Pretreating Delintered Cottonseed to Increase Yield of Whole Kernels

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Abstract

Pretreatment of delintered glandless seed before decortication by (a) heating seed containing different kernel moistures with live steam followed by drying with indirect heat, (b) heating seed containing different kernel moistures with live steam followed by rapid cooling with air, (c) heating seed containing different kernel moistures with superheated steam followed by drying with indirect heat, and (d) heating seed containing different kernel moistures with superheated steam followed by rapid cooling with air to ambient temperatures, was investigated. Also reported are analytical data which allow an assessment of any changes in protein quality resulting from the treatments applied and data from organoleptic evaluations of treated and untreated glandless cottonseed kernels prepared as high-protein edible nuts.

Introduction

Glandless cottonseed has been under investigation as a source of food protein throughout the present decade. Until the past year, however, attention centered on its use in the production of meals, flours, protein concentrates and protein isolates (1–3). Recently at the Texas A&M University Oilseed Products Research Center (OPRC) a high-protein nutlike product was produced from undefatted glandless cottonseed kernels with a minimum of processing (4). These edible nuts (Tamunuts) were successfully tested as an ingredient in spreads, candies, cookies and other bakery items and in direct consumption snack foods.

It is anticipated that with the availability of glandless cottonseed in commercial quantities a market will exist for whole or coarse glandless cottonseed kernels suitable for use as a source of nut meats.

The present work was conducted to devise processing methods that would increase the yield of whole and coarse kernels during decortication of the seed. This objective was accomplished by pretreating the kernels while still in the hull to render them more resistant to breakage during dehulling.

Experimental Procedures

Screen Analyses of Kernels

At the beginning of these investigations a type and size of hand screen was selected that would retain only kernels large enough for use as Tamunuts. A 4 lb sample of whole and broken glandless kernels was screened through a set of vertically stacked, round-holed 12 in. × 12 in. hand screens ranging from $^{12}/_{64}$ in. to $^{7}/_{64}$ in. in hole diameter. The percentage of kernels retained on each screen was calculated. The procedure was then repeated using a duplicate sample with a similar set of slotted hand screens.

Small Scale Experimentation

The initial phase of investigation was conducted with laboratory scale equipment.

Glandless seed of the Watson GL-16 variety delintered to 4.3% linters content were prepared for treatment by hand screening over a $^{11}/_{64}$ in. × $^{3}/_{4}$ in. slotted screen to remove undersized seed. Experimental units for treatment application were formed from 900 g of screened seed.

A completely randomized statistical design was followed. Six treatments were compared with four replications of each. Treatments compared and the manner in which they were applied were as follows.

Treatment 1. Untreated seed containing 6% kernel moisture. These seed were dehulled directly for use as a control.

Treatment 2. Seed were moistened by spraying to produce 8% kernel moisture when resealed in glass jars and allowed to equilibrate one week.

Treatment 3. Seed containing 6% kernels moisture were steamed at atmospheric pressure with live steam for 4 min and then dried with indirect heat for an additional 2 min and dehulled while hot. Steaming was effected in a thick-walled aluminum kettle, 7 in. in diameter by 7 in. deep (Fig. 1). The seed were stirred during steaming by a sweep-type agitator connected to a low rpm driving shaft overhead. The kettle bottom was heated indirectly by an electric hot plate and the kettle walls by an insulated steam jacket of copper tubing.

After steaming, seed were decorticated in a Bauer Bros. laboratory disc huller. The rotating plate of the huller was $8\frac{3}{4}$ in. in diameter. It was direct-connected to a 3 hp reversible electric motor running at 1750 rpm.

Treatment 4. Seed containing 6% kernel moisture were steamed under atmospheric pressure with live steam for 4 min in the kettle and then removed immediately and spread before a pedestal fan for rapid cooling to ambient temperature before dehulling.

Treatment 5. Seed moistened to 8% kernel moisture were steamed under atmospheric pressure with

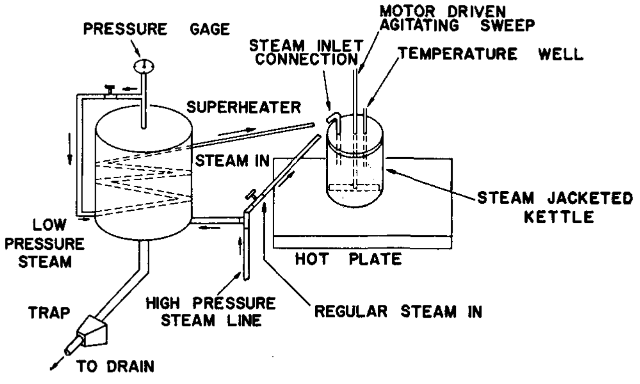

FIG. 1. Cottonseed steaming kettle with connections for live steam or superheated steam.

