Deterioration of Cottonseed Meats During Storage[1]

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Abstract

This work has shown that the prevention of a rise in free fatty acid content during the storage of cottonseed meats is of first importance. No significant effects of storing cottonseed meats upon oil color or gossypol content were found despite the free fatty acid rise. Storage of cottonseed meats is shown to be practical if storage conditions are favorable. This means that the meats should be relatively dry and not allowed to become heated. Screening the meats and storing only the coarser fraction will improve the storage performance.

A useful formula was developed to aid in understanding and predicting the free fatty acid rise which occurs under uniform conditions. The effects of adding fresh screenings from linter motes to the meats stream were found to be minor and unimportant.

Introduction

THE TREND IN THE COTTONSEED PROCESSING INDUSTRY is toward larger processing units and a longer operating season. This means that deterioration of cottonseed and its products is becoming increasingly important. Possible adoption of alternate operating methods has been handicapped by lack of knowledge concerning the storability of such intermediate products as delinted seed or cottonseed meats (kernels).

The storage of cottonseed has been studied extensively (1). Storage at high-moisture contents or at high temperatures promotes the formation of free fatty acid. The rate of acid formation is higher for damaged seed or seed with a high initial fatty acid content. Pigmentation increases during storage. In general, factors affecting seed storage would be expected to affect meats storage. In addition, because of the loss of the natural protective seed coat, deterioration might be expected to be more rapid and possibly to be accompanied by other undesirable phenomena not noticed in the case of whole seed.

Experimental

Semi-plant studies were made in which cottonseed meats were stored different lengths of time at various moisture levels. The stored meats were analyzed and then processed. The products obtained were also analyzed to determine if their quality was affected. The semi-plant program was supplemented by laboratory study of small samples. All analyses were made according to the standardized procedures of the American Oil Chemists' Society.

Procedure

It was necessary to add water to the seed to obtain the higher moisture levels. This was accomplished by adding the desired amount of tap water to the circulating seed in a Kelley batch-feed mixer. Mixing was continued several minutes after all the water was added to assure even distribution. The seed were held in the mixer for one week to permit the added moisture to be absorbed. Twice a day the seed were mixed for 5-minute periods to prevent overheating or local "hot spots." Despite this mixing, seed temperatures rose approximately 15F when moisture contents were high.

Delinting, hulling, and separating procedures were the same for all semi-plant runs. Coarse meats were taken from the top of the lower tray of a Bauer Bros. separator. Few fines were present. The coarse meats obtained at each of three moisture levels were stored 1, 5, 25, and 82 days before processing.

In processing, the coarse meats were flaked by passing them through a Flake-All machine. Flake thickness was approximately 0.03 in. The flakes were extracted with hexane, and the miscellas were distilled in a vacuum still to obtain the product oils. The meals were air-dried to remove hexane. Quality of the oils obtained was measured by determining their free fatty acid content, gossypol content, refining loss, and AOCS-refined-and-bleached colors. Meats were tested for free and total gossypol content.

Data

Table I lists the results obtained. Line 1 shows that free fatty acid content of the coarse meats is a function of both moisture level and storage time. Storage time had considerably more effect at the high moisture level. Lines 2 and 3 shows that coarse meats with high free fatty acid contents yielded, as expected, high acid oils with correspondingly high refining losses. However, despite the variations in free fatty acid content and refining loss, oil colors did not follow any apparent pattern, as is shown in Line 4. Line 5 indicates that high gossypol content oils were produced from high-moisture-level meats (not cooked). Free and total gossypol for meals produced from high-moisture meats was slightly lower (Lines 6 and 7), probably because more gossypol was in the oil.

The principal disadvantage of storing these coarse cottonseed meats was the rise in free fatty acid con-

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TABLE I
Storage Results

Days in storage	7.5% Moisture				8.9% Moisture				13.2% Moisture			
	1	5	25	82	1	5	25	82	1	5	25	82
FFA-oil in coarse meats	0.5	0.4	0.4	0.8	0.4	0.5	0.8	1.5	1.0	1.7	13.6	31.0
FFA-oil produced from coarse meats	1.0	1.0	1.1	1.5	0.9	1.0	1.3	1.8	1.8	2.2	15.2	28.2
Refined loss oil from coarse meats	4.5	4.5	5.4	10.6	5.3	4.5	5.4	7.4	8.5	9.1	34.2	79.6
AOCS-refined-color oil from coarse meats	3.9	3.5	3.9	3.7	3.8	4.0	3.6	3.1	4.8	4.9	3.4	4.1
% Gossypol in oil	.36	.36	.36	.37	.29	.33	.37	.41	.60	.72	.54	.33
% Free gossypol in meal	.76	.82	.84	.76	.92	.89	.79	.75	.51	.31	.66	.61
% Total gossypol in meal	1.14	1.13	1.12	1.04	1.18	1.12	1.03	0.93	.78	.75	.91	.97

