Processing Factors Affecting Air Classification of Defatted Cottonseed Flour for Production of Edible Protein Products[1]

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ABSTRACT

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Processing factors evaluated for their effects on gossypol contents and yields of air-classified cottonseed flour included hull contents, moisture of cottonseed flakes before hexane extraction, flake-drying methods, residual lipids of flakes after hexane extraction, and heat treating of flakes before milling. Important factors in obtaining low gossypol cottonseed flours were maximum removal of hulls, drying of flakes to 2% moisture before extraction in a high velocity through-flow type dryer, and extraction of flakes to about 2% residual lipids. Heating before milling did not improve air-classification yields or lower gossypol content.

The potential of cottonseed proteins for human foods has been recognized for several years (Bressani et al 1966, Harden 1975, Martinez et al 1970). Cottonseed is the most widely grown oilseed crop other than peanuts in the world (Pandey 1976) and is second to soybeans in production (FAO 1975). Development of edible protein products from cottonseed has been limited, primarily because of the presence of pigment glands that contain toxic gossypol. Several approaches (Gardner et al 1976) have been devised for removing these pigment glands from cottonseed.

The successful introduction of air-classification technology in the wheat industry (Jones et al 1959; Lykken and Rozsa 1956; Stringfellow et al 1962, 1964; Wichser 1958), has created new interest in this means of separating pigment glands from milled cottonseed flour. Earlier, limited air-classification studies of glanded cottonseed (Martinez 1969, Meinke and Reiser 1962) were unsuccessful in obtaining the accepted limit of 0.045% free gossypol (FDA 1974) for edible cottonseed flour. Meinke and Reiser (1962) were able to obtain edible flours only after extracting air-classified materials with polar solvents.

Air classification recently has been shown to have potential for preparing edible flours from glanded cottonseed (Kadan 1977). Air classification can readily separate intact pigment glands from a flour stream. If any pigment gland damage has occurred before air-classification, however, final products will have high gossypol content. Several processing operations can play an important role in gland damage. The method of milling prior to air classification obviously affects gland damage. As reported by Kadan et al (1979), the Rietz mill, a fixed-hammer disintegrator equipped with a sizing screen, has been effective in producing fine flours with little pigment gland damage.

This study was designed to evaluate several processing factors that could affect the production of edible products by air classification of defatted, glanded cottonseed flours. Such factors as moisture in flakes before hexane extraction, methods of drying flakes, lipid content of flakes, hull contaminaion, and drying before milling were studied.

MATERIALS AND METHODS

Several series of pilot plant experiments each evaluated certain processing factors. Delintered, dehulled, prime quality Mississippi glanded cottonseed was used for this study. Cottonseed kernels with about 1% hulls were prepared in pilot plant hulling and purification equipment. The kernels were flaked to a thickness of 0.015 in. through Ross smooth oilseed flaking rolls. Flakes were dried at 82°C in a high velocity, through-flow type Blue M dryer, except in one experimental evaluation of different drying methods. Dried flakes were batch extracted in basket extractors with hexane at ambient temperature. Extracted flakes were desolventized at 82°C for 2 hr under vacuum. Desolventized flakes were milled in a Rietz RP-6 disintegrator equipped with a sizing screen having

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0.016-in. diameter openings. The milled flours were air classified three times in a Donaldson Acucut A-12 air classifier with an air flow of 70 standard ft^3/min, always reclassifying the fines fraction (Kadan et al 1979). The first, second, and third classifications were conducted at 750, 850, and 950 rpm, respectively.

To evaluate the effect of flake moisture before solvent extraction, cottonseed kernels were divided into two lots and dried to moisture contents of 2 and 5%, respectively. The dried flakes were then extracted with three passes of fresh hexane. An overall solvent/meal ratio (w/w) of 1.5:1 or an average of 0.5:1 per pass was used. Extraction time was approximately 20 min per pass. Flakes were then desolventized, milled, and air classified.

