centrifuge, however this results in some yield loss.

Another operational concern is that the alkali also reacts with triglycerides in the oil, increasing yield loss. Consequently, the neutralization parameters (type of alkali, solution strength, temperature, agitation, and time) must be optimized to minimize the loss. Moreover, there can be additional losses from emulsification and suspension of oil droplets in the soap solution. The resulting byproduct of caustic refining is known as soap stock.

Caustic refining may be done as a batch in a tank or in a continuous system. In batch refining, the aqueous emulsion of soaps formed from free fatty acids, along with other impurities, settles to the bottom and is drawn off. In a continuous system, the emulsion is separated with centrifuges. Oils that have been refined with sodium carbonate generally require a light re-refining with sodium hydroxide to improve color. After water washing, oil may be dried by heating in a vacuum, or by filtering through a dry filter-aid material.

Maintaining effective neutralization while minimizing yield loss depends on critical instrumentation to ensure efficient and safe operation.

Oil Flow, In and Out

An accurate picture of oil flow in and out of the unit allows calculation of overall efficiency and yield loss. A mass flow measurement provided by Emerson's Micro Motion ELITE Flow and Density Meters paired with the Micro Motion 5700 Coriolis Transmitter (Figure 7) delivers a highly accurate picture, even across a wide turndown range.

FIGURE 7

For precise flow and density measurement for liquids, gases, and multiphase flow, Micro Motion ELITE Coriolis Flow and Density Meters deliver accurate, repeatable measurements for challenging applications. When the ELITE sensor is paired with a Micro Motion 5700 Transmitter, the onboard data historian features analyzes process events, fluid quality, and measurement stability over long and short periods of time, providing valuable process insights. Smart Meter Verification Basic diagnostic software is available as a standard to ensure confidence that the meter is operating properly.

Alkali Flow

Flow of sodium hydroxide must be carefully controlled to ensure consistent saponification of free fatty acids. Monitoring the dosing rates requires a Rosemount Magnetic Flow Meter (Figure 8) designed to withstand caustic solutions, while providing accurate readings across a wide turndown range.

FIGURE 8

Emerson's Rosemount Magnetic Flow Meter family includes the 8705 Flanged Magnetic Flow Meter (left), which can be fitted with the 8732 Field Mountable Transmitter (right) capable of providing sophisticated diagnostics.

Vacuum Vessel Control

The final vacuum drying stage depends on critical pressure control, while maintaining optimum level in the vessel. Pulling negative pressure in a vessel can confuse many level measurement technologies, so operators should depend on Emerson's Rosemount 3051S Electronic Remote Sensor (ERS) system (Figure 9), capable of providing both the interior pressures and an accurate level reading, regardless of pressure.

FIGURE 9

Rosemount ERS technology uses two sensors to measure the head and vapor pressure, enabling accurate level readings under conditions of positive or negative pressure.

Buffer, Soap, Wash Water Level Management

Caustic refining requires additives and collected liquid storage in tanks alongside the unit. To avoid any of these either going empty or overflowing, it is necessary to monitor level continuously. Emerson's 2051L Level Transmitter (Figure 10) is a reliable and practical approach for these applications.

FIGURE 10

Rosemount 2051L Level Transmitters provide level measurements, and they are available with a variety of process connections, materials, and output protocols. This transmitter is safety certified, and it allows for Tuned-System Level assembly and direct mounting.

Bleaching

Bleaching

Most oils, outside of the characteristic green hue of virgin olive oil, tend to be nearly colorless. This makes consistency easier to maintain, avoiding differences due to feedstock variability. Removing color is normally achieved by mixing a powdered adsorbent such as Fuller's earth, activated carbon, or activated clays. These agents collect a range of impurities, including chlorophyll and carotenoid pigments, which are then removed by filtration.

Bleaching requires mixing adsorbent with the oil, heating it, and agitating for 10 - 30 minutes in a vessel under slight vacuum to avoid absorbing oxygen. After the adsorption process has reached equilibrium, the clay is filtered out using a bank of filters. The process also helps to remove remaining soap, trace metals, phosphatides, and sulfur compounds. Bleaching often reduces the resistance of oils to rancidity because some natural antioxidants are removed, together with impurities.

Effective use of adsorbent agents while minimizing loss of desired components depends on critical instrumentation to ensure efficient and safe bleaching operations.

Deodorization

Deodorization

Even after all the previous refining steps, small quantities of volatile components can still be present, which can result in problematic tastes and odors. These must be removed to avoid output capable of ruining food batches where such oils are an ingredient, or where consumers react negatively when opening a new bottle.

