Perspectives on Processing Methods, Equipment and Procedures

T.L. MOUNTS, Northern Regional Research Center, Agricultural Research Service,
US Department of Agriculture, Peoria, IL 61604

ABSTRACT

World population growth and increasing per capita consumption will place significant demands on the food oils industry in the coming years to maximize efficiency of raw material use and to optimize processing operations. Other demands on the processor of food oils center on resolving issues that are already impacting on the industry, i.e., energy conservation, pollution abatement, and diminishing reserve of petroleum-based resources. Research now in progress in the laboratory may form the basis for the industry response to these challenges. Innovative methods of raw material preparation will be needed to obtain a higher quality oil. Alternative solvent processing could use alcohol or aqueous extraction or supercritical fluids. Each of the processing techniques used to produce a finished edible oil from crude oils, from degumming through alkali refining and bleaching to deodorization, is subject to change, and the form of these changes can be perceived from the directions of current research. Formulation of solid fats from liquid oils may see a shift from metal-catalyzed reactions to the use of immobilized enzymes. Implementation of many of the process changes will depend on equipment development and application of advanced engineering concepts to assure their assimilation into the food oil industry. By projecting the successful integration of the chemical, process design and engineering sciences, a realistic picture of the year 2000 can be formulated.

Previous papers presented in this Conference have provided a comprehensive insight into the current state-of-the-art in the fats and oils industry. It is my intent to consider some possible scenarios in a look to the future of edible oil processing. Although predicting the future can be precarious, an extrapolation from those new technologies just developed or now being researched can provide a conjecture of things yet to be.

World population is rising at 1.5% per year, and it is estimated that by 1992 the total fats and oils world per capita demand will rise from the current 12.9 kg to 14.9 kg. This population growth and increasing per capita consumption will place significant demands on the food oils industry to maximize efficiency of raw material use and to optimize processing operations.

Traditionally, economics and engineering feasibility have been the major criteria stimulating change in the oil industry. Recently, and anticipated in the future, superimposed on these interests have been socioeconomic theories, values, and trends.

Energy conservation will continue to be a primary factor influencing change. The single most important increase in the cost of oil processing has been in utilities. Much research is being directed to those energy-intensive operations of the industry to determine how best to perform the process with the least expenditure of energy. Another potential energy-related development that will have an impact on the food oils industry is diversion of edible oils to provide an annually renewable diesel fuel. Research throughout the world is being successfully directed to facilitating the use of triglyceride oils as a power source. Vegetable oils are being reconsidered as annually renewable sources of industrial raw materials after being replaced for several decades by the then cheaper petrochemicals. Such demands on the sources of edible oils dictate that the food oils industry minimize processing losses.

Already, many of the resources of the edible oil processors are devoted to emission control and effluent management. The emphasis on environmental quality will continue to play a role in government-industry relations, hopefully moderated by cost-benefit considerations. Emission standards in California have influenced decision-makers to opt for oilseed extraction plants that do not involve the use of solvents. The lower oil yield is deemed more acceptable than the cost involved to satisfy regulatory standards. Large volumes of steam are used in solvent extraction and oil refining processes. Boiler equipment designers must be concerned with boiler stack gases, which may include sulfur dioxide, particulate matter (fly ash) or nitrogen oxides depending on the type of fuel used and the firing equipment. Effluent streams are potential sources of water pollution. From the extraction process, the effluent consists of condensed stripping steam that has contacted the oil or meal in the desolventizing steps. This water contains minor quantities of meal dust or oil that add to the biological oxygen demand and must be removed in waste-water treatment systems. Oil processing generates effluent from degumming, refining and deodorization steps, including suspended solids, oil and grease. Solid wastes are generated from bleaching and hydrogenation operations. Thermal pollution is another concern of processors using large amounts of water in cooling towers and heat exchangers. Concerns for environmental quality are not limited to high-technology countries, but are also of interest in developing countries desiring to gain from the experiences of others. Pollution abatement will play a role in shaping the oil industry of tomorrow.

