Kirk-Othmer Encyclopedia of Chemical Technology.

LECITHIN

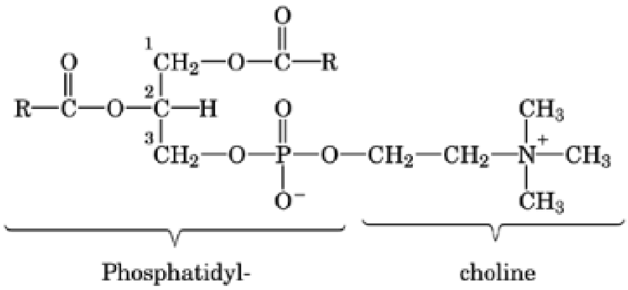
The name lecithin was first used (1) to describe a sticky, orange-colored, phosphorus- and nitrogen-containing material, initially isolated from egg yolk in 1847 and in subsequent years from brain, blood, bile, and other organic materials. The word is derived from the Greek *lekithos* meaning in the feminine form "egg yolk" and in the masculine form "yellow pea soup." Subsequently, it was demonstrated in 1867–1868 (2) that the nitrogen-containing component of egg lecithin is choline, an organic base already known to be present in the bile. Lecithin and other phospholipids are of universal occurrence in living organisms. They are constituents of biological membranes and are involved in permeability, oxidative phosphorylation, phagocytosis, and chemical and electrical excitation.

Lecithin [8002-43-5] is not only used in the strict scientific sense to describe pure phosphatidylcholine. (Fig. 1), but also to describe crude phospholipid mixtures containing phosphatidylcholine (PC), phosphatidylethanolamine (PE), phosphatidylinositol (PI), other phospholipids, and a variety of other compounds such as fatty acids, triglycerides, sterols, carbohydrates, and glycolipids. Structures having only one acyl group at the glycerol backbone, predominantly in position 1, are called lysolecithin [9008-30-4]. The International Lecithin and Phospholipid Society (ILPS) has published the following definition for lecithin and phospholipid (4): lecithin is a mixture of glycerophospholipids obtained from animal, vegetable, or microbial sources, containing a variety of substances, such as sphingosylphospholipids, triglycerides, fatty acids, and glycolipids. The pure phospholipids, which can be isolated ultimately from the mixture, are defined as lipids containing phosphoric acid. The term phospholipids is no longer recommended but is still used in the technical literature. Commercial lecithin is currently available in more than 40 different formulations varying from crude oily extracts from natural sources to purified and synthetic phospholipids. Many of these products are defined according to the stage of the purification process from which they are obtained and fall into three broad categories (Table 1) varying in their constituents both qualitatively and quantitatively.

Industrial lecithins from a variety of sources are utilized (Tables 2 and 3). The main sources include vegetable oils (eg, soy bean, cottonseed, corn, sunflower, rapeseed) and animal tissues (egg and bovine brain). However, egg lecithin and in particular soy lecithin (Table 4) are by far the most important in terms of quantities produced. So much so that the term soy lecithin and commercial lecithin are often used synonymously.

1. Physical Properties

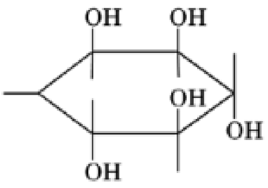
Commercial crude lecithin is a brown to light yellow fatty substance with a liquid to plastic consistency. Its density is 0.97 g/mL (liquid) and 0.5 g/mL (granule). The color is dependent on its origin, process conditions, and whether it is unbleached, bleached, or filtered. Its consistency is determined chiefly by its oil, free fatty acid, and moisture content. Properly refined lecithin has practically no odor and has a bland taste. It is soluble in aliphatic and aromatic hydrocarbons, including the halogenated hydrocarbons; however, it is only partially soluble in aliphatic alcohols (Table 5). Pure phosphatidylcholine is soluble in ethanol.



(1)

$-CH_2-CH_2-\overset{+}{N}H_3$

(2)



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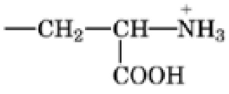
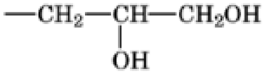


$-CH_2-\underset{COOH}{\underset{|}{CH}}-\overset{+}{N}H_3$

(4)



$-CH_2-\underset{OH}{\underset{|}{CH}}-CH_2OH$

(5)

Fig. 1. Chemical structure of phosphatidylcholine (PC) (**1**) and other related phospholipids. $R-\overset{O}{\overset{\|}{C}}-O-$represents fatty acid residues. The choline fragment may be replaced by other moieties such as ethanolamine (**2**) to give phosphatidylethanolamine (PE), inositol (**3**) to give phosphatidylinositol (PI), serine (**4**), or glycerol (**5**). If H replaces choline, the compound is phosphatidic acid (**6**). The corresponding IUPAC-IUB names are (**1**), 1,2-diacyl-*sn*-glycero(3)phosphocholine; (**2**), 1,2-diacyl-*sn*-glycero(3)phosphoethanolamine; (**3**), 1,2-diacyl-*sn*-glycero(3)phosphoinositol; (**4**), 1,2-diacyl-*sn*-glycero(3)phospho-L-serine; and (**5**), 1,2-diacyl-*sn*-glycero(3)phospho(3)-*sn*-glycerol.

Table 1. Categories of Commercial Lecithin

Natural	Refined	Modified
Plastic	*Deoiled*	*Physically*
unbleached		custom-blended
bleached		natural and refined
doubled-bleached		
Fluid	*Fractionated*	*Chemically*
unbleached	alcohol-soluble	
bleached	alcohol-insoluble	
double-bleached		*Enzymatically*

In water, a particle of lecithin exhibits myelin growth, ie, cylindrical sheets that are formed by bilayers and are separated by water which may break up into liposomes (vesicles with a single bilayer of lipid enclosing an aqueous space). Phospholipids more generally form multilamellar vesicles (MLV) (5). These usually are converted to unilamellar vesicles (ULV) upon treatment, eg, sonication. Like other antipolar, surface-active agents, the phospholipids are insoluble in polar solvents, eg, ketones and particularly acetone. Acetone does, however, dissolve the triglyceride carrier, and this difference in solubility provides a convenient means of separating, purifying, and measuring the phospholipids.

