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Effect of Degumming Conditions on Removal and Quality of Soybean Lecithin

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ABSTRACT

A commercially extracted crude soybean oil (570 ppm phosphorus, 1.74% acetone insolubles) was degummed in the laboratory under a wide range of reaction conditions (water concentration, temperature, time and agitation). The reaction conditions were correlated with phosphorus removal from the oil as well as with color and acetone-insoluble content of the gum fraction. Efficiency of removal of phosphorus-containing compounds was independent of time, temperature and agitation. Water concentration had the most significant effect on removal of phosphorus from crude soybean oil. Some darkening of the lecithin was observed at temperatures above 60 C and with increased agitation. Individual conditions of time and temperature had relatively little effect on the acetone-insoluble content of the gums. Low agitation rates and water in concentrations of other than 2% (either more or less) entrained excessive amounts of oil in the gums. Under our experimental conditions, the optimal conditions with respect to phosphorus removal, lecithin color and acetone-insoluble content are estimated to be: time—short (15 min); agitation—moderate to rapid (400 rpm); temperature—60 C; water concentration—2% or an amount close to the phosphatide content of the crude oil. Bleaching with hydrogen peroxide to produce single-bleached lecithin was investigated. From limited data, it appears that when degumming and bleaching are performed simultaneously, effectiveness of bleaching is a function of peroxide concentration and time. Thus, longer degumming times are required to prepare bleached lecithin compared to unbleached products.

INTRODUCTION

Soybean oil is the only commercial source of lecithin, and worldwide production amounts to 100,000 tons/year (1,2). Industrially, lecithin is recovered by treating the crude oil with water; under these conditions the gums are precipitated from solution, separated by centrifugation, and finally dried (2-5). Conditions affecting the yield and quality of lecithin are largely undefined in the literature, particularly when degumming is carried out by agitating the oil in a tank. Factors affecting the efficiency of continuous centrifugal degumming have been reported (6). Oils degummed under commercial conditions typically contain 5-20% of their original phosphatides as measured by their elemental phosphorus contents (7). Thus, a more complete understanding of the degumming process could lead to higher yields and improved lecithin quality.

EXPERIMENTAL—PROCEDURES

Crude Oil, Analytical Methods

A commercially extracted crude soybean oil was used throughout the investigation. It contained 570 ppm phosphorus and 1.74% acetone insoluble (AI) as determined by official AOCS methods CA 12-55 and Ja-4-46, respectively. The equivalent phosphatide (acetone insoluble) calculates to 1.81% (0.0570 × 31.7) (8) and agrees well with the observed value.

Degumming

Crude soybean oil (2,000 g) was charged into a 3-L round-bottomed flask fitted with a stirring shaft and a paddle-shaped Teflon impeller 7.5 cm long driven by a variable-speed motor. The oil was purged with nitrogen through a sinter glass stick for 2 min and brought to the desired temperature under a nitrogen blanket; then the motor was started, and the desired amount of distilled water was added. When degumming was completed, the mixture was cooled to 40 C and the gums were separated by centrifugation at 1,900 rpm for 15 min. The degummed oil was removed by decantation.

Removal of Water from Crude Gums

To characterize the composition of the crude gums and to isolate lecithin without forming additional color bodies, a method was needed to remove the hydration water from the crude gums. Several methods were investigated. The first method consisted of partitioning the crude gums between hexane and ethanol according to the following procedure: crude gums (ca. 20 g) were weighed into a 250-mL Erlenmeyer flask along with an equal weight of hexane. With magnetic stirring, absolute ethanol was then added from a buret until a distinct phase separation occurred. After transfer of the contents to a separatory funnel, the lower layer, consisting of water and ethanol, was discarded. The upper layer (lecithin, oil, color bodies, hexane) was freed of solvent at 30 C under vacuum. The second method consisted of driving water from the crude gums by vacuum stripping (2 hr, 60 C, 28 in. water) on a rotating evaporator. A comparison of these methods is shown in Table I. Although vacuum stripping did not increase color bodies in the lecithin, water removal was low and variable (57-74%) compared to ca. 96% for the partition method. For this reason, the partition method was used throughout the study.

Single-Bleached Lecithins

Single-bleached lecithin was prepared according to the foregoing degumming procedure except that the desired amount of hydrogen peroxide (30% in water, Fisher ACS) was added to the water used for degumming.

