Introduction to the Use of Lecithins

Solae Europe, S.A.
2, Cheomin du Pavillon
CH-1218 Le Grand Saconnex
Switzerland

Solae, LLC
P.O. Box 88940
St. Louis, MO 63102
USA
Tel +1 800 325 7108

www.solae.com

Lecithins, the Natural Choice of Emulsifier !

Lecithins offer mankind unlimited applications in not only food but also animal feed as well as many industrial applications. In order to appreciate what lecithins can do in practice it facilitates the understanding by first reviewing the chemical nature of lecithins, they way they are extracted, refined and processed from nature and the basic properties that are generated by these process steps.

The lecithin molecule has a unique structure that allows formation of rigid multilayer membrane structures, often referred to as "liquid crystal mesophases". Nature use this property for the membrane structure of all living cells and thus lecithin occur in plants and animals. Very few other food emulsifiers occur in nature, but lecithin is the one-and-only emulsifier that is used directly as a dietary supplement and eaten by the spoonfuls, sprinkled on foods or enjoyed as health beverages !

The most economic source for commercial production of lecithin are the seeds from soya beans, sunflower- and rape seeds.

Lecithin, the E-number 322

Although lecithin has an E-number it is often just declared simply as "lecithin" and it enjoys a positive consumer acceptance. Table 1 shows the European definition of lecithin:

> *Lecithin are mixtures or fractions of phospholipids obtained by physical procedures from animal or vegetable food stuffs;*
> *they also include the hydrolysed products obtained through the use of harmless and appropriate enzymes. The final product must not show any signs of residual enzymatic activity.*
> *Lecithins may be slightly bleached in aqueous medium by means of hydrogen peroxide. This oxidation must not chemically modify the lecithin phosphatides.*

Table 1: Definition of Lecithin

Molecular Structure of Lecithin

Table 2 shows the molecular structure of Phospholipids. They are very analogue to triglycerides but have only two fatty acids esterified to glycerol. The big difference compared with triglycerides is that the third position of the glycerol moiety is phosphorylated and further esterified with side chain moieties that also contribute to the lecithin functionality. The phosphatidylcholine is excellent for emulsification – and also the choline fragment can not be synthesised by the human body and needs to be supplemented in the diet. Phosphatidylethanolamine is less functional as emulsifier, more sensitive to Calcium in hard water and it is responsible for the darkening of lecithins on extended heating. A third significant component is Phosphatidylinositol and finally Phosphatidic acid is simply phosphorylated diglyceride with no side chain on the phosphorous group. The added functionality's of these side chains are important since the objective of many lecithin process steps is to alter the relative content of these components.