Table 2. Composition of Lecithins, Oil-Free Basis, %

Phospholipid	Soybean lecithin	Corn lecithin	Sunflower-seed lecithin	Rapeseed lecithin	Peanut lecithin	Egg lecithin	Bovine brain lecithin
phosphatidylcholine	21	31	14	37	23	69	18
phosphatidyl-ethanolamine	22	3	24	29	8	24	36
phosphatidylinositol	19	16	13	14	17		2
phosphatidic acid	10	9	7		2		2
phosphatidylserine	1	1				3	18
sphingomyelin						1	15
glycolipids	12	30		20	12		

Table 3. Fatty Acid Composition of Oil-Free Lecithins, %[a]

Fatty acids[b]		Soybean lecithin	Rapeseed lecithin	Sunflower-seed lecithin	Egg lecithin
palmitic acid	C16:0	18.4	5.0	8.0	37.0
stearic acid	C18:0	4.0		2.0	9.0
oleic acid	C18:1	10.7	63.0	20.0	32.3
linoleic acid	C18:2	58.0	20.0	67.8	16.7
linolenic acid	C18:3	6.8	9.0	0.5	
arachidic acid	C20:0			0.5	
arachidonic acid	C20:4				5.0
others		2.1	3.0	1.2	0

[a] Percent of total fatty acid content.

[b] See Fats and fatty oils.

Commercial lecithin is soluble in mineral oils and fatty acids but is practically insoluble in cold vegetable and animal oils. However, it melts and disperses readily in hot vegetable and animal oils, but on cooling it separates unless a considerable percentage of mineral oil, fatty acid, or another coupling agent is added. Commercial plastic lecithin is converted into fluid lecithin by increasing the free fatty acid content. This softening or liquification of the commercial product also may be accomplished by other acids, eg, glycerophosphoric acid, phosphoric acid, or other mineral acid, and by almost any other organic or inorganic acid that is soluble or dispersible in lecithin. It may be liquified by complexing with divalent salts, eg, calcium chloride and by adding lower aliphatic esters of fatty acids.

Commercial lecithin is insoluble but infinitely dispersible in water. Treatment with water dissolves small amounts of its decomposition products and adsorbed or coacervated substances, eg, carbohydrates and salts, especially in the presence of ethanol. However, a small percentage of water dissolves or disperses in melted lecithin to form an imbibition. Lecithin forms imbibitions or absorbates with other solvents, eg, alcohols, glycols, esters, ketones, ethers, solutions of almost any organic and inorganic substance, and acetone. It is remarkable that the classic precipitant for phospholipids, eg, acetone, dissolves in melted lecithin readily to form a thin, uniform imbibition. Imbibition often is used to bring a reactant in intimate contact with lecithin in the preparation of lecithin derivatives.

When commercial lecithin is mixed with water it readily hydrates to a thick yellow emulsion. Upon dilution and agitation with water the emulsion may be thinned to almost any desired dilution. Emulsions of commercial lecithin are subject to microbial attack and must be preserved if they are to be stored for extended periods of time. In special cases, the emulsifying power of lecithin may be improved by using an alcohol or glycol imbibition of lecithin instead of lecithin. Such an imbibition is particularly useful in emulsifying hydroxy fatty

Table 4. Composition of Commercial Soy Lecithin[a] and Egg Lecithin, wt %

Compound	Soy lecithin	Egg lecithin
phosphatidylcholine	10–15	65–70
phosphatidylethanolamine	9–12	9–13
phosphatidylinositol	8–10	
phosphatidylserine	1–2	
phosphatidic acid	2–3	
lysophosphatidylcholine	1–2	2–4
lysophosphatidylethanolamine	1–2	2–4
phytoglycolipids	4–7	
phytosterines	0.5–2.0	
other phosphorus-containing lipids	5–8	
sphingomyelin		2–3
saccharose	2–3	
free fatty acids	max 1	max 1
mono-, diglycerides	max 1	traces
water	max 1.5	max 1.5
triglycerides	ca 35–40	10–15

[a] Acetone-insoluble matter ca 60.

Table 5. Solubility[a] of Lecithin and Various Phospholipids

Phospholipids[b]	Hexane	Benzene	Ethanol	Acetone
lecithin	+	+	±	−
phosphatidylcholine	+	+	+	−
phosphatidylethanolamine	+	+	±	−
phosphatidylinositol	+	+	−	−
phytoglycolipid	±	+	+	−
lysophospholipids	±	+	+	+

[a] Soluble (+), insoluble (−), and partially soluble (±).
[b] Lysophospholipids are soluble in water; the others are dispersible in water.

acid-containing glycerides, eg, castor oil and blown marine oils. Lecithin emulsions tend to be precipitated by the addition of acids or salts, but such precipitation may be hindered by using a suitable synthetic detergent.

Commercial lecithin is a wetting and emulsifying agent inasmuch as its constituents, eg, fatty acid-containing phospholipids, are amphiphatic in chemical structure, having strongly lipophilic, fat-forming acid nuclei at one end of the molecule and a strongly hydrophilic amino or phosphoric acid nucleus at the opposite end. Lecithin is one of the very few natural and edible surface-active agents of this type that is soluble or dispersible in oil. Phosphatidylcholine and phosphatidylethanolamine are cationic and anionic at the same time, ie, they are zwitterions or amphoteric compounds. However, phosphatidic acid and the phosphoinositides are quite strong acids and therefore are anionic. If present, the phosphosphingosides and galactosphingosides are anionic and nonionic, respectively. It is evident, therefore, that commercial lecithin has the structural aspects of an anionic interface modifier.

The phospholipids present in commercial soybean lecithin fall into two groups according to molecular size. The alcohol-soluble fraction has a lower molecular size and has a higher monomer content. It is more reactive than the alcohol-insoluble fraction which has a higher molecular size and more of the nature of a polymer phase. In the colloidal system represented by the mixed phospholipids, the micelles represent the higher molecular weight constituents as the dispersing phase, and the lower molecular weight constituents represent the continuous or intermicellar phase.

Because of the zwitterion formation, mutual buffering action, and the presence of strongly acid components, soybean phospholipids have an overall pH of about 6.6 and react as slightly acidic in dispersions-in-water or in solutions-in-solvents. Further acidification brings soybean phospholipids to an overall isoelectric point of about pH 3.5. The alcohol-soluble fraction tends to favor oil-in-water emulsions and the alcohol-insoluble phospholipids tend to promote water-in-oil emulsions.