[1] Operated by the Texas Engineering Experiment Station for the Cotton Research Committee of Texas.

superheated steam for 4 min and then immediately spread before a fan for rapid cooling to ambient temperature.

Again the 7 in. diameter kettle was used, but for this treatment steam was taken from a superheater positioned as shown in Figure 1.

Treatment 6. Seed containing 6% kernel moisture were steamed under atmospheric pressure with superheated steam for 4 min and then immediately spread before a fan for rapid cooling to ambient temperature.

Experimental units of seed were randomly assigned to treatments. Runs were made and treatments applied in random order.

Handling and Analysis of Seed After Decortication

All experimental units, regardless of treatment, received the same handling during and after dehulling.

After dehulling, and separating the hulls and kernels by screening with 14/64 in. round-holed screen, a further separation of kernels into coarse and fine fractions was achieved by pouring the kernels through the airstream of a 16 in. pedestal fan.

The coarse fraction was then rescreened over a 8/64 in. × 3/4 in. screen and uncut seed removed by hand picking.

Samples of the hand-picked 8/64 in. × 3/4 in. plus kernels were analyzed for moisture and volatiles, protein solubility, free fatty acid, and free and total gossypol.

Pilot Plant Scale Investigations

Guided by laboratory scale data, larger experiments were conducted in the OPRC pilot plant. A randomized complete-block statistical design was followed. Six treatments were compared as in the smaller runs but treatments previously used were modified. Also, in the larger tests three replications were made instead of four.

Treatments were applied to experimental units from the same lot of seed previously used. Sixty pounds of seed comprised an experimental unit. The seed were not screened to remove undersized seed.

Treatments compared and the manner in which they were applied were as follows.

Treatment 1. Untreated seed containing 6% kernel moisture. These seed were dehulled directly for use as a control.

Treatment 2. Seed containing 6% kernel moisture were steamed at atmospheric pressure with live steam for 6 min and then dried with indirect heat for an additional 9 min and dehulled while hot.

Steaming was accomplished in a 40 in. diameter cooker manufactured by the French Oil Mill Machinery Co. The cooker had four vertically stacked kettles with sweep-type agitators and steam-heated bottoms. As a matter of convenience, the bottom kettle was used. Steam was injected into the seed as it was circulated.

After steaming, seed were dehulled using a 24 in. diameter Bauer Bros. disc huller mounted over a 36 in. Bauer Bros. No. 153 separating unit. The huller was operated at 894 rpm. Feed rate to the huller was 2100 lb/hr. Prior to the test runs, optimum huller settings were established for dehulling treated and untreated seed. During each test run, uncut seed from the first pass through the huller were recycled through the huller twice more. Hulls were not recycled through the huller.

Treatment 3. Seed containing 6% kernel moisture were steamed at atmospheric pressure with live steam for 6 min and then passed immediately through a rotary air dryer three times for rapid cooling to ambient temperature before dehulling.

The rotary dryer consisted of a cylindrical chamber 2.5 ft in diameter and 11 ft long rotating on its horizontal axis with the discharge end lower than the feed end. It employed a stream of air at an ambient temperature of 90–94 F flowing countercurrently to hot, steamed seed moving through it. Lifting plates on the inside of the cylinder continually elevated the seed and dropped them through the current of air.

Treatment 4. Seed containing 6% kernel moisture were moistened to produce 11% kernel moisture after equilibrating for one week. The moistened seed were dehulled directly from storage.

Treatment 5. Seed moistened to 9% kernel moisture were steamed at atmospheric pressure for 6 min with live steam anad then dried with indirect heat for an additional 9 min before being dehulled while hot.

Nine per cent moisture was produced in the seed by spraying them with water.

Treatment 6. Seed moistened to 9% kernel moisture were steamed at atmospheric pressure for 6 min with live steam and then passed immediately through the rotary dryer three times for rapid cooling to ambient temperature before dehulling.

Runs were selected and treatments applied in random order within each block.

Handling and Analysis of Dehulled Seed

All experimental units, regardless of treatment, received the same handling and analysis after dehulling.

The separating unit divided the kernels into coarse and fine fractions and aspirated the hulls into an overhead cyclone collector. The coarse fraction was weighed and a 2.5 lb representative sample hand screened over a 8/64 in. × 3/4 in. screen. Material retained on the screen was weighed after removing any uncut seed by hand picking.

