Technical News Features

Pacing Technologies in the Fats and Oils Industry[1]

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INTRODUCTION

Technology is the practical application of scientific knowledge derived from engineering or any other basic science. Within the context of practical application, it is implicit that the expected end result is a commercial product (i.e., the product could be a new process, an equipment, a consumer product, or improvements thereof) (1). In the fats and oils industry, some of the needs triggering technology innovations are: cost savings, environmental and safety concerns, and nutrition issues.

Like industries, technologies are dynamic. They have a life cycle and go through stages of maturity.This transition follows an "S-shaped" curve (Fig. 1). Like industries, technology maturity can be classified in four phases: embryonic or emerging, growth, mature, and aging. Not all technologies go through the entire cycle. Some never achieve full development potential and are abandoned.

Technologies have widely differing potential for competitive impact (generally in two main areas: product differentiation and cost advantage). This is the basis for the classification of technology into base, key and pacing technologies.

- *Base* technology is available or known to all industry participants; it cannot provide competitive advantage.
- *Key* technology is a proprietary technology and is critical to the basis of competition.
- *Pacing* technologies are those technologies in the developmental stage with a demonstrated ability to change the basis of competition.

Some, but not all, of the pacing technologies of today will be tomorrow's key technologies; and some key technologies become base technologies and serve as foundation for the industry.

The classification of technologies is useful in evaluating how a company's technology compares to its internal needs and targets and to those of its competition, and in providing direction for its R&D efforts. This discussion will be confined to just one element of the overall matrix – the pacing technologies.

There are numerous new and emerging technologies in the fats and oils industry. Only a few will be covered in this discussion without implying that the others not included in this discussion fall outside the domain of pacing technologies. Indeed, there are a number of pacing technologies in the nonfood category that we will not even mention.

To elucidate the processing steps which will be affected by the six pacing technologies to be discussed, reference is made to Figure 2 – the classical edible oil processing scheme (using soybean oil, the world's major oil source as model); it includes further processing technologies to produce modified fats and oils.

Six pacing technologies are:

Automation and process control – impacts on all operations from seed handling to extraction, refining and quality control.

Physical refining – impacts traditional caustic refining of soybean oil.

[1]Presented at the 74th AOCS annual meeting, Chicago, 1983.

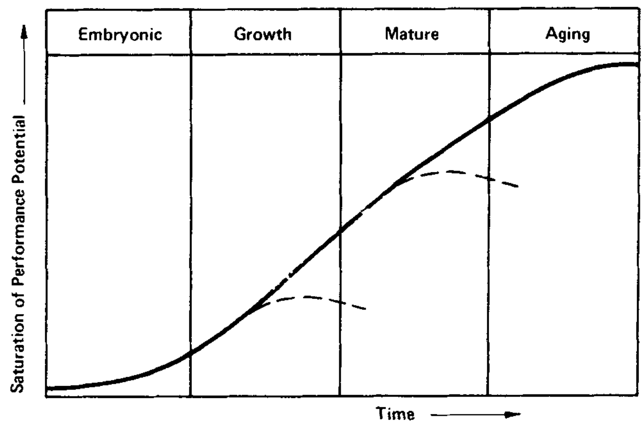


FIG. 1. Cycles and maturity stages of technology.

Critical fluids – alternative to hexane extraction; deodorization and fractionation.

Enzyme-assisted oil extraction – process alternative to traditional extraction.

Fluidbed technology – impacts traditional drying, dehulling, and toasting/desolventizing technologies.

Enzymes for selective interesterification – new products.

AUTOMATION

Automation is at the leading edge of pacing technologies. In fact, for some companies, automation is already a key technology.

The degree of automation in the fats/oils industry is increasing. The modern plants built within the past few years have a high level of sophistication in automation and in process control technologies. Even old plants are being upgraded to accommodate cost-saving measures provided by instrumentation and process control devices.

Microchip technology has revolutionized food processing, including the edible oil industry. Microprocessor-based instrumentation systems are becoming more and more popular for control of processes. A fully automated soybean oil extraction plant has been operating in Finland (2) since 1980 and microprocessors are running a new soybean oil refinery (3) in Des Moines, Iowa.

Enormous changes have occurred in automation and process control technologies. In 1978, when Staley began operation of its corn wet milling plant in Lafayette, Indiana, that plant was considered one of the most automated plants (if not the most automated) in the food industry. Yet only four years later, the Staley group considers that Indiana plant to be two generations behind Staley's Des Moines plant. This gives an idea of the magnitude of the changes.

To the companies with automated plants, such as Staley and the Finnish firm Raision Tehtaat, automation and process control have been moved from a pacing to a key

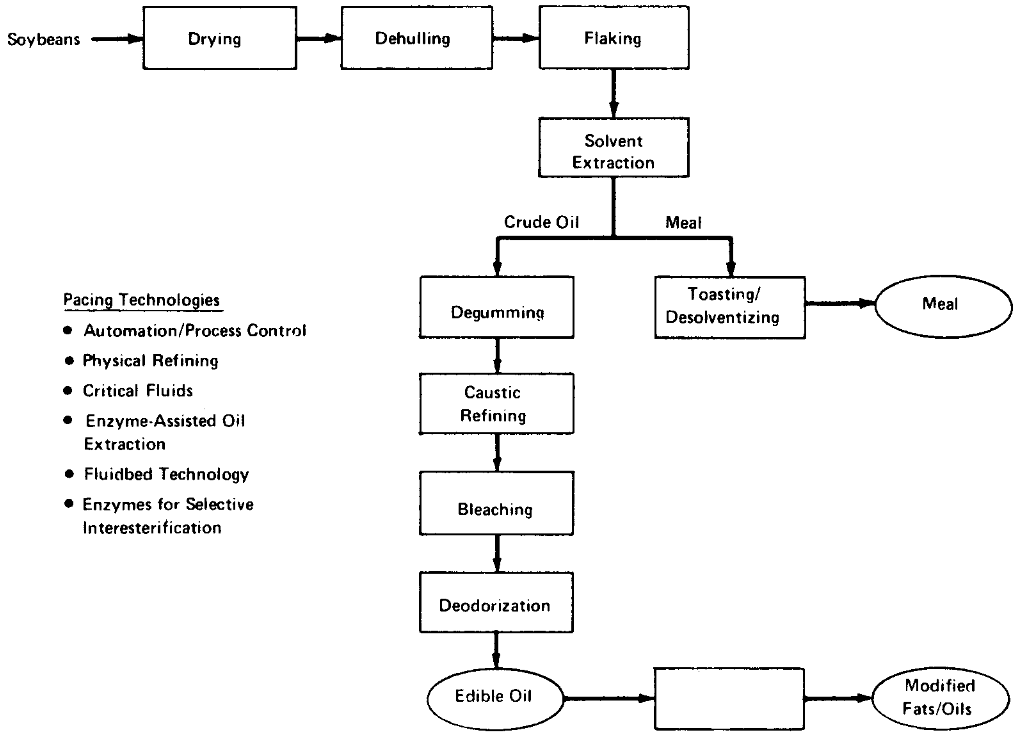


FIG. 2. Schematic of edible oil processing.

technology.

Some advocates of automation have proposed an integration of process control with production control. In process control, the operator's task is to draw the right conclusions from the process conditions signaled to him; he has to coordinate, to plan and to keep log sheets. This allows him to coordinate between control loops and to optimize unit operations. By using modern microelectronic-based control systems, it is possible to move to another phase–production control. Here, the operator's information is taken to a higher level to do computerized planning operations and updatings, and to retrieve data for use as inputs to accounting systems and management information systems.

To date there are no plants known to be using an integrated process and production control network.

Those companies that have adopted automation have been able to justify capital cost of computerized control technologies based on perceived advantages. The advantages of automation from the viewpoint of those who have operated such plants for a few years include: safety, i.e., prevent hexane-caused explosion; energy conservation; labor savings; reliable operation; and consistent product quality.

In automated fats and oils plants, the on-line sensing/analyzing equipment monitors the following: hexane concentration, temperature, pressure, rate of flow, tank level, pH, weight, mass, turbidity and color. The on-line color measuring equipment, edible oil colorimeter (EOC) made by McClosky Scientific Industries, Inc., is one of the newest additions to available on-line sensing/analyzing equipment (4). Further inroads into full-scale automation could be attained with development of more on-line sensor/analyzer equipment. There is a need for development of on-line equipment for determination of fatty acids, *cis* and *trans* isomers, flavor and odor, just to name a few.

PHYSICAL REFINING

Physical refining is a pacing technology for soybean oil refining but it is a key technology in sunflower and corn oil, and a base technology for the refining of other oils such as those from coconut, palm and palm kernel.

In physical refining, the caustic soda treatment, used primarily for the removal of free fatty acids (FFA), is eliminated and instead the vacuum steam distillation process (steam refining) serves a dual purpose of removing FFA and deodorizing by removal of volatiles.

The physical refining of soybean oil has been faced with problems attributed primarily to high and variable phosphatide content of soybeans (5). Thus the degumming or pretreatment process must ensure efficient removal or prevention of formation of phosphatides, particularly the so-called nonhydratable phosphatides (NHP). Besides phosphatides, iron content (less than 2 ppm required) and oxidation state of the feedstock are used to assess physical refinability of the degummed soybean oil.

