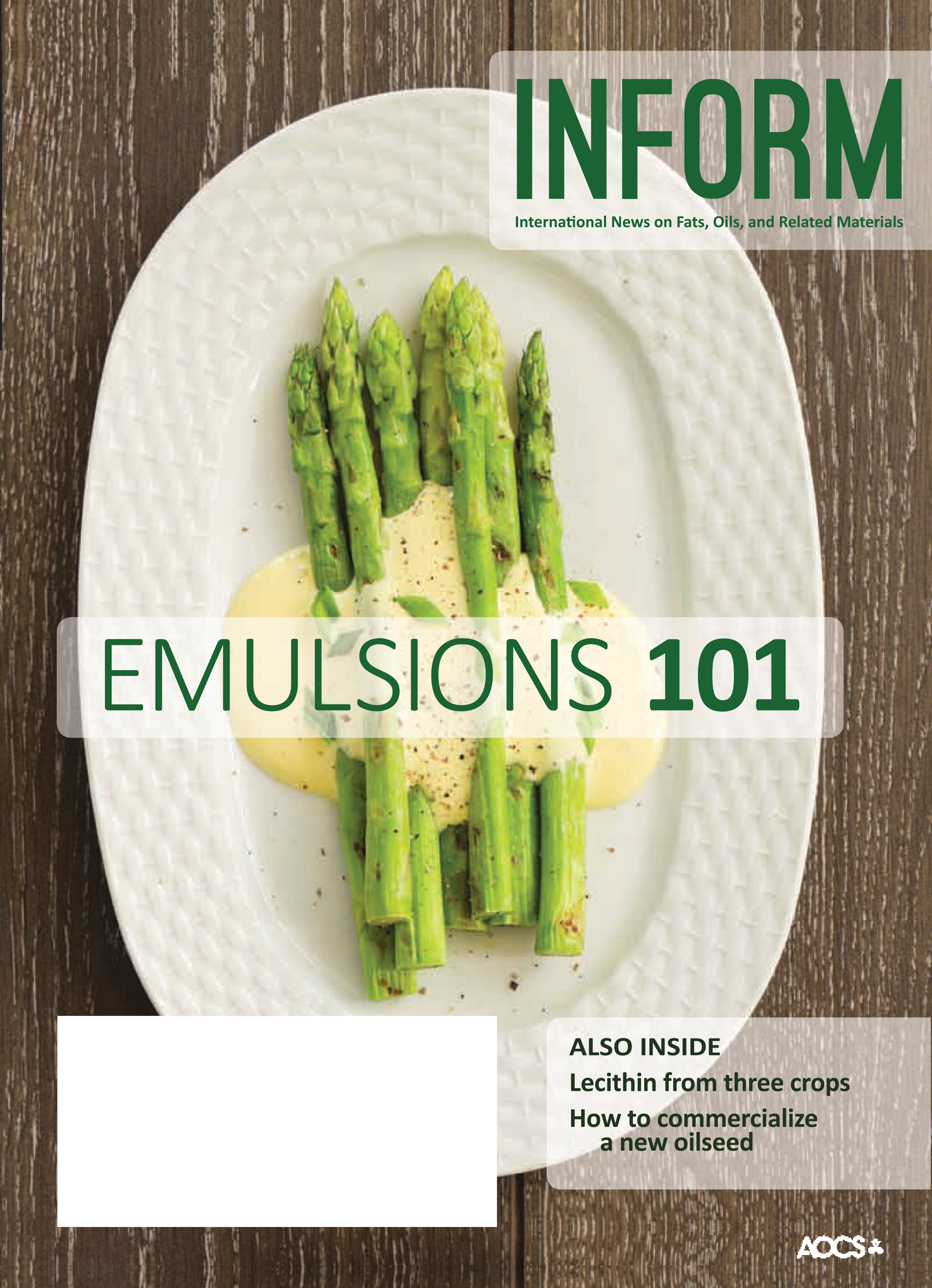
INFORM April 2014 Volume 25 (4) 193–272

# INFORM

International News on Fats, Oils, and Related Materials



# EMULSIONS **101**

**ALSO INSIDE**

**Lecithin from three crops**

**How to commercialize a new oilseed**

AOCS

# The changing world of lecithins

**Willem van Nieuwenhuyzen**

Lecithin is one of the most common phospholipids (PL)—a class of polar lipids that support life functions. PL are present in all of our body's cells, where they regulate the transport of molecules across the cell membrane. Vital organs such as our brain are full of them, and their potential has captured the imaginations of scientists from the medical, pharmaceutical, and (health) food sectors for more than a century.