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TABLE I

Comparison of Methods for Removing Water from Crude Gums

Hydration[a] water (%)	Method			
	Vacuum stripping		Partition	
	H_2O removed (%)	Lecithin color[b]	H_2O removed (%)	Lecithin color
1	57.0	17	93.3	17
3	66.0	17	105.7	17
5	74.3	17	88.3	17
Mean	65.8		95.8	

[a]Degumming carried out at 60 C, 15 min, 300 rpm agitation.
[b]Gardner-Hellige scale.

TABLE II

Degumming Conditions from the Literature

Parameter	Quantity	Reference	Ref. no.
Water:	75% wt of gums	Crauer (1972)	6
	1-2.5%	Brian (1976)	2
	2-3%	Van Niewenhuyzen (1976)	1
	3%	Bernardini (1973)	11
	1%	Norris (1964)	5
	2%	Carr (1976)	3
	Equal to wt gums	Braae (1976)	10
	2-5%	Andersen (1953)	12
Temperature:	32-49 C	Norris (1964)	5
	50-70 C	Van Niewenhuyzen (1976)	1
	65-75 C	Bernardini (1973)	11
	70 C	Carr (1976)	3
	95 C	Andersen (1953)	12
Agitation:	Vigorous	Bernardini (1973)	11
	Mechanical agitation	Carr (1976)	3
Time:	30-60 min	Carr (1976)	3
	10-15 min	Braae (1976)	10

Lecithin Color

Lecithin color was determined according to the Gardner-Hellige color scale. A Hellige color comparator was used (Hellige Inc., Garden City, NJ). The Gardner-Hellige scale ranges from 1 to 18 (1 lightest, 18 darkest). Color was determined by placing the lecithin in a glass sample tube and visually matching it against the color wheel while holding the tube against a fluorescent light source.

RESULTS

Effects of Degumming Parameters on Hydration and Removal of Phosphatides

Industrially, soybean oil is degummed by two basic processes: (a) batch degumming, in which agitation of the oil in tank is followed by centrifugal separation of the phosphatides and oil. Batch degumming is the principal method used in the U.S. (3). Typical hydration conditions are reported to be 2% water by volume of oil, time 1/2-1 hr, and temperature 70 C (4). (b) The other process is continuous centrifugal degumming, in which preheated crude oil (80 C) and water are metered into a continuous indwell pipe line agitator, held for a short period, and then pumped to a centrifuge where the gums and oil are separated (1,9, 10). This process is practiced extensively in Europe. The efficiency of centrifugal degumming is dependent on the amount of water used to hydrate the gums and the discharge pressure of the oil from the centrifuge (4,6).

Conditions for degumming crude oils, as reported by various authors, are summarized in Table II. Wide ranges of water concentrations, times and temperatures have been advocated for degumming.

Our first objective was to study the effects of time, water concentration, agitation and temperature on the degumming of soybean oil in a simulated agitated tank reactor.

The experimental design consisted of making four degumming runs, in which three of the four parameters were held constant whereas the fourth was varied. This process was repeated until all parameters had been varied. Results from the 16 degumming runs are shown in Table III.

Time

In runs 1-4, time of degumming was varied from 5 to 60 min. The results show that hydration of the gums is rapid, since the phosphorus content was reduced from 570 to 51 ppm after 5 min of degumming time (91.0% removal). Increasing the time of degumming to 15 and 45 min removed only slightly more phospholipid, i.e., 92%; in 60 min, 94.8% of the phosphatides was removed.

Temperature

The effects of degumming temperature on phosphorus removal are detailed in runs 5-8. Temperature has relatively little effect on phosphorus removal. Varying the temperature from 40 to 90 C removed 92-95% of the phosphorus. The optimal temperature appears to be 75 C. However, as will be discussed later, temperatures above 60 C are apt to darken the crude fluid lecithin.