Concerns for human health and welfare may well suggest a reexamination of accepted practices in the food oil industry. While most emphasis has been placed on increasing the protein content of the diet in developing countries, an equal emphasis must be put on providing for the calorific demands. Food oils provide the dietary supply of calories that can assure proper utilization of protein consumed. New technologies must be devised to facilitate the availability, deliverability and desirability of food oils in situations where economics, cultural background, and deficient distribution systems are impediments. The more moderate aspects of the search for "natural or organic" foods, as differed from the strident extremes of the "food faddist," will influence how the food oil industry responds to the demand for providing foods of highest nutritive value.

These then appear to be the major factors that will modify our thinking on economic and engineering feasibility in shaping tomorrow.

Perhaps the most esoteric picture of the future of the food oil industry is embodied in the application of supercritical fluids. This technology was discussed early in the conference as applied to oilseed extraction. It is of high interest and is especially attractive when carbon dioxide is considered as the supercritical fluid. Although the supercritical phase has been an observed phenomenon for over 100 years, investigations of its practical application have intensified in recent years. Currently, its commercial viability in the food industry is limited to high-value, low-volume processes such as decaffeination of coffee and extraction of hops. Research indicates that supercritical carbon dioxide is a highly selective extraction medium. Oils extracted from soybean, cottonseed and corn have lower phosphatide levels, improved color characteristics and easier refinability than the same oils obtained by hexane extraction (1,2). Carbon dioxide is an economic and safe extraction solvent, and its use as a supercritical fluid responds to many of the concerns of the oilseed extraction industry. The major obstacle to the implementation of this technology is its applicability to large-volume continuous systems; that is, can engineering solutions be devised to move solid materials in and out of a high-pressure extraction zone?

Such a system is conceptualized in Figure 1 and illustrates moving solid material through a zone of high pressure for extraction, separation, recycling and recompression. The availability and cost of hexane solvent and environmental concerns may combine to generate increased activity to resolve the economics and engineering feasibility considerations. But, beyond its application for oilseed extraction is the possible use of supercritical fluids for edible oil processing and byproduct treatment. Investigations already underway indicate that supercritical fluid technology might be advantageously interfaced with existing edible oil processes to give improved systems. The highly selective solubility of triglycerides relative to phospholipids observed in the extraction of soybeans suggests an appropriate application to the production of oil-free lecithin, a high value byproduct of soybean oil processing. Elimination of solvent from this process is especially desirable due to the difficulties involved in removing solvent residues. A laboratory process using supercritical carbon dioxide for deodorizing fats and oils already has been patented by Kurt Zosel of Germany but has yet been commercially implemented (3). This countercurrent continuous process (Fig. 2) is simple and highly efficient in operation and eliminates the possibility of hydrolysis, always a concern in current deodorization practices.

Soybean oil, stored in tank 1, was continuously fed through an injector pump 2 into the top of a 15-m long column 3. The column, with an internal width of 6 cm, was filled with glass balls and widened out at the bottom. It was heated to 90 C by means of a heating jacket (now shown). The oil flowed over the glass balls to the bottom of the column and was continuously removed through valve 4. Countercurrently, carbon dioxide was circulated upwards through the column from below by way of a centrifugal blower 5 and separator 6. The separator was also heated to 90 C and was filled with activated charcoal to remove impurities from the stream of supercritical carbon dioxide. The system was filled with carbon dioxide through valve 7 before deodorization was begun, and slight losses of carbon dioxide were replaced during the operation. Oil was fed into the top and removed from the bottom of the column at the rate of ca. 5 kg/hr. The hold-up in the column was ca. 1.5 kg of oil.

It is claimed that this process gives an odorless and flavorless soybean oil with a low residual free fatty acid content. Although this is only a laboratory-scale system now, the potential for energy savings by low-temperature deodorization of oils may stimulate its application in the future. Other investigations are determining the differences in solubility between triglycerides and other crude oil constituents, both desirable and undesirable, such as tocopherols, sterols, hydrocarbons, color compounds and free fatty acids. Depending on the results of these research efforts, a totally integrated system of edible oil processing using supercritical carbon dioxide can be postulated. Such