Samples of the 8/64 in. × 3/4 in. plus fraction

TABLE I

A Comparison of Types and Sizes of Screens for Glandless Cottonseed Kernels

Screen type	Per cent kernels retained on various sizes of screens						
	12/64 in.	11/64 in.	10/64 in.	9/64 in.	8/64 in.	7/64 in.	Less than 7/64 in.
Round holes	4.7	21.3	47.0	20.2	5.1	1.2	0.5 Less than 8/64 in.
Slotted (slots 3/4 in. long)	0.4	1.0	4.6	20.2	30.2	43.9	....

TABLE II

Coarse Kernels Yields from Laboratory Scale Experiments

Treatment No.	Coarse kernels[a] as per cent of delintered seed dehulled	Coarse kernels[a] as per cent of total kernels in seed dehulled
1	29.7	47.7
2	48.9	78.6
3	52.6	84.6
4	49.0	78.8
5	54.3	87.4
6	32.8	52.7

[a] Whole kernels and kernels particles retained on 8/64 in. × 3/4 in. slotted hand screen.

TABLE III

Analytical Data on Coarse Kernels[a] from Laboratory and Pilot Plant Experiments

Treatment No.	Moisture & volatile %	Free fatty acid %	Protein solubility %	Gossypol free %	Gossypol total %
Laboratory runs					
1	5.5	0.30	95.2	0.041	0.046
2	7.7	0.48	96.6	0.040	0.045
3	5.0	0.45	96.1	0.043	0.044
4	5.5	0.49	92.9	0.042	0.042
5	7.1	0.50	92.5	0.036	0.040
6	5.2	0.49	91.2	0.048	0.050
Pilot plant runs					
1	5.8	0.28	96.5		
2	5.5	0.50	94.7		
3	6.8	0.38	96.8		
4	10.7	3.72	97.0		
5	8.7	0.43	94.4		
6	9.2	0.50	97.3		

[a] Whole kernels and kernel particles retained on 8/64 in. × 3/4 in. slotted hand screen.

were analyzed for moisture and volatiles, free fatty acid, and protein solubility.

Organoleptic Evaluation of Tamunuts from Treated Seed

Tamunuts were prepared from each of the six 8/64 in. × 3/4 in. plus fractions of treated kernels by the OPRC toasting process (4). Samples of these nuts were randomly served to judges in accordance with a randomized complete-block design. That is, each judge scored all six treatments (one block) at each of four judging sessions (replications). Tasting sessions were held on consecutive days in midmorning and midafternoon. Each sample was coded to obscure the treatment it had received. In addition, the coding was changed from session to session.

Samples of Tamunuts were analyzed for moisture and volatiles, oil, protein, and protein solubility.

All protein determinations were made using the Kjeldahl method. Soluble protein percentages reflect the portion of the protein that was soluble in 0.02 N NaOH.

Results and Discussion

Table I compares percentages of duplicate samples retained on screens of different types and sizes. Samples screened were taken from the coarse kernels fraction at the separating unit. Untreated glandless seed with 6% kernel moisture were being processed. Material retained on the 10/64 in. round-holed screen was smaller than that retained on the 8/64 in. × 3/4 in. screen and, consequently, less desirable. Twenty-seven per cent of the sample passed through the 10/64 in. screen and 43.9% passed through the 8/64 in. × 3/4 in. screen. Thus, the 8/64 in. × 3/4 in. screen was used to classify kernels as acceptable or unacceptable for use as nuts.

Table II contains data on yields of acceptable kernels from different treatments in the laboratory scale runs. These percentages were calculated after determining the yields, the weights of seed actually dehulled, and the total weight of the kernels in the seed actually dehulled, and adjusting the respective weights to a water-free basis.

An analysis of variance was performed on acceptable kernel yields as per cent of total kernels weight using observations from 24 runs. The differences among treatments were significant at the 5% level.

A 5% Duncan's multiple range test comparison of treatments means showed no significant difference existed between the yields from Treatments 5 and 3. Treatment 5 was significantly higher in yield than Treatments 4, 2, 6 and 1. Yields from Treatments 2, 4 and 3 were not significantly different.

These results showed that steaming delintered seed having 6% kernel moisture produced higher yields of acceptable kernels than a duplicate lot of seed moistened to 8% kernel moisture.

The yield of acceptable kernels was increased from 47.7% of total kernels from untreated seed to 84.6% from the same seed when steamed and dehulled hot.