The word "lecithin" comes from the Greek "λέκιθος," meaning "egg, the start of life." Indeed, egg and egg yolk are full of PL, which are active emulsifying components. That knowledge initiated the search for cheaper, more available emulsifiers that could replace eggs in food recipes. Lecithin from soybeans conquered the food industry during the 1940s, when US planting and crushing of soybeans accelerated. Since then, soybean-based lecithin has greatly extended the portfolio of effective emulsifier systems and given rise to what is still the leading group of emulsifiers.

The widespread planting of genetically modified (GM) soybeans, which began in 1995, has caused disruptions in supply streams of commercial food-grade lecithin from traditional soybean varieties that previously flowed from the United States and Latin America to Europe. More recently, sourcing requirements for identity-preserved (IP) non-genetically modified (GM) soy ingredients and lecithin for the European food market have affected lecithin production worldwide. As the availability of traditional non-GM soybeans from the United States and Latin America has decreased, the sourcing of IP soy lecithin from other regions and lecithin from sunflower and canola (rapeseed) has grown. The analytical efforts required for IP tracing are enormous in terms of management time, logistics, and costs.

- **The planting of genetically modified (GM) soybeans has caused disruptions in supply streams of commercial food-grade lecithin from traditional soybean varieties that previously flowed from the United States and Latin America to Europe.**

- **More recently, sourcing requirements for identity-preserved (IP) non-GM soy ingredients and lecithin in the European food market have affected lecithin production worldwide. As the availability of traditional non-GM soybeans from the United States and Latin America has decreased, the sourcing of IP soy lecithin from other regions and of lecithin from sunflower and canola has grown.**

- **Meanwhile, the analytical efforts required for IP tracing are enormous in terms of management time, logistics, and costs.**

## COMPOSITION OF LECITHIN FROM THREE DIFFERENT CROPS

Lecithin from soy, sunflower, and canola is produced to comply with food-grade regulatory specifications. The chemical analyses include acetone-insoluble matter, hexane-insoluble matter, acid value, moisture, peroxide value, Gardner color, and viscosity. Specifications in international trade are based on AOCS Official Methods & Recommended Practices. Increasingly, the PL composition of lecithin is analyzed by high-performance liquid chromatography and $^{31}P$ nuclear magnetic resonance, which provide valuable information on product characteristics and functional emulsifying performance (Fig. 1). For example, phosphatidylcholine (PC) and lysophospholids promote oil-in-water emulsion stability, while phosphatidylethanolamine (PE) has water-in-oil promoting properties

Typical PL values, summarized in Table 1 (page 256), illustrate that the compositions of lecithin from soy, sunflower, and canola are quite close. PL + glycolipids + complex carbohydrates account for the acetone-insoluble matter as measured by classical chemical routine analysis (AOCS Official Method Ja 4-46). The fatty acid (FA) composition of the three types of lecithins (PL plus oil) follows largely the FA composition of the oil (Table 2, page 256).

In other oil crops such as cottonseed, corn germ, palm, palm kernel, and coconut, the low content of PL in the crude oil does not justify economic recovery of the lecithin for commercial use.

## PRODUCTION

In the crushing mill the oil is solvent-extracted from the crushed seed, whose cell walls contain relatively high amounts of PL. The extracted oil contains 2–3% PL (0.4–0.6% on the basis of seed), which is removed in the so-called degumming step. In the degumming step water is added to the oil, enabling the PL to dissolve in the heavy water phase, while the oil with a low phosphorus (<100 ppm P, preferably <5 ppm P in the case of physical refining) content is then suitable for low-cost refining. This is in a nutshell the recovery of the lecithin gums,

