ing in almost every part of the continental United States in which cotton is grown.

The average bleach color of the continuously refined oil is approximately equal to the bleach obtained by batch refining.

With cotton oil, a rough idea of the saving in loss to be expected from any given tank of crude may be gained by comparing the ratio of loss to F.F.A. as shown by the settlement sample. When this ratio is low we should expect a somewhat lower saving than when it is high. For instance, to cite a concrete example:

Car	F.F.A.	Settlement Loss	Continuous Loss	% Saving	% Absolute Saving
1	1.4	6.6	4.00	44.4	2.6
2	1.4	5.8	4.10	29.3	1.7

The F.F.A. loss ratio of the first car is nearly normal while that of the second car is low. The continuous process gave almost identical yields of oil with each tank, but the saving in the case of the second was 15% less than with the first.

We have also noted that the relative percentage saving decreases as the F.F.A. of the crude increases, but the absolute saving in refined oil is greater. As an example of this phenomenon:

Car	F.F.A.	Settlement Loss	Continuous Loss	% Saving	% Absolute Saving
1	3.3	11.8	8.8	25.4	3.0
2	8.5	21.9	16.7	24.9	5.2

For an average season the saving in neutral oil throughout the year will amount to approximately 2.5% of the crude refined.

The soap stock produced by the continuous method shows an average F.F.A. of approximately 40.0%.

When corn oil is continuously refined, the saving over conventional batch methods will amount to approximately 25% of the loss normally suffered, and with peanut oil the saving in a comparatively small number of runs on which we have data will amount to approximately 25%.

Work has been done on the possibility of using the Continuous Refining Process for hard oils such as cocoanut, palm and palm kernel. The normal losses by the conventional method on such oils as cocoanut and palm kernel are so low as to minimize the savings possible through loss reduction, so that factors other than reduction in loss must be found to justify the installation of the continuous process on an economic basis. Research along these lines is being continued. However, some refiners are using their washing equipment to wash cocoanut oil with marked success, and have been able to produce as good a washed oil with one wash through the continuous plant as with two or more washes through regular batch equipment.

INTERPRETATION OF COTTONSEED OIL MILL PRODUCTS ANALYSIS

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Hundreds of thousands of chemical tests are made each year on cottonseed and its products, some for settlement purposes, others for control, a few for experimental purposes; a fair proportion, we suspect, are made from habit. What do these tests convey to you? Probably very few of us see in a laboratory certificate all the meaning it carries. The significance of analytical reports varies in considerable degree among the different individuals who have occasion to examine them. To your laboratory-bound and laboratory-minded chemists who make them they often represent hardly more than percentage compositions, although high and low protein values generally spell "loss" to anyone close to an oil mill. To the average mill executive high or low values of certain determinations imply that circumstances or his superintendent is losing or saving him money. The mill superintendent regards laboratory reports as the yardstick of his performance; and well may he! This individual, more closely than anyone, watches the percentages and their daily variations, and considers perhaps their implication regarding the quality of his work rather more than the actual losses or savings represented to his employer. But thanks to this employer, he is not unaware of these.

We have intended to indicate that interpretation of oil mill analyses is generally qualitative. Let us bring the chemical engineering attitude to bear on this matter. Engineering is, above all, quantitative whenever possible. With a slide rule constantly within reach, and accustomed to calculating losses or saving as might be due, for example, to variations in the amount of smoke issuing from his stack, or perhaps to changes in the average daily humidity, we should expect the engineer to examine very inquiringly all the oil mill products analyses for the possibility of quantitatively assigning the effect of variations of the percentages of each of the components or values or properties determined. Unfortunately, the contact between chemical engineers, as a class, and oil mills has been very slight. Although a few superintendents might possess the curiosity and insight to penetrate into the deeper interpretation of their laboratory reports, the majority of them appear to develop their talents rather more on mechanical lines. Admittedly, the problems of an oil mill are very largely mechanical, and it is not surprising that advancement has proceeded principally in this direction.

In this paper, a system of laboratory reporting will be described, which was developed with the purpose of deriving the maximum benefits from chemical control of oil mill operations; or, expressed in plain words, of saving the most money. This is no new aim in the industry, and some of the practices here related also are not new. Our aim has rather been to breathe new life into an old striving by a clear definition of all factors involved, no matter how slight they may appear to be. There is no need to dwell on the necessity of this in these latter days of shrinking spread between manufacturing costs and products' price.