Pure soybean phospholipids are hygroscopic and subject to oxidation. On the other hand, shelf-life properties are good where residual soybean oil and tocopherols are present, eg, with commercial lecithin containing 30–40% neutral oil as a carrier, or where the substantially oil-free phospholipids contain 1–2% residual oil and a fractional percentage of tocopherols. Unlike the glycerides, commercial lecithin is not resistant to high temperatures. When heated above 80°C under anhydrous conditions, it darkens in proportion to the time of heating and decomposes as the temperature increases above 120°C; however, it is somewhat less sensitive as a minor ingredient and especially in aqueous systems.

2. Chemical Properties

In general, the presence of fatty acid groups in the phospholipid molecule permits reactions such as saponification, hydrolysis, hydrogenation, halogenation, sulfonation, phosphorylation, elaidinization, and ozonization (6).

2.1. Hydrolysis

The first effect of either acid hydrolysis or alkaline hydrolysis (saponification) is the removal of the fatty acids. The saponification value of commercial lecithin is 196. Further decomposition into glycerol, phosphoric acid, and head groups (ie, choline, ethanolamine, etc) may follow prolonged heating. Lecithin may also be hydrolyzed by enzymes.

2.2. Acyl Side-Chain Reactions

Many reactions occur in the R group of the fatty acid residue (see Carboxylic acids; Fats and fatty oils).

2.2.1. Hydrogenation

Lecithin can be hydrogenated. The resulting lecithins have only saturated fatty acid residues (palmitic or stearic acid) and are more or less colorless and crystalline.

2.2.2. Hydroxylation

Commercial lecithin can be hydroxylated at the unsaturated fatty acid chains by treatment with concentrated hydrogen peroxide and acids like lactic or acetic acid.

2.2.3. Autoxidation

The autoxidation (7) of unsaturated fatty acids in phospholipids is similar to that of free acids. Primary products are diene hydroperoxides formed in a free-radical process.

2.3. Browning Reactions

The fluorescent components formed in the browning reaction (8) of peroxidized phosphatidylethanolamine are produced mainly by interaction of the amine group of PE and saturated aldehydes produced through the decomposition of fatty acid hydroperoxides.

2.4. Other Reactions of Phospholipids

The unsaturated fatty acid groups in soybean lecithin can be halogenated. Acetic anhydride combined with the amino group of phosphatidylethanolamine forms acetylated compounds. Phospholipids form addition compounds with salts of heavy metals. Phosphatidylethanolamine and phosphatidylinositol have affinities for calcium and magnesium ions that are related to interaction with their polar groups.

3. Manufacture and Processing

Crude soy lecithin is obtained as a by-product during the degumming process of soy oil. The phosphorus-containing compounds are removed to improve the stability of the oil.

Only a minor proportion of the total lecithin that is potentially available in the vegetable processing industry is produced. If the phospholipids are not to be made into commercial lecithin, they may be left in the crude oil or, if they are to be separated from the crude oil as wet gum, they may be mixed into soybean meal for animal feed.

The lipids are initially extracted from the soy beans with hot hexane. The resulting miscella is then filtered to remove fines (minute particles of flaked seed, protein, metal impurities, etc). Hexane is removed by distillation with steam, and the crude soybean oil is treated with water, swells, and the oil-insoluble aggregates of phospholipids precipitate out. Typical processing is shown in Figure 2. After drying and before being filled into drums, the commercial lecithin is held in a work tank where addition of fluidizing agents, bleaching agents, or other material may be made.

3.1. Purification Processes

Separation of neutral and polar lipids, so-called deoiling, is the most important fractionation process in lecithin technology (Fig. 3). Lecithin is fluidized by adding 15–30% acetone under intensive agitation with acetone (fluidized lecithin:acetone, 1:5) at 5°C. The mixture goes to a separator where it is agitated for 30 minutes. The agitator is then stopped and the lecithin separates. The oil micella is removed and the acetone evaporated. After condensation the acetone is returned into the process.

Depending on the deoiling rate, the lecithin in the separation tank is again treated with acetone in the same way. This is repeated two to three times. The residual acetone is then removed in container 5 at $<80°C$, dried, and separated to powder and granular lecithin in the classifier. Newer processes using less acetone and achieving deoiled lecithin having acetone insoluble matter as high as 99.9% have been described (9).

Due to possible environmental problems with acetone, new technologies are being developed for the production of deoiled lecithins involving treatment of lipid mixtures with supercritical gases or supercritical gas mixtures (10–12). In this process highly viscous crude lecithin is fed into a separation column at several levels. The supercritical extraction solvent flows through the column upward at a pressure of 8 MPa (80 bar) and temperature between 40 and 55°C. The soy oil dissolves together with a small amount of lecithin.

The mixture of propane, carbon dioxide, soy oil, and lecithin leaves the separation column and enters the first regeneration column. By increasing the temperature to 75°C, the lecithin is selectively precipitated. Due to its higher density, liquid lecithin flows down through the Sulzer packings of the regeneration column. It is drawn off and pumped back to the top of the separation column as reflux. The practically lecithin-free extraction agent leaves the first regeneration column at the top and is expanded in another regeneration column. The dissolved soy oil is precipitated at 6 MPa (60 bar) and 100°C, and continuously drawn off. The regenerated hot extractant leaves the second regeneration column at the top, is cooled, recompressed to 8 MPa (80 bar), and fed anew to the bottom of a separation column. In the separation column, lecithin flows down through the Sulzer packings, countercurrent to the extraction solvent. On its way down it comes into contact with increasingly

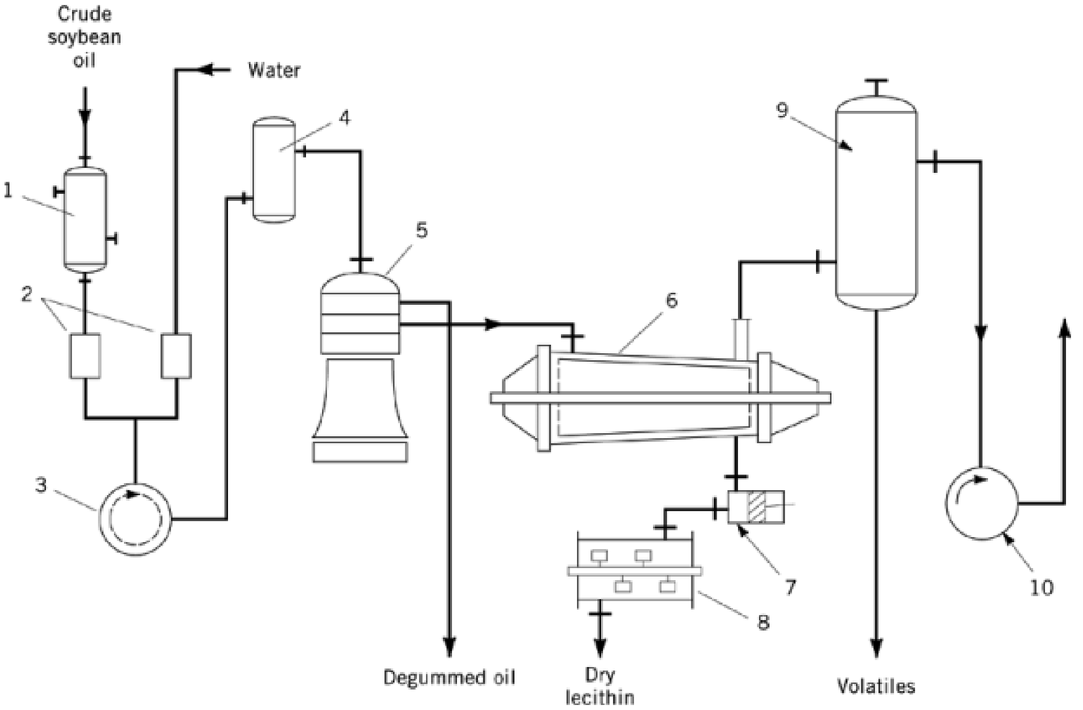


Fig. 2. Flow sheet of lecithin producing unit. Crude soybean oil is heated in the preheater, 1, to 80°C, mixed with 2%water in the proportion control unit, 2, and intensively agitated in 3. The mixture goes to a dwelling container, 4, and is then centrifuged after a residence time of 2–5 min. The degummed oil flows without further drying to the storage tanks. The lecithin sludge is dried in the thin-film evaporator, 6, at 100°C and 6 kPa (60 mbar) for 1–2 min and is discharged after cooling to 50–60°C in the cooler, 8. 9 and 10 are the condenser and vacuum pump, respectively.

pure solvent and is completely deoiled. The liquid mixture of propane, carbon dioxide, and lecithin is collected at the bottom of the separation column. It can be continuously drawn off through the product vessel or through an expansion valve.

Alcohol fractionation redistributes the phospholipids according to their respective hydrophilic and lipophilic properties (13). A process to produce fractionated phospholipids with a phosphatidylcholine (PC) content of more than 30% and a PC/PE (phosphatidylethanolamine) quotient of ca 4 has been developed. With this process it is possible to produce 1000 t per year.

The crude lecithin is thermostated to ca 30°C and mixed with a 5–10% sunflower monoglyceride (ca 50% mono content) and treated with 30% by weight ethanol, 90% by volume. This is then mixed with enough ethanol of the same or higher concentration that solvent and lecithin are in a ratio of 3:1 (vol/wt). The mixture is cooled to ca 20°C, stirring at such a rate that no emulsion is formed, and transferred into a settling vessel. The phases separate very rapidly. The slightly turbid upper phase is fed to a disk centrifuge by an intermediate vessel. After clarification it is passed by another intermediate vessel; after the addition of neutral oil, by a prewarmer into a downflow evaporator where the main part of the ethanol is removed. The remainder of the solvent is removed from the preconcentrated extract in a film evaporator. The lower phase, containing the ethanol-insoluble phospholipids, is collected; the fraction separated in the centrifuge is concentrated either using a Bollmann evaporator or a horizontal film evaporator. The ethanol in the condenser receivers is combined with that obtained from the recovery plant and adjusted to the required concentration before being used. The

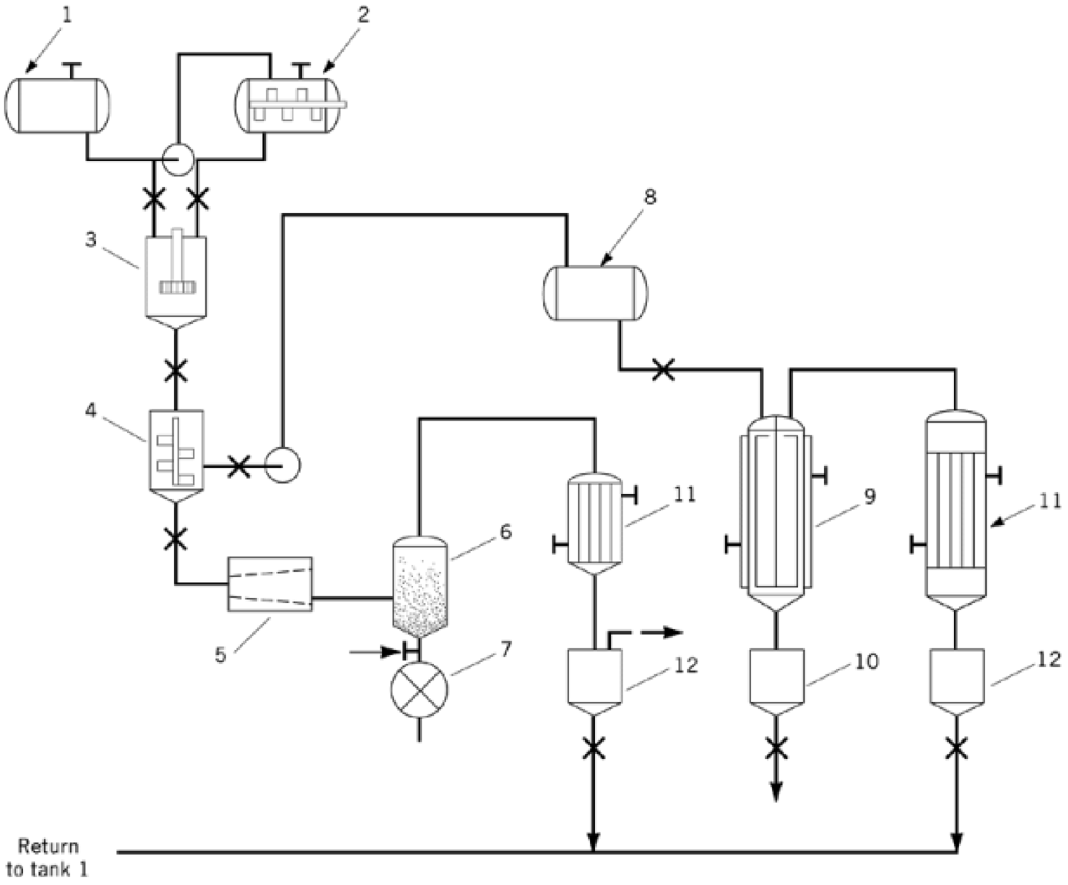


Fig. 3. Discontinuous deoiling of soy lecithin. 1, Acetone storage tank; 2, lecithin storage tank; 3, mixer; 4, separation tank; 5, filter/decanter; 6, dryer; 7, classifier; 8, oil miscella tank; 9, evaporator; 10, oil extract tank; 11, condenser; and 12, acetone storage tank.

efficiency of the process is ca 35%. Increasing the ethanol–lecithin ratio to 5:1 allows this to be raised to 44% without the PC/PE ratio being reduced.

To produce highly purified phosphatidylcholine there are two industrial processes: batch and continuous. In the batch process for producing phosphatidylcholine fractions with 70–96% PC (Fig. 4) (14, 15) deoiled lecithin is blended at 30°C with 30 wt % ethanol, 90 vol %, eventually in the presence of a solubilizer (for example, mono-, di-, or triglycerides). The ethanol-insoluble fraction is separated and dried. The ethanol-soluble fraction is mixed with aluminum oxide 1:1 and stirred for approximately one hour. After separation, the phosphatidylcholine fraction is concentrated, dried, and packed.

In the continuous process for producing phosphatidylcholine fractions with 70–96% PC at a capacity of 600 t/yr (Fig. 5) (16), lecithin is continuously extracted with ethanol at 80°C. After separation the ethanol-insoluble fraction is separated. The ethanol-soluble fraction runs into a chromatography column and is eluted with ethanol at 100°C. The phosphatidylcholine solution is concentrated and dried. The pure phosphatidylcholine is separated as dry sticky material. This material can be granulated (17).

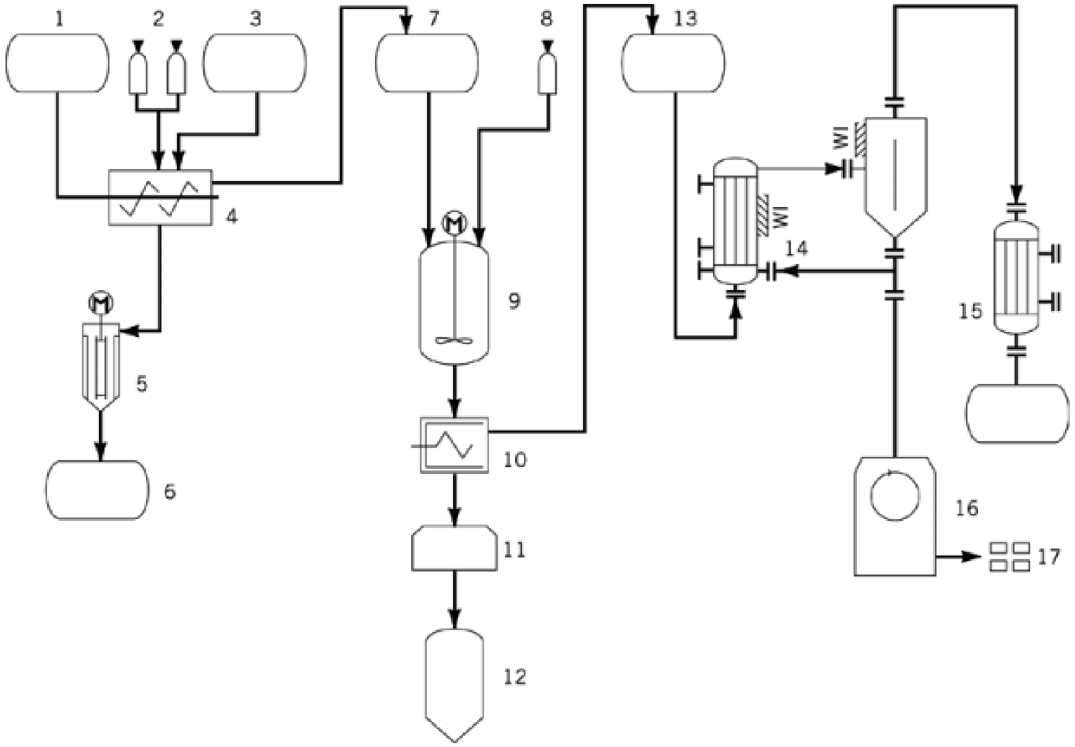


Fig. 4. Batch process for producing phosphatidylcholine fractions. 1, Ethanol storage tank; 2, deoiled lecithin; 3, solubilizer; 4, blender; 5, film-type evaporator; 6, ethanol-insoluble fraction; 7, ethanol-soluble fraction; 8, aluminum oxide; 9, mixer; 10, decanter; 11, dryer; 12, aluminum oxide removal; 13, phosphatidylcholine solution; 14, circulating evaporator; 15, cooler; 16, dryer; and 17, phosphatidylcholine.

4. Commercial Grades

There are six common commercial grades (18) of lecithin available (Table 6) including (*1*) clarified lecithins found either in the full miscella, crude oil, or directly as lecithin; (*2*) fluidized lecithins wherein the fluidization is done by adding calcium chloride, fatty acids, vegetable oil, or special diluents; (*3*) compounded lecithins which are special-purpose products made by direct addition of emulsifiers like sorbitan esters, polysorbates, or other surface-active agents; deoiled lecithin may be combined with selected additives to improve handling and performance; (*4*) hydroxylated lecithins which are highly water dispersible and made by the reaction of hydrogen peroxide and lecithin in the presence of a weak acid-like lactic or acetic acid; (*5*) deoiled lecithins for which the resulting dried product is available in different particle size with free flowing properties; it can be blended with other free flowing carriers; and (*6*) fractionated lecithins made from crude lecithin or deoiled lecithin by extraction with alcohol, resulting in alcohol-soluble and alcohol-insoluble fractions with different functionality. Fractions with different phosphatidylcholine content are commercially available. Besides these common commercial grades, more special products are available, eg, enzymatically modified lecithin and phospholipids, semisynthetic phospholipids, and acetylated lecithins.