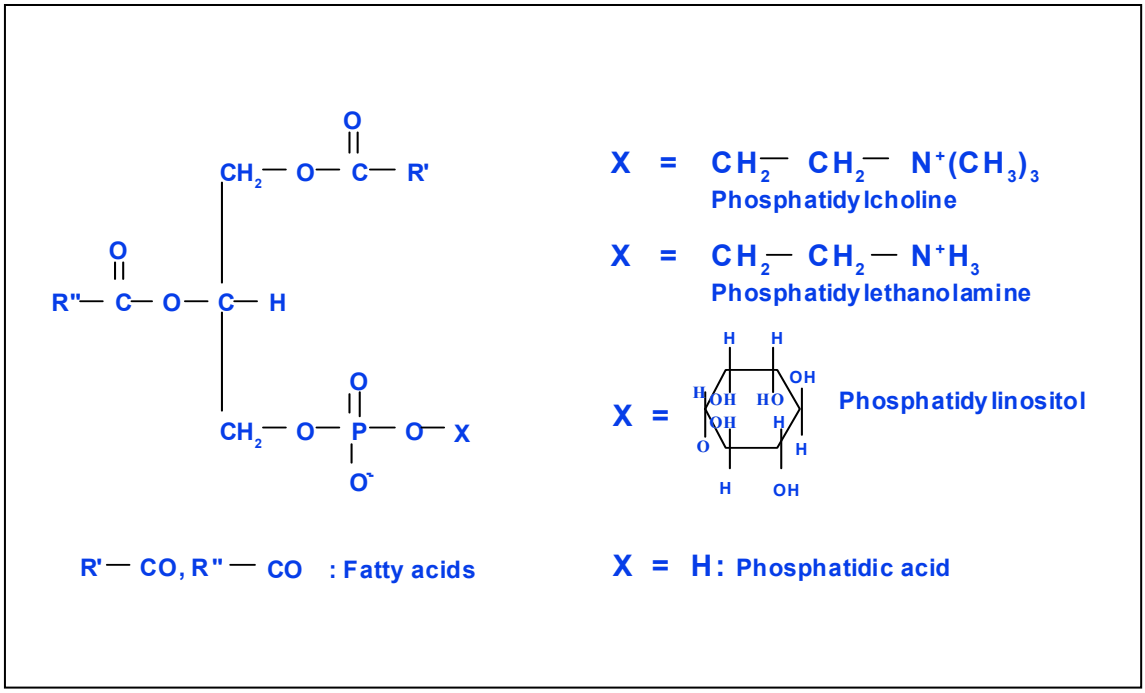


Table 2: Molecular Structure of Phospholipids

Table 3 exhibits a comparison between triglycerides, monodi- and monoglyceride and then the phospholipids. It is evident that the lecithins have strikingly similar structures, especially if the lecithin is "hydrolysed", and thus it is not so strange that their application properties have many similarities. The two biggest applications of these molecular structures are in baking and in emulsification. No doubt lecithins earn their special extra unique release/lubrication property due to their phosphorylated nature.

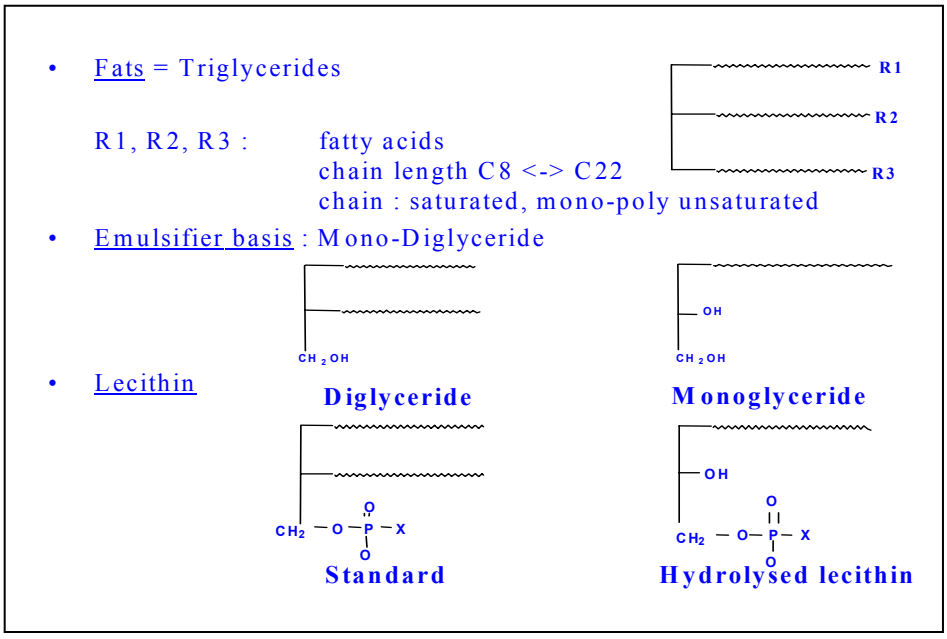


Table 3: Comparison of Molecular Structures

Analytical Comparison of Lecithin

Table 4 shows a comparison of the main phospholipid isomers of lecithins from different common sources. The content of phosphatidylcholine is always characteristically higher in American soybean lecithin by several percent. Sunflower lecithin and Rape seed lecithin grown in Europe approximate this level. The phosphatidylcholine of egg yolk is extremely high and explains some of the unique properties of eggs in baking- and in emulsification applications. The reason eggs, and especially egg yolks, are so difficult to "replace" is that the high level of phosphatidylcholine interact with several egg yolk proteins, that are not commercially available. Phosphatidic acid offer no emulsification properties. A proper commercial level would be 4-6 %.

