Production of Food-Grade Cottonseed Protein by the Liquid Cyclone Process[1]

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ABSTRACT

A brief background is presented on the development of the Liquid Cyclone Process as modified to process glanded cottonseed kernels from the Texas high plains into a gland-free 65+% protein flour. Southern Regional Research Center's pilot plant process is described and related to the commercial process that will become operational in early 1974 at Plains Cooperative Oil Mill, Lubbock, Texas. Some of the functional properties of the flours and results of their evaluation in food application are discussed.

INTRODUCTION

An adequate supply of low cost, high quality protein food is needed to break the vicious cycle of poverty, malnutrition, and disease. The projected world protein deficit (as 70% protein concentrate) by 1975 is 2,157,000 metric tons; with projected population growth, the protein deficit will double by the year 2000 (1).

In the U.S., market surveys indicate current sales of only 0.9-1.1 billion lb protein of a total market potential of 3.1 billion lb a year. Thus, there is an untapped market potential of ca. 2 billion lb protein a year (2).

Cottonseed is one of the principal oilseeds in the world, with an annual production of 24 million metric tons (3). Ca. 20% is protein, which represents ca. 6% of the world's total supply of edible protein (private communication–data compiled from various U.S. Department of Agriculture reports by Research Cost Analyses). Most of the cottonseed currently is used as cattle feed where there is a conversion ratio from plant to animal protein of 6 or 7 to 1.

For 20 years, research has been concentrated on producing a glandless variety of cottonseed with satisfactory fiber characteristics. A satisfactory glandless variety will someday be a reality; however, three years ago, Plains Cooperative Oil Mill recognized that the Liquid Cyclone Process (LCP) developed at the Southern Regional Research Center offered the quickest and most reliable means of introducing cottonseed protein from glanded seeds into the nation's food supply (4). The cottonseed flour produced by this process was analyzed as the best ever made in quantity from such cottonseed. Because of the quality and protein content of the flour, Grain Processing Corp., Muscatine, Iowa, became interested in its potential and obtained several hundred lb for evaluation. Subsequently, Plains Cooperative Oil Mill and Grain Processing Corp. joined together in an agreement to produce and market cottonseed flour for food uses under the trade name Pro-Fam C-650.

After Plains Cooperative Oil Mill became committed to the production of the LCP flour, there was need to determine if the cottonseed kernels from cottonseed produced on the Texas high plains would process like kernels from cottonseed produced in the Mississippi Delta area on which the basic process was developed. Some differences were noted.

Intensive research effort at Southern Regional Research Center led to minor alterations in preparation for the processing of the Texas kernels and to a simplification of the LCP. The modifications were: the moisture level of the kernels before comminution was reduced from 3% found best for Delta seed to 1.5% for the Texas seed and flaking followed by solvent milling in a stone mill was replaced by dry milling in a wide-chamber, sieveless, impact stud mill. The yield of flour based upon input of oil-free solids to the process was increased from 34 to ca. 45%.

In fall 1970, as soon as the LCP had been shown to be adaptable to cottonseed from both the Mississippi Delta and the Texas high plains, a petition was filed with the Food and Drug Administration requesting approval of the LCP cottonseed flour as a food additive. This approval was granted and appears in the Federal Register of July 13, 1973 (5).

THEORY AND PROCESS

A cross section of a glanded and of a glandless cottonseed is shown in Figure 1. The glanded cottonseed on the left contains dark specks in the kernel. These are the pigment glands, containing ca. 40% gossypol. Figure 2 shows a scanning electron micrograph of a gossypol gland still embedded in and surrounded by cell tissue. The differences in the relative sizes of the pigment glands and spongy mesophyll cells makes it possible to separate them.

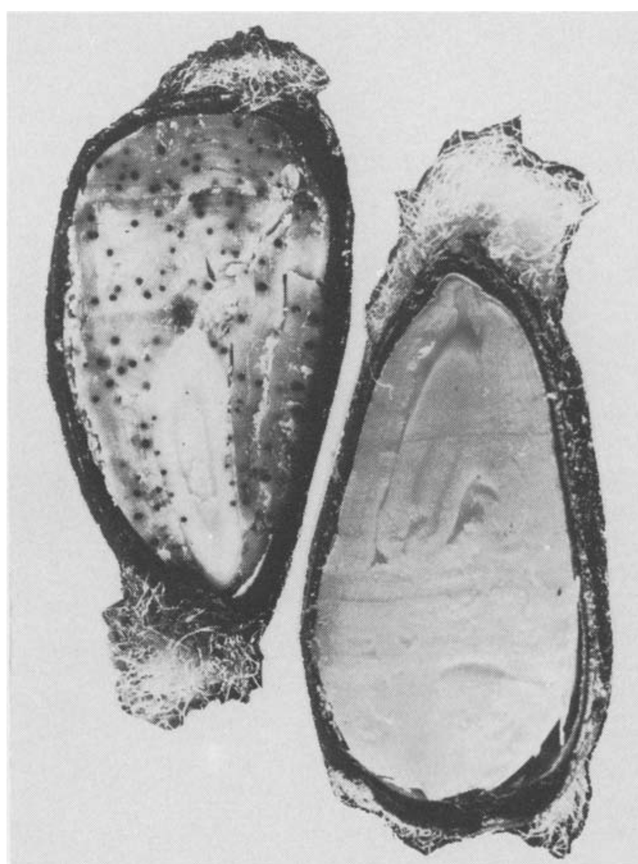

FIG. 1. Cross sections of glanded and glandless cottonseed.

[1]One of seven papers presented at the symposium, "Processing Methods for Oilseeds," AOCS Spring Meeting, New Orleans, April 1973.

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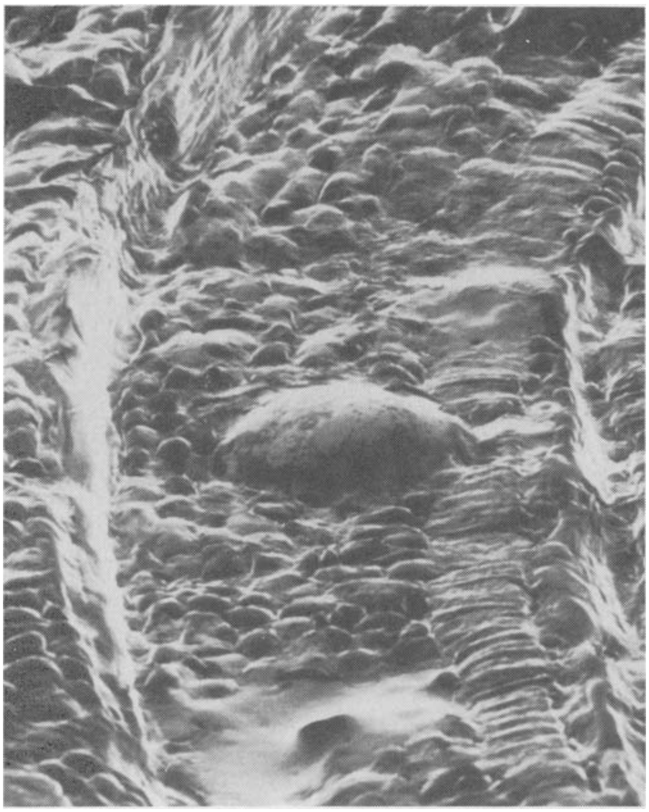

FIG. 2. Scanning electron micrograph of cross section of partially hydrated glanded cotton embryo. Large bulbous shape in center of figure is pigment gland. Small round cells are spongy tissue of the mesophyll.

FIG. 3. A single cottonseed pigment gland showing pigment streaming out on contact with water.

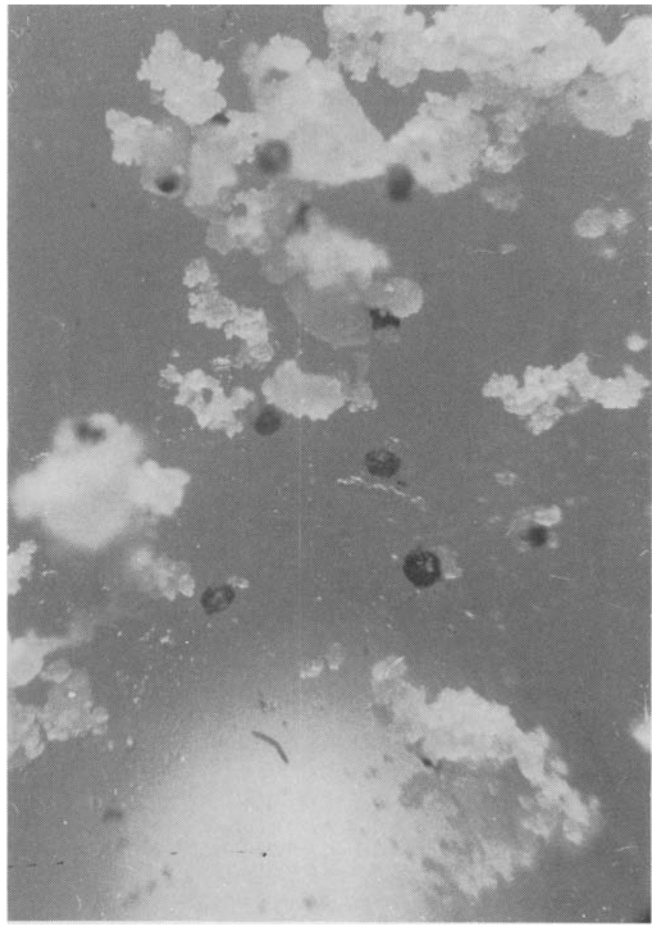

FIG. 4. Cottonseed tissue and pigment glands in hexane showing integrity of glands.

The spongy mesophyll cells contain aleurone grains or protein bodies, spheresomes (lipid particles), globoids (phytin storage sites), and a nucleus.

Essentially all of the glands can be separated intact by the liquid cyclone into the underflow meal fraction, thereby minimizing gossypol in the overflow flour fraction. Glandless cottonseed, of course, present even fewer problems to the LCP. With kernels from glandless seed, a high-protein cottonseed flour somewhat lighter in color than the flour from glanded seeds can be produced. In addition, the cyclone underflow product from glandless seed, which has ca. 50-54% protein, also can be used as a food additive or as a starting material for production of cottonseed protein isolates.

In conventional oilseed processing operations, combinations of moisture, heat, and shearing pressure rupture most of the pigment glands. Such conditions induce gossypol to combine with lysine in the protein. In the resulting meal product, the available lysine and protein solubility are lowered; and, in many instances, the residual free-gossypol content causes it to be somewhat toxic to nonruminant animals.

Figure 3 shows a pigment gland being ruptured by moisture with the gossypol flowing out to react with protein. Gossypol imparts a red-orange color to both cottonseed meal and oil. When cottonseed kernels are dried to under 2% moisture content and comminuted in an impact-type mill, the glands are detached from the protein containing tissue and will maintain their integrity in hexane as is illustrated in Figure 4.

Depicted in Figure 5 is the settling of a milled cottonseed kernels-hexane slurry under conditions of 1 *g* for periods of time. The slurry in the middle cylinder has classified itself from bottom to top as follows: coarse meal

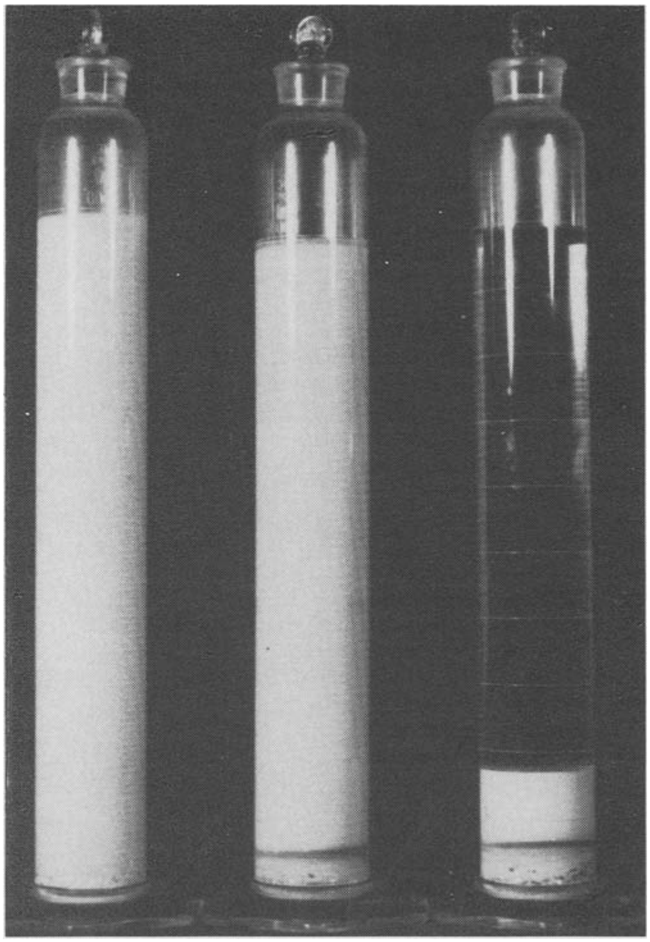

FIG. 5. Settling of hexane-slurried milled cottonseed meats at different time intervals.

particles with embedded glands and hulls, a layer of pigment glands, and a suspension of high protein flour particle in miscella. This suspension is equivalent to the overflow fraction from the liquid cyclone. The LCP capitalizes on the rates at which the different fractions settle in liquid media; and, by use of centrifugal force, it accentuates the separation.

Figure 6 is a flowchart of the LCP used in the Southern Regional Research Center pilot plant in New Orleans, La. Whole and cracked meats, essentially hull-free, obtained from prime quality Texas cottonseed, are dried to 1-1/2% moisture content. The purpose of drying is threefold: (A) to remove water, which is an excellent solvent for rupturing the pigment glands; (B) to toughen the pigment glands; and (C) to make the proteinaceous material more friable. The latter two factors are critical to comminution or milling of the dried kernels, which is the next step in the process. Comminution of the cottonseed kernels is one of the most important operations. Without adequate comminution, the yield of flour will be low; with too much or severe comminution, the pigment glands will be ruptured. A sieveless, wide-chamber, Alpine American Contraplex unit was found to be effective comminuting equipment. This unit makes it possible to mill Texas high plains cottonseed kernels satisfactorily and also simplifies the original process by eliminating flaking of kernels followed by solvent milling in a stone mill. The Contraplex has two counter-rotating discs with several rings of studs. The discs operate separately from the mill side and from the door at 9500 and 2500 rpm, respectively. The wide-chamber construction minimizes buildup of flour on the walls of the mill.

The desirability of using hull-free meats must be stressed, even though the liquid cyclone can effectively remove as much as 3% hulls from the slurry. Milling of hulls

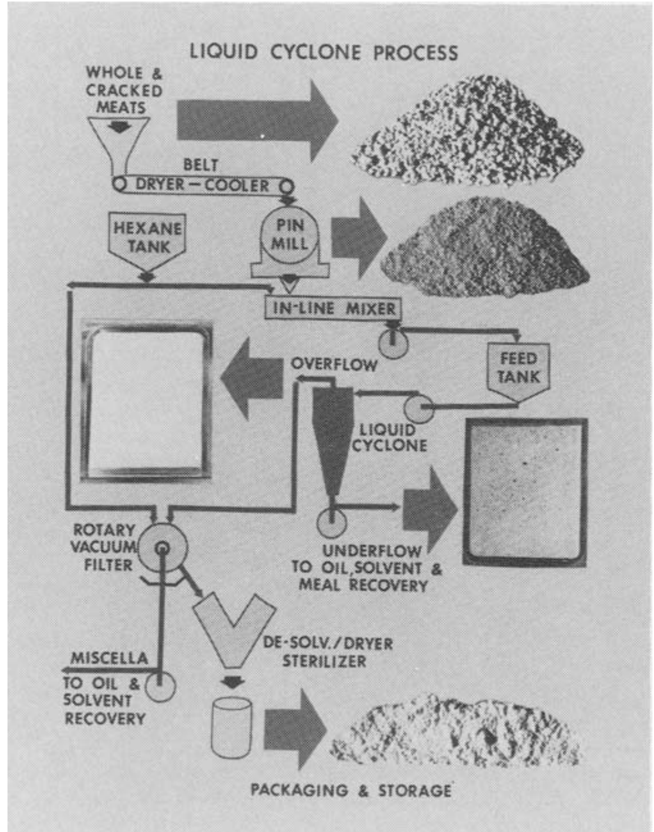

FIG. 6. Flowchart of modified Liquid Cyclone Process for removal of pigment glands from glanded cottonseed.

with the meats increases power requirement and, most importantly, causes some gland rupture. This rupture must be minimized if a satisfactory flour product for food uses is to be produced.

From the flowchart, it can be seen that hexane is added to the milled meats to produce a slurry suitable for classification in the liquid cyclone. The commercial size cyclone is only 3 in. in diameter and 10 in. high. The cyclone must be of metal to prevent the buildup of static electricity that would be generated by a nonpolar solvent slurry in contact with other materials, such as ceramics. Such a cyclone can produce ca. 12 tons flour/day.

In operation, a 20-22% solids slurry is pumped under an optimum pressure of 40 psig. The slurry enters tangentially into the upper portion of the cyclone. The centrifugal forces generated within the cyclone yields two fractions. One of these fractions is a light overflow slurry containing 13-15% high protein, gland-free solids. On a wt basis, the overflow fraction accounts for ca. 70% product slurries. The other fraction is a high gossypol, coarse meal underflow slurry containing 43-45% solids. The ratio (split) of overflow slurry to underflow slurry is controlled by adjusting the speed of the underflow slurry pump. In adjusting the split, visual observation of the underflow is most important. Experience has shown that when the optimum split has been achieved, the underflow slurry visible in a sight glass under the cyclone has a slow, laminar flow as it leaves the cyclone. Turbulence, which is indicative of disruption of classification within the cyclone, results in the appearance of pigment glands in the overflow fraction. This condition calls for immediate readjustment of the split control. Turbulence in the underflow usually can be avoided by maintaining control of the solids content of feed slurry. After the desired split has been attained, the overs-unders fractions are directed to their respective solids recovery operations. In the commercial installation at Lubbock, Texas, an additional cyclone is used to recover

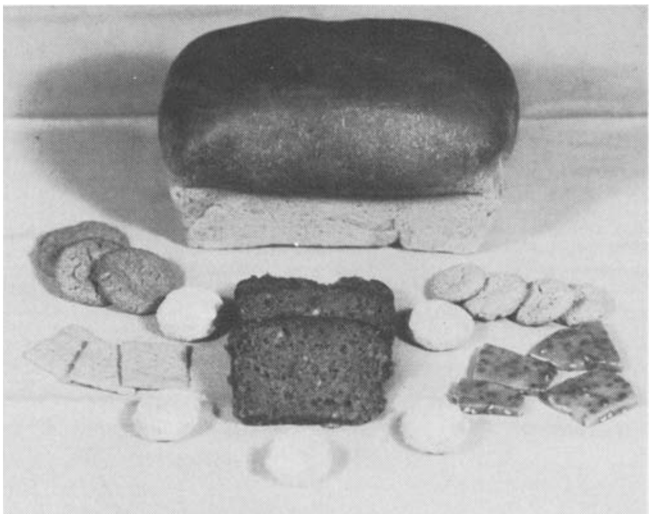

FIG. 7. Bakery products prepared at Texas Tech University in which 15-20% wheat flour was replaced with cottonseed flour.

entrained fine flour from the underflow slurry fraction, thus enhancing the yield of high protein, low gossypol flour.

Cottonseed flour from the overflow slurry fraction is recovered in a totally enclosed, rotary, vacuum, drum-type filter covered with a nylon cloth. The filter surface (33%) is submerged. Cake 1/8 in. thick is accumulated on the submerged drum under vacuum (20 in. of mercury).

Early laboratory tests indicated that the filter cake cracked readily if not kept wet with solvent or miscella. This problem carried over to pilot plant operations. It was solved by maintaining a uniformly distributed slurry wash on the cake soon after the drum emerges from the slurry trough and by maintaining a uniformly distributed solvent wash on the cake at the top of the rotating filter drum. Presently, a solvent-to-cake ratio of 1.75 to 1.0 seems optimum. After one hexane displacement wash, the lipids in the filter cake average ca. 0.60% on a dry basis.

