Effects of Expander Process on the Phospholipids in Soybean Oil

F. Zhang, S.S. Koseoglu* and K.C. Rhee
Food Protein R&D Center, Texas A&M University, College Station, Texas 77843-2746

Crude oils were extracted from soybean flakes and collets by conventional and expander processes, respectively. The phospholipids were removed by degumming, and the lecithins were produced by using commercial procedures. The effects of the expander process on the degumming efficiencies were evaluated. The differences in the phosphatide compositions of the oils and the lecithins produced from expander and conventional processes were compared by high-performance liquid chromatography. The phosphorus content indicated that expander-processed oil contained more phosphorus (985 ppm) than the conventional oil (840 ppm). However, the phospholipids in the expander-processed oil were more hydratable than those in the conventional oil. After degumming, the phosphorus content in the expander-processed and conventional oil were reduced by 93.2 and 78.6%, respectively. The expander-processed lecithin contained 74.3% acetone-insoluble matter (AI), and the conventional lecithin contained 65.8%. More phosphatidylcholine was found in the expander-processed lecithin (39.78%, based on AI) than in the conventionally processed lecithin (34.19%). The phosphatidylinositol contents of the expander-processed lecithin and the conventional lecithin are almost the same (19.95 and 19.97%). The phosphatidylethanolamine in the expander-processed lecithin (12.36%) was lower than that in the conventional lecithin (18.07%).

KEY WORDS: **Degumming, expander, lecithin, phospholipid.**

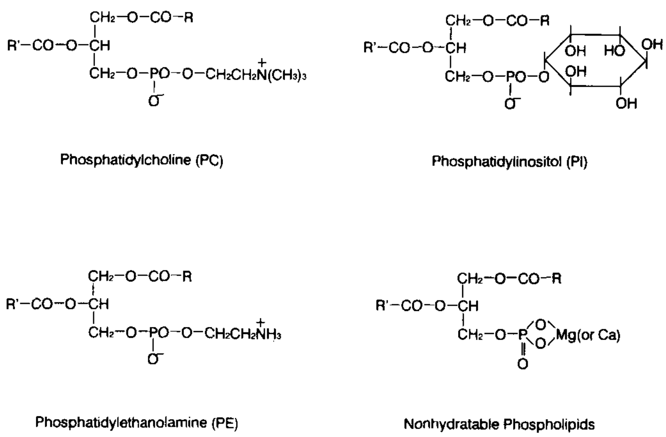
Degumming is the first step of the edible oil refining process that removes the phospholipids from the crude oil by water hydration. There are two purposes of degumming. One is to remove the phospholipids to produce a good quality refined oil. Another is to make lecithin, which is an important emulsifier used in food and many other industries (1–3).

Oil refiners work toward the complete removal of the phosphorus compounds to produce high-quality edible oil products. Most phospholipids in soybean oil are hydratable and can be easily separated from crude oil by the degumming process, but a portion of the phospholipids are nonhydratable. The presence of these nonhydratable phospholipids in the oil reduces the efficiency of degumming, requires further acid treatment and consequently causes neutral oil loss (4,5). Most of the nonhydratable phospholipids are formed because of enzymatic reactions (2). Phospholipases in the flakes or collets are able to hydrolyze the phosphatides into phosphatidic acids, which further combine calcium or magnesium and become salts of phospholipids—nonhydratable phospholipids (Scheme 1) (6). During bean handling and oil extraction, many factors could also affect the enzymatic reaction and content of the nonhydratable phospholipids (3). The phospholipids could be oxidized by lipoxygenases. Oxidized phospholipids can form complexes with the soy protein that will allow them to remain in the meal as hexane-insoluble constituents (7).

*To whom correspondence should be addressed at Food Protein R&D Center, Texas A&M University, Faculty Mail Box 183, College Station, TX 77843-2746.

Commercial lecithin is produced by degumming of soybean oil. Lecithin is a mixture of several phosphatides (8). The major functional ones are phosphatidylcholine (PC), phosphatidylethanolamine (PE) and phosphatidylinositol (PI) (Scheme 1). Each of these phosphatides has a unique acyl chain and a polar head group, which give the surfactant characteristics of lecithin. Both the history of the soybeans and the conditions used for extracting the oil affect the phosphatide content of the crude oil and the lecithin (1). Properties of the lecithins would be different if the composition and the relative concentration of the phosphatides are different (9).