Components PHOSPHOLIPIDS	Typical value (%)			
	Soya	Sunflower	Rape	Egg Yolk
Phosphatidylcholine PC	15	16	16	69
Phosphatidylethanolamine PE	11	8	8	24
Phosphatidylinositol PI	10	13	11	-
Phosphatidylserine PS	<1	<1	<1	3
Phosphatidic acid PA	4	3	4	-

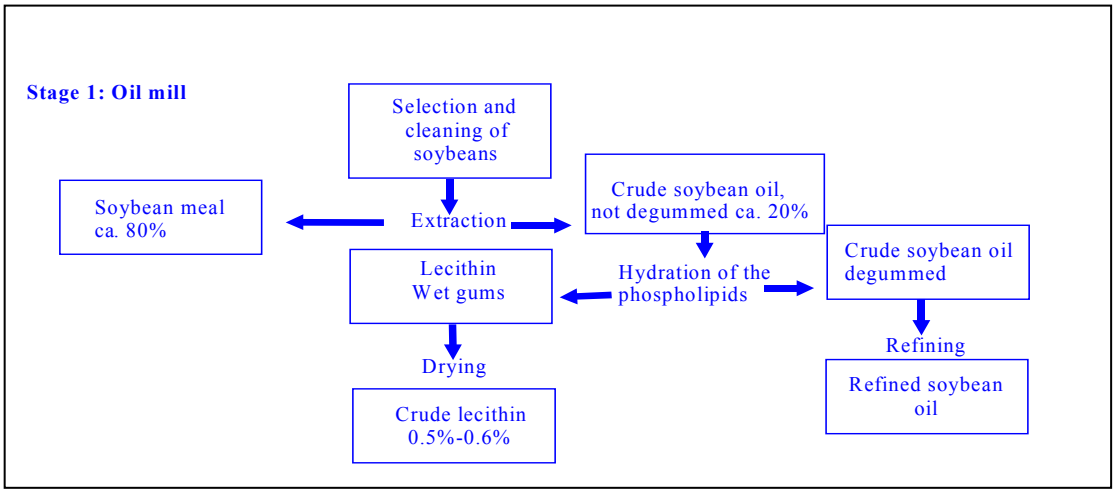
Table 4: Phospholipid Isomers of Vegetable Lecithines

Commercial Production of Lecithin

Table 5 shows the principles of seed crushing and manufacturing of crude lecithin. Since lecithins chemically are analogues to oils they follow the oil in the hexane extraction of crushed seeds but since they are much more hydrophilic than the oils it is possible to make them absorb added water. Then lecithins swell by forming their characteristic liquid crystal mesophases. This process is called degumming. The viscous lecithin gum or slurry in water must be dried quickly under vacuum and under controlled temperature, otherwise the lecithins either spoil microbially or they brown by too high drying temperatures.

Table 5: Production of Crude Lecithin

A number of additional processing steps are possible in order to refine the crude lecithin. These possibilities are listed on table 6 as well as their common Solae trade names. From left lecithin can be hydrolysed enzymatically (the STERNPHIL-range), the phosphatidylethanolamine component



can be acetylated (STERNPHIL CA, not permitted for European foods), the filtered lecithin can supplemented by other liquid components for viscosity control (STERNPHIL 450), lecithin can be distributed on the surface of dry powders or spraydried (STERNMULS), it can be de-oiled (CENTROLEX) or the valuable phosphatidylcholine can be enriched by fractionation (STERNLIPID).