TABLE III

Degumming of Crude Soybean Oil: Effects of Time, Temperature, Agitation and Water

Run no.	Degumming conditions				Degummed oil[a]		Crude gums		Lecithin[c]	
	Time (min)	Temp (C)	Water (%)	Agitation (rpm)	Phos. (ppm)	Phosphorus removed (%)	%	Hexane sol.[b] (%)	Color	AI (%)
1	5	60	2	400	51	91.1	4.46	55.2	17-	58
2	30	60	2	400	46	92.1	4.54	56.0	16+	58
3	45	60	2	400	46	92.1	4.51	55.6	17-	58
4	60	60	2	400	30	94.8	4.06	51.1	17-	55
5	15	40	2	400	44	92.3	4.68	57.3	17-	60
6	15	60	2	400	42	92.6	4.51	55.2	16	64
7	15	75	2	400	28	95.1	4.93	53.6	17	66
8	15	90	2	400	41	92.8	4.34	54.5	17-	60
9	15	60	2	200	46	91.3	4.95	60.7	16+	50
10	15	60	2	300	35	93.9	5.14	61.1	16	56
11	15	60	2	400	41	92.8	4.89	59.2	17-	59
12	15	60	2	500	39	93.2	5.31	62.4	17	64
13	15	60	2	400	47	91.8	4.65	57.5	17-	57
14	15	60	5	400	60	89.5	7.15	30.1	16+	59
15	15	60	1	400	63	89.0	5.65	82.3	16	49
16	15	60	1/2	400	89	84.4	4.43	88.7	16	44

[a]Crude oil: 570 ppm phosphorus, 1.74% acetone insolubles (AI), 1.81% equivalent phosphatide.
[b]Corrected for water bound to crude gums.
[c]Lecithin color according to Gardner-Hellige scale; color an AI determined on ethanol/hexane fractionated gums.

Water Concentration

The effects of water concentration on phosphorus removal are shown in runs 9-12. Water concentrations of 0.5 and 1% are insufficient to hydrate the gums. These concentrations removed 84.5 and 89.5% phosphorus, respectively. Increasing the water to 5%, however, removed about the same amount of phosphorus, i.e., 90%. Optimal water concentration appears to be closest to the phospholipid content of the crude oil. At 2% water, 92% of the phosphorus was removed in 15 min.

Agitation

The effects of agitation are shown in runs 13-16. Varying the agitation from 200-500 rpm had very little if any effect on phosphorus removal. Under the conditions just given, 91.9-93.2% of the phosphorus was removed.

Effects of Degumming Parameters on Lecithin Color

Previous work at the Northern Regional Research Center has shown that the color of soybean lecithin is due to carotenoids, brown pigments and porphyrins (13). The brown color most likely is an aldehyde-amine reaction product formed by heating of the oil during the solvent-stripping step. Other factors influencing the color of soybean lecithin include: (a) age, origin and quality of soybeans, (b) pretreatment prior to crushing (dehulling and removal of dust, cracking, conditioning, flaking), (c) the depth and thickness of the flakes and temperatures during solvent extraction, (d) conditions during hydration (degumming), and (e) lecithin processing conditions (1). No information is available on the effects of degumming parameters on lecithin color.

Our second objective was to study the effects of hydration conditions on the color of unbleached fluid lecithin.

Unbleached fluid lecithin (2/3 phosphatide-1/3 oil) should have a Gardner-Hellige color of 17 or less (14). A color above 17 indicates that the conditions of degumming were too drastic and degradation of the lecithin had occurred (B.F. Szuhaj, personal communication). Although none of the experimental conditions (Table III) produced lecithin with color beyond 17, indications are that degumming parameters have slight effects as measured by the Gardner-Hellige color scale. A one-unit difference can be readily observed, and an experienced operator can estimate fractional differences in color. At a degumming temperature of 60 C, time has little or no measurable effect on color (runs 1-4, Table III).

With moderate degumming times (15 min), temperatures above 60 C may lead to slight darkening of the lecithin as shown in runs 5-8 (Table III). Degummings made at 75 and 90 C produced lecithins with colors of 17, compared to 16 at 60 C.

Similarly, agitation (runs 9-12, Table III) has a slight effect. Degumming at low agitation rates (200, 300 rpm) produced lecithin with colors of 16, compared to 17 for runs made at 400 and 500 rpm. However, as will be discussed later, low agitation is apt to entrain more oil in the crude gum. The effects of water concentration (runs 13-16) on lecithin color are small, and varying the water concentration from 0.5 to 5% produced lecithin with colors of 16-17-.