Expanders have been used in oilseed processing since the early 1970s. However, their usefulness in oilseed preparation and excellent extractability of collets were not recognized until recently. Many oil mills in the United States have now incorporated expanders in their processing (10). The expander is a simple form of an extruder and has an interrupted flight screw, with bolts extending from the barrel into spaces between the discontinuous flights to increase shearing (Fig. 1). Soy flakes are fed into the expander and are heated as they are conveyed through the expander barrel. The high temperature (steam injection) and shearing action



SCHEME 1

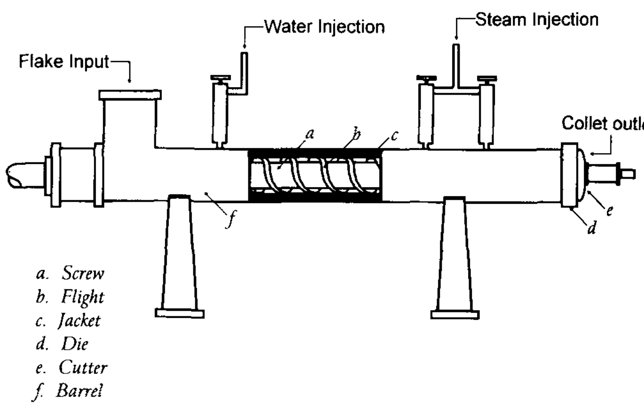
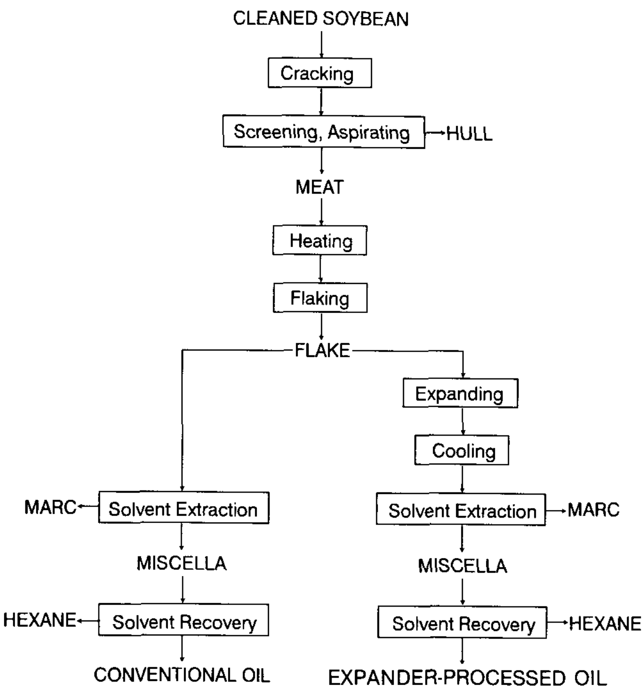


FIG. 1. Single-screw expander for making collet.

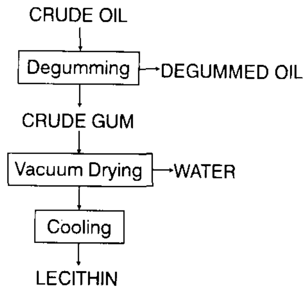
convert soy flakes into porous collets at the exit of the barrel due to destruction of the cell structure, protein denaturation and the sudden release of the steam from the product. Expanders are known to increase lecithin recovery by 50–100% (11). However, information on effects of the expander process on phosphatide composition is limited. Therefore, the objectives of this study were to evaluate the effects of the process on crude oil degumming efficiency and to investigate its effects on the phosphatide compositions in the crude soybean oil and lecithin products.

EXPERIMENTAL PROCEDURES

Crude soybean oils were produced at the pilot plant facilities of the Food Protein R&D Center of Texas A&M University (College Station, TX) by following the flow diagram given in Scheme 2, where MARC is the meal to be desolventized. The processes were simulations of commercial practice and were conducted under the same conditions. Cleaned soybean seeds (160 kg) with a moisture content of 10% were cracked and then passed through an aspirator to remove the hulls. The cracked beans were flaked to 0.010–0.012″ thickness after they were heated to 160°C. The flakes were divided into two parts. One part had the oil extracted directly by hexane at 60°C. This is considered the conventional process, and the lecithin obtained from this oil is called "conventional lecithin" throughout this paper. The other part of the flake was expanded into collets by an extruder at 280 rpm with direct injection of steam, and the oil was extracted from the collets with hexane. The lecithin produced by this process is called "expander-processed lecithin." The two crude oils were degummed separately in the laboratory (Scheme 3). Water was mixed into the oil with agitation at 65–70°C for 30 min, and then centrifuged at 2000 rpm for 10 min. The amount of water to be added was calculated by multiplying total phospholipid content by a factor of 0.75. The water in the wet gums was removed by a rotary vacuum evaporator at 60–70°C until the moisture content of the lecithin was reduced to about 1% (1).



SCHEME 2



SCHEME 3

Phosphatide compositions were determined by the Hurst and Martin, Jr. Method (12) with a Waters Associates (Milford, MA) high-performance liquid chromatographic (HPLC) system. The column was a 3.9 mm × 30 cm μPorasil (Waters Associates). The mobile phase was acetonitrile/methanol/85% phosphoric acid (780:10:9, vol/vol/vol). Pure forms of PC, PE and PI were dissolved in chloroform to obtain various concentrations for the calibration curves. PC, PE and PI standards were purchased from Sigma Chemical Co. (St. Louis, MO). The standards were stored in a freezer until they were used. The analysis for phosphorus, acetone-insoluble (AI) matter, moisture, hexane-insoluble matter and acid value were conducted by AOCS Methods Ca 12-55, Ja 4-46, Ja 2b-87, Ja 3-87 and Ja 6-55, respectively (13). The calcium and magnesium content in the crude oils were determined by atomic absorption spectrophotometer (14).

RESULTS AND DISCUSSION

Table 1 shows some physical and chemical properties of the lecithins prepared by conventional and expander processes. AI matter in the expander-processed lecithin was higher (74.3%) than in conventional lecithin (65.8%). This indicates higher phospholipid content in the expander-processed lecithin. Hexane-insoluble matter was almost the same for both crude lecithins. Because the crude oils were not filtered before the degumming, the value of the hexane-insoluble matters appeared higher than that normally achieved in practice. The acid value for expander-processed lecithin was 26.4 mg KOH/mg, where the conventional lecithin had a acid value of 23.4 mg KOH/mg. Both met the commercial specifications for soybean lecithin (1).

The phosphatide content of an oil is usually determined as total phosphorus and can be converted to phospholipid content by multiplying with a factor of 31.2. The efficiency

TABLE 1

Characteristics of the Lecithin Samples

	Conventional lecithin	Expander-processed lecithin
Acetone-insoluble matter (%)	65.8	74.3
Moisture (%)	0.89	0.95
Hexane-insoluble matter (%)	0.22	0.20
Acid value	23.9	26.4

of the degumming was evaluated by comparing phosphorus content in the oils before and after degumming (Table 2). The phosphorus in the conventional and expander-processed oils was 840 and 985 ppm, respectively. The degumming treatment reduced phosphorus to 184 ppm in the conventional oil and to 67 ppm in the expander-processed oil. Figure 2 shows the significant difference between the degumming efficiencies of the two oils. Expander-processed oil had 93.2% of the phosphorus removed by degumming, whereas conventional oil only had 78.6% reduction in phosphorus content. Expander-processed oil was much more efficiently degummed than the conventional oil.

Nonhydratable phospholipids are usually in the form of calcium or magnesium salts. Calcium and magnesium, if they are not bonded with the phospholipid, are in the form of ions, which can be easily removed by water degumming. Therefore, the remaining calcium and magnesium in the degummed oil usually indicates the nonhydratable phospholipid level of the oil. Table 3 shows that the crude conventional oil contained a higher level of calcium (175 ppm) than the expander-processed oil (92 ppm). The degumming processes reduced calcium in both oils. However, calcium content reduction in the expander-processed oil is higher (55%) than in the conventional oil (16%). The similar trend can be seen in magnesium contents. During degumming, magnesium in the expander-processed oil was reduced from 38 to 12 ppm. For conventional oil, magnesium content was reduced from 44 to 32 ppm, which was not as significant as the expander-processed oil. The expander process resulted in less nonhydratable phospholipids in the crude oil. This is in agreement with phosphorus content and degumming efficiency discussed previously.