CONTINUED ON NEXT PAGE

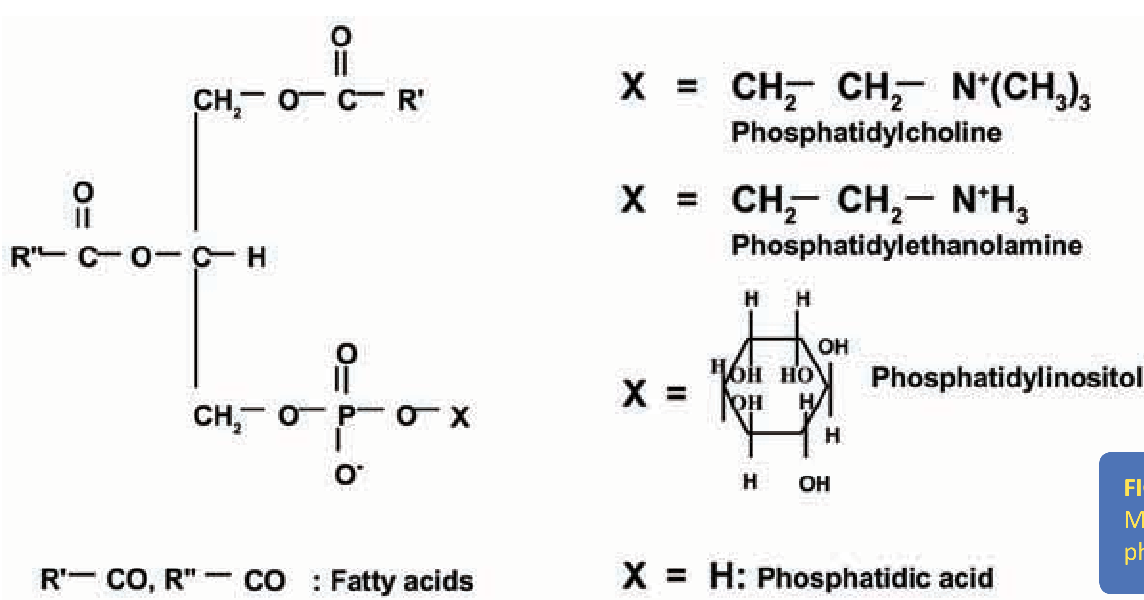



**FIG. 1.** Molecular structure of phospholipids.

**TABLE 1.** Phosphopipid and total composition of three liquid vegetable lecithins[a]

| | Soy lecithin (%) | Sunflower lecithin (%) | Canola lecithin (%) |
|---|---|---|---|
| Acetone-insoluble matter | | | |
| Phospholipids | | | |
| Phosphatidylcholine | 15 | 16 | 17 |
| Phosphatidylethanolamine | 11 | 8 | 9 |
| Phosphatidylinositol | 10 | 14 | 10 |
| Phosphatidic acid | 4 | 3 | 4 |
| Other phospholipids | 7 | 6 | 6 |
| SUB-TOTAL: all phospholipids | 47 | 47 | 46 |
| Glycolipids | 11 | 11? | 11? |
| Complex carbohydrates | 4 | 4? | 4? |
| TOTAL: acetone-insoluble matter | 62 | 63 | 62 |
| Acetone-soluble matter Oil + added fatty acid | 37 | 36 | 37 |
| Moisture | <1 | <1 | <1 |
| **TOTAL** | 100 | 100 | 100 |

[a]Slightly modified from W. van Nieuwenhuyzen and M.C. Tomás, Update on vegetable lecithin and phospholipid technologies, Eur. J. Lipid Sci. Technol. 110:472–486 (2008).

**TABLE 2.** Fatty acid composition, in percentage, of three vegetable lecithins

| Fatty acid | Soy lecithin | Sunflower lecithin | Canola lecithin |
|---|---|---|---|
| C16:0 | 16 | 11 | 7 |
| C18:0 | 4 | 4 | 1 |
| C18:1 | 17 | 18 | 56 |
| C18:2 | 55 | 63 | 25 |
| C18:3 | 7 | 0 | 6 |
| Others | 1 | 4 | 5 |

which are dried to lecithin or are sprayed back on the meal (Fig. 2).

*SOY LECITHIN.* Soybeans are the primary commercial source of vegetable lecithin. Solvent extraction of soybeans is carried out in large crushing plants with capacities of 1,000–6,000 metric tons per day, yielding 18% oil. The extracted oil is filtered to optimize the oil degumming efficiency as well as the production of lecithins with low residual dirt (earth, seed protein residue), expressed as hexane insolubles (HI; in the United States) or toluene insolubles (TI; in Europe).

The water degumming process (Fig. 2) may give the best quality of standard lecithin. The gums removed from the oil in the enzymatic degumming step may contain high amounts of hydrolyzed lysophospholipids with new functional properties. The gums with 20–50% moisture are removed from the oil by continuously operating decanters. Lecithin is dried in rotating film evaporators within 1–2 minutes to a content of <1% moisture, achieving long shelf life and good liquidity. The product is rapidly cooled, preventing post-darkening. Standard lecithin is adjusted for oil content and viscosity; and it is used for processing modified PL, such as hydrolyzed, acetylated, hydroxylated, fractionated, or deoiled lecithins.

*SUNFLOWER LECITHIN.* Oilseed-type sunflower seeds have mostly black hulls that tend to stick to the meat. Sunflower crushing requires dedicated crushing plants since the seeds are smaller than soybeans. Dehulling efficiency may influence the natural wax content of 0–1% in lecithin. Hence, additional expelling (pressing) is often used to squeeze out oil and reduce the original oil content of the seed (~40%) down to 15% in the press cake; the press cake is then hexane-extracted to reduce the oil to under 0.5%. Both press oil and extraction oil streams are combined for degumming. Sunflower lecithin yields are about 0.3% on seed basis. Intensive filtration of the non-degummed oil is important for obtaining lecithin with low-impurity HI contents of less than 0.3%.

Sunflower lecithin is a preferred alternative to soy lecithin in Europe. The FA composition of sunflower lecithin is attractive. Its taste-flavor profile is pleasant (nutty-like), and its emulsifying properties are good. The main sunflower-growing regions are Argentina, France, Hungary, Ukraine, and Russia.

*CANOLA LECITHIN.* Canola seed crush and lecithin production are quite similar to sunflower processing; most often an expelling step is used to squeeze out oil from an original 40% to below 20%, followed by solvent extraction. Since canola contains chlorophyll components, lecithin from canola may have a slight greenish tone. This is masked, however, in food recipes because the usual dosage content is less than 0.5%. Canola varieties of rapeseed produce little or no erucic acid (C22:1) and thioglycosides, in contrast to lecithin produced from high-erucic acid rapeseed. The lecithin is used in food, feed, and technical industries. Canola lecithin is produced in Canadian, European, and Chinese crushing plants.

