Pilot-Plant Scale Grinding and Pressing of Jojoba Seeds

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ABSTRACT

Jojoba seeds were successfully milled at ambient temperature using a modified 8 in. single disk attrition mill. Rates to 4000 lb/hr at low energy input (1.7 kwh/ton) were achieved. The oil was expressed with a laboratory screw press at yields from 27. to 33.6%. Multiple linear regression analysis showed the oil yield to be a function of the motor amperage and feed moisture content. The press throughput rate was a function of the motor amperage and the amount of fine and coarse particles in the milled feed.

INTRODUCTION

Jojoba *(Simmondsia chinensis)*, a bush native to the Sonoran desert, yields seeds containing about 50% liquid wax composed largely of esters of straight chain, monounsaturated C_{20} and C_{22} alcohols and acids (1). The oil, as extracted, has a high degree of purity and uniformity and is very resistant to oxidation. Jojoba oil is similar to sperm whale oil in composition and could substitute for it should a large enough supply become available (2).

The cultivation of jojoba bushes for the production of seeds may lead to utilization of the relatively nonproductive arid regions of the Southwest, providing an additional source of income to the people living in these areas.

In 1972 ca. 40 tons of seeds was harvested by Indians in Arizona and California to provide a stockpile for the testing of jojoba oil. About 10 tons of seeds was mechanically pressed at Western Regional Research Center in 1973. Because the seeds are large, about 1/4 in. diameter by 1/2 in. long, milling was required before the oil could be efficiently extracted. Several types of mills were tested, unsuccessfully, until the seeds were frozen to solidify the wax (3). However, freezing is an additional expensive processing step and a way to eliminate it was sought.

This paper describes a method of efficiently milling the seeds at ambient temperature and discusses the subsequent screw pressing of the meal to obtain the oil.

EXPERIMENTAL

About 4000 lb of dehulled jojoba seeds from the 1975 harvest season was received in February 1977. Individual bags were blended using a Marion mixer (Rapids Machinery Co., Marion, Iowa. Serial No. 64061), and stored at room temperature (22-26 C).

Grinding

The seeds were milled at ambient temperature (23-26 C) using an 8 in. single disk attrition mill (CE-Bauer, Springfield, Ohio, style 148-8) driven by a 5 HP motor. The mill was modified by increasing the rotation speed to 3600 RPM and adding 2 L-shaped case wipers to the rotating disk to sweep the housing clear of meal and prevent plugging.

Particle size of a ground product from this type of mill is dependent upon both the type of milling plates used and the spacing between plates. Small samples (3-4 lb) of seed were ground at several plate spacings with each of the plate sets available. The particle size distribution from these ground meal samples was compared to that obtained from a frozen -34 C sample of seeds ground through the Reitz disintegrator (Model RD 9, 3/16 in. screen) as in previous runs. The mill housing and plates were also visually examined for meal buildup.

Two sets of plates were selected for more extensive testing. Set No. I consists of intermeshing devil's tooth plates (No. 8816-8817) with fine pointed teeth which are triangular in cross section and increasing in height toward the plate center. The rotor plate has thin curved feeder blades near the center. Set No. II has intermeshing devil's tooth plates with uniform coarse teeth, tapered and rectangular in cross section by 9/16 in. deep (Fig. 1).

In subsequent grinding experiments with plate sets I and II, 300-lb lots of jojoba seeds were used. The spacing between plates was varied from 0.001-0.035 in. and 0.001-0.150 in. for sets I and II, respectively. Grinder energy consumption on selected runs was measured with a recording wattmeter (Esterline Angus Co., Inc., Indianapolis, IN, Model A6010). The mill was fed at rates sufficient to obtain rated full load amperage (13 amps) on the drive motor.

The particle size distribution of the milled samples was determined by sieving frozen (-23 C) 400-500 g samples for 15 min in a testing sieve shaker (W.S. Tayler Co., Cleveland, OH, Ser. No. 14876) containing U.S. series 12, 14 and 20 mesh screens. Sieving was done in a room maintained at 2 C to prevent melting of the wax and blinding of the screens. The meal retained by each screen was weighed and expressed as a percentage of the original sample weight.