Table III contains analytical data on acceptable kernels from laboratory and pilot plant runs. Those analyses showed the treatments applied had left the protein quality undamaged as reflected by solubility measurements.

Yield data from pilot plant runs are summarized in Table IV. These percentages were calculated by the same methods as those in Table II.

An analysis of variance showed differences among treatments to be significant at the 5% level. A comparison of treatment means using Duncan's multiple range test showed all treatments to be significantly different from each other at the 5% level except Treatments 4 and 2.

All treatments improved the yield of acceptable kernels over untreated seed. Application of live steam to seed with 6% kernel moisture and dehulling while hot (Treatment 2) produced yields as high as those from seed moistened to 11% kernel moisture. Treatment 2 increased the acceptable kernels yield from 28.8% of total kernels for untreated seed (Treatment 1) to 53.8%. Only Treatments 5 and 6, in which premoistened seed were steamed, exceeded Treatment 2 yields.

The free fatty acid content of Treatment 4 kernels had risen to 9.5% when analyzed 9 days after moistening the seed. Moistening seed to increase the yield of large kernels has disadvantages in that it requires a holding period for the moisture to equilibrate and results in kernels of higher moisture

TABLE IV

Coarse Kernel Yields From Pilot Plant Scale Experiments

Treatment No.	Coarse kernels[a] as per cent of delintered seed dehulled	Coarse kernels[a] as per cent of total kernels in seed dehulled
1	17.9	28.8
2	33.5	53.8
3	30.5	49.0
4	34.2	54.9
5	39.0	62.7
6	42.1	67.7

[a] Whole kernels and kernel particles retained on 8/64 in. × 3/4 in. slotted hand screen.

TABLE V

Free Fatty Acid in Kernels from Treated Seed

Treatment No.	Days elapsed after treatment	Moisture & volatile %	Free fatty acid %
1	9	5.5	0.25
	44	6.0	0.30
	50	5.9	0.30
2	9	5.4	0.50
	44	7.9	0.50
	50	7.6	0.50
3	9	6.5	0.35
	44	6.8	0.40
	50	6.7	0.40
4	9	10.3	9.50
	44	11.0	27.70
	50	11.2	29.50
5	9	7.7	0.40
	44	9.6	10.30
	50	8.9	11.60
6	9	8.9	0.50
	44	9.7	12.80
	50	9.2	13.80

TABLE VI
Analytical and Sensory Evaluation Data on Tamunuts Prepared from Treated Seed

Treatment No.	Mean score	Moisture & volatile %	Oil %	Protein %	Protein solubility %
3	7.05	1.6	41.3	34.69	88.0
2	6.45	1.8	41.3	34.38	85.6
1	6.20	1.7	41.0	32.19	89.0
6	5.60	1.7	41.6	33.63	83.7
5	4.71	1.8	41.3	34.56	90.1
4	3.60	1.9	41.0	31.56	88.5

content. Such kernels can be stored for only a short period before deteriorating in quality. This was apparent in kernels receiving Treatment 4. Free fatty acid data on treated kernels are given in Table V.

Scores assigned Tamunuts by the taste panel reflected flavor and texture damage from some treatments. Table VI contains mean scores assigned each product and corresponding analytical data.

Treatment differences and differences due to judges each proved to be significant at the 5% level. The range test comparison of treatment means showed no significant difference for products from Treatments 3, 2 and 1 at the 5% level. Neither were products from Treatments 2, 1 and 6, nor Treatments 6 and 5 significantly different. A real difference did exist between products from Treatments 4 and 5.

This evaluation indicated that steaming unmoistened seed did not adversely affect the flavor of the kernels. Kernels from moistened seed received the lowest scores. These high moisture kernels were markedly inferior in quality.

An account of the use of steam as a processing technique to overcome extreme brittleness in abnormally dry glanded cottonseed during decortication appeared in the cottonseed processing literature in the 1930's (5). A successfully operated conditioner or humidifier was developed to add moisture to seed by steaming under low pressure prior to hulling, separating and rolling. The procedure reportedly reduced shattering of hulls and kernels in the huller, improved hulls and kernels separation, improved rolling, and produced better meals and oils. No supporting analytical or production data were reported.

The concept of marketing glandless cottonseed kernels for food uses is new to cottonseed processors. It is anticipated, however, that markets will exist for such a product in the future and processors will adopt new processing practices to obtain the highest possible yields of whole kernels and large kernel particles from their seed. These investigations have demonstrated that steaming delintered seed, in the manner described, before dehulling will greatly increase (if not double) the yield of kernels suitable for Tamunuts.

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