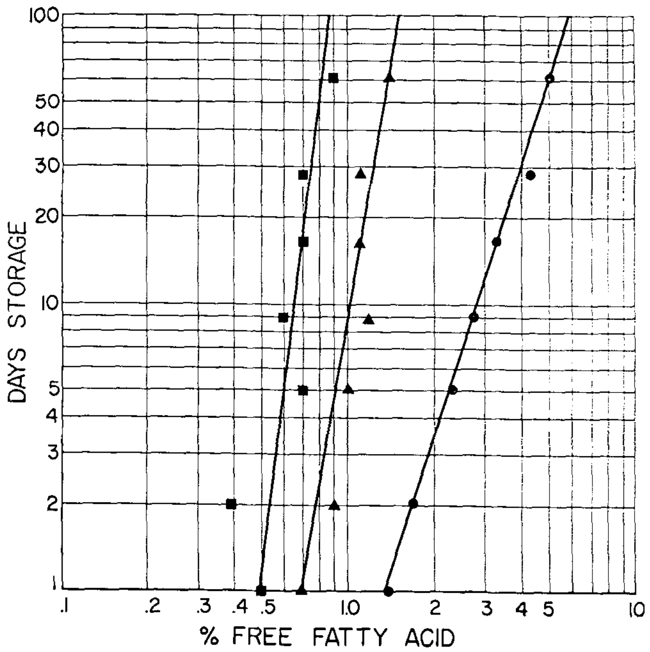

FIG. 1. Free fatty acid changes during meats storage (7.7% moisture in meats).

tent (true for cottonseed also). Because of the importance of free fatty acid rise, factors other than moisture level were investigated to determine their effect. The influence of particle size was studied by subdividing a fresh "mill-run" sample of cottonseed meats as follows. One fraction was the coarse material removed by screening over a ⅛-in. hole diameter screen. One fraction was the fine material which passed through the screen. The last portion was the same as the original sample, containing both fine and coarse meats. These three samples were stored, and their free fatty acid contents were periodically determined. The data are plotted on Figure 1. The finer meats deteriorated much more rapidly.

It will be noticed that these data, when plotted on log-log paper, tend to lie on a straight line. This permits the rise in free fatty acid to be expressed mathematically: $T_2/T_1 = (FFA_2/FFA_1)^K$. T represents time of storage in days, FFA represents the corresponding free fatty acid content, and K is a constant representing the slope of the line when plotted as in Figure 1.

The ability to describe the development of free fatty acid by formula is of theoretical and practical interest. From the practical standpoint only two free fatty acid determinations are necessary to predict future storage effects if storage conditions are unchanged. From the theoretical viewpoint a comparison of K values permits the "storability" of different meats to be noted. When this is done, the initial free fatty acid contents must also be considered. A convenient comparison can be made by computing and comparing the times necessary for a specified rise in free fatty acid content to occur, say, 1%.

Another formula has been described in the literature (2) for predicting the free fatty acid rise in stored cottonseed:

$$d\ FFA/dt = k \times FFA \times (100 - FFA)$$

If the quantity (100 − FFA) is considered constant, which is practically true for low acid concentrations, the formula becomes similar to that for a first-order reaction. When this assumption is made, the two formulas become related and the k values can be compared:

$$k = \frac{\ln \frac{T_2}{T_1}}{T_2 - T_1} \times \frac{1}{100\,K}$$

Thus the k's are related according to the log mean storage time. The validity of this relationship was checked by plotting the data given for cottonseed in Reference 2, as described above, and obtaining the K value. The k was then computed by using the log mean relationship. The resulting numerical value was 0.00034 vs. the k of 0.00036 given in the reference.