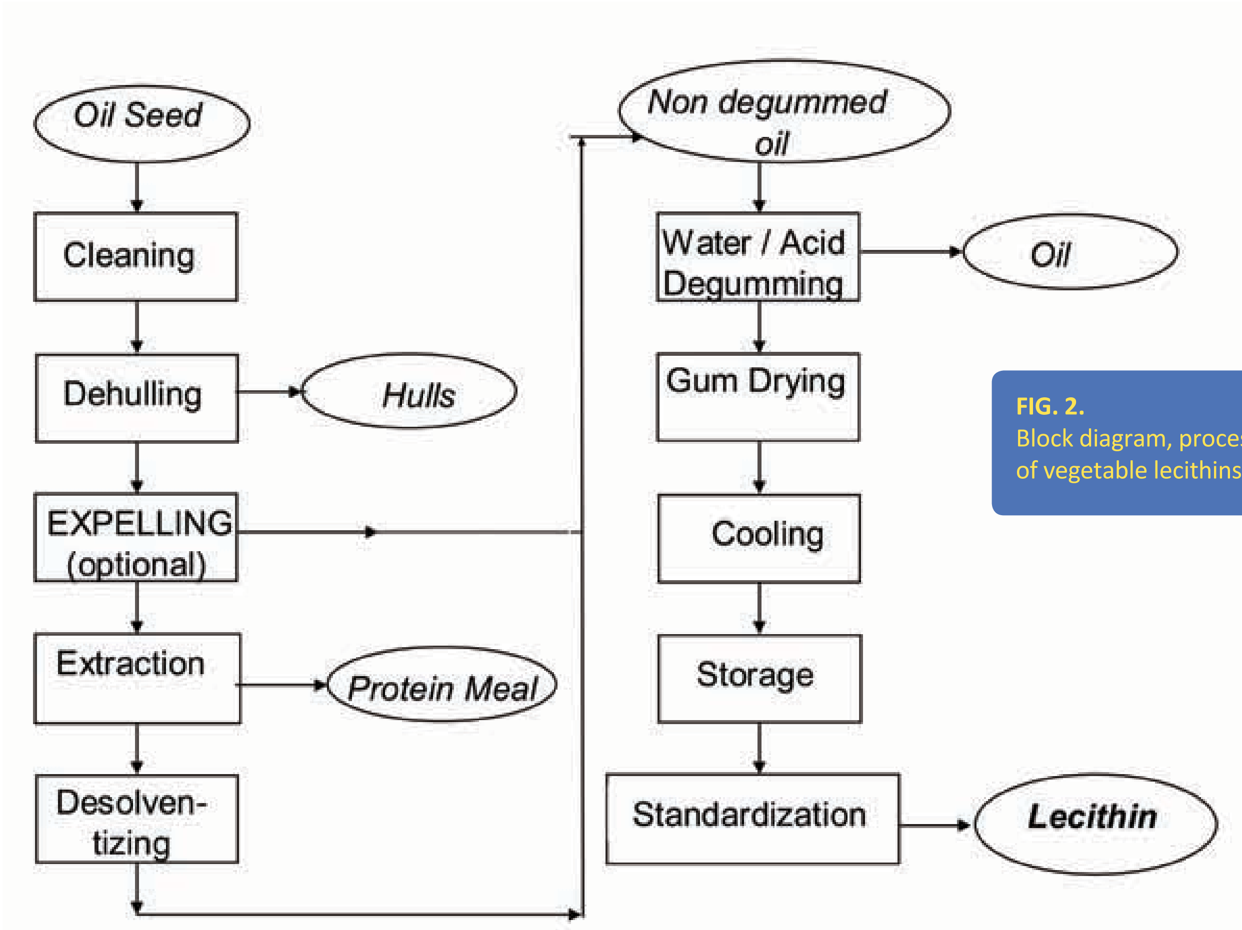



**FIG. 2.** Block diagram, processing of vegetable lecithins.

## KEY CHARACTERISTICS

PL are polar lipids with a hydrophilic and a lipophilic part. They concentrate at the interface between oil and water and reduce the interfacial tension. This property facilitates the formation of emulsions. In food emulsion recipes, the low amount (often <0.5%) of lecithin supports emulsion stability in interactions with the three main food components—fat, protein, and carbohydrates—and other texturizing ingredients. The aims of emulsion stability are the prevention of creaming, coalescence in larger droplets, sedimentation, and separation during the shelf life.

Phosphatidylcholine (PC) forms a lamellar layer in the interface between oil and water, different from the reversed hexagonal phase of phosphatidylethanolamine (PE) or the hexagonal phase of lysophospholipids (Fig. 3, page 258). This knowledge is useful for applying lecithins having adapted, modified, or fractionated PL composition. The enzymatic hydrolysis, acetylation, and alcohol fractionation processes, which improve the functional properties of lecithin, all have in common that the zwitterion group of the PE is modified or removed. The modified lecithins have hydrophilic-lipophilic balance (HLB) values of 2–12, a property used in emulsifier characterization. The specialties are produced on plant scale on the basis of soy lecithin. Nowadays sunflower lecithin and canola lecithin are also sourced for producing standard and modified lecithins. Of course, the switch to another type of lecithin or

CONTINUED ON NEXT PAGE

## Learn more about lecithin

You can meet the author of this article and build your knowledge about lecithin at the "Lecithin Functions in Technology and Nutrition" short course, June 12–13, 2014, in the Gothic city center of Ghent, Belgium. The course, which is co-sponsored by the International Lecithin and Phospholipid Society (ILPS) and Ghent University, will enhance your knowledge of:

- the technological functions of soy, sunflower, and rapeseed/canola lecithins
- nutrition-related properties of egg, marine, milk, and soy phospholipids
- preparation and characterization of emulsions and liposomal dispersions
- physical chemistry of polar lipids

More than 20 world-class presentations and laboratory demonstrations will present topics on vegetable- and animal-sourced lecithins in many practical applications.

More program and registration information can be found at www.ilps.org/index.php/lecithin-short-course.html.