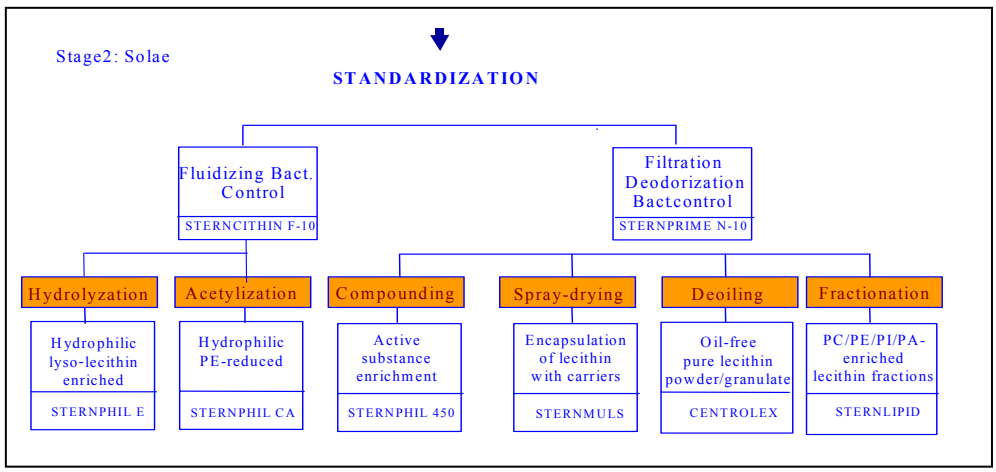


Table 6: Refining of Lecithin

Individual Proces Steps for Lecithin – De-oiling

Table 7 shows the de-oiling of lecithin. The phospholipids are insoluble in acetone and thus acetone allows an extraction of the inactive 40 % vegetable oil of the crude lecithin. The de-oiled lecithin is obtained after evaporation of the acetone. The extraction can either be a batch- or a continuous process. Table 8 shows the free flowing deoiled lecithin.
Deoiled lecithin has several advantages: the powder has convenient handling, it has a more neutral taste since the unsaturated fatty acids of vegetable oil has been removed; deoiled lecithin is more hydrophilic than standard lecithin.

Table 7: De-oiling of Lecithin

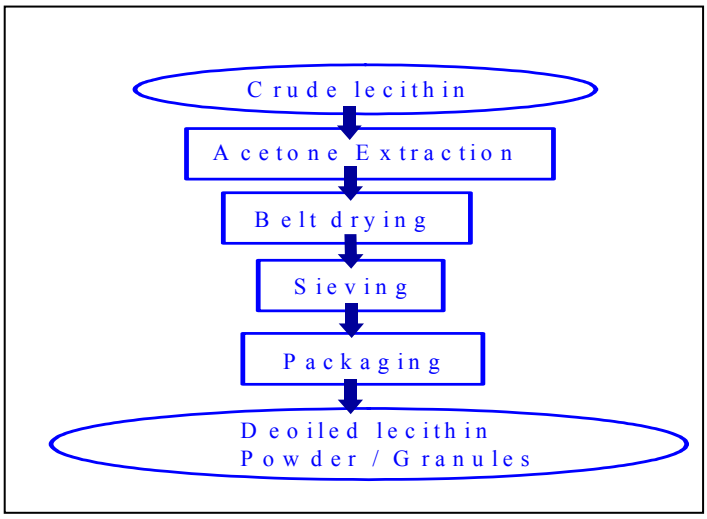
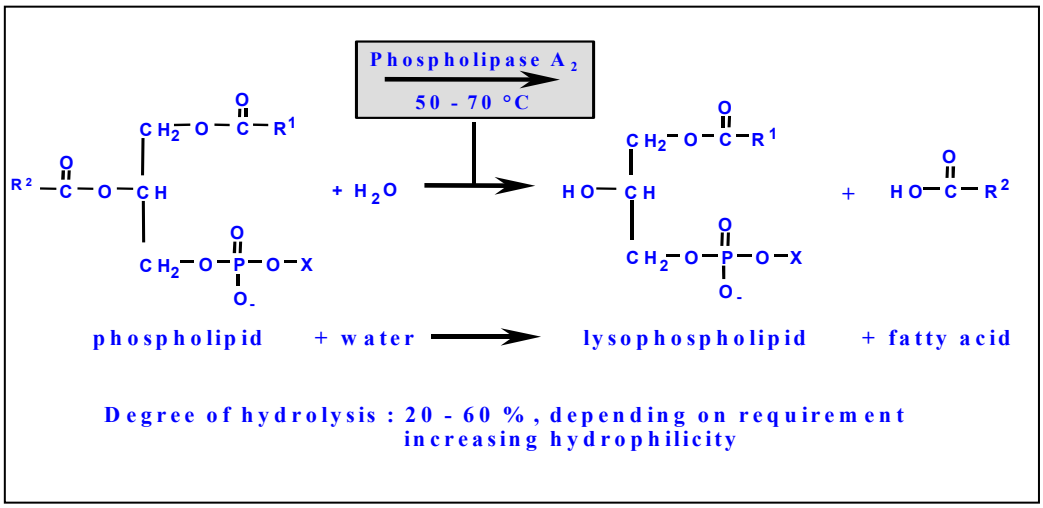


Table 8: Free Flowing Deoiled Lecithin

Individual Proces Steps for Lecithin – Hydrolysis

Table 9 shows the principles of enzymatic hydrolysis of phospholipids. Food grade enzymes are used that allow selective hydrolysis of the fatty acids in the "2" position. The process conditions determine the extent of the hydrolysis as well as the relative hydrolysis of the different kinds of phospholipids. From an application point of view it is important to differentiate between low, medium and high "degree of hydrolysis". This degree of hydrolysis is traditionally defined as content of hydrolysed phosphatidylethanolamine (PE) divided by total PE (unchanged and hydrolysed PE). Note, that this definition does not consider the hydrolysis of any other phospholipid isomer. It is a serious complication that HPLC analysis of phospholipids is still not fully quantitative and reproducible, and that the only accurate method of analysis is the expensive ^{31}P-NMR method (nuclear magnetic resonance of the phosphorous 31 isotope). The resulting lecithin is deliberate mixtures of phospholipids with either one fatty acid (Lysophospholipids) or two fatty acids.
Hydrolysed lecithin has several advantages: it is more hydrophilic depending on the "degree of hydrolysis" and this allows the use of lecithins in cream emulsion types as well as in frying margarines; the "monoglyceride like structures" with only one fatty acid are much more effective in bakery products for "softness" or longer shelf life.

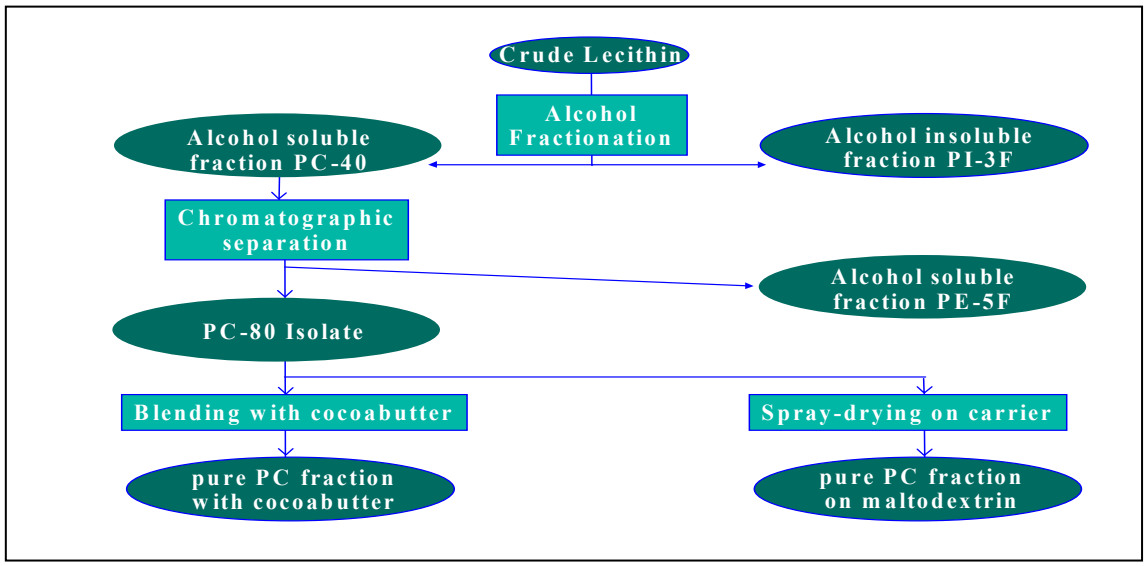
Table 9: Hydrolysis of Lecithin



Individual Proces Steps for Lecithin – Fractionation

Table 10 shows the principle of fractionation. Phosphatidylcholine PC is relatively more soluble in ethanol than all other phospholipids. This allows a semi quantitative fractionation of PC which can be decanted from a "bottom fraction" with relatively less PC, the so called PE-fraction. It is possible to obtain PC contents in the range of 30-50 % by this process. Further fractionation require the more expensive chromatographic separation techniques that allow semi commercial production of 80 % Phosphatidylcholine which contrary to common belief about lecithins is a solid material at usual temperatures and very difficult to handle in practice unless sprayed on a carrier.
Fractionated lecithin has several advantages: The PC-fraction is choline enriched for dietary purposes; it has its own characteristic Hydrophilicity and emulsification properties; it is less sensitive to Calcium in hard water; it is less sensitive to browning on extended heating. The PE-fraction find special uses in emulsification and baking applications.