Different drying methods were evaluated by drying cottonseed flakes to 2% moisture in one of the following dryers: Blue M high velocity through-flow type, F. J. Stokes shelf heat type, or Proctor-Schwartz low velocity across-flow type. Drying times were 50, 120, and 180 min, respectively. Temperatures were maintained at 82° C. The dried flakes were then extracted with five passes of fresh hexane to approximately 1.8% lipids, with an overall solvent/meal ratio (w/w) of 2.0:1 or an average of 0.4:1 per pass. The defatted flakes were then desolventized, milled, and air classified.

The effects of flake residual lipids were studied by dividing dried flakes (Blue M dried to 2% moisture) into six lots. Each lot was extracted with various amounts of hexane and various numbers of passes to generate six different levels of lipids in the flakes, which were then desolventized, milled, and air classified.

To evaluate the effect of hull material, all visible hull pieces were removed from the kernels. The kernels were then divided into three lots. One lot was left as-is,ie, essentially free (less than 0.5% hulls) of hull material. Known amounts of hulls were added to the other two lots to obtain one with 2% and the other with 4% hull contents. Kernels were then flaked, dried to 2% moisture in the Blue M, extracted to 1.8% residual lipids, desolventized, milled, and air classified.

The effects of a drying step after desolventization were also investigated. Desolventized flakes were divided into two lots, one lot as-is in moisture content (about 2.5%), the other dried in the Blue M at 82°C for 30 min to about 1.5%. Both lots were then milled and air classified.

Proximate analyses and gossypol assays were conducted according to official AOCS methods. Air-classification yields were calculated as weight of product divided by the weight of the starting unclassified, defatted flours multiplied by 100. All data are reported on an as-is moisture content of 8% and are the mean values of three replicates. Statistical analyses included analysis of variance and Duncan's multiple range test (1955).

RESULTS AND DISCUSSION

Moisture contents of the flakes before hexane extraction appear to be important in obtaining low free gossypol, air-classified fractions (Table I). Flakes dried to 2% moisture resulted in lower gossypol air-classified products compared with those with 5% moisture. Air-classified flour yields, however, appeared to be unaffected by moisture content of the flakes. Drying the flakes may have a twofold effect: 1) The extended heating period given to the 2% moisture flakes may toughen the pigment glands, thus resulting in less gland damage during subsequent processing, and 2) for a given solvent/meal ratio, lipids were not as easily extracted from the 2% moisture flakes as from the 5% moisture flakes. The additional lipids in the 2% moisture flakes may lubricate and protect the pigment glands during milling.

The importance of drying flakes to produce low gossypol flours is further demonstrated by data in Table II. As can be seen, the method of drying appears important with respect to gossypol content of the product. Comparison of the gossypol contents of the products from the three types of dryers showed that the product with the lowest gossypol was produced by the high velocity, through-flow dryer. Apparently pigment gland toughening is more readily accomplished with a drying method that employs high-output heating. Yields of air-classified flours produced from flakes dried in the low velocity, across-flow dryer were lower than the yields of flours dried by the other method.

The residual lipid content of the defatted flakes, also affected pigment gland damage as shown in Table III. As the lipid content of

TABLE I
Effect of Moisture Content of Flakes Prior to Extraction on the Composition and Yield of Air-Classified Products[a]

Moisture (%)	Gossypol Free (%)	Gossypol Total (%)	Protein[b] (%)	Lipid (%)	Yield (%)
2	0.053a	0.103a	62.1a	2.15b	36a
5	0.068b	0.125b	63.8a	1.36a	35a

[a] Means within columns followed by the same letter are not significnatly different ($P < 0.05$) (Duncan 1955).

[b] Protein = 90 N × 6.25

TABLE II
Effect of Drying Method on the Composition and Yield of Air-Classified Products[a,b]

Drying Method	Gossypol Free (%)	Gossypol Total (%)	Protein[c] (%)	Lipid (%)	Yield (%)
High velocity through-flow	0.045a	0.080a	64.4a	1.26b	36b
Shelf dryer	0.064b	0.124b	65.6a	1.02a	35b
Low velocity across-flow	0.065b	0.114b	65.8a	1.15b	32a

[a] Flakes were dried to 2% moisture at 82°C before solvent extraction.

[b] Means within columns followed by the same letter are not significantly different ($P < 0.05$) (Duncan 1955).

[c] Protein = % N × 6,25.

TABLE III
Effect of Residual Lipids on the Composition and Yield of Air-Classified Products[a]

Defatted Flake Lipid Level (%)	Gossypol Free (%)	Gossypol Total (%)	Protein[b] (%)	Lipid (%)	Yield (%)
0.50	0.081d	0.155c	67.1d	0.41a	41c
1.00	0.080d	0.150c	65.9c	0.68b	38bc
1.40	0.070c	0.122b	65.0c	0.75bc	40c
1.58	0.051b	0.089a	64.1bc	0.81c	35b
1.90	0.045ab	0.083a	63.0b	1.03d	35b
2.50	0.040a	0.080a	60.9a	1.50e	31a

[a] Means within columns followed by the same letter or letters are not significantly different ($P < 0.05$) (Duncan 1955).

[b] Protein = % N × 6.25.

TABLE IV
Effect of Hull Material on the Composition and Yield of Air-Classified Products[a]

Hull Content	Gossypol Free (%)	Gossypol Total (%)	Protein[b] (%)	Lipid (%)	Yield (%)
Hand-picked[c]	0.040a	0.083a	64.3a	1.20a	35a
2%	0.051a	0.091a	63.8a	1.26a	35a
4%	0.150b	0.215b	63.6a	1.38a	36a

[a] Means within columns followed by the same letter are not significantly different ($P < 0.05$) (Duncan 1955).

[b] Protein = % N × 6.25.

[c] All visible hull material removed.

the defatted flakes decreased, gossypol contents of the air-classified products increased. This agrees with the assumption concerning the effects of lipids on pigment gland damage. The increase in lipids apparently affects the ability of the Rietz mill to pulverize the flakes into very fine flours. This is demonstrated by decreased yields of air-classified flours produced from flakes with higher lipid contents (Table III). Protein values similarly decreased with higher flake lipid contents. These protein decreases are not just the effect of lipid dilution on the nitrogen assays, since the same trends hold true when the data are calculated on a lipid-free basis. A compromise between gossypol content and yield must be made. Some sacrifice in lipid recovery during extraction is necessary to obtain products with the lowest gossypol content. A lipid content of approximately 2% appears satisfactory for production of edible products with acceptable yields.

Inadequate removal of hulls and hull pieces from kernels during hulling and purification also contributes to pigment gland damage and subsequent high gossypol, air-classified products. Based on our pilot plant operations, we believe that kernels with about 1% hulls can be produced commercially. Table IV shows that gossypol content of products increased as hull content increased. Hull material is somewhat disintegration-resistant, compared with other kernel components. This fact results in an accumulation of hull material within the Rietz sizing screen area during milling. This buildup of hull pieces acts as an additional grinding medium, which in turn promotes pigment gland damage. Work now under way suggests that hull-induced pigment gland damage is much less pronounced when a pin mill is used for disintegration.

Since drying the flakes before solvent extraction was beneficial in producing low gossypol products, we felt that an additional heating step after desolventization might also be helpful in further toughening the pigment glands. However, little or no differences were observed in gossypol contents of products when the desolventized flakes were dried from 2.5 to 1.0% moisture. Further heating of the flakes after desolventization apparently does not further toughen the glands.

By following the findings of this study (proper kernel purification to 1% hulls, drying of flakes to 2% moisture in a high velocity, through-flow type dryer, and solvent extraction to about 2% lipids), several experimental runs produced cottonseed flours in yields of 35 to 40% with free gossypol contents of 0.040–0.045%.

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