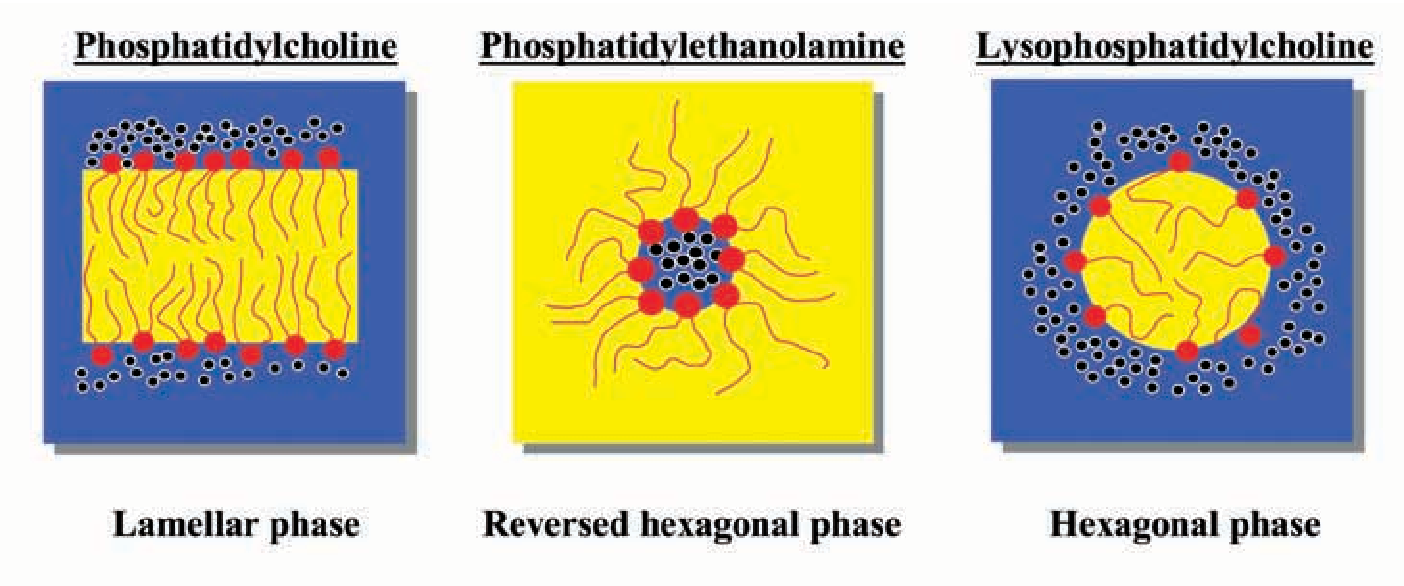



**FIG. 3.** Phospholipid structures at the oil/water interface.

supplier always requires the optimization of dosage in the food recipe including sensorial evaluation.

## APPLICATION

The use of lecithins in food, feed, and technical products is manifold. The main applications in food are given in Table 3. Food scientists have achieved a strong match of key properties and uses for lecithins.

Feed industries use lecithin as emulsifier in milk replacers for feeding of calves and piglets and as a choline and energy supply source in broiler feed. Aquaculture is a fast-growing sector using lecithin, where it serves as an invaluable wetting agent and nutrient in feed pellets, in particular for particular shrimp and salmon feed. Southeast Asia and Latin America use this expertise.

In technical industries, the use of lecithin for lubrication and emulsifying properties in leather processing, paper coating, paints, plant crop protection, and soil bioremediation is validated or has new potential. Lecithins from all three oilseed sources can be used.

In the pharmaceutical sector, soy PL, often deoiled lecithin powder or pure PC fractions, are used as excipient in drug formulations. All approved dossiers and formulations are based on well-defined soy PL compositions. These lecithin specialties are processed from standard lecithin source from either GM or non-GM soybeans, which are available in abundance. This strategy will continue, since availability of the required soy PL is secured.

## MARKET STRUCTURE

Vegetable lecithin, as co-product having a 0.3–0.8% yield on a seed basis, influences the crushing calculation only marginally. As an alternative to drying lecithin gums, the gums can be sprayed on the seed meal, contributing to the meal price value. If that outlet is not feasible, dried lecithin gums can still provide value as a "feed oil" additive with high monounsaturated FA/polyunsaturated FA content as an energy source in animal feed.