Darkening of lecithin during degumming would be expected to be dependent on time as well as temperature. To determine what experimental condition would lead to darkening, four degumming runs were made at 90 C for periods up to 1 hr. Results are shown in Table IV. After 5 min at 90 C, the lecithin had a Gardner-Hellige color of 16+, whereas degumming for extended periods (30, 45 and

TABLE IV

Degumming of Crude Soybean Oil at 90 C: Effect of Time on Lecithin Color

Time (min)	Temp (C)	Water (%)	Agitation (rpm)	Phosphorus		Lecithin color[a]	AI (%)
				Oil (ppm)	Removed (%)		
5	90	2	300	55	91.0	16+	58
30	90	2	300	55	91.0	17-	58
45	90	2	300	54	91.0	17+	58
60	90	2	300	53	91.2	17-	64

[a]Color according to Gardner-Hellige scale; color and acetone-insoluble (AI) determined on ethanol-precipitated gums.

TABLE V

Preparation of Single-Bleached Lecithin: Effect of H_2O_2 and Time on Color

Run no.	Time (min)	Temp (C)	Agitation (rpm)	H_2O_2 (%)	H_2O_2 (%)	Lecithin color[a]	AI (%)
1	5	60	200	2	0.1	15-	57
2	15	60	200	2	0.1	15-	53
3	30	60	200	2	0.1	14-	58
4	5	60	200	2	0.5	15-	63
5	15	60	400	2	0.5	15-	57
6	30	60	200	2	0.5	14-	64
7	5	60	200	2	1.0	14	64
8	15	60	200	2	1.0	14	61
9	30	60	400	2	1.0	14-	69

[a]Color and acetone-insoluble (AI) determined on ethanol-fractionated gums.

60 min) produced lecithins with colors of 17- to 17+. Phosphorus removal data indicate that longer degumming times at high temperature (90 C) offer no advantage, because phosphorus content of the degummed oils was constant at ca. 53-55 ppm regardless of degumming time.

Preparation of Single-Bleached Fluid Lecithin

Single-bleached fluid lecithin is prepared commercially by the action of hydrogen peroxide on the gums (9). The reaction may be carried out by adding the peroxide along with the water of hydration or by treating the crude gums with peroxide after centrifugal separation from the degummed oil. Little information is available concerning the bleaching of soybean lecithin with hydrogen peroxide.

Our third objective was to study the effects of time and peroxide concentration on the color of single-bleached fluid lecithin. According to manufacturers' specifications, single-bleached lecithin should have a color of 14- (10). Results of these studies are shown in Table V. In runs 1-3, time was varied from 5 to 30 min, and other parameters were held constant. Under these conditions, from 15 to 30 min is required to meet the color specifications of 14-. Runs 4-6 represent identical degummings except the peroxide concentration was increased to 0.5%. With respect to color, the results were identical to runs 1-3 (0.1% peroxide).

According to Sartoretto (9), 1% hydrogen peroxide is used to manufacture single-bleached lecithin. Degummings made with this concentration are summarized in runs 7-9. Runs made under similar conditions without peroxide produced lecithin with colors of 16-17 (runs 4, 11 and 13, Table III). From limited data, it would appear that bleaching is a function of time as well as of peroxide concentration. With short degumming time (5 min, runs 1, 4 and 7), bleaching is fairly rapid but then levels off. For example, a comparison of runs 2 and 4, 15-min degumming time with 0.1 and 0.5% peroxide, respectively, shows that with increasing time, additional peroxide has no effect in the bleaching of color bodies. Bleaching is time-dependent as demonstrated by the color of the lecithin after 30 min of degumming (runs 3, 5 and 9). Regardless of peroxide concentration, a color of 14- was not achieved in less than 15-30 min of degumming time.

Because low agitation produced lighter colored lecithin (Table I), the bleaching study was carried out at 200 rpm. To check the possibility that higher agitation rates would promote faster bleaching with peroxide, several runs were made at 400 rpm. A comparison of runs 4 and 5, 200 and 400 rpm, respectively, shows that increasing the agitation has no effect on bleaching. At 0.5% peroxide, the lecithin had colors of 15- despite the differences in degumming times—5 vs 15 min.