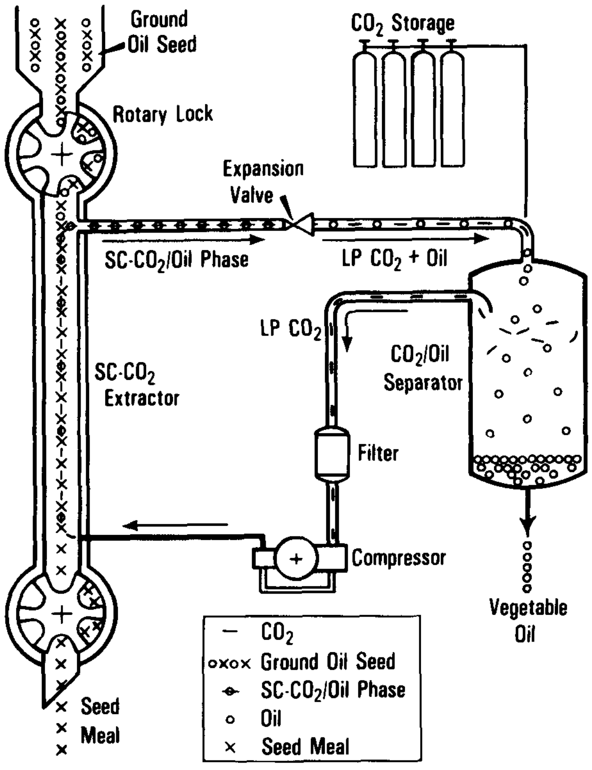

FIG. 1. Conceptualization of continuous system for supercritical extraction of oilseeds.

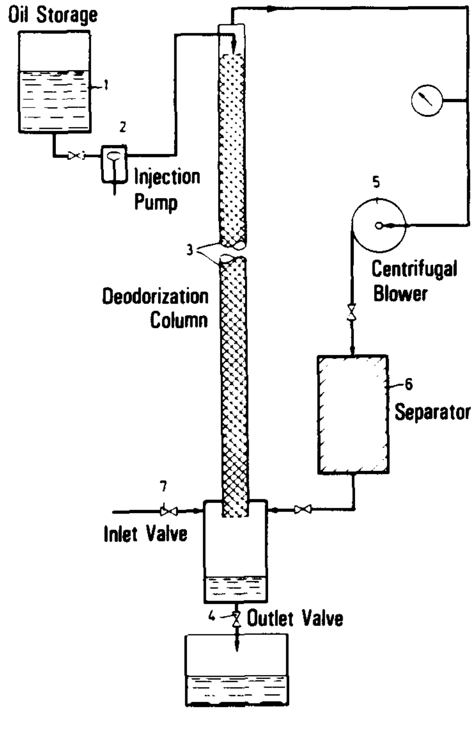

FIG. 2. System for supercritical deodorization of fats and oils.

a system would consist of separate chambers where the appropriate selection of pressure and temperature parameters would facilitate the purification of the crude oil exclusive of chemical processes. A direct advantage would be elimination of effluent streams and offensive process emissions. Such a departure from current procedures is highly speculative and fraught with the pitfalls inherent in research to develop new technology.

The goal of eliminating chemical processing in the purification of crude oils is also inherent in the effort to apply physical refining to all edible oils. Palm, palm kernel and coconut oils have been physically refined since 1950. However, the application of this process to other oils, notably soybean oil, is of current and future interest. The technology of physical refining has been thoroughly discussed earlier; it is essentially a combination deacidification-deodorization process. Crude oil pretreatment is especially important for a successful and economical application of physical refining. Early attempts to apply this technology to soybean oil failed due to inconsistent quality of the crude oil and inadequate pretreatment to overcome these inconsistencies. Recent development of an alternative crushing and solvent extraction process for soybeans gives an oil reported to be water degummable to less than 0.05% phosphatides, which is easily pretreated to an acceptable standard oil for physical refining. This development and the delineation of other appropriate oil pretreatment parameters should facilitate the application of physical refining to soybean oil, the world's major edible oil. The replacement of chemical refining with this deacidification/deodorization process as a uniform technique for preparation of edible oils, regardless of the sources, appears to be the most likely response of the food oils industry to increasing energy costs and growing sensitivity for environmental problems. Implementation of physical refining will require a demonstrated capability of producing high-capacity oils on a consistent basis. A number of processors are now applying this technology to oils other than palm, palm kernel and coconut, and their experience will provide needed information.

If the adoption of physical refining as a total replacement for chemical refining does not develop, alternatives to current practices for use of the soapstock byproduct from alkali refining may be employed. The neutralized dried soapstock process is being used on a limited basis as replacement for the acidulation process, which contributes significantly to waste effluent (4). This alternative process (Fig. 3), which involves converting the soapstock to neutral pH and drum drying, gave a product that performed well as the fat source in feeding trials with broilers, laying hens and cattle. Use of such a process could reduce the load on plant waste-water treatment facilities while producing a commercially viable product.

The papers on automation give a revealing insight into the future of the edible oil industry. New transducers are being developed to monitor process conditions. Information obtained can be fed to a process control computer to

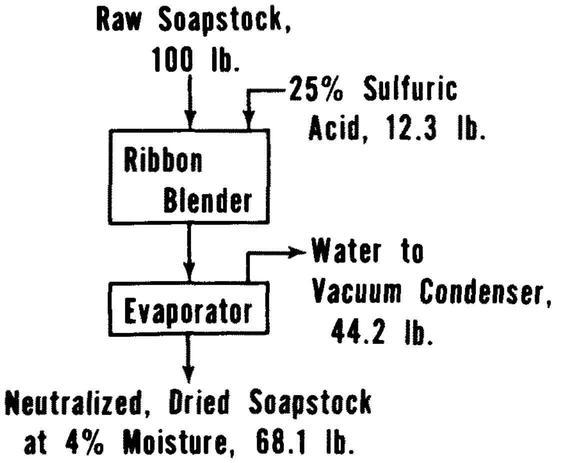

FIG. 3. Flow diagram—neutralized dried soapstock.

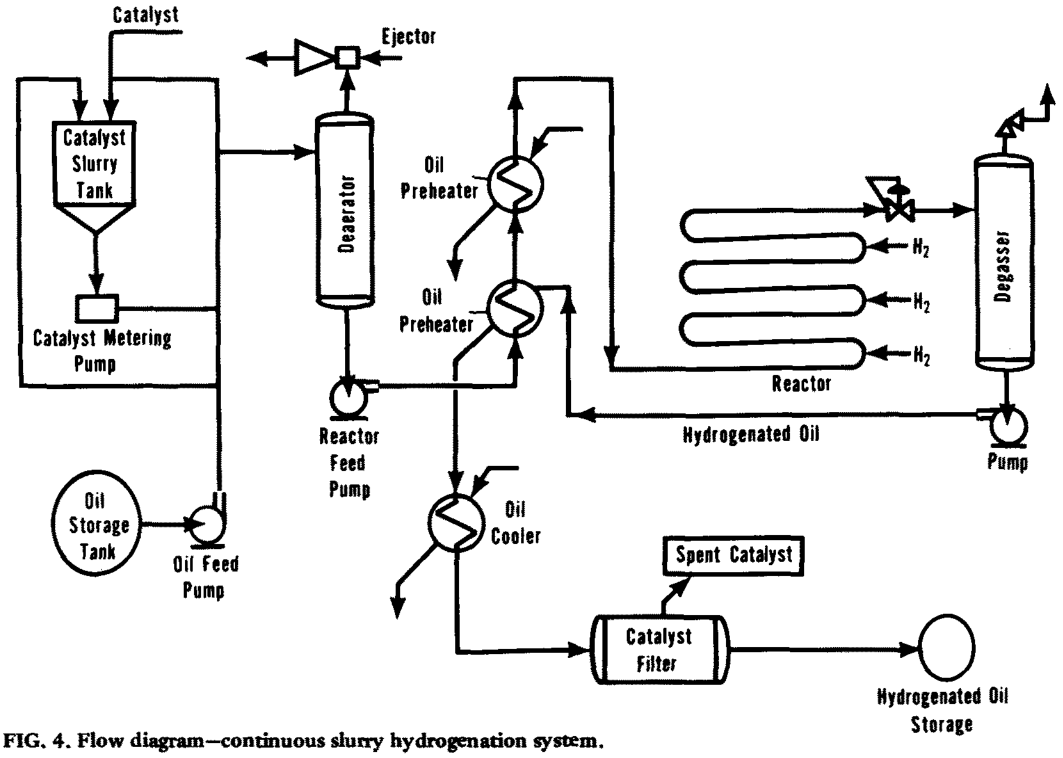

FIG. 4. Flow diagram—continuous slurry hydrogenation system.