The cake is removed from the filter drum by a combination of nitrogen gas blow back and a doctor blade. The filter has its own two stage vacuum pump.

The filter cake is desolventized in the pilot plant in a jacketed, twin-shell, rotary, V-type blender equipped for vacuum and solvent recovery operations. In the commercial installation, the filter cake is desolventized in a flash desolventizer unit. This operation is followed by a vacuum deodorizer process to strip out the final traces of solvent.

The solids in the underflow slurry fraction are recovered by a totally enclosed, horizontal, rotary, vacuum, pan-type filter. The cake is desolventized in Schneckens-type units.

The miscellae from both filtering operations are combined and processed for oil and solvent recovery.

FOOD APPLICATION

Over the last three years, ca. 8000 lb of edible flour having a light creamy color and a bland flavor have been produced from glanded cottonseed in the Southern Regional Research Center pilot plant. Most of this flour has been used for evaluation in food applications throughout the industry.

Grain Processing Corp. reported that the protein content of five lots of LCP flour supplied by Southern Regional Research Center and evaluated by them approached 70% on a moisture-free basis. The nutritional quality was excellent, and the protein effeciency ratio (PER) determined in their laboratory ranged from 2.51-2.67 for the 5 lots. These values compare to the standard of sodium caseinate which has a PER of 2.50 (6).

Water absorption determinations indicated that the cottonseed flour absorbed 2-1/2 times its wt of water. In comparison, soy concentrates and isolates absorbed 5-6 times their wt (6).

Oil absorption values of the cottonseed flour were 1-1/2 times its wt and were similar to those for soy products. Oil emulsification values generally range from 245-260 ml oil/g flour. Various soy isolates had values of 100 to over 300 ml/g and soy concentrates from less than 100-250 ml/g. These functionality tests are not standard industry procedures, but they give some indication of relative differences to assist the food processor in devising formulations (7).

Several institutions have been conducting research on various aspects of food applications: Texas A&M University, texturized vegetable protein products; Texas Woman's University, recipes for institutional feeding; and Texas Tech University, a variety of baked goods (Fig. 7) (7-9). The school lunch program and institutional foods, where an economical source of highly nutritional food additive is essential, may offer a market for these products.

In evaluations carried out at Grain Processing Corp. (6), LCP flour has been used at levels up to 8% in beef patties and up to 6% in sausage. In these products, frying losses were reduced; and desirable flavor and texture were developed. In meatball, gravy, and chili preparations, the separation of fat and moisture was retarded by the presence of cottonseed flour. Through proper formulation, cottonseed flour was as desirable as soy products for use in these preparations. Also, the color and flavor of the samples that contained cottonseed flour were excellent.

In baking evaluations (6), a replacement of 3% wheat flour with LCP flour produced an excellent white bread with only slight darkening of crumb color. In cake doughnuts up to 13% LCP flour was substituted. A desirable yellow color, comparable to an egg-rich product, was produced. In devil's food cake, a substitution of 10% LCP flour produced an excellent product with good color, flavor, and texture. The flour did impart a greenish color to waffles and pancakes and a grayish cast to white layer cake. This characteristic is undesirable.

Research on extruded products containing LCP flour is underway at Grain Processing Corp. and Texas A&M University. Based upon limited work at Grain Processing Corp., extruded cottonseed flour materials indicate promise for use in meat products and cereals.

Research at Southern Regional Research Center and Grain Processing Corp. indicate that one of the most promising uses for LCP cottonseed flour is in the form of a 95% protein isolate with almost complete solubility at pH 3.5. This isolate shows excellent promise for protein fortification of carbonated and citric acid beverages (6,10). The isolate has a white color and is an excellent whipping agent. It compares favorably with egg white solids and sodium caseinate (6).

PLANT PROGRESS

After 2 years of equipment testing and engineering planning, construction of the $2.4 million plant at Lubbock, Texas, was started in the spring of 1972. It is designed by Engineering Management Inc., Des Plaines, Ill., to produce 25 tons a day or 15 million lb a year of food-grade cottonseed flour and should be operational by early 1974.

ACKNOWLEDGMENT

W.R. Goynes provided Figure 2.

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