Citrus Oil Recovery During Juice Extraction

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Citrus process plants around the world produce citrus juice and a number of by-products. One of these by-products is cold press citrus oil. The recovery of cold press oil is an important economical consideration in citrus processing operations, not only when a considerable volume is processed, but also in terms of economic value. Cold press lemon oil commands a significant value and is considered the product in some lemon producing areas, juice being the by-product.

In this article, the FMC oil recovery system and a review of the currently applied processing technology will be discussed. There are three unit operations (extraction, particulate separation and concentration) involved in the recovery of oil from citrus fruits. Each unit operation may involve the use of more than one piece of equipment.

Extraction

Citrus oil is in oil sacs of oblate- to spherical-shaped oil glands located irregularly and at different depths in the outer, colored, portion of the peel (flavedo) of the fruit (Figure 1).

The recovery of the oil by the FMC process occurs during juice extraction. This simultaneous extraction of juice and oil is considered by many processors to be an economic advantage.

The FMC citrus juice extractor employs the "whole fruit extraction" principle. This principle relies on the unique design of the juicing components, which are upper and lower cups, upper and lower cutters, strainer tube or pre-finisher tube and orifice tube. The components interact during the extraction cycle in such a way that various parts of the fruit are separated instantaneously.

The extraction cycle begins with a fruit being positioned into the lower cup. The fruit is peeled by the motion of the converging upper and lower cups in synchronization with the action of the upper and lower cutters. Initially, as the upper cup moves downward, the fruit takes the shape of the profile formed by the converging cups. As the cups continue to converge, the fruit continually takes the shape of the dynamic cup profile and is subjected to increasing external pressures. Simultaneously, the peel deflects, causing the oil glands to burst and release their oil.

At this point, a round peel plug is cut by the lower cutter, opening a round hole on the bottom of the fruit. This opening provides a pressure relief point where the juice and other fruit parts exit from inside the fruit. Next. a round peel plug is cut on the top of the fruit by the upper cutter, allowing the peel to exit through a clearance above the upper cup.

During the extraction process, water is introduced through a specially designed spray ring, located at the upper cup, to capture the oil and small peel pieces in an oil-in-water emulsion called oil slurry (Figure 2). It is important that the oil released from the oil glands be washed away to prevent the oil from being reabsorbed by the peel.

The amount of water used is very important to the oil recovery process. It has been shown that a specific amount of water per ton of fruit or per box of fruit is necessary for optimum oil recovery. Once that level of water usage is reached, one sees very little added benefit in terms of increased oil recovery per volume of additional water used. Another important consideration is the quality of the water. In order to ensure the proper functioning of the spray ring, it is necessary that the water used be free of impurities, such as sand or insoluble solids, which might plug the orifices in the spray ring and reduce the efficiency of the system.

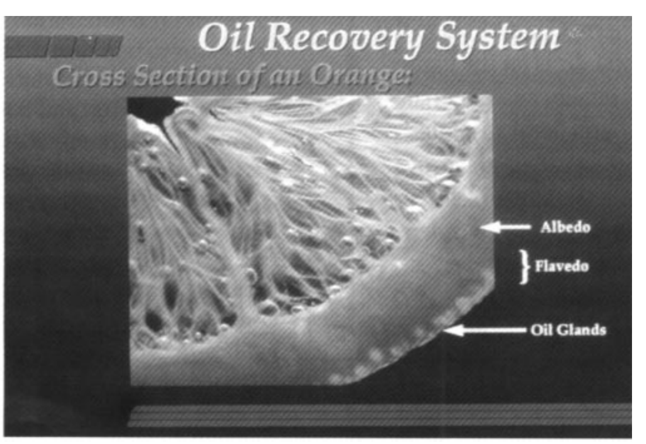

Figure 1. Cross section of an orange showing the location of oil glands in the flavedo

This article is adapted from José Flores' presentation at the International Citrus Symposium, January 29, 1996, in Orlando, Florida.

Figure 2. Cross section of the FMC extractor indicating the position of the spray ring and the flow of the oil slurry

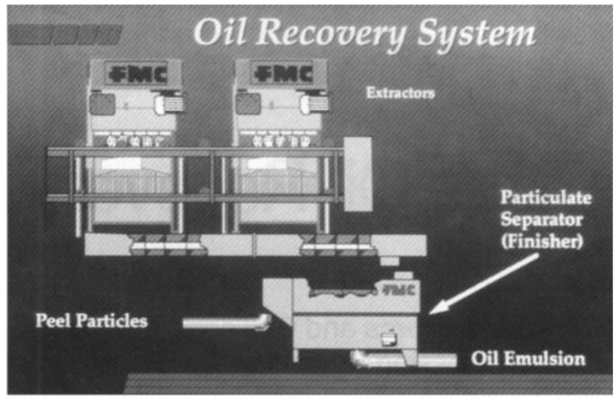

Figure 3. Flow diagram of the removal of solids from the oil emulsion

The optimum amount of water that should be applied during extraction depends not only on the amount of oil contained in the fruit, but also on the amount of peel surface that is fed into the extractor per unit of time. Therefore, the amount of water depends on the type of fruit that is being processed, its size and the extractor that is being used. FMC has determined that 18-30 L/min/extractor is the range of water use in which the amount of oil recovered from the fruit remains constant.

Depending on the type, condition and size of the fruit, as well as other factors such as fruit feed and water flow to the extractor, the FMC oil extraction stage has the capability of recovering up to 85% of the oil content in the fruit.

Particulate Separation

The second unit operation in oil recovery is the removal of particulate from the oil slurry. In this stage, the oil slurry is passed through a particulate removal unit (Figure 3). For this operation, the Florida citrus industry commonly uses a finisher that removes the small peel particles, called "frit" in the trade, by means of a rotating screw or paddle within a cylindrical screen. In other parts of the world, vibrating screens or internally fed rotary screens are also used.

The tightness of the finisher should be carefully controlled. If the pressure in the finisher is too high, the result will be an excess of insoluble solids in the emulsion, creating efficiency problems down stream. Conversely, large quantities of oil could be lost with the particulate waste stream if the pressure in the finisher is too low.

The recovered solids are next subjected to a washing/pressing process using a screw or paddle finisher to recover any oil still remaining in the solids. The oil emulsion obtained from this stage is concentrated by centrifugation (Figure 4).

During the last decade, FMC has continued to introduce improved mechanical versions of finishers (75CX and 200CX) to handle the separation of solids, thus allowing the juice processor to increase capacity and efficiency without sacrificing oil quality. Recently, FMC introduced a new paddle finisher (UPF 100 and 200) that can be used to replace the commonly used screw finisher, or as part of the overall particulate separation process.

Also, FMC has implemented an alternative process for high value oil products such as lemon. The process allows the use of low pressures during the separations of solids without compromising the recovery of oil. This process consists of a primary solids separation at low pressures using a vibrating screen to produce an oil emulsion that has low viscosity and is low in solids. A paddle finisher also could be used to accomplish this operation. This emulsion is passed through a cyclone to remove or reduce sand contained in the emulsion, then fed into a series of centrifuges for its concentration.

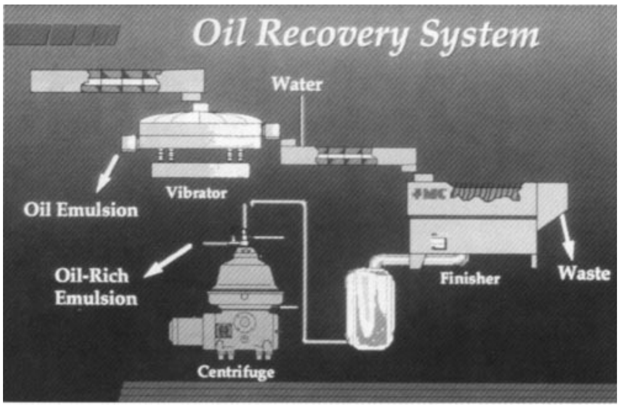

Figure 4. Flow diagram for the recovery of oil from peel particles using a washing/pressing process

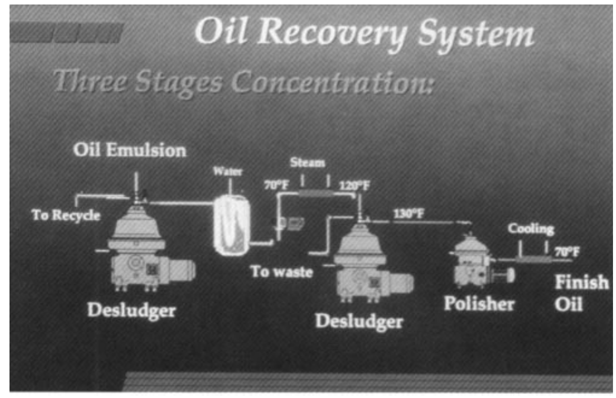

Figure 5. Concentration of citrus oils using a three-stage centrifuging process

Concentration

In the third unit operation, the citrus oil is concentrated by performing a two- or three-stage centrifugation process on the aqueous emulsion obtained from the pressed peel.

The first and second stage are accomplished by using an oil separator or desludging centrifuge. The oil emulsion is separated into three phases: an aqueous phase, a solid phase called sludge and an oil-rich emulsion (60-80% oil) phase called cream. The oil-rich emulsion is fed to a final centrifuging stage which uses a smaller centrifuge called a polisher. This centrifuge separates the concentrated citrus oil from aqueous waste. The aqueous discharge is usually a waste stream that is added to the peel before the dehydration process and recovered as d-limonene or sent to the spray field.

Careful consideration should be given to the centrifuge operation. It is desirable to maintain both a constant flow rate of feed oil emulsion to the centrifuge and a constant back pressure. In the event that either of these conditions changes, it is necessary to adjust the other in order to maintain a constant separation zone in the centrifuge bowl and, in turn, the concentration of the oil particles in the oil-rich emulsion. Sometimes a second desludger stage is used to concentrate the oil to 90%.

The centrifugal separation of the oil emulsion is also influenced by temperature. As the temperature of the emulsion increases, the differential between the densities and viscosities of both the oil and water phases also increases, consequently increasing the efficiency of this process. The recommended operating temperature to concentrate oil in the polisher or second-stage desludger is 120°–130°F. However, to reduce the loss of volatile compounds, the oil must be cooled down before exposing it to the atmosphere (Figure 5).

Waste Management

Water consumption and waste discharge have been a major concern in the recovery of oil from citrus. Citrus processors worldwide face stiff environmental restrictions and increased costs derived from the waste discharge from their oil recovery system.

FMC has developed a water recycling system to minimize water consumption and waste discharge. In this recycling system, the aqueous discharge effluent from the desludger is sent to a surge take-up water tank. It is then passed through an automatic filtering system before being recycled back to the extractors. This process permits a citrus plant to considerably reduce its water usage and waste discharge without affecting the oil yield and quality.

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