Cottonseed

Our practice in reporting seed results differs in no important respect from the universal one. Under yields, in addition to the oil and cake yield, we report loss in terms of pounds per ton. This figure is determined by the moisture and foreign matter contents and is taken from a table calculated by assuming certain cake, hull, oil, and lint yields and certain moisture contents of these products. The assumption should of course be based on the experience of the locality in which a mill or group of mills occurs. Subtracting the sum of loss and cake and oil yields from 2,000 gives the yield in hulls and lint, which products have been grouped together. A system of lint-cut control based on a direct lint-on-seed determination is in the experimental stage; and should a method of rapid lint estimation, which is being tried, prove to be successful, hull yields and lint yields may be reported separately.

Hulls

The losses due to the hulling and separating operations are probably the most easily evaluated of any of the chemical losses in an oil mill. The meats or meat fragments which go out with the hulls represent just so much cake loss and loss of the oil contained in the meats. The following constituents of hulls are reported: whole seed, meats in whole seed (assumed to be ½ of seed), whole meats, meat dust, and total meats. The calculation of the cake loss from the percentage of total meats is very simple assuming a hull yield of 600 lbs. per ton of seed. It is usual practice to assume meats to be ⅓ oil. As it is so common, however, that meat dust is the only form of meats present, and as varying and uncertain quantities of hull bran may go through the screen with the meat dust in separating it, quantities of these fine screened particles were accumulated and the oil content determined. The average of several determinations was very close to 20%, only ⅗ or 0.6 the oil content assumed for meats. We therefore use a factor of .60 for converting the percent of hull bran-meat dust mixture into percentage of meat dust. The percentage of total meats is divided by three to give the percentage of oil in the meats. Cake loss is given below the analysis expressed in pounds per ton of seed and in cents per ton of seed.

As a basis for calculating oil loss in hulls, one may set an arbitrary value of "total oil in hulls" as representing average good work, and figure a loss or gain in pounds of oil and cents per ton of seed, according to whether the reported value is above or below this standard. Or the minimum amount of oil in clean hulls might be determined by occasionally extracting the hand-separated hulls from carefully hand cut seed, and consider this value as an ideal of practically perfect work toward which the mills should strive. The authors favor and practice this method of evaluation, especially since certain mills under their observation have been able for many days at a time to attain the ideal. Repeated determinations made on seed from various localities in Texas yielded values of the minimum oil content of hulls ranging, in general, from

.15% to .30%. The representative average value adopted was 0.25%. Should, therefore, the total oil figure for a given sample be 0.35% we have,

0.35 — 0.25 = 0.10% oil in hulls above minimum

600 lbs./ton × 0.10% = 0.6 lb., oil loss/ton of seed

0.6 × 4c/lb. = 2.4c/ton, loss

In making out reports in practice the values are rapidly taken from tables calculated for various market prices of the products.

A possible improvement in this method of reporting would result from considering the separating and hulling losses independently. We should have, then:

Hulling Loss or Loss by Absorption

Oil Loss = (% oil in clean hulls — 0.25%) × 6 (lbs./ton seed)

Separating Loss

Cake Loss = 6 × % of total meats (lbs./ton of seed)

Oil Loss = ⅓ × % of total meats × 6 (lbs./ton)

Since ⅓ of the weight of the meats if figured in on two losses, it is apparent that greater accuracy would obtain by taking only ⅔ of the meats percentage for calculating the cake loss. This becomes of importance only in the case of rather high losses.

Cake and Meal

In the cake analysis we find the greatest possibilities for evaluating in monetary units skill in mill operation. Probably no other quantity found on oil mill laboratory reports is watched more closely than is the protein content. Hardly less important is the oil content, the measure of extraction efficiency.

The calculation of the loss incurred by making cake of protein content above or below the basis value involves two factors, one, a loss in both cases, is most conveniently expressed in terms of pounds of cake and cents per ton of seed. The other factor depends on the greater production and consequent lower manufacturing cost resulting from making high protein cake, or corresponding higher manufacturing cost (in cents per ton of seed) when low protein cake is produced. The method of calculating this is best shown by an example, which will give an idea of how a convenient table may be prepared.

Consider the basis to be 43% protein cake and assume a normal yield of 950 lbs. of cake per ton of seed. Then, when the cake contains 44% protein, we have,

$950 \times \frac{44}{43} = 972$ lbs. of cake, which might have been made, or

972 — 950 = 22 lbs. of hulls, which might have been sold as cake.

Since hulls are normally worth about ¼ as much as cake, we take, $22 - \frac{22}{4} =$ 17 lbs. of cake actually lost. A table is constructed giving this loss as well as the manufacturing cost loss or gain for other protein values.

When the protein content is below 42.5%, the loss is figured on the basis of a 12½% discount (04 ⅛) of the contract price of cake for each 1% of ammonia below 8.37%, calculating it preferably back to the ton of seed basis, and making allowance for the increased yield of cake resulting from the admixture of hulls, not neglecting the value of the hulls so added. Thus, for 41% cake, the ammonia deficiency is

8.37 — 7.98 = 0.39%

The deduction is,

12.5% × 0.39 = 4.88%

Assuming a 950 lb. yield of 43% cake, the deduction is, in terms of pounds of cake per ton of seed,

950 × .0488 = 46.4 lbs.