provide immediate response to variations in prescribed parameters. Such developments should enhance the conversion of the last of the batch unit operations, hydrogenation, to a continuous process. Precise information on *trans*-isomers, iodine value and thermal properties will facilitate flexible operations to produce hardened products meeting diverse user specifications. Continuous slurry reactors (Fig. 4) have been commercialized to a limited extent (5), and research on their applicability to copper chromite-catalyzed selective hydrogenation is being investigated at NRRC. Continuous hydrogenation of soybean oil with a fixed copper chromite catalyst in a trickle bed reactor was reported recently (Fig. 5) (6). Advantages of the system were stated to be a lower reaction temperature and less formation of conjugated dienes while retaining the linolenic acid selectivity. In the future, such systems may be applied with specialty catalysts designed for specific applications or with conventional nickel catalysts to produce required base stocks for margarines and shortenings.

Recently reported work on enzyme-induced interesterification to modify the physical properties of fat indicates the potential that biotechnology may have in the future of the edible oil industry (7). Dr. Macrae described extracellular microbial lipases that catalyze the hydrolysis of triglycerides. The reaction is reversible and, as a result of the concurrent breakdown and resynthesis, there is exchange of the fatty acids between the triglyceride molecules. By limiting the water availability during reaction, hydrolysis is inhibited and interesterification is enhanced. The research determined seven microorganisms that gave nonspecific lipases and six that gave lipases which were specific for the 1- and 3-positions of the triglycerides. Use of the nonspecific enzyme gave random interesterification as with chemical reactions. However, the specific lipases catalyzed reactions to give products not obtainable by chemical interesterification methods.

As examples of demonstrated application of the technique, Dr. Macrae offered the conversion of palm oil to the more valuable cocoa butter and, using a lipase specific for the 2-position of the triglyceride, the introduction of linoleic acid into the triglyceride molecule of olive oil.

Both batch and packed bed continuous reactions were facilitated by immobilizing the enzymes of kieselguhr. The reaction proceeded rapidly and at low temperature, -40 C. Such opportunities are only now becoming apparent, and much research and evaluation is required. However, it is a viable concept that low-temperature enzymatic processes may be used to impart desired properties to oil and fat products.

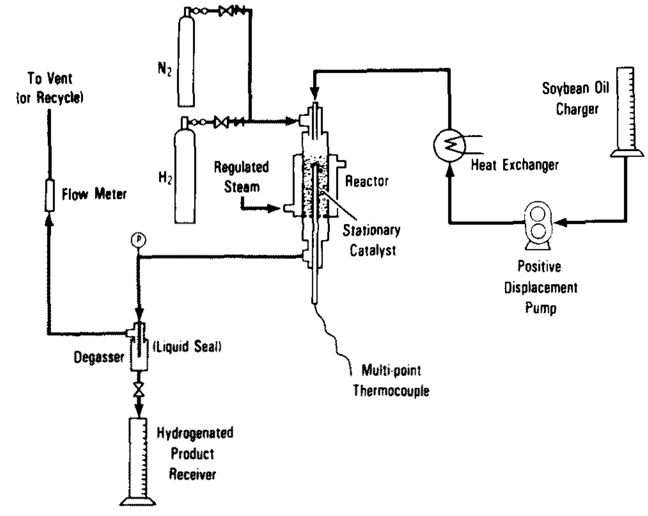

FIG. 5. Flow diagram—trickle bed hydrogenation system.

Based on our experience in the past, change in the food oils industry will be well conceived and based on thorough evaluation of effects on product quality and profitability. Changes will occur to meet the needs of economy, energy conservation, environmental concerns and human health and welfare.

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