There are interesting developments in improved degumming (i.e., "wet pretreatment" or "superdegumming" vs "dry degumming") technologies as well as on alternative crushing/extraction technologies (6). Moisture-heat treatment of the soy flakes prior to extraction inactivates the enzymes (phospholipases) and thus prevents formation of the NHP. This modified crushing/extraction route gives soybean oil that can be water degummed to less than 0.05% phosphatides and is readily amenable to physical refining.

These developments coupled with sensitivity to chemical disposal problems (inherent in traditional caustic refining) will expedite the application of physical refining to soybean oil.

CRITICAL FLUIDS

The use of compressed gases and supercritical fluids in fats/oils processing has been an area pursued by several groups with much enthusiasm.

The extraction of various oilseeds and other fats/oils sources shown in Table I have been tested. These include soybeans, corn, rapeseed, sunflower, peanuts, avocados and

TABLE I

Fats/Oils Sources Tested by Extraction with Critical Fluids[a]

Source	General observations
Soybeans	Glycerides and nonpolar liquids readily soluble Virtually free of lecithin
Corn	Glycerides and nonpolar liquids readily soluble
Rapeseed (canola)	Glycerides and nonpolar liquids readily soluble
Sunflower	Glycerides and nonpolar liquids readily soluble
Peanuts	Glycerides and nonpolar liquids readily solbule
Avocado	Glycerides and nonpolar liquids readily soluble Oil extractability moisture dependent
Jojoba	Wax esters readily soluble

[a]The extractants tested by various groups include liquid and supercritical carbon dioxide, supercritical propane and ethane.

jojoba beans.

In principle, since fats and oils are made up of various glycerides, critical fluids can be used to extract fats and oils from any of the present sources, with due consideration given to process parameters of pressure, temperature and fluid velocity.

The most common extractant used has been liquid or supercritical carbon dioxide (critical temperature = 31.5 C, critical pressure = 72.9 atm) because of its advantages in terms of nonflammability and low cost. However, the equilibrium solubility of fats and oils in supercritical carbon dioxide (i.e., 40 C, 200 atm) is low and estimated to be less than 0.2% (w/w). Indeed, at pressures below 300 atm, liquid CO_2 is a better solvent than supercritical carbon dioxide. For example, solubility in liquid CO_2 (10 C, 200 atm) is ca. 0.5%. To obtain higher solubilities – i.e., 1.5% (w/w) – operating pressures as high as 500 atm are required. Because capital equipment cost is very sensitive to operating pressure requirements, there are serious questions as to the economic viability of the use of extremely high pressure conditions.

For this reason, other extractants with critical pressures lower than carbon dioxide have been investigated. These fluids include propane (T_C = 97 C, P_C = 42 atm) and ethane (T_C = 32 C, P_C = 48 atm). Fats and oils glycerides are also readily soluble in these critical fluids at pressures much lower than that required to obtain similar or greater solubility with carbon dioxide.

Solvent flammability is the major disadvantage of these critical fluids and would require installation of special safety measures, including isolation of the extraction area from the rest of the process operations.

At this time, continuous high pressure processing of liquids can be performed with available equipment but the handling of solids is still a semicontinuous batch operation, requiring a minimum of two extraction vessels operated alternately. Designs for continuous processing of oilseeds at high pressures have been proposed but such equipment is not yet available.

The use of critical fluids is not confined to extraction. Supercritical carbon dioxide also has been demonstrated to be effective for deodorization as well as for fractionation of fats and oils. The fractionation of coconut oil, cocoa butter and butterfat has been reported (7,8).

A question raised by many has been, "Will critical fluids extraction ever be competitive with traditional methods of processing oilseeds?" A justifiable assessment of this question will have to take into account the effect of critical fluids extraction on the total process of edible oil production, including aspects related to quality of the meal produced, not only for feed production but also for the production of the analog vegetable proteins. Economy of scale can dramatically influence cost. In the case of soybeans, wherein new plants with capacities of 500-1000 tons/day now appear to be the norm, critical fluids extraction may become a reality in the distant future.

ENZYMES

A recent publication by Fulbrook (9) focused on the use of enzymes as processing aids in the extraction of oils from oilseeds. The enzymes are believed to be aiding in physically dislodging or releasing the oil globules from the protein and polysaccharide matrix. The laboratory process tested is described schematically in Figure 3.

Enzymes from several producing organisms have been tested at enzyme concentrations of 1, 2 and 3% (w/w). The yield of oil increases with increasing enzyme concentration, its effect tapering off at the 2-3% level. The respective yields for rapeseed and soybean are shown in Table II for enzyme systems from *Bacillus* and two strains of *Aspergillus niger*.