Effect of Degumming Parameters on Yield and Composition of Crude Gums and Fluid Lecithin

The treatment of crude soybean oil with water commonly is considered a simple reaction in which the phospholipids hydrate, form gels that swell, and precipitate from solution. Centrifugal separation of the hydrated phospholipids usually will yield ca. 3.5% of gummy material consisting of ca. 25% water and 75% oil-soluble material. The oil-solubles will consist of ca. 1/3 entrained oil and ca. 2/3 AI, i.e., phosphatide (5). Although phosphorus removal data (Table III) indicated that a substantial portion (84.5-95%) of the phosphatides were removed by degumming, the AI content of the crude gums showed considerable variability (44-64%). These observations indicated that variable amounts of oil were entrained in the gum fraction. Therefore, the crude gums, consisting of hydration water, phosphatides and oil, were characterized.

The theoretical yield of crude gums can be approximated based on the phosphorus contents of the crude and degummed oils and the weight of water used for hydration. The equation we have developed is:

$$\% \text{ crude gums} = \frac{(W)(CO)+(P_1)(CF)(CO)-(P_2)(CF)(CO)}{(AI) \times (CO)} \times 100,$$

where W = % water (g/g); CO = wt crude oil (g); P_1 = wt phosphorus crude oil (g/g); CF = correction factor relating % phosphorus to acetone insolubles; P_2 = wt phosphorus

in degummed oil (g/g); and AI = acetone insolubles in gums assuming no excessive entrainment of oil (g/g). For this crude oil, CF = 30.5, AI = 0.63 g/g. In simple form, the equation becomes:

$$\% \text{ crude gums} = \frac{W + (P_1 - P_2)(CF)}{(AI)} \times 100$$

The actual yield of crude gums is obtained experimentally by weighing the foots obtained from centrifugal separation of the degummed oil.

It should be pointed out that, although the relationship between the phosphorus content of crude oil and its AI content is rather constant at ca. 30-32 (8), this relationship may or may not be strictly valid for degummed oils (15).

Figure 1 is a comparison of the theoretical yield of crude gums (phosphatides, oil and hydration water) against the experimental values. As may be seen for runs 1-14, for which sufficient water was used to hydrate the gums, the approximated values agree with the observed yields. The agreement is quite good, in spite of the difficulties in handling the viscous crude gums. It will be noted that the major discrepancies between the experimental and theoretical values occurred where agitation and hydration water were varied, i.e., runs 9-12 and 13-16, respectively. It can be assumed that values higher than theory result from excessive amounts of oil entrained in the crude gums.

The composition of the crude gums is depicted in Figure 2 and is broken down into hexane solubles (triglycerides and phosphatides, corrected for bound water), AI or phosphatides, and entrained oil. The results generally bear out that increased yields of crude gums in runs 9-16 arise from excessive amounts of oil entrained in the gum fraction, as indicated by the closeness of the bottom two lines representing AI and entrained oil, respectively.

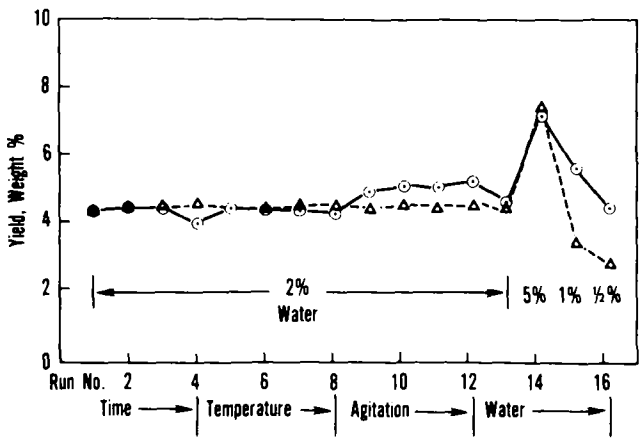

FIG. 1. Effect of degumming parameters on yield of crude gums. △ = theory, ⊙ = found.

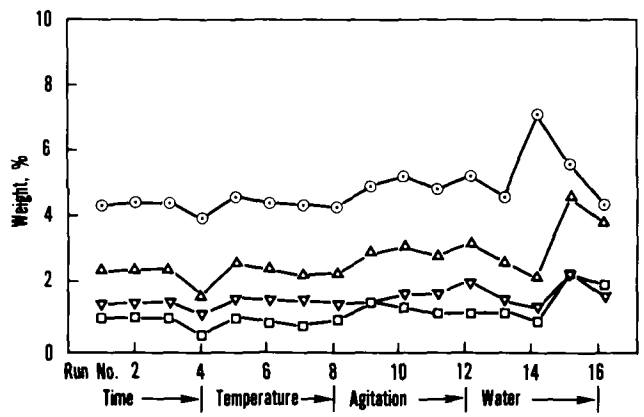

FIG. 2. Composition of gums from crude soybean oil. ⊡ Crude gums, △ hexane solubles, ▽ acetone insolubles, ⊟ entrained oil.

Effects of Degumming Parameters on AI Contents

To aid in the discussion, data relating to phosphorus removed and AI contents of the hexane solubles are depicted in Figure 3. (The run numbers correspond to those in Table I.) Commercial fluid lecithins usually specify a minimum of 62-64% AI. Some degumming runs fell short of this range, but this may be due to inefficient centrifugation afforded by a laboratory centrifuge and uncontrollable variations obtained therewith. Nonetheless, the following observations may be made with respect to the AI content of the gum fraction: (a) long degumming times do not increase the AI content. In fact, there is some evidence of a reentrance of the gum phase into the oil as shown by the lower yield of crude gums and hexane-soluble material after 60 min (run 4, Fig. 2). (b) The temperature of degumming appears to be optimal between 60-75 C. (c) Increasing the agitation is important to the AI content, because there appears to be a direct relationship between agitation rate and AI content. With low agitation rates, the results suggest that more oil is entrained in the crude gums; this effect has been discussed previously. (d) Water concentration has a definite effect on both the amount of phosphorus removed and the AI content of the crude gums. No advantage to using more than 2% could be demonstrated, and concentrations of less than 2%, i.e., 0.5 or 1.0%, markedly lowered the AI content. Lowered AI contents may result because water corresponding to less than the approximate phosphatide content of the crude oil is insufficient to hydrate the gums.

Effect of Hydrogen Peroxide on AI Content

As mentioned previously, low agitation rates appeared to produce lighter colored lecithin. Therefore, the bleaching study was carried out at 200 rpm agitation. Runs made without hydrogen peroxide had low AI content, i.e., 50% (Fig. 3). It will be noted, however, that gums from the bleaching study (Table V) contained higher AI contents, which increase with hydrogen peroxide concentration. This may be due to hydroxylation of the lecithin by hydrogen peroxide (16,17).

Optimal Degumming Conditions

Based on the brief survey reported here, the following

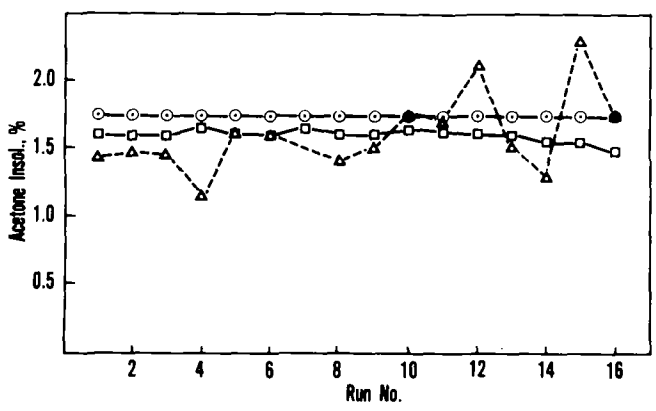

FIG. 3. Effects of degumming parameters on phosphorus removal and acetone-insoluble content of gums.

conditions are estimated to be optimal for phosphorus removal, lecithin color and AI content of crude lecithin: Time—short, 15 min or less; temperature—60-75 C; agitation—rapid, 400 rpm; water concentration—near the phosphatide content of the crude oil.

The properties of lecithin produced under these conditions are comparable to commercial preparations. For example, lecithin produced in the laboratory had Gardner-Hellige colors of 16-17 and acetone insoluble contents of 59.5 ± 2.3% whereas commercial preparations had colors of 17 and AI contents of 62-64%.

Material Balance

The recovery of AI (phosphatides) as a percentage of the crude oil for the 16 degumming runs is shown in Figure 4. Because all the phosphorus in crude soybean oil is associated with the phosphatides (17), complete removal of phosphorus would yield a theoretical recovery of AI equal to the AI of the crude oil, i.e., 1.74%. As degumming removed only 84.4-94.8% of the phosphorus, the observed values are less than theoretical. In general, the experimentally determined data agree reasonably well with the theoretical values.

The equation for determining the percentage recovery of AI is:

$$\% \text{ AI} = [(g)(HS)(AI_{HS})] \times 100$$

AI = g AI/g crude oil; g = crude gums/g crude oil; HS = g hexane solubles/g crude gums; AI_{HS} = g AI/g hexane solubles.

Material balance calculations are complicated by a number of factors: (a) the difficulties in handling the viscous lecithin introduce errors in estimating the yield of crude gums. (b) All phosphorus and AI values reported here represent the means of triplicate and duplicate determinations, respectively. Although satisfactory agreement was obtained, these determinations are tedious and subject to absolute errors. (c) The crude gums bind appreciable and variable amounts of water. Although this was corrected for, it can affect the value for the hexane-soluble portion of the crude gums. (d) Occasionally, during separation of water from the crude gums, emulsions are formed that introduce errors in determining the yield of hexane solubles.

The most notable discrepancies in the material balance data occur in runs 4, 12, 14 and 15. In run 4, the yield of crude gums and the AI contents of the hexane were lower than expected and account for the low yield of AI. This is particularly perplexing because of the low phosphorus content of the degummed oil; the recovery of AI should have been higher. On the other hand, run 12 yielded more crude gums with a higher-than-expected AI content. Runs 14 and 15 represent degummings made with 5 and 1% water, respectively. In run 14, a large excess of hydration water was present and an appreciable quantity was not removed during isolation of the hexane soluble. The excess water led to a sizable correction for bound water. Furthermore, the presence of excess water in the hexane-soluble portion may have had an effect on the AI content determination.

In run 15, in which low amounts of water were present in the crude gums, excessive amounts of triglycerides were present in the hexane solubles. These may not have been completely removed during the AI determinations and, if so, would lead to high AI recovery.

Statistical Treatment of Data

Data given in Tables III and IV were used to fit the model $Y = A + Bx + CK^2$, where Y equals either phosphorus removed, yield of crude gums, acetone insolubles, or color,

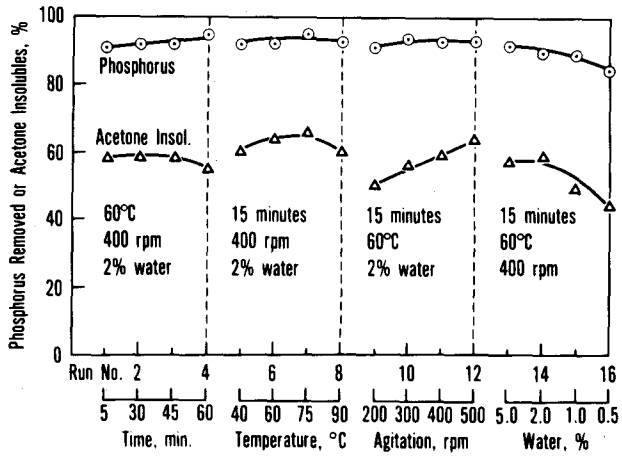

FIG. 4. Recovery of acetone insolubles from crude soybean oil. ● Theory, acetone-insoluble content crude oil. □ Calculated from phosphorus content of degummed oil. △ Experimental acetone-insoluble content of hexane solubles.

X equals the parameters of degumming, time, temperature, water concentration and agitation. Statistically significant associations were observed as follows. With respect to % phosphorus removed, water concentration had a significant effect on both % phosphorus removed and the yield of crude gums. The effects of temperature, agitation, water and time on the AI content of the hexane solubles were all statistically significant. Although there was some evidence that higher temperatures promoted darkening of the lecithin, the small differences were not significant.

DISCUSSION

Results obtained in this study indicate that the conditions of hydration used for degumming of crude soybean oil can affect the manner in which the crude gums behave in a small laboratory centrifuge. Most notably, low agitation rates and insufficient or excessive hydration water tend to entrain excessive amounts of oil in the gums, or perhaps lecithin emulsifies more oil into the water phase.

It is not clear why water concentration and agitation have an effect on the composition of the gum fraction. However, as viewed under a microscope, the reaction of water with phospholipids or the reaction between water and an admixture of phospholipids and phosphatides is a complex one as shown by Desnuelle (18). When water and phosphatides are mixed, cylindrical filaments are formed quickly and grow continuously in the direction of the water. The theoretical explanation for this phenomenon is as follows. When intermolecular cohesion within a substance is distinctly greater than the affinity of the molecules for water, the substance is insoluble. Between these two extremes exists a number of intermediate states in which water merely penetrates into the molecular structure without destroying it. The substance is then said to swell. Phospholipids behave as amphipathic substances as the polar groups of the phosphatides tend to plunge into the water while the hydrocarbon chains remain outside. Thus, phosphatidic molecules are oriented in contact with water, taking up parallel positions to one another and forming a monolayer with a polar and nonpolar side. The nonpolar side then attracts the hydrocarbon chains of other molecules. Thus, a second layer is built up in which the position of the molecules is reversed. The two layers form what is known as a double layer (18).

On the other hand, the reaction between water and a solution of phosphatides and triglycerides (i.e., a crude

soybean oil) is markedly different. When mixed, instead of sending filaments into the water, the oily phase is progressively invaded by anisotropic and isotropic forms that contain definite proportions of glycerides and phospholipids. The interpretation of this phenomenon is as follows. When water is contacted with a solution of phosphatides and glycerides, mixed double layers are formed that contain both phosphatide and glyceride molecules. Within these layers, the two types of molecules interact; the energy of interaction varies according to the proportions of the two types of molecules and passes through a maximum at ca. 70% phosphatides and 30% glycerides. The building up of the most stable mixed layer corresponds to the maximal interaction energy. Thus, any mixed layer formed spontaneously at the water surface must contain phosphatides and glycerides in the 70:30 ratio, and this has been confirmed experimentally (18). This accounts for the fact that lecithin produced by hydrating, centrifuging and drying contains appreciable amounts of glycerides.

The experimental data presented here show that water concentration and agitation in some unknown fashion affect the proportion of glycerides entrained in the hydrated gums.

Crauer (6) has reported that use of the improper amount of hydration water has a deleterious effect on the quality of both the crude gums and the degummed oils. Separations made in a small, high-speed centrifuge showed that when the gums have been properly hydrated, a compacted gum phase and a clear degummed oil fraction is obtained. Too much water yields three phases consisting of hazy, degummed oil, a free water phase, and a fluid, yellow phase due to high oil content of the gums. Too little hydration water results in dark, viscous gums and hazy oil. Thus, there is some evidence that the effects of water observed here may be analogous to those in commercial operations. Whether the effects of agitation would prevail in commercial operations is not known and requires further investigation.

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Compositions of Commercial Corn and Soybean Lecithins

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ABSTRACT

The lipid and fatty acid compositions of commercial corn and soybean lecithins were compared. The types of lipids were similar, but the proportions varied. The ratio of glycolipids to phospholipids was 0.36 for corn lecithin and 0.14 for soybean. Phosphatidylcholine and phosphatidylinositol were major phospholipids in both lecithins. In soybean lecithin, the percentage of phosphatidylethanolamine equaled that of phosphatidylinositol, but in corn, the percentage of phosphatidylethanolamine was only about one-fourth the percentage of phosphatidylinositol. High levels of phosphatidic acid in both the corn and soybean preparations indicated some degradation of the phospholipids during processing. The major differences in fatty acid compositions were a higher percentage of oleic acid and lower percentages of stearic and linolenic acids in corn compared to soybean. The lower level of linolenic acid should give corn lecithin greater resistance toward autoxidation and the development of off-flavors.

INTRODUCTION

In recent years in the U.S., soybeans have been the sole source of commercial lecithin (1). With the phenomenal growth now occurring in the demand for corn sweeteners, other products of the corn refining industry, such as corn lecithin, may become available and competitive.

The physical properties of a commercial lecithin are determined by the proportions and the fatty acid compositions of the various phospholipids and other lipids that it contains. In this study, we compared the lipids of a commercially prepared corn lecithin with the lipids from a commercial soybean lecithin.

MATERIALS AND METHODS

Materials

The samples of corn and soybean lecithins were provided by the A.E. Staley Co. of Decatur, IL. The soybean lecithin sample was a fluid type, usually ca. 65% acetone insoluble.

Silicic Acid Columns

The lipids of the crude lecithins were separated into classes