But, $950 \times \frac{8.37}{7.98} = 996$ lbs. of cake is the actual yield.

and, 996 — 950 = 46 lbs. of cake are gained by hull admixture. If the value of hulls is ⅓ that of cake,

$46 - \frac{46}{3} = 31$ lbs., is the net cake gain due to increased yield, and,

46.4 — 31 = 15.4 lbs. of cake is the loss resulting from delivery of low protein cake. Moreover, knowing the cost of working a ton of seed when basis cake is made, it is a simple matter to evaluate for various protein values the increase or decrease in this cost, assuming of course, that the limiting factor in the capacity of the mill is the cake production. If it costs $3.00 to run a ton of seed yielding 950 lbs. of 43% cake,

$\$3.00 \times \frac{43}{44} = \$2.93$, will be required to handle seed yielding 44% cake.

The saving in manufacturing cost is therefore 7c.

Extraction efficiency is measured by the difference between the standard of a given watch sample and a certain "expected standard" calculated from the average analysis of the seed being crushed. In the back of the National Cottonseed Products Association *Rule Book* is a table giving extraction standards in terms of the ammonia content of seed. This is used, although the value found is modified somewhat according to the oil content of the seed, on the assumption, which is confirmed by experience, that the more oil in the seed, the more will be left in the cake. Assuming a certain cake yield, the calculation of the loss or gain in pounds of oil per ton of seed crushed as the actual standard is above or below the expected standard, is obvious. Here again it is desirable to construct a table for ready reference.

Finally, a slight loss or gain above some average condition is found in the cake moisture content. A superintendent who can make basis protein cake containing 9% moisture is saving (assuming 1,000 lb. cake yield) ten pounds of hulls per ton of seed, which, at $6.00 per ton for hulls, is 3c per ton of seed crushed, or for a medium size mill, $3.00 per day.

Crude Oil

The authors prefer to grade crude oil on the basis of its refining loss as compared to an "expected loss" which represents the average value for a particular free fatty acid content. This value is taken from a graph, where the loss is plotted against the free fatty acid content for a large number of samples covering several years of observation. A table is prepared showing this relationship, and adjacent to it, one giving the monetary loss on a ton of seed basis in terms of the difference between the actual loss and the expected loss. Variations in the price of oil must of course be taken into consideration, as well as the value of soap stock.

As an indication of the magnitude of the losses or gains likely to be found in common practice, it might be stated that these may make the difference, over a period of crushing, between profitable operation and operation at a loss, in cases where the economic balance in other respects is close. Various factors besides the skill of the superintendent influence the performance as measured by the above standards. Perhaps the most important of these are, (1) the nature and condition of the seed being worked, (2) the uniformity of the seed from day to day, (3) the nature and condition of the mill equipment. Due consideration of these is necessary for a sane interpretation of calculations made as above. It would be beyond the scope of this paper to discuss all the factors affecting the individual quantities treated here.

In general, hulling and separating losses may vary between zero and 20c per ton of seed. With good equipment they should not be over 5c per ton, gauged by the market values of recent years. With poor equipment they should not rise above 10c per ton.

When working uniform seed, protein fluctuation losses should be lower than 6c per ton of seed, and with good control might well be kept below 4c. However, if the seed is worked out of cars coming from a variety of well separated points of origin, it may reasonably go over 10c. A mill should rarely show a loss due to poor extraction. Gains from low standards might vary between 10c and 30c per ton of seed. This figure for a given poundage varies widely with the market price of crude oil.

Monetary losses chargeable to refining losses above the losses expected from given free fatty acid values may vary up to 15c per ton of seed. The gains due to low refining losses may be as high as 10c per ton, but rarely exceed this figure. This value depends principally on cooking conditions, nature of seed, and the degree of settling of the oil.

In summation, therefore, a mill may show under favorable conditions and with skillful superintendence net gains as high as 20c per ton of seed, and under adverse conditions, with careless and indifferent superintendence, losses as high as 30c per ton, or higher, may result. This is a spread of 50c per ton of seed or 20% of a representative manufacturing cost.

Periodically, reports are made in which the analytical values on all the products reports are averaged, and the average losses and gains are shown for the various products as well as being combined into a net or overall gain or loss. Moreover, at less frequent intervals during the crushing season and at its end, these reports are combined to form a "composite mill report," which shows the performance up to that time. This affords, therefore, a clear comparison of the mill's work, not only between various periods of one season, but between different seasons. In this method, the incentive towards improvement is apparent, while the possibilities for making interesting observations and drawing important conclusions are manifold.