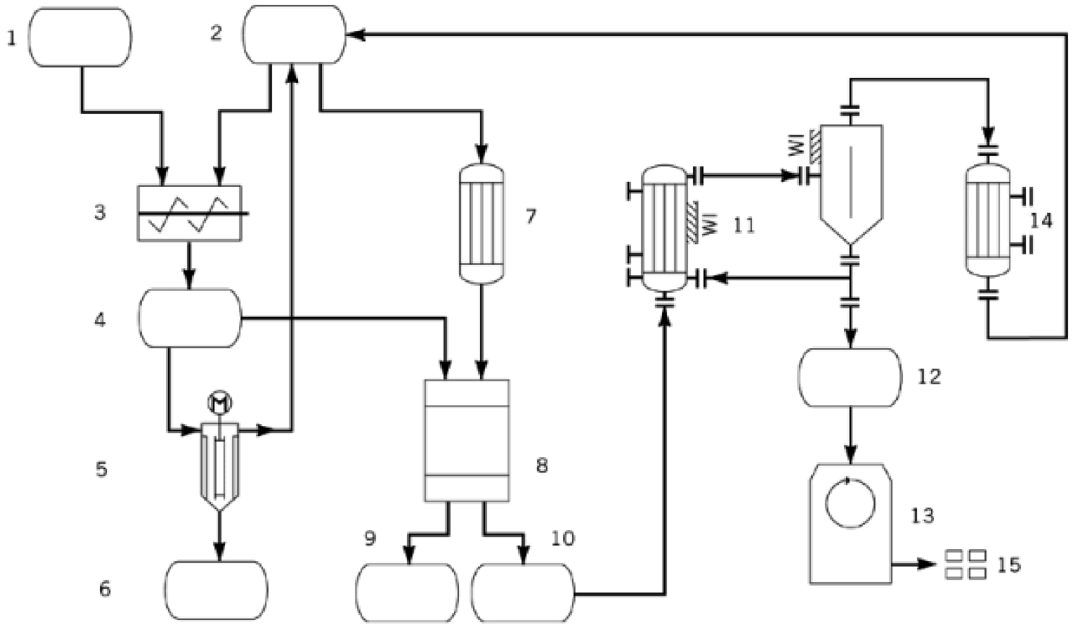


Fig. 5. Continuous process for producing phosphatidylcholine. 1, Lecithin; 2, ethanol; 3, blender; 4, diffuser; 5, thin-type evaporator; 6, ethanol-insoluble fraction; 7, heat exchanger; 8, chromatography column (SiO_2); 9, prestream; 10 and 12, phosphatidylcholine solution; 11, circulating evaporator; 13, dryer; 14, cooler; and 15, phosphatidylcholine.

5. Economic Aspects

The total commercial lecithin potential if all vegetable oils were degummed worldwide would be 552,000 t (Table 7). Although soybean, sunflower, and rape lecithins are available in the market, the principal commercial interest is only in soybean lecithin. The annual worldwide production is 130,000 t (Table 8).

6. Specification and Standards

The specifications of the *Food Chemical Codex* (FCCIII) and several other agencies are given in Table 9. The product to which they refer is defined as food-grade lecithin from soybeans and other plant sources consisting of a complex mixture of acetone-insoluble phospholipids (mainly phosphatidylcholine, phosphatidylethanolamine, and phosphatidylinositol) combined with various amounts of other substances such as triglycerides, fatty acids, and carbohydrates in varying proportions. The specified product contains 50% or more of phospholipids of differing grades, forms, and color.

The *U.S. Pharmacopeia* (USP XXII) or *National Formulary* (NFXVII) (20) also provide a similar description; however, the peroxide value is not defined (Table 9). These specifications are also given in the *Handbook of Pharmaceutical Excipients* (HPE), published jointly by the American Pharmaceutical Association and The Pharmaceutical Society of Great Britain (21), which defines lecithins both from plants and eggs. The *Merck Index* (22) specifies a slightly lower acid value. The *Japanese Monograph* (ISCI-II) (23) specifies a slightly lower acetone-insoluble matter and a lower heavy-metal content.

The European Community specifications (Guideline 78/664/EWG) for lecithins (E322) (24) are also included in the *Monographs for Emulsifiers for Foods* (second edition) of the European Food Emulsifier

Table 6. Commercial Lecithins, % Composition

Component	Crude	Deoiled	Alcohol-soluble fraction	Alcohol-insoluble fraction	PC 70[a]	PC 90[b]
phosphatidylcholine	10–15	20–25	40–55	8–12	75–80	90–98
phosphatidylethanolamine	9–12	22	21	24	10	
phosphatidylinositol	8–10	16	2	27		
polar lipids, others	8–12	15	9	16	7	3
soybean oil	40	3	3	3	3	3
carbohydrates	5	8	3	10		
sterols, glycosides	3	6	7	4		
moisture	1	1	1	1	1	1
miscellaneous	4	4	1	4	4	
trademarks[c]	Alcolec (ALC) Nathin (NP) Centrocap (CS) Yelkin (ADM) Leciprime (RI)	Alcolec (ALC) Phospholipon 25 (NP) Centrolex (CS) Yelkinol (ADM) Lecigran (RI)	Alcolec (ALC) Nathin (NP) Phosal (ALC/NP)	Alcolec (ALC) Nathin (NP)	Phospholipon 80 (ALC/NP) Phosal (ALC/NP)	Phospholipon 90 (ALC/NP) Phosal (ALC/NP)

[a] PC > 70%.
[b] PC > 90%.
[c] Names of companies (suppliers) are given in parentheses. ADM = Archer Daniels Midland; ALC = American Lecithin Co.; CS = Central Soya; NP = Nattermann Phospholipid GmbH; RI = Riceland.

Table 7. Commercial Lecithin Potential from Vegetable Oils

Type of oil	World production,[a] 10^6 t	Hydratable lecithin, %	Lecithin yield, t
soybean	16.44	2.2	361,680
sunflower-seed	7.37	0.5	36,850
rapeseed	9.37	1.0	93,700
cottonseed	4.32	0.8	33,840
peanut	3.45	0.4	13,800
corn	1.00	1.2	12,000
Total			*551,870*

[a] 1991/1992.

Manufacturer's Association (EFEMA) (25). These differ in some respects from the U.S. specifications. E322 distinguishes between lecithins, which may be from plant sources or from eggs, and hydrolyzed lecithins. The latter are permitted a higher acid value and somewhat lower content of acetone-insoluble matter than non-hydrolyzed lecithin, though both European specifications for acetone-insoluble matter are stricter than those of the FDA. This also applies to the specification for the peroxide value, though the U.S. specifications are marginally stricter with regard to water and heavy-metal content. E322 also specifies that lecithin should contain not more than 2% volatile matter by drying at 105°C for one hour.

Table 8. Lecithin Worldwide Production

Type	World capacity, t	Average sales price, $/kg
crude lecithin	132,000	0.62
deoiled lecithin	12,000	4.40
phospholipid fraction PC 35	1,000	7.48
phospholipid fraction PC 70	600	128.90
phosphatidylcholine $PC > 90$	50	253.00

Table 9. U.S., British, Japanese, and European Specifications for Purity[a]

Parameter[b]	FCC III	USP XXII/NF XVII + HPE	E322	E322 and EFEMA	ISCI-II
definition	lecithin vegetable	lecithin	lecithin	hydrolyzed lecithin	soybean phospholipid
acetone-insoluble matter, %	≥ 50	≥ 50	≥ 60	≥ 56	≥ 40
hexane-insoluble matter, %	≤ 0.3	≤ 0.3	$\leq 0.3^c$	$\leq 0.3^c$	≤ 0.3
volatile matter, %			$\leq 2^d$	$\leq 2^d$	≤ 2
H_2O, %	≤ 1.5	≤ 1.5	≤ 2	≤ 2	≤ 2
As, ppm	3	3	3	3	2
Pb, ppm	≤ 10	≤ 10	≤ 10	≤ 10	
heavy metals, ppm	40	40	50	50	20
peroxide value	≤ 100		≤ 10	≤ 10	≤ 10
acid value	≤ 36	≤ 36	≤ 35	≤ 45	≤ 40
iodine value					
liquid		95–100			
granule		82–88			

[a] Food-grade lecithins.
[b] Packing and storage should be in well-closed containers.
[c] Toluene-insoluble.
[d] At 105°C for 1 h.

7. Analytical and Test Methods

The standard methods (26) of analysis for commercial lecithin, as embodied in the Official and Tentative Methods of the American Oil Chemists' Society (AOCS), generally are used in the technical evaluation of lecithin (27). For example, the AOCS Ja 4-46 method determines the acetone-insoluble matter under the conditions of the test, free from sand, meal, and other petroleum ether-insoluble material. The phospholipids are included in the acetone-insoluble fraction. The substances insoluble in hexane are determined by method AOCS Ja 3-87.

Acid value (AOCS Ja 6-55) is the number of milligrams of potassium hydroxide necessary to neutralize the acids in one gram of sample. Peroxide value (AOCS Ja 8-87) is the number of milliequivalents of peroxide per 1000 grams of sample, which oxidize potassium iodide under the conditions of the test. The oxidizing substances are generally assumed to be peroxides or other similar products of fat oxidation. The Karl Fischer (AOCS Ja 26-87) method determines the actual water content of lecithin by titration with Fischer reagent which reacts quantitatively with water. Other methods for moisture determination are in AOCS Ja 2a-46. The Gardner Color (AOCS Ja 9-87) method determines lecithin color by comparison of an undiluted sample to standards of a specified color. Method AOCS Ja 10-87 determines Brookfield viscosity in mPa(=cP) of a fluid lecithin at a specified temperature. Another method is the viscosity of transparent liquids by bubble time (AOCS Ja 11-87).

The iodine value (AOCS Cd 1-25) is a measure of the unsaturation of fats and oils and is expressed in terms of the number of centigrams of iodine absorbed per gram of sample (% iodine absorbed).

The total phosphorus content of the sample is determined by method AOCS Ja 5-55. Analysis of phospholipid in lecithin concentrates (AOCS Ja 7-86) is performed by fractionation with two-dimensional thin-layer chromatography (tlc) followed by acid digestion and reaction with molybdate to measure total phosphorous for each fraction at 310 nm. It is a semiquantitative method for PC, PE, PI, PA, LPC, and LPE. Method AOCS Ja 7b-91 is for the direct determination of single phospholipids PE, PA, PI, PC in lecithin by high performance liquid chromatography (hplc). The method is applicable to oil-containing lecithins, deoiled lecithins, lecithin fractions, but not applicable to lyso-PC and lyso-PE.

To determine the phospholipid and fatty acid compositions chromatographic methods (28) like gas chromatography (gc), thin-layer chromatography (tlc), and high performance liquid chromatography (hlpc) are used. Newer methods for quantitative determination of different phospholipid classes include ^{31}P-nmr (29).

8. Health and Safety Factors

Environmental considerations encourage degumming of crude vegetable oils. A large part of the soybean oil produced is degummed but only some of the wet gums (lecithin hydrate) are processed to finished lecithin; however, this proportion increases as the demand for commercial lecithin grows. The phospholipids are biodegradable, but their presence in streams and water resources, especially in the form of soap stock, is undesirable. Fatty acid recovery from phospholipids is less than with neutral oils because of the lower fatty acid content. There are no known health hazards involved in the production of commercial lecithin from crude vegetable oils because the phospholipids are nonvolatile and are a nonirritating food material. Care must be exercised in the use of small quantities of benzoyl peroxide which is required in the manufacture of highly bleached grades and in the acetone or alcohol fractionation of crude lecithin in the manufacture of purified grades.

The safety of lecithin is also confirmed by the World Health Organization (WHO). WHO has not set any acceptable daily intake (ADI) to lecithin as a foodstuff, but the FDA has awarded it GRAS status (generally recognized as safe; CFR No. 182.1400/184.1400).

9. Uses

The worldwide uses of lecithin break down as follows: margarine, 25–30%; baking/chocolate and ice cream, 25–30%; technical products, 10–20%; cosmetics, 3–5%; and pharmaceuticals, 3%.

9.1. Animal Feed

In animal feeds (1–3% lecithin) lecithin is an emulsifier; wetting and dispersing agent; energy source; antioxidant; surfactant; source of choline, organically combined phosphorus and inositol; and lipotropic agent. It is used in a milk replacer formula for calves (approximately 10,000 t of lecithin are used for this purpose) and for veal production, in mineral feeds, poultry feeds, fish foods, pet foods, and feeds for fur-bearing animals (30).

9.2. Baking Products

In baking products and mixes (0.1–1% lecithin) lecithin is an emulsifier, stabilizer, conditioning and release agent, and antioxidant. In yeast-raised doughs it improves moisture absorption, ease of handling, fermentation tolerance, shortening value of fat, volume and uniformity, and shelf life. In biscuits and crackers, pies, and cakes (1–3% based on shortening), it promotes fat distribution and shortening action, facilitates mixing, and acts as a release agent (31). Frozen doughs with liposomal encapsulated yeast show substantially more volume (32). Phospholipid fractions can replace chemical emulsifiers (33) and also function as fat reducers (34).