Worldwide soybean production forecasts for 2012–2013 were 271 million metric tons (MMT); canola, 61 MMT; and sunflowerseeds, 37 MMT (US Department of Agriculture estimates, May 2011; www.fas.usda.gov/data/oilseeds-world-markets-and-trade). Although the lecithin market grows steadily, only an estimated 15–20% of the potential

**TABLE 3.** Survey of lecithin applications in selected foods

| Application | Functions |
|---|---|
| Baked goods | Volume improvement, fat dispersion<br>Firmness, freshness |
| Chocolate | Viscosity modification |
| Chewing gum | Rheology, tackiness, brittleness |
| Instant drinks dairy/cocoa | Agglomeration, wetting, dispersibility |
| Margarine | Anti-spattering in frying, emulsification, mouth feel |
| Pan release agent | Wetting, anti-sticking |

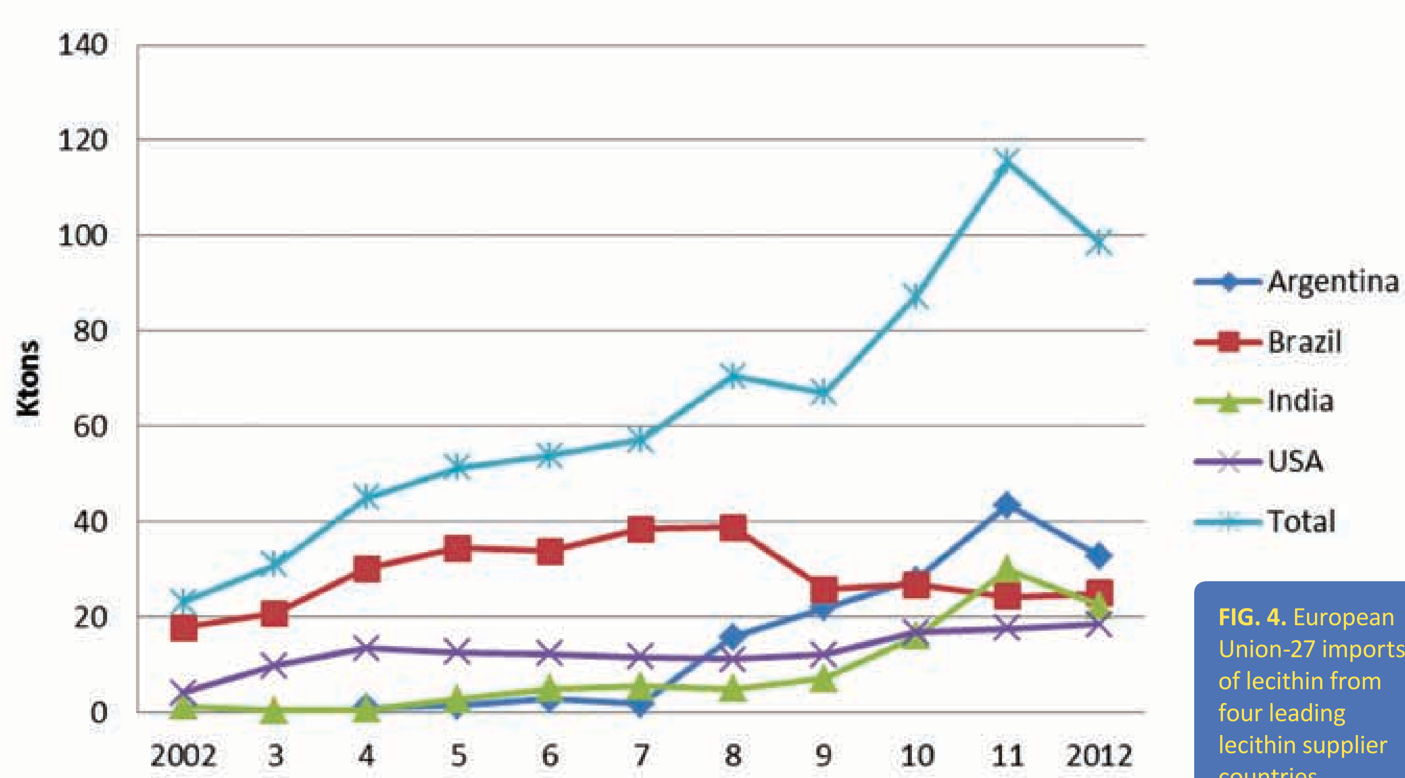



**FIG. 4.** European Union-27 imports of lecithin from four leading lecithin supplier countries.

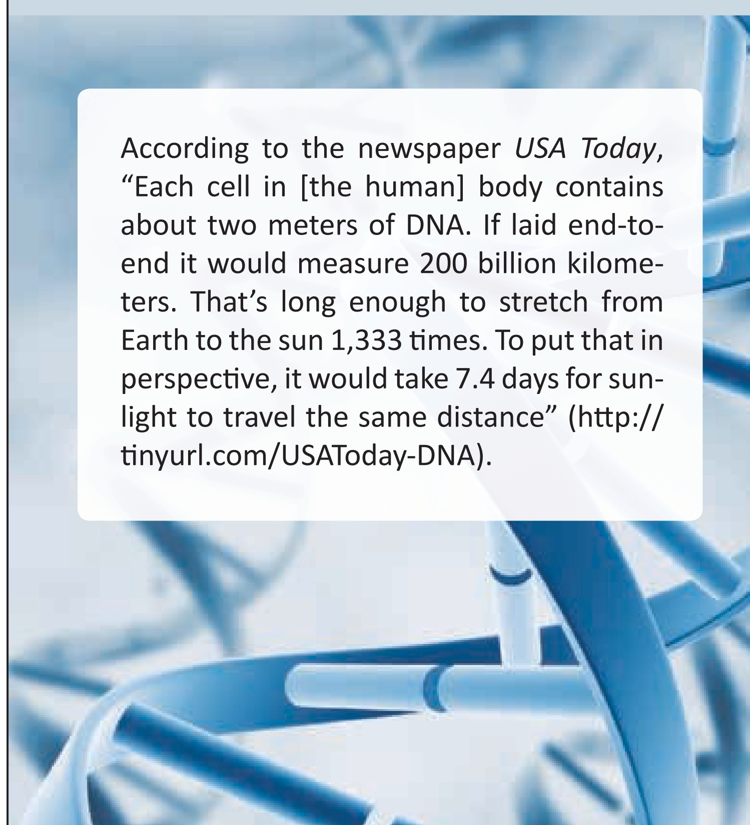
gums are processed into lecithin-standard quality and specialties with dedicated technological and nutritional functions in high-value pharmaceutical, (health) food, and feed segments. These market segments are served by dedicated lecithin manufacturing companies, either affiliates of the large crushing multinationals or independent companies. Those companies have expertise in IP sourcing of raw materials; lecithin modification facilities; and logistic tools for transport, special tank parks, and hygienic filling stations in addition to quality assurance and applications laboratories. Industrial