Pressing

Oil was expressed from 300-lb lots of ground seeds using a 200-lb per hour laboratory single screw press (Simon-Rosedowns, Ltd., Cannon Street, Hull, England, Serial No. 6373/2/2) operated at 9.5 RPM. The press is equipped with a steam jacketed feed reservoir (i.e., conditioner) containing an internal rotating mixer arm. Feed was preheated in the reservoir to 80-90 C before pressing. The feed falls from an outlet on the bottom of the reservoir, controlled by a sliding gate, into the hopper feeding the screw. Spacings between the lining bars in the 4 3/8 in. diameter sectioned expeller chamber were 0.025, 0.015 and 0.010 in. for the first, second and third sections, respectively, from the feed entrance. The main screw has

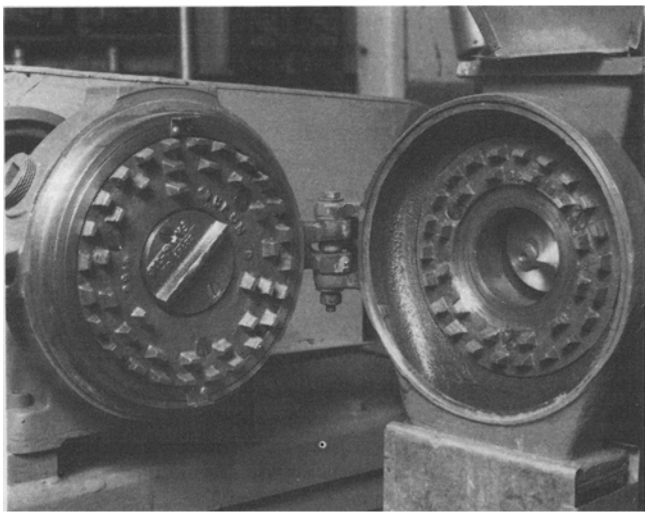

FIG. 1. Attrition mill with intermeshing coarse tooth plates (Set II) and L shaped case wipers in place.

TABLE I

Attrition Mill Data

Attrition mill plate set No.	Plate gap 10^{-3} in.	Energy consumption kwh/Ton	Milling rate lb/hr	Particle size -20 mesh (Fine) %	+12 mesh (Coarse) %
I.	1	15.7	423	80.5	1.6
Small devil	15	12.1	524	72.2	4.8
tooth	35	5.8	1689	47.7	30.0
II.	1	3.2	2648	44.1	24.7
Large devil	70	2.4	3513	39.0	38.0
tooth	150	1.7	4086	30.3	50.3
Rietz (3/16" screen)	---	---	---	35.9	42.2

TABLE II

Screw Pressing Data Used for Stepwise Regression Analyses

Exp. No.	Oil[a] yield %	Pressing rate lb/hr	Pressing moisture %	Press motor amps	Meal particle size -20 mesh (Fine) %	+12 mesh (Coarse) %
1	31.4	208	3.87	8.0	44	24
2	33.2	194	3.53	7.4	75	4
3	33.6	199	3.70	8.2	48	30
4	32.8	139	3.68	8.0	81	2
5	30.9	212	3.84	7.6	39	38
6	30.7	203	4.08	8.1	30	50
7	27.0	207	4.56	8.2	41	29

[a]Based on seed weight. Oil yield based on the total oil would be 2.3 times these values.

3 sections of interrupted auger with pitches of 3, 2.5 and 1.615 in. and 3 tapered sections along its length. The auger shaft diameter increases from 63% of the inside diameter of the cage at the feed end to 86% at the discharge end. The overall compression ratio of the press is about 21:1. Additional pressure is developed by tightening a collar on the discharge end of the press, forcing a cone into, and restricting the opening. The collar was adjusted during operation so the motor was drawing 8-10 amps.

After allowing the press to reach equilibrium conditions, usually 30 min, samples of feed entering the hopper were collected each 20 min. during the experimental run. The oil and pressed cake were collected for 1 hr, weighed and sampled.

The yield of oil was calculated from the weight of pressed cake and oil collected during the 1 hr run. The weight of oil was corrected for the amount of meal that was extruded along with it. This correction ranged from 1.6 to 3.2% of the oil weight.

Samples of milled feed, pressed cake and oil were analyzed for moisture, nitrogen, fiber, ash and fat (ether extractable) according to AOAC methods (4).

RESULTS AND DISCUSSION

Milling of Seeds

The results of the milling experiments with the attrition mill and disintegrator are shown in Table I. For the attrition mill, power consumption ranged from 1.7 to 15.7 kwh/ton and feed rates from 423 to 4086 lb/hr depending on the plate type and plate spacing used. The throughput and power consumption correlated with the amount of fine material (-20 mesh) produced. Set II plates required less power, had greater throughput capacities than Set I, and produced less fine material. Within each plate set, increasing the spacing reduced the amount of fines produced.