Table 10: Fractionation of Lecithin



Individual Proces Steps for Lecithin – Hydroxylation & Acetylation (Non E 322)

Information on these process steps is added in order to complete the review. These types of lecithins are not permitted for foods in Europe, albeit they are allowed for foods in North America. In Europe they are used in technical applications.
Hydroxylation of the unsaturated fatty acids of the phospholipids is made in the presence of peroxide and organic acids resulting in the highest possible lecithin Hydrophilicity. Hydroxylated lecithin is superior for emulsification of cakes and cookies, but can only be used in North America.
Acetylation of the amino group in phosphatidylethanolamine is achieved by reaction with acetic anhydride resulting in better resistance to browning on heating as well as in different functional properties. Acetylated lecithin finds use in Europe for "leather tanning".

Individual Proces Steps for Lecithin – Combinations of Process Steps

Lecithin comes in many different types: refined, deoiled, hydrolysed and fractionated. Furthermore it is possible to combine any of these processes to make for instance hydrolysed-deoiled lecithin or fractionated-deoiled lecithin.
When lecithin has been investigated scientifically for its functionality then most often there are no references to the nature of the specific lecithin tested, even at academic levels ! For example there are many examples of excellent bakery work with lecithin with specific mentioning of the types of conventional emulsifiers tested, but with no mentioning of the "lecithin" tested ! In these cases one should assume that *only standard lecithin* was tested – and even standard lecithin varies. No wonder lecithin suffers from too little recognition for its many attributes.
The point of modifying lecithin is precisely to obtain "tailor-made" properties - within one single E-number. The ability to cover a wide span of applications is quite unique and not like any other emulsifier. The best simple illustration of this is the range of HLB values in table 11. HLB is Hydrophilic Lipophilic Balance value designed for differentiation of emulsification properties of emulsifiers – in simple water/oil systems. At a glance one can tell that the various processes for lecithin creates "tailor made" properties from water-in-oil emulsification (margarines) to oil-in-water emulsification (creams) all within the same E-number. In applying HLB values the food technologist should remember, that the HLB system does not consider the interaction of other common food components for example caseinate, and it does not at all describe non-emulsification properties, such as starch interactions in bakery products, viscosity reduction in chocolate products and release properties in baking or frying.