9.3. Candy

In confections (1% lecithin) made with oil or fat, lecithin emulsifies and distributes fat in caramels, nut brittles, nougats, etc; it also prevents fat separation and greasiness. It has a fixative action for flavors (35) (see Flavors and spices). Also, lecithin is an emulsifier and conditioning agent for chewing gum base.

Chocolate (0.3–0.5% lecithin) lecithin is a wetting agent and emulsifier. It facilitates mixing, saves processing time and power, saves cocoa butter, stabilizes viscosity, increases shelf life, counteracts moisture thickening, and aids release of molded goods (see Chocolate and cocoa).

9.4. Cosmetics and Soaps

One to five percent lecithin moisturizes, emulsifies, stabilizes, conditions, and softens when used in products such as skin creams and lotions, shampoos and hair treatment, and liquid and bar soaps. Since the introduction of Capture in 1986, liposomes produced from phospholipids are commercially available worldwide (36, 37).

9.5. Food

Lecithin is a widely used nutritional supplement rich in polyunsaturated fatty acids, phosphatidylcholine, phosphatidylethanolamine, phosphatidylinositol, and organically combined phosphorus, with emulsifying and antioxidant properties (38).

In dehydrated foods (0.05–0.3% lecithin) lecithin is a release agent in drying, and it aids in rehydration. In instant foods (0.5–3% lecithin) lecithin is used for its wetting, dispersing, emulsifying, and stabilizing properties in beverage powders and mixes including milk powders, dessert powders, powdered soups, etc.

9.5.1. Ice Cream

Lecithin (0.15–0.5%) emulsifies, stabilizes, improves smoothness and melting properties, and counteracts sandiness in storage. Lecithin is also used as an emulsifier in whipped toppings.

9.5.2. Macaroni and Noodles

Lecithin (0.25–5%) is used as a conditioning agent and antioxidant, improves machining, counteracts disintegration and syneresis, and improves color retention.

9.5.3. Margarine

Lecithin (0.15–0.5%) is an emulsifier and an antispattering and browning agent; it improves frying properties and spreadability and shortening action in table margarine. It is also used in bakers' margarine.

9.5.4. Edible Oils and Fats

Lecithin (0.01–2%) is used as an emulsifier, wetting agent, and antioxidant; it extends shelf life, especially of animal fats; increases lubricity (shortening value); improves stability of compound shortenings; and lowers cloud point of vegetable oils.

9.5.5. Inks and Dyes

Lecithin (0.5–3%) is a wetting, dispersing, and suspending agent promoting uniformity, color intensity, and ease of remixing (especially printing inks). In dyes, lecithin (0.5–2%) is a coupling agent, especially for water-soluble colors in fatty media.

9.6. Liposomes

Lecithin, and more specifically purified phospholipids, are used to produce liposomes (39) for the food (40), cosmetics, pharmaceutical, agrochemical, and technical fields.

9.7. Paints

Lecithin (0.5–5% of pigment) is a wetting agent, dispersing agent, suspending agent, emulsifier, and stabilizer in both oil-base and water-base (latex- and resin-emulsion) paints. It facilitates rapid pigment wetting and dispersion, saves time in grinding and mixing, permits increased pigmentation, stabilizes viscosity, aids in brushing, and improves remixing after storage.

9.8. Petroleum Products

Lecithin (0.005–2%) is used as an antioxidant, detergent, emulsifier, and anticorrosive agent, and for lubricity and antiwear. It is added to gasoline to stabilize tetraethyllead and for its inhibition and anticorrosive effects. After reaction with aliphatic amines it is used as a detergent in motor oils for inhibition, detergent, and lubricity effects. Also, it is used in miscellaneous oils including household lubricants and cutting oils, in fuel oils for surfactant and inhibition effects, and in drilling muds as an emulsifier.

9.9. Pharmaceuticals

Lecithin is used especially as a dietetic source of phosphatidylcholine required in lipid metabolism including enzyme systems involved in cholesterol metabolism, for the metabolism of fats in the liver, and as a precursor of brain acetylcholine neurotransmitter. Dosage ranges from 2 g/d for substantially pure soybean phosphatidylcholine to as high as 60 g/d for whole, mixed, and substantially oil-free soybean phospholipids (containing about 25% phosphatidylcholine) in liver disorders, in cardiovascular disease, in neurologic disease associated with impaired acetylcholine function, in skin disorders involving deranged lipid metabolism (eg, psoriasis), in telangiectasia, in nervous tension derived from extended physical fatigue, and as an emulsifier and wetting agent, eg, in penicillin dispersions and in emulsions for intravenous alimentation. Highly purified soybean phosphatidylcholine also is given intravenously when solubilized in water and is effective in some conditions in smaller amounts than the polyenephosphatidylcholine given orally.

Lecithin and especially lecithin fractions with high phosphatidylcholine content are used as excipients and as an active drug. Phosphatidylcholine with a high content of unsaturated fatty acids (polyenephosphatidylcholine) are on the market in several countries in both oral and parenteral form as a lipid lowering agent (Lipostabil) and liver protector (Essentiale) (41, 42). These phospholipids show membrane protective effects and have gastroprotective capability (43). Phospholipids in the form of liposomes are interesting tools for drug targeting and drug delivery (44).

9.10. Plant Protection

Lecithin (0.5–10%) and phospholipid fractions are used in fertilizers (qv), herbicides (qv), insecticides, and fungicides as emulsifiers or to increase the effectiveness of the active ingredient (45). In insecticides (0.5–5% lecithin), lecithin is used for improved emulsification, spreading, penetration, and adhesion (see Insect control technology).

9.11. Plastics

Lecithin (0.5–1.5%) is used for pigment dispersion and as a slip or release agent. It also may be sprayed on molds. It has surfactant effects in organosols and plastisols (see Surfactants).

9.12. Release Agents

Lecithin (2–10%) is used as a surfactant and antisticking agent in sprays for cookware and in lubricants and release agents for general food application and industrial purposes.

9.13. Elastomers

Lecithin is a wetting and dispersing agent and mold-release agent in rubber. It increases plasticity and facilitates working. It emulsifies latex mixes and aids in preparing solvent dispersions and in vulcanizing. In sealing and caulking compounds it is used for wetting, dispersing, and plasticizing effects (see Elastomers, synthetic).

9.14. Textiles

Lecithin (0.2–0.5%) is used for emulsifying, wetting, softening, and conditioning especially in sizing and finishing. It imparts soft, smooth handle and also is used as a spray to reduce cotton (qv) dust.

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