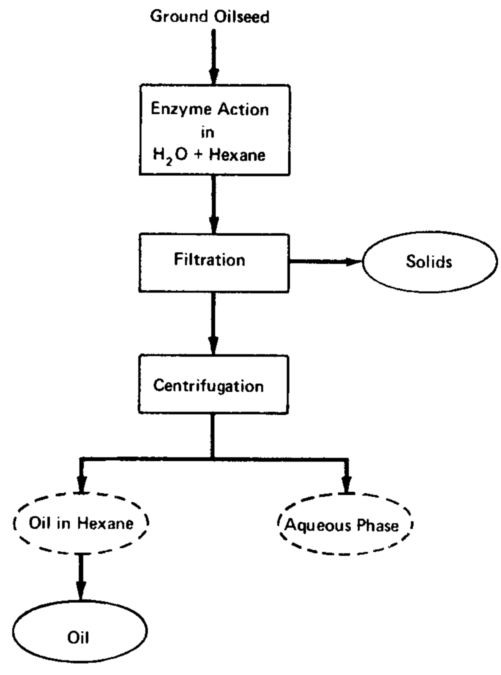


FIG. 3. Schematic operation for enzyme-assisted extraction of soybean and rapeseed oil. (Source: reference 9).

TABLE II

Effect of Different Enzyme Systems on Oil Yield (enzyme concentration = 3%, w/w)

	Yield of oil obtained[a]	
Enzyme producing organism	Rapeseed	Soybean
Bacillus	65.5	63.3
Aspergillus niger, type 1	70.5	83.8
Aspergillus niger, type 2	72.2	89.8

[a]Percentage relative to total soxhlet extractable oil; rapeseed and soybean contained 30 and 20% oil, respectively.
Source: reference 9.

The advantages of enzyme-assisted oil extraction in comparison to conventional extraction are reportedly: it requires small amounts of solvents and low energy usage; it yields oil of good quality within Codex specifications and eliminates need for further refining; and for rapeseed, aqueous phase processing allows ready separation of the phytic acid and other toxins from the high protein meal.

FLUIDBED TECHNOLOGY

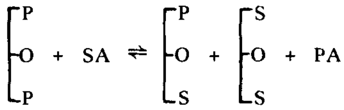
Fluidbed technology has been introduced in several stages in the processing of soybeans (10,11). These include fluidbed conditioning of cracked beans, fluidbed dehulling and conditioning, and fluidbed meal drying-cooling. The advantage of fluidbed technology is that the heat exchange processes between free flowing solids and gases are faster and more economical than in conventional installations. It has been reported that the heat requirement of the fluidbed process is ca. 50% of the traditional standard process.

SELECTIVE INTERESTERIFICATION

Interesterification is used in the fats and oils industry to produce triglyceride mixtures with different properties. At present, this process is carried out using a chemical catalyst, such as sodium metal or sodium alkoxide, to promote acyl migration among the glyceride molecules. The product is a complex mixture of glycerides with modified properties, but wherein the fatty acyl residues are randomly distributed among the glyceride molecules.

It has been reported recently that certain extracellular microbial lipases can promote site-specific or fatty acid-specific interesterification (12). These selective lipases can be exploited to produce glyceride mixtrures which cannot be obtained by chemical interesterification processes. Of special significance are the 1,3-specific lipases, such as those from *Aspergillus niger, Mucor javanicus* and various *Rhizopus* species.

A potential commercial application of 1,3-specific lipases is in the production of the valuable cocoa butter equivalent (CBE) from less expensive materials, such as the midfraction obtained from the fractionation of palm oil. This midfraction contains predominantly the triglyceride 1,3-dipalmitoyl-2-olein (POP). In the presence of stearic acid (SA), the site-specific lipase converts the POP to the primary cocoa butter triglycerides: 1(or 3)-palmitoyl-3(orl)-stearoyl-2-olein (POS) and 1,3-distearoyl-2-olein (SOS).



Ideally, the reaction products are as indicated above. In experimental practice, however, side reactions have been observed by Macrae (12) which could in fact be due to the presence of other triglycerides besides POP in the palm oil midfraction. An example of the POS and SOS enrichment that occurs when the palm oil midfraction is interesterified with stearic acid in the presence of *Aspergillus niger* lipase as catalyst is shown in Table III. There is a distinct decrease in POP concentration and an increase in POS and SOS.

TABLE III

***Aspergillus niger* Lipase Catalyzed Interesterification of Palm Oil Midfraction and Stearic Acid[a]**

Triglyceride species[b]	Amount in triglyceride mixture	
	Palm midfraction (%)	Interesterified product (%)
POP	58	19
POS	13	32
SOS	2	13
Others[c]	27	36

[a]Reaction conditions: 2:1 ratio of palm oil midfraction and stearic acid at 40 C for 16 hr.
[b]P = palmitate; O = oleate; S = stearate.
[c]Mixtures of at least 4 triglycerides with saturated fatty acid groups.
Source: reference 12.

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