with determination of more complete experimental data. Further study of methyl chloroform may be desirable, especially if it should reach a more favorable price in relation to the other solvents. The cost data used were those of June, 1952, and obviously may vary with time. No evaluation of either the oil or the meal, other than the oil color data in Table III, was made.

Summary

Data for specific-gravity concentration curves were determined for soybean oil miscellas, using methyl chloroform, ethylene dichloride, and propylene dichloride as solvents. Extraction rates of five solvents extracting soybean oil were found to increase in the following order: 1,2,3-trichloropropane, methyl chloroform, ethylene dichloride, propylene dichloride, and trichloroethylene. As the result of pilot plant runs on ethylene and propylene dichlorides and consideration of other data the preliminary conclusion was reached that propylene dichloride could be used at a higher temperature where it would be more satisfactory than ethylene dichloride but less so than trichloroethylene.

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Loss of Oil in Hulling Tung Fruit in the Field and at the Mill

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FOR a number of years the tung oil industry has been interested in the possibility of hulling tung fruit on the farm, provided it can be done economically. The hull fraction constitutes about 55% of the air-dry weight of tung fruit. Hulling in the field would therefore decrease by 55% the weight of material hauled to the mill, leave the hulls on the farm for use as mulch, and relieve the mill of the problem of disposing of the hulls.

The disc huller used in tung mills in this country removes the hulls and breaks or removes a large proportion of the shells. It also damages some of the kernels. From previous experience with other oilseeds it might be expected that a rapid increase in free fatty acids would result through break-down of the oil unless the broken seeds were dried or expressed immediately. This was found to be the case also with tung. The moist broken seed developed free fatty acids rapidly and heated spontaneously unless forced ventilation was used for drying. However, investigations by Holmes, Pack, and Gilbert (1) showed that the hulled nuts can be safely stored and processed efficiently after drying to 10% moisture at temperatures below 175°F. Mills have installed well-designed seed dryers (2), in which nuts previously hulled in the field or at the mill can be successfully dried prior to storage and processing.

The disc huller used at domestic mills can be mounted on a tractor and used in the orchard to hull fruit. This huller operates most efficiently on fruit containing 15-20% moisture (3). Farmers hesitated, at first, to hull fruit in the field because they thought excessive loss of oil might result from this type of operation. A number of growers were willing to hull fruit in the field if they could be assured that no excessive loss of oil occurred.

Tests made at the mills have shown that loss of oil occurs during hulling and as a result of inability to press all the oil from the ground seeds and kernels (3). Laboratory examination of samples of commercial hulls revealed that the loss of oil during hulling resulted from the presence of pieces of kernels and appreciable quantities of oil in the fine portion of the hull material. Microscopic examination of the latter material showed the presence of fine kernel particles which were very oily. The shell and hull particles however contained no oil (3). Data are available which show that the mills recover about 85.5% of the oil in the fruit. In the case of tung nuts hulled in the field the recovery of oil based on the amount of oil in the hulled nuts should be higher, simply because that part of the loss caused by hulling has taken place before the nuts are delivered to the mill.

Materials and Methods

In the hulling operation the partly dried fruit is passed through decorticators and separators to remove the thick hull and the loose shells from the hulled nuts. The hulled nuts are subsequently ground to a meal and pressed to express the oil.

The hulls and shells are aspirated from the seeds and kernels at the mills, and samples of hulls are collected from the bottom of the cyclone. Collecting representative samples of hulls during hulling in the field was more difficult because the hulls aspirated from the separator pass through a long horizontal pipe supported some 20 feet above ground level and are then discharged to the ground. The sampler used during the first season consisted of a large burlap sack supported by a hoop attached to a pole. During the second season the sampler consisted of a long cylindrically-shaped piece of burlap with one opening attached to a large hoop fastened to a pole and the other end open. A cord was attached at the open end so that it could be quickly closed. In collecting a sample, the hoop was placed over the discharge end of the horizontal separator pipe and the other end of the burlap cylinder was closed by drawing the cord.

Samples of whole fruit, hulls, and hulled nuts were collected in the field and at the mills while the fruit was being hulled with the disc hullers.

Since the kernel particles are too small to be separated manually from the hull material, the oil which they contain must be determined by extraction. This analysis is complicated by the fact that the hulls contain a certain amount of non-oil extractable material. Total extract must therefore be corrected for the non-oil portion. Calculation of the oil lost in the hulls to the basis of the original fruit requires a knowledge of the oil content of the hulls, the weight of the whole fruit, and the weight of hulled nuts, or alternatively analyses of the whole fruit, hulled nuts, and hulls. Since in commercial hulling the weights of the whole fruit and hulled nuts are seldom known, it is necessary to use the latter method.