The remaining volatiles can be eliminated following a two-step process. First, deaeration removes dissolved oxygen because it contributes to oil turning rancid, particularly when heated. This requires heating the oil via a heat exchanger to 40° to 80° C, and then moving it to a vessel under vacuum. Once this is done, it is possible to heat the oil further via a second heat exchanger, and then placing it in a vessel where steam is injected, raising the temperature to 200° to 260° C, while applying strong vacuum (2 to 9 millibars) capable of drawing out any remaining volatiles. In some processes, this is done in a single vessel, slowly raising the temperature.

Once this is completed, the oil is cooled, and small amounts of citric acid may be added to extend shelf life. The final step is usually polishing filtration before going to the packaging stage. Effective deodorization requires critical instrumentation to ensure correct temperature control, while supporting efficient and safe operation.

Dissolved Oxygen

Oxygen is an enemy of many food products since it contributes to the oxidation of complex fats, resulting in rancid flavors, made all the faster by heat. Since deodorization requires heating, it is important to remove as much oxygen as possible at the outset. This can be measured using Emerson's Rosemount Hx438 Dissolved Oxygen (DO) Sensor (Figure 11) in combination with a Rosemount transmitter.

FIGURE 11

Emerson's Rosemount Hx438 Steam Sterilizable Dissolved Oxygen Sensor, combined with a Rosemount 1058 Dual Channel Transmitter, provides an accurate reading of any remaining DO in oil prior to deodorization.

Overfill Level Protection

Avoiding overfilling and emptying incidents with processing vessels and associated storage tanks requires reliable level switches, such as a Rosemount 2120 Level Switch (Figure 12), to warn operators when liquid has crossed a critical point. The Rosemount 2120 level switches are factory calibrated and offer a self-monitoring capability to alert in situations requiring service attention.

FIGURE 12

The Rosemount 2120 Level Switch Vibrating Fork provides reliable level detection of liquids with a wide range of viscosities. It has no moving parts, needs no calibration, and is virtually unaffected by process conditions such as flow, turbulence, bubbles, foam, vibration, solids content, liquid properties, and product variations.

Packaging

Packaging

Edible oils can be distributed using a wide range of packaging options, from rail cars to half-liter bottles for supermarkets. In all cases, oil taken from bulk storage tanks is measured using flow meters to produce information for custody transfer, invoicing, and inventory control. The specific process requirements and critical control points vary for each type and scale of filler.

Packaging is an exercise in custody transfer, which means that both sides of the transaction, buyer and seller, must agree on what has changed hands. Emerson has deep expertise with successful custody transfer applications in countless industries. The measurement technology and product family valued for its versatility and accuracy is Emerson's Micro Motion ELITE Coriolis Flow and Density Meters (Figure 3). When paired with a Micro Motion 5700 Coriolis Transmitter (Figure 7), valuable process insight is possible using data historian features, analyzing process events, fluid quality, and measurement stability over long and short periods of time. Smart Meter Verification diagnostic software ensures reliable service with minimum maintenance. Micro Motion ELITE Flow and Density Meters are available in a wide range of sizes to cover any packaging application including rail cars and totes, down to individual bottling and canning lines.

Digital Health Monitoring for Heat Exchangers

Digital Health Monitoring for Heat Exchangers

Digital transformation for edible oils has become a requirement for producers wanting to improve quality, safety, and profitability. The processes involved in edible oil refining all involve changing the temperature of the product, both heating and cooling at various stages. Most of these use plate or shell-and-tube heat exchangers, heated with saturated steam or cooled with chilled water.

In daily operation, internal fouling is a universal problem. Particulates carried by the oil, particularly in the earliest refining steps, deposit on heat exchanger surfaces, reducing heat conductivity in proportion to the thickness. Determining how efficiently a heat exchanger is operating depends on having at least a minimum complement of instrumentation (Figure 13):

- Process fluid temperature differential (inlet compared with outlet) and flow
- Process fluid flow
- Steam temperature, pressure, and consumption

Using the measurements from these instruments, it is possible to determine how much heat is actually being transferred. Emerson's Plantweb Insight™ Heat Exchanger application makes this evaluation much easier and more accurate, and it also determines overall energy consumption and efficiency, while guiding maintenance efforts to clean out fouling.

FIGURE 13

It only takes a small group of pressure and temperature instruments, combined with Plantweb Insight preconfigured analytical data analysis software, to measure and optimize heat exchanger performance.

Optimizing Edible Oil Production

Implementing measurement instrumentation in edible oil production is essential for maintaining quality, safety, efficiency, and sustainability. Given the wide range of edible oil applications—spanning food preparation, personal care products, pharmaceuticals, nutritional supplements, and biofuels—precise and reliable process control and safety systems are necessary to support growth and meet market demand. Integrating these technologies addresses current challenges while equipping the industry to adapt to future trends and innovations, ensuring long-term success and sustainability.

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