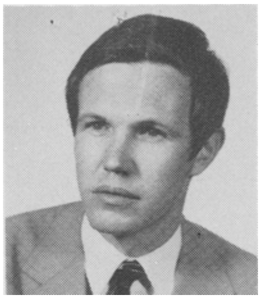
# Lecithin Production and Properties



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## ABSTRACT

Soy lecithins are important emulsifiers used in the food, feed, pharmaceutical, and technical industries. Native lecithin is derived from soybean oil in four steps: hydration of phosphatides, separation of the sludge, drying, and cooling. Such lecithin has both W/O and O/W emulsifying properties. Products with improved emulsifying properties can be obtained by modifications, involving mainly fractionation in alcohol, hydrolysis (enzymatic, acid, or alkali), acetylation, or hydroxylation. Careful processing is required to produce lecithins of a high chemical, physical, and bacteriological quality.

## INTRODUCTION

The world demand for lecithins is estimated at 100,000 tons per year. Of this, 30,000 tons are used in Western Europe. Lecithins are important natural emulsifiers for addition to foods, feeds, pharmaceutical, and technical products. Much attention must be paid to processing to achieve a successful production and modification of tailor-made lecithin specialities.

## ORIGIN

Technically, lecithins can be derived from egg yolk and various oilseeds such as flax, cottonseed, corn germ, sunflower seed, rapeseed, and soybeans. Soybean lecithins are used mainly because of their continuous availability and excellent properties, especially emulsifying behavior, color, and taste.

Normal soybean lecithin is a blend of several phosphatides dissolved in oil. A typical lecithin composition is given in Table I.

## PRODUCTION OF SOYBEAN LECITHIN

Crude soybean oil contains 2-3% phosphatides. The removal of the phosphatides and further processing to native lecithin are performed in four unit operations (Fig. 1).

### Hydration of Phosphatides

Water (2-3%) is mixed thoroughly with the oil at 50-70 C. The phosphatides hydrate to form a sludge. Instead of water, a combination of acids or acid anhydrides with water may be used.

### Separation of the Lecithin Sludge

In the case of desliming with water, the sludge after a hydration is removed from the oil by centrifuging in line at 50-70 C. A deslimed crude soybean oil containing ca. 0.25-0.5% phosphatides and a lecithin sludge containing 40-50% water are obtained.

### Sludge Drying

Lecithin is dried to a low moisture content, preferably $< 1\%$, to improve keepability and fluidity. For the drying of lecithin sludge batch, semibatch and continuous drying film evaporators are used. Horizontal film evaporators have the following advantages:

- Large capacity per unit area
- Short drying time
- Adjustability of thickness of film
- Adequate process control.

Vertical thin film evaporators (countercurrent principle) can work very well but are more sensitive because the lecithin film can break within the apparatus as the viscosity of the sludge increases very rapidly at 15-5% water (Fig. 2). Vertical evaporators might be considered for the production of specialities or in cases where organic solvents or acids must be stripped.

Working conditions for processing native lecithin are given in Table II.

To obtain good quality, exact process conditions and control are required. Temperature adjustment and exact residence time are particularly important for a light-colored product.

### Cooling

Cooling lecithin to below 50 C is necessary to prevent

TABLE I

Typical Composition (%) of Soy Lecithin

| | |
|---|---|
| Phosphatidyl cholin (cholin lecithin) | 20 |
| Phosphatidyl ethanolamine (cephalin) | 15 |
| Phosphatidyl inositide | 20 |
| Phosphatidic acids, other phosphatides | 5 |
| Carbohydrates, sterols | 5 |
| Triglycerides | 35 |