Although the percentages of oil in whole fruit, hulled nuts, and hulls are all that are needed for the calculations, no reliable information was available for correcting the extract from the hulls for the non-oil fraction. An estimate of the magnitude of this correction was obtained as follows: Samples of hulls were separated into a coarse fraction (retained on 0.5-inch screen) and a fine fraction (passing through this screen). Care was taken that all kernel particles passed into the fine fraction. The coarse and fine fractions were ground in a Bauer No. 148 laboratory mill[1] fitted with No. 6912 plates which rotated at 3,600 r.p.m. The plates were adjusted to produce a fine meal (plate setting from 0.006 to 0.010 inch apart). The ground samples were analyzed for moisture and petroleum naphtha-extractable material (4). The extract from the coarse fraction is a measure of the non-oil extractable material in the hulls while that from the fine fraction is a measure of the oil in the kernel particles mixed with the hulls plus the non-oil extractable material in them. The oil in the fine hull fraction is obtained by correcting the extractable material in the fine fraction for the extractable material in the hulls. As the proportion of hulls in the fine fraction is only a little less than 100%, it can be assumed that the non-oil extract of the fine fraction is the same as that in the coarse fraction; therefore the extract from the fine fraction can be corrected by subtracting the extract from the coarse fraction.

Calculations.

Let
a = % oil in whole fruit.
b = % oil in hulled nuts.
$a/b \times 100 = c$ = % hulled nuts, assuming no loss of oil in hulling.
$100 - c = d$ = % hulls.

If
e = % oil in hulls (corrected for substances extracted other than oil).
$d \times e = f$ = oil in hulls expressed as percentage of the whole fruit.
c, d, and f are approximations because some oil is lost in kernel fragments aspirated out with the hulls.

More accurate results can be obtained by a second approximation calculated as follows:

Let
a' = % oil in whole fruit that is left in hulled nuts.
$a' = a - f$.
$a'/b \times 100 = c'$ = % hulled nuts.
$100 - c' = d'$ = % hulls.
$e \times d' = f'$ = % oil lost in hulls on basis of whole fruit.
$f'/a \times 100$ = % of total oil in fruit lost in hulls.

The steps as given above in calculating a', d', and f' can be repeated, and each time the results obtained will be closer approximations of the loss in hulling, but the changes after the second approximation are insignificant. The number of tons of whole fruit required to yield one ton of hulled nuts can be obtained by dividing 100 by c'.

Results and Discussion

Analytical data for the fruit, hulled nuts, and hulls collected during hulling are given in Table I. The above method of calculation, carried through the second approximation, was used to calculate the loss of oil in the hulls expressed as a percentage of the whole fruit.

The percentages of the hulls, shells, and kernels for the first nine samples of whole fruit and hulled nuts are given in Table II to show the proportions of these components in the fruits and in the hulled nuts. The components were separated by hand from a gallon sample of hulled nuts, weighed, the moisture contents determined, and the results calculated to a dry basis.

TABLE II
Components of Nine Samples of Whole Fruit and Hulled Nuts (Dry Basis)

No.	Whole fruit			Hulled nuts		
	Hulls	Shells	Kernels	Hulls	Shells	Kernels
	%	%	%	%	%	%
1	38.7	22.9	38.4	0.9	17.6	81.4
2	41.4	22.6	36.0	5.0	24.7	70.4
3	43.2	22.8	34.0	2.5	24.3	73.3
4	43.1	21.7	35.2	1.1	25.7	73.2
5	41.1	22.3	36.6	0.9	12.3	86.8
6	42.6	22.4	35.0	1.3	20.5	78.2
7	35.9	23.4	40.7	0.6	14.1	85.3
8	......	......	......	2.0	22.3	75.7
9	......	......	......	0.3	27.1	72.6

Practically the only hulls in the hulled nuts were attached to small seeds which passed intact through the shaker screen.

There appeared to be no appreciable difference between the loss of oil during hulling in the field and at the oil mill, provided in each case the hullers were kept in good condition and were properly adjusted. The average loss of oil in the field was found to be 2.8% and at the mill 2.7%. Reference to Table I shows that the loss of oil in hulling varied from 0.6-7.3%; the average was 2.7%. In these hulling operations there was no apparent relation between the moisture content of the fruit and the loss of oil. However analysis of hulls from one mill appeared to indicate that there was an optimum moisture content corresponding to a minimum loss of oil. Tung fruit containing 33.9, 24.3, and 20.2% moisture showed losses of oil of 3.6, 1.7, and 1.3%, respectively, on the basis of the whole fruit.

With an average loss of oil of 2.7% in the field hulling and a recovery of 85.5% of oil at the mill when processing whole tung fruit, the expected overall recovery of oil in processing dehulled tung nuts would be 85.5/(100.0 – 2.7) × 100, or 87.9%.

As shown in Table I, it required an average of 2.18 tons of dry fruit to yield one ton of hulled nuts. This ratio will increase somewhat if wet fruit are hulled as it has been found that the moisture content is

[1] Identification of equipment, by giving name of manufacturer, should not be construed as an endorsement of such equipment by the U. S. Department of Agriculture.