To summarize then, a formula was developed for predicting the free fatty acid rise during the storage of cottonseed meats. It was found to apply to cottonseed as well, and it was found to be related to a previously described formula developed for cottonseed. Both formulas are useful only when storage conditions are uniform, and they both require a knowledge of initial conditions when comparisons are to be made.

Further Studies

With the aid of the above information, further studies of free fatty acid development were conducted. Three different samples of cottonseed were selected. Sample A was in the original sacks as received in the laboratory. Sample B was similar to A except that it had been subjected to considerable mechanical handling. Sample C was the same as B, but it had been moistened to 12% moisture, held several days, and redried to the starting moisture content. Despite these different treatments all samples had practically identical analyses.

Meats were prepared from each sample and screened into various fractions. These meats fractions were then stored, and their performancee was determined. The data which were obtained corroborated the straight-line relationship previously discussed. Results are given in Table II in terms of the number of days of storage required to bring about a 1% rise in free fatty acid content.

Although the initial analyses for A, B, and C were the same, the storage performance varied considerably. This is an important observation as it shows that a seed analysis, usually the only information available, is not reliable in determining whether the meats obtained may be safely stored. Mechanical and other abuses apparently affected meats-storage quality. Again, as shown in Table II, the coarse fraction of meats was found to be superior for storage.

The effects of particle size were studied by using larger samples in the semi-plant. Coarse meats taken from the top of the lower separator tray were com-

TABLE II
Days Required for a 1% Rise in Free Fatty Acid

Seed sample	Meats Treatment				Average
	Non-screened	On ⅛-in. screen[a]	On 3 × 38 screen[b]	Through 3 × 38 screen[c]	
A	15.0	120.0	86.0	3.0	56.0
B	6.3	59.0	16.0	2.2	20.9
C	5.4	15.0	11.0	2.4	8.5
Average	8.9	64.7	37.7	2.5	

[a] Meats retained by screen with ⅛-in. diameter holes.
[b] Meats passed by screen with ⅛-in. diameter holes and retained on screen with .03-in. by .38-in. slots.
[c] Meats passed by screen with .03-in. by .38-in. slots.

pared with mill-run meats. In 25 days the mill-run meats gained 0.9% to 1.1% more in acid content than did the coarse meats. Oil colors and gossypol contents were not affected.

In all of the proceeding work the finer meats fractions were substantially higher in initial free fatty acid content than were the coarse fractions. It was felt that the poor storage performance of fines could be attributed to the high initial fatty acid content and not be considered a function of particle size or surface area. An experiment to check this point was made in which some coarse meats were subdivided. A portion was then ground in a food chopper to obtain finer particles. Presumably all fractions then had the same initial fatty acid content.

Again the finer meats deteriorated more rapidly. Their behavior however was peculiar in that, for the first 8 or 10 days of storage time, they did not differ from the coarser meats. The rate of free fatty acid formation then rose abruptly and rapidly.

The mechanism of free fatty acid formation has been studied by many workers (1). Most investigators agree that enzymatic activity is responsible. Some believe that naturally occurring enzymes present in the seed are the principal factor. Others think that enzymes produced by micro-organism activity are responsible (3,4,5). A combination of these two enzyme sources could likely be involved; their relative importance would be determined by existing conditions.

When seed of the same analysis yield meats of widely different storage quality, the cause may be a difference in micro-organism population. Seed receiving more severe mechanical treatment would have a higher percentage of cracked and bruised seed. These could be a source of infection without being plentiful enough to affect the analysis.

The effects of elevated storage temperatures were not studied in the semi-plant because of the many practical difficulties involved. However the desirability of controlling storage temperatures is well established for almost any perishable commodity. Anyone storing cottonseed meats would need to provide for their cooling when necessary.

Oil mills usually drop the screenings from the motes obtained in delinting into the meats stream. This is done because a large percentage of this material is meats resulting from cottonseed which are hulled during the delinting process. An experiment was conducted to determine whether these screenings might injure the oil quality. The motes obtained in delinting 600 pounds of seed were collected, weighed, and screened. The screenings were put through the Flake-All machine, then extracted with hexane. The oil obtained was surprisingly good. It was quite high in chlorophyll pigments content, but these are readily removed in bleaching and are not considered harmful. It is reasonable to assume therefore that no damage results from including fresh motes screenings with the meats stream, especially considering the relatively small portion of screenings which are obtained.

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