The milled feed obtained with plate Set II at a spacing of 0.070 in. has a particle size distribution comparable to that obtained with the disintegrator. Rawles (3) reported a throughput of 700-800 lb/hr for this disintegrator using frozen seeds. Assuming at least half the rated horsepower was used in those experiments, the power consumption was calculated to be 11-24 kwh/ton. Thus, to produce comparable ground seed, the attrition mill used only 10-22% of the power required by the disintegrator and had a throughput five times greater. Perhaps most importantly, the beans could be ground with the attrition mill without being frozen.

While the initial work of Rawles (3) included some runs with the attrition mill, clogging was experienced during operation at 1200-2200 RPM. No clogging was experienced in this work using any of the available plate sets following the modification of the mill to its present condition.

Mechanical Expression of Oil

Results of the pressing experiments using 300-lb lots of seed ground through the attrition mill are shown in Table II. The composition of the starting material and fractionated products are presented in Table III. Oil yields, corrected for sediment, of 27.0 and 33.6% were obtained using feed containing 3.5 to 4.5% moisture. Oil yield was inversely proportional to moisture content. Rawles (3) reported that this press operated best when the feed material was between 3 and 4% moisture. Other oil seeds such as cotton, sesame and soybean give the highest oil yields at moisture contents of 2-3% when screw pressed (5). From Rawles (3) we calculate oil yields of 31.7%, 39.1 and 37.8% for 1974, 1975 and 1976, respectively. We did not attempt to determine the optimum conditions for pressing nor to determine the interaction between moisture content and temperature.

The pressing data were subjected to stepwise regression analysis to determine suitable multiple linear regressions describing the oil yield (%) and pressing rate (lb/hr). Feed

TABLE III

Composition of Jojoba Products[a]

Component	Moisture %	Nitrogen %	Fiber %	Fat %	Ash %
Seed[bc] as received	4.67 ± 0.17	2.31 ± 0.06	6.64 ± 0.30	43.63 ± 1.10	2.18 ± 0.07
Pressed meal[b]	4.27 ± 0.61	3.60 ± 0.06	9.84 ± 0.24	15.33 ± 1.79	3.43 ± 0.14
Wax	0.10	0.04	---	100.00	0.00
Hull	8.38	1.39	14.00	3.53	4.22
Seed, hull free	4.15	2.48	5.83	51.44	1.74

[a]Dry weight basis except % moisture; all values are single analyses except where noted.
[b]Mean value and standard deviation of 7 samples, single analyses.
[c]Seeds as received contained 8.5% hull by weight.

moisture (%), press motor amperage, percent fine particles and percent coarse particles (Table II) were used as independent variables. The final regression equations, which include only those independent variables for which the reduction was significant at $P \leqslant 0.10$, are as follows:

Oil yield (%) = 43.5 + 2.10 (motor amperage) - 7.39 (feed moisture, %); $R^2 = 0.985$.

Pressing Rate (lb/hr) = 667 - 37.2 (motor amperage) - 2.68 (% fine) - 1.62 (% coarse); $R^2 = 0.879$.

The coefficient of determination (R^2) expresses the fraction of variability in the dependent variable explained by its multiple linear regression on the independent variables. Thus, for the oil yield and pressing rate, 98.5 and 87.9% of the variability in the data is explained by the respective regression equations.

The oil yield is determined solely by the press motor amperage and the feed moisture content. The particle size distribution is not significant. This indicates that the Set II attrition mill plates at the widest spacing, giving the highest mill throughput and lowest energy consumption, is the most economical set of grinding conditions among those tested. Our lower oil yields may be explained by the fact that our feed material had a higher moisture content than that of Rawles (3). While the equation is truly valid only over the range of experimental conditions tested, it suggests that significantly higher oil yields can be obtained if the press can be successfully operated with the feed moisture contents of 2-3% found to be optimum for other oil seeds in commercial plants. The pressing rate was dependent on motor amperage and the particle size distribution of the feed material. Press capacity is reduced by running at high motor amperages and by feed material containing large percentages of fine and coarse particles.

The oil content of pressed meal ranged from 13.7 to 18.4% corresponding to oil yields of 33.6 and 27.0%, respectively. With the addition of a cooker and drier to adjust feed moisture and possibly a second pressing of the cake, an increased yield would be expected, resulting in a lower residual oil in the pressed meal. Should the economics be favorable, the remaining oil could be recovered by solvent extraction.

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