TABLE 2

Total Phosphorus Content in the Oils

Oil sample	Before degumming [phosphorus (ppm)]	After degumming [phosphorus (ppm)]
Conventional oil	840	184
Expander-processed oil	985	67

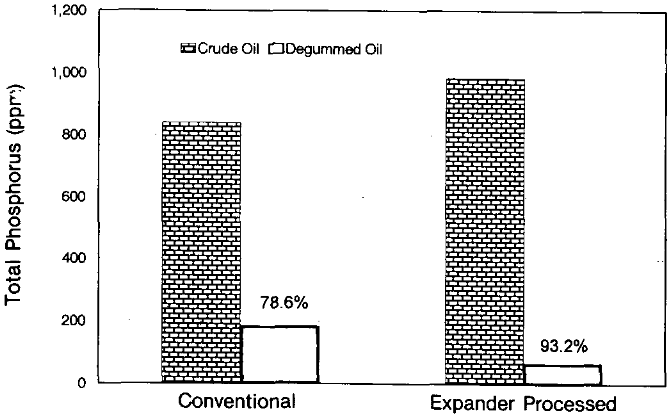


FIG. 2. Total phosphorus content in the oils and degumming efficiency.

TABLE 3

Calcium and Magnesium Content in the Oils

	Conventional oil		Expander-processed oil	
	Crude	Degummed	Crude	Degummed
Calcium (ppm)	175	147	92	41
Magnesium (ppm)	44	32	38	12

The HPLC method was used to determine the three major phosphatides. Table 4 gives the PC, PE and PI compositions found in the two crude oils. Crude oil produced by the expander process had 1.21% PC and 0.85% PI, which are higher than those found in the conventional oil (0.83% PC and 0.62% PI). The PE in the conventional and expander-processed oil were 0.50 and 0.55%, respectively. The relative proportions of the three phosphatides were different. Expander-processed oil contained a higher percentage of PC than did the conventional oil. PC is the most hydrophilic component of all the phosphatides occurring in soybean oil. Consequently, the crude oil with higher PC content tends to result in higher degumming efficiency.

Phosphatide compositions of the lecithin products obtained from conventional and expander processes were also analyzed by HPLC (Table 5). Based on the AI matter, the expander-processed lecithin had 39.78% PC, which was higher than that of the conventional lecithin (34.19%). PE in the conventional lecithin was 18.07%, while PE in the expander-processed lecithin was only 12.36%. PI values of the conventional and expander-processed lecithins were 19.97 and 19.95%, respectively. The difference in the composition of lecithin will also result in a difference in its functionalities (9). PC has high oil-in-water emulsifying properties and plays a leading role in lecithin applications. Higher PC content makes expander-processed lecithin an excellent oil-in-water emulsifier.

According to Sessa and Rackis (15), soybean lipoxygenase can oxidize the unsaturated fatty acids of PC. The oxidized phospholipids form complexes with soy protein during extraction, thus reducing the lecithin yield (7). However, the lipoxygenase is easily deactivated by heating

TABLE 4

Phosphatide Composition in the Crude Oils[a]

Phosphatides (%)	Conventional oil	Expander-processed oil
Phosphatidylcholine	0.83	1.21
Phosphatidylethanolamine	0.55	0.50
Phosphatidylinositol	0.62	0.85

[a]Based on the crude oil.

TABLE 5

Phosphatide Composition in the Lecithins[a]

Phosphatides (%)	Conventional lecithin (AI = 65.8%)	Expander-processed lecithin (AI = 74.3%)
Phosphatidylcholine	34.19	39.78
Phosphatidylethanolamine	18.07	12.36
Phosphatidylinositol	19.97	19.95

[a]Based on the value of the acetone-insoluble (AI) matter.

(16). The lipoxygenases in soy flakes may be deactivated by the high-temperature treatment applied during the expander process, resulting in less PC oxidation. Most of the original PC could be hexane-extracted with the oil and then removed by the degumming process. Furthermore, the hydration activity of other phosphatides increases with higher PC in the oil because of their interaction (5). Higher PC content in the oil results in a higher hydration degree of the phospholipids. The expander process alters the structure of the soy flakes and, therefore, may increase the extractability of phospholipids from the meal. All of these effects may combine into a higher phospholipid yield and different phosphatide composition in the lecithin when the expander process is used.

The expander process has a considerable effect on the phosphatide composition of the crude oils. It increases the PC content, as well as the total amount of phospholipids in the crude oil. This results in a high degumming efficiency, higher lecithin yield and higher PC content in the lecithin product.

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