TABLE I
Composition of Hulls and Components of Hulling Operations (Dry Basis)

No.	Location of huller	Moisture in fruit[a]	Oil in fruit	Oil in nuts	Kernel in nuts	Extract in coarse hulls	Extract in fine hulls	Fine hulls in total	Oil lost in hulls (on basis of fruit)	Ratio of fruit to nuts	Oil lost in hulls,% of total
		%	%	%	%	%	%	%	%	%	
1	Field	16.9	23.4	49.7	81.4	1.02	3.51	38.3	0.51	2.17	2.2
2	Mill	18.8	22.2	43.4	70.4	1.13	3.28	50.8	0.55	2.00	2.5
3	Mill	15.5	22.1	47.7	73.3	0.98	2.55	36.9	0.31	2.19	1.4
4	Mill	33.9	22.0	45.7	73.2	1.05	4.15	47.4	0.79	2.15	3.6
5	Field	21.7	22.6	53.5	86.8	0.86	5.97	53.5	1.66	2.54	7.3
6	Field	19.2	19.6	43.9	78.2	0.57	2.23	44.8	0.42	2.29	2.1
7	Field	15.2	24.1	50.4	85.3	1.27	4.25	52.8	0.85	2.16	3.5
8	Mill	16.4	21.1	48.6	75.7	1.06	2.20	41.2	0.27	2.33	1.3
9	Mill	23.0	22.7	45.1	72.6	0.82	2.87	37.2	0.39	2.02	1.7
10	Mill	14.6	24.8	51.6	79.2	1.25	2.38	72.2	0.43	2.12	1.7
11	Mill	20.2	24.4	48.2	74.4	0.83	2.34	43.1	0.33	2.00	1.4
12	Mill	17.2	23.1	46.0	72.2	0.62	3.28	32.4	0.44	2.03	1.9
13	Mill	18.1	26.9	56.8	83.0	1.50	4.26	55.3	1.41	2.19	3.2
14	Field	25.7	23.8	41.9	64.0	0.66	1.52	36.6	0.15	1.76	0.6
15	Field	30.9	20.4	55.8	83.7	1.23	2.96	42.8	0.56	2.82	2.8
16	Field	15.4	22.6	45.2	71.3	1.05	2.59	53.9	0.44	2.04	1.9
17	Field	13.8	25.2	47.3	71.6	1.11	2.67	58.1	0.44	1.91	1.7
18	Mill	15.6	24.4	54.3	81.6	1.56	5.99	61.9	1.62	2.38	6.6
19	Mill	14.7	25.7	51.5	76.1	1.24	4.72	46.5	0.87	2.08	3.4
20	Mill	23.8	24.7	50.4	78.6	1.08	4.57	59.4	1.30	2.16	5.3
21	Mill	14.0	21.7	50.1	75.4	1.69	2.36	44.8	0.19	2.43	0.9
Av.		19.2	23.2	48.9	76.6	1.08	3.36	48.1	0.66	2.18	2.7

[a] On an as is basis.

higher in the hulls than in the nuts except under very unusual conditions.

Summary

Methods for analyzing commercial tung hulls for oil have been developed. Samples of tung hulls from mill and field hulling operations have been collected and analyzed. The loss of oil when the fruit are hulled was found to vary from 0.6% to 7.3%, with an average loss of 2.7% based on the total amount of oil in the fruit. The difference in the loss of oil between grove and mill hulling was not significant. With a loss of 2.7% of the oil in hulling, a recovery of 87.9% oil on the hulled nuts would be equivalent to a recovery of 85.5% oil on the whole fruit.

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An Inexpensive Soap Stock Conversion Plant[1]

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ENGINEERS in the United States have excelled in carrying out large scale chemical plant operations both efficiently and profitably. Very often however the careful planning for maximum economy which goes into large scale plant design is not carried over to small operations. The result is generally discouraging from the point of view of the magnitude of the investment required and the anticipated return on this investment. This paper presents an illustration of the successful application of sound engineering design to the small scale conversion of vegetable oil foots to a crude fatty acid product. This plant (shown in Figures 1 and 2) was designed for a vegetable oil refiner in the Southwest in 1950. Constructed the same year, it has since given over two years of satisfactory operation.

Product Economics

The factors imposing rigid economy on the plant design are to be found in the product economics. At best, the conversion of soap stock (raw foots) to crude fatty acid is a marginal operation. This is seen by a comparison of the recent average delivered value of 1.5c/lb. of 50 wt. % raw cottonseed foots and 3.5c/lb. of the 95 wt. % acidulated foots (i.e., crude fatty acid). On the basis of an average freight cost of 2c/ton-mile and a processing cost of 0.75c/lb. of 95% product, the maximum economical shipping distance for soap stock is seen to be 120 miles.

Thus with the nearest possible consumer 300 miles away, faced with a negligible or non-existent demand for his crude foots and prevented by antipollution regulations from discharging his soap stock into the municipal sewerage system, the refiner had no alternative but to upgrade his crude foots to a marketable product in order to dispose of this waste material. The low profit margin available made it mandatory that the capital investment required to accomplish this processing be held to a minimum without any corresponding sacrifice in process efficiency or increased labor or maintenance costs.

Process Requirements

Processing of the raw foots (soap stock) discharged from the vegetable oil refining plant consists of three basic steps:

a) acidification or acidulation (with 66°Bé sulfuric acid) of the highly basic, diluted soap stock feed to convert the soap into free fatty acids;

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