users prefer long-term supply relationships that allow them to secure high-quality performance of lecithins, used at low dosage, to achieve remarkable functions. It is in this manner that business-to-business lecithin expert companies develop profitable projects.

Changes in IP requirements, particularly in Europe, have led to a remarkable shift in the lecithin imports in the European Union (EU-27). Figure 4 illustrates Eurostat EU import statistics over a 10-year period from four leading lecithin-producing countries, totaling 100 kilotons (100,000 metric tons) in 2011. Data on increased imports may reflect higher consumption, lower European soy lecithin production, increased availability of IP non-GM soy lecithin from Brazil and India, and sunflower lecithin from Argentina. Replacing soy lecithin allows food manufacturers also to omit the labeling of "soy" as an allergen on consumer packaging, if appropriate.

---

*Willem van Nieuwenhuyzen is director of Lecipro Consulting, the Netherlands, www.ilps.org.He may be contacted by email at willem@lecipro.nl. He also acts as executive director of the International Lecithin and Phospholipid Society, www.ilps.org.*

## [FAST FACT]



According to the newspaper *USA Today*, "Each cell in [the human] body contains about two meters of DNA. If laid end-to-end it would measure 200 billion kilometers. That's long enough to stretch from Earth to the sun 1,333 times. To put that in perspective, it would take 7.4 days for sunlight to travel the same distance" (http://tinyurl.com/USAToday-DNA).