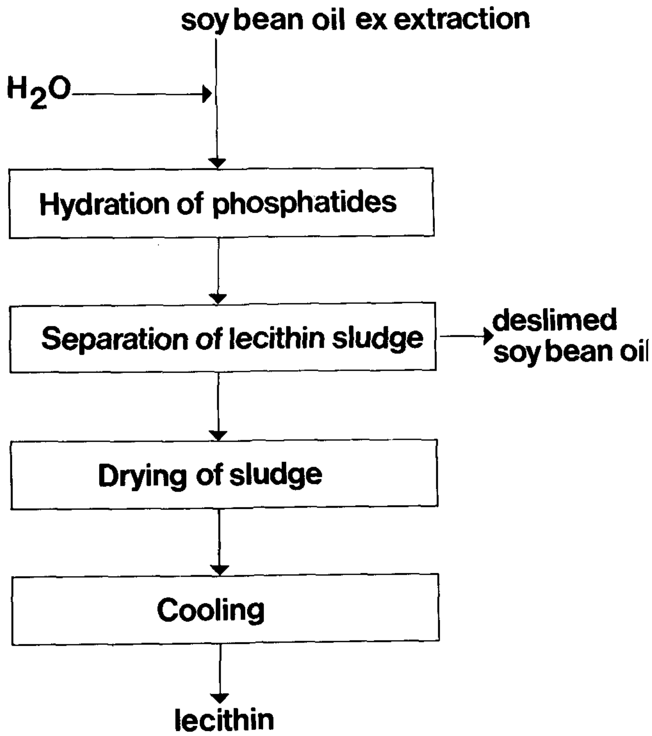


FIG. 1. Production of native lecithin.

TABLE II

Average Process Condition for Lecithin Production

Starting product: Sludge 50% moisture
End product: Lecithin <1% moisture

| Process | Batch (Bollmann) | Continuous (horizontal film evaporator) |
|---|---|---|
| Temperature | 60-80 C | 80-95 C |
| Residence time | 3-4 hr | 1-2 min |
| Vacuum | 20-60 Torr | 50-300 Torr |
| Advantage | Effective bleaching in situ possible | Less color degradation |

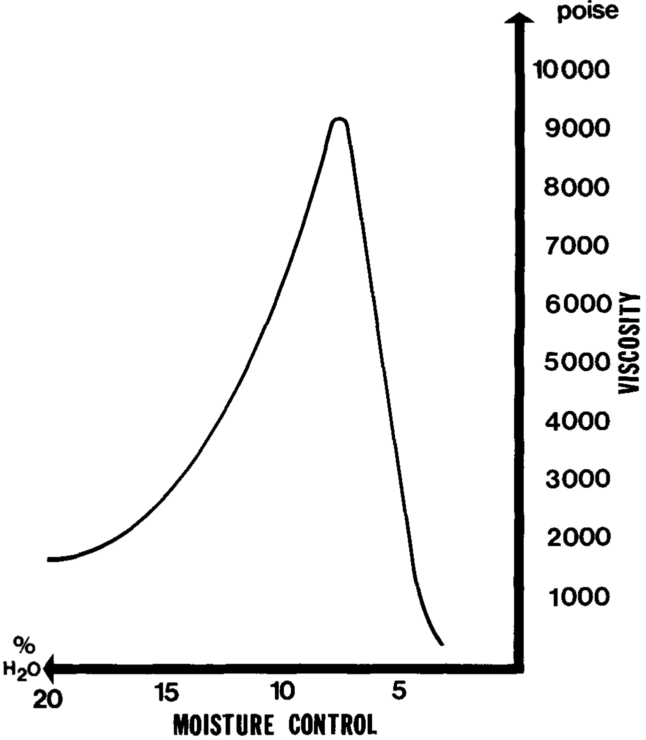


FIG. 2. Viscosity of lecithin sludge at 70 C in relation to water content.

postdarkening. At 20-30 C, lecithin can be stored for months without significant change in quality.

## PROPERTIES

The physical properties, particularly the emulsifying properties, determine the uses of lecithin. A range of lecithins can be used as excellent emulsifiers, stabilizers, and dispersing agents. For this reason, lecithin has acquired an important position as the so-called "natural emulsifier."

### Emulsifying Properties

An emulsifier is a substance with a hydrophobic and a hydrophilic part which has the capacity to form W/O or O/W emulsions by reduction of interfacial tension. Food products consist not only of water and oil but also of proteins, carbohydrates, and other components. Therefore, the term "emulsifier" is to be understood in a much wider sense as surface active agent. Some applications of the "emulsifier" lecithin are viscosity reduction in chocolate, antispattering in margarine, protein interaction in baked products, starch complexing effect in baked products, emulsifier and stabilizer in calf milk replacer, retardation of fat crystallization in chocolate, and dispersing effect in instant drinks.

In order to know the specific requirements for the emulsifier, it is important to know as much about the processing of the end products as possible. Important data, for example, are the quality of all the ingredients, pH, salt

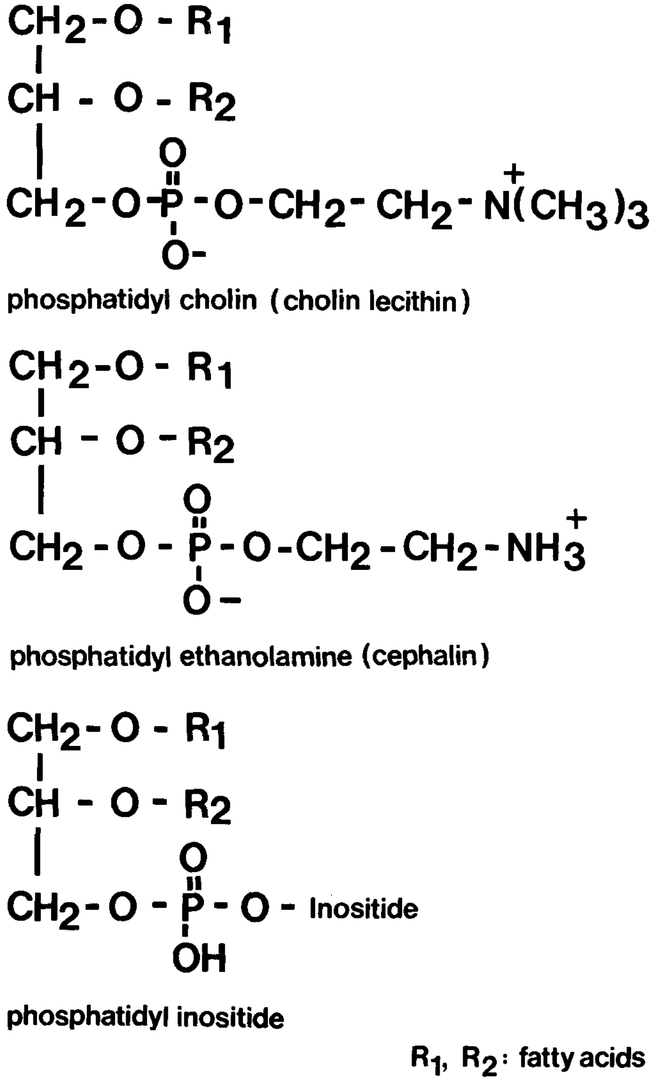


FIG. 3. Chemical structure of the three typical phosphatides.

content, and amount of dispersed phase and globule size distribution.

The formulas for the various phosphatides (Fig. 3) indicate that the hydrophobic and hydrophilic parts are balanced and that soy lecithin can be used as emulsifier. Native lecithin has weak W/O and O/W emulsifying properties. In fact, "cholin lecithin" has O/W promoting characteristics, and other components, such as cephalin, have W/O promoting properties.

The type of emulsion obtained by using native lecithin depends mainly on the oil:water ratio. Also, water hardness is important inasmuch as some components, especially cephalin, are flocculated by Ca and Mg ions and are, therefore, inactivated as emulsifiers.

More stable emulsions are formed when lecithins are used in combination with other surface active agents such

**Modification by physical means**

**Alcohol fractionation → cholin lecithin concentrate**

**Modification by enzymes → partially hydrolyzed lecithin**

**Modification by chemicals**

**Acids ) → partially hydrolyzed lecithin**
**Alkali )**

**Acetic anhydrid → acetylated lecithins**

**Lactic acid and hydrogen peroxide → hydroxylated lecithin**

FIG. 4. Important modified lecithin products.

as monoglycerides or water soluble polymer such as proteins. However, very often a modified lecithin can do the job, too.

The principle of modification of lecithin is often the removal or transformation of the cephalin fraction. The O/W properties are enhanced, and the Ca and Mg sensitivity is reduced. Such a modification may be the following (Fig. 4):

*Alcohol fractionation:* Cholin lecithin dissolves more easily than cephalin in alcohol. With temperature, alcohol concentration, and fractionation time as processing variables, concentrated cholin lecithin products are produced. Using 90% ethanol, products with a cholin lecithin:cephalin ratio of $>$ 5:1 can be made. The product has improved emulsifying properties and acts as an anti-spattering agent in saltless margarine.

*Enzymatic hydrolysis:* By using the enzyme phospholipase A, the fatty acids at the $\beta$-position of the lecithin molecules are hydrolyzed. Practically, the enzyme is homogenized with the sludge at 60-70 C. By variation of the enzyme concentration and the reaction time, the degree of hydrolysis can be controlled. The enzyme is inactivated afterwards. These lecithins are more hydrophilic and have stronger O/W emulsifying properties and reduced Ca sensitivity. The products can be used in, for instance, milk replacers.

*Hydrolysis by acids and alkali:* Fatty acids are split off under acid and alkaline conditions. However, these processes are less specific than enzymatic hydrolysis. Often lecithins with an undesirable dark color are obtained.

*Acetylation:* Treatment with acetic anhydride acetylates the amino group of the cephalin. A low degree of acetylation of the lecithin is achieved by desliming the oil with acetic anhydride. With temperature, reaction time, and amount of acetic anhydride as processing variables, the process can be performed with both lecithin sludge and dried lecithin. After acetylation, a fractionation may be carried out to obtain a cholin lecithin enriched product. The principle of the process is that the "zwitter-ion" group of the cephalin is blocked, which improves the O/W emulsifying properties.

*Hydroxylation:* High concentrations of hydrogen peroxides in combination with acids, especially lactic acid, form hydroxyl groups in the unsaturated fatty acid chains. The O/W emulsifying properties are improved remarkably as the product is easily dispersible in cold water. However, up to now, its application in foods has been legally limited in many countries.

The several processes described can be combined to achieve even more sophisticated products. On a laboratory scale, other modifications have been developed; however, except for special products for pharmaceutical application, they do not seem to be of interest in food applications.

TABLE III

Influences on Lecithin Color

| | |
|---|---|
| Soybeans: | origin (soil) |
| | quality (split, green beans) |
| | age |
| Pretreatment of beans: | dehulling |
| | cleaning (dust) |
| Extraction: | depth |
| | temperature |
| Desliming conditions | |
| Lecithin processing conditions | |

### Quality of Lecithin

Other factors which do not influence the emulsifying properties but are of importance in the quality of lecithin are color, purification, and microbiology.

*Color:* The color of native lecithin is normally reddish brown. A light-colored product is obtained by careful bleaching, preferably with hydrogen peroxide. The bleaching reaction can be performed in the sludge or in the dried product. For food applications, unbleached products are often used because many food laws in Europe limit the peroxide value to maximum 10 meq/kg. Normally in Europe soybeans of yellow II quality are used. Bean selection and optimal processing conditions are advised for the production of light-colored unbleached lecithins. The most important influences on the color are given in Table III. This list shows that a dark lecithin does not always mean that the processing was inadequate because the beans themselves may be the principal factor.

*Purification:* Soy lecithins contain 30-40% unrefined soybean oil. Some applications require purified lecithin because of neutral taste, light color, or absence of oil. Often the purification is performed by fractionation with specific solvents, of which acetone is preferred commercially. The oil and fatty acids are dissolved in the acetone, and the phosphatides are precipitated. The phosphatides can be dissolved in a refined oil or can be dried as such into powdered and granulated form. The process costs are high, and this may be the reason why deoiled lecithins have only a modest market share.

*Microbiology:* Lecithin as an ingredient for foods is often dissolved in hot oil at 50-70 C. Nevertheless, a close microbiological control on the lecithin production line is required to ensure that a food grade lecithin does not significantly contribute to the bacterial count or constitute a potential source of infection of the food product. It is possible to produce lecithin of very good microbiological quality and keepability. Lecithin generally has a low water content and also a low water activity.

## ECONOMIC ASPECTS

The market value of a lecithin product will be determined by its functionality, quality, and the balance between production and demand. For lecithin, there are two alternatives: spraying lecithin sludge on the meal or producing highly standardized lecithin specialities. When all the required human effort, adequate machinery, process and product control and handling are studied intensively, an exact calculation will show that production costs of first-class food grade lecithin products are high. When market prices of native lecithin are low, it may be more profitable to spray the sludge on the meal.