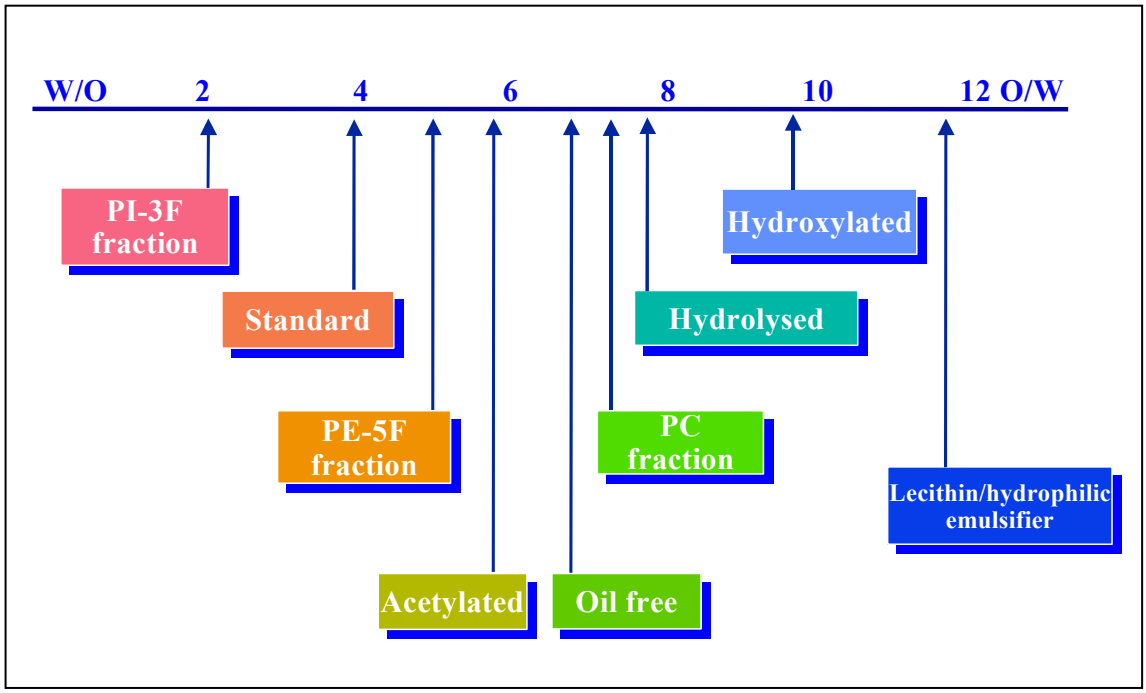


Table 11: HLB Values of Modified Lecithins

Analytical Comparison of Processed Lecithins

After the thorough review of lecithin manufacturing, proces steps and chemistry we can now look at the analytical comparison of table 12. Obviously the content of active phospholipids increases by 40 % after deoiling and clearly there is an enrichment in phosphatidylcholine after fractionation. In addition to 40 % vegetable oil the native lecithin also contains about 15 % glycolipids and carbohydrates. It is not commercially possible to remove these components but generally they are not disturbing the functionality of lecithin. However these components cause characteristic haze or precipitation if lecithin is re-dissolved in oils and kept over longer times.
Lecithin is traded on the basis of the content of phospholipids measured as Acetone Insolubles or AI. The AI must be legally minimum 60 %. Table 12 also show some typical values of Acetone Insolubles which obviously are very high for deoiled lecithin.

Typical % Values

COMPONENTS	**Standard Lecithin**	**Deoiled Lecithin**	**Fractionated Lecithin**
PHOSPHOLIPIDS Phosphatidylcholine PC LPC	16	25	39
phosphatidylethanolamine PE LPE	13	20	8
Phosphatidylinositol PI LPI	10	15	3
Phosphatidic acid PA LPA	6	9	1
Other PL	3	5	1
GLYCOLIPIDS Sterolglycoside	7	10	6
Galactodiglyceride	4	6	3
COMPLEX CARBOHYDRATES			
Sucrose	1	2	1
Raffinose	½	1	½
Stachyose	2	3	1
ACETONE INSOLUBLES AI.	62	96	64
NEUTRAL OIL	37	3	35
WATER	<1	<1	<1

Table 12: Analytical Comparison of Soya Lecithins

Functionalities and Benefits of Lecithins

We are now ready to appreciate the many functionality's and benefits and to work with different lecithins. Table 13 shows the importance of selecting the type of processed lecithin that suits the desired functionality. As stated earlier, one can not just test "a lecithin" and conclude solely on that basis.

Application	Funcionality	Type of Lecithin
Baked goods	Volume Improvement Anti-staling Fat Dispersion Machinability	Hydrolyzed & Deoiled
Chocolate	Viscosity Modification Yield Point Reduction	Standard Lecithin & Fractions
Ice Coating	Water Entrapment	Fractions
Instant Drinks Dairy & Cocoa	Wetting & Dispersibility	Compounded Lecithin & Deoiled Hydrolyzed
Margarine/Spreads	Emulsification Antispattering	Standard Lecithin Hydrolyzed and Fractions
Release Agents	Separation Ease of cleaning	Standard Lecithin Hydrolyzed & Deoiled Acetylated & Hydroxylated

Table 13: Functionality of Modified Lecithin in Foods

Table 14 offers an overview of commercial lecithins in relation to specific applications and desired benefits.

Type	Application	Benefits
Refined Fluid STERNMULS, STERNPHIL	Fatty Powders, Bakery, Margarine, Dressings, Coatings, Paints....	Wetting, Emulsifying, Dispersing, Release, Lubricating....
Refined Powder STERNMULS, LECIFLOW, STERNBAKE	Bread, Wafers, Biscuits, Pastry, Sauces.....	Shelf Life Extension, Stabilizing,Dispersing, Emulsifying.....
Deoiled CENTROLEX	Fatty Powders, Bakery, Confectionery, Dietetic Supplements, Nutritional Products.....	All the above, PLUS convenience of form, purity, blandness.
Fractions CENTROLEX FP	Dietetic Formulas, Nutritional Products, Infant Formulas, Neutral taste products.	All the above, PLUS high Choline levels for health.

Table 14: Benefits of Lecithins in Foods