Experiments with Vegetable Oil Expression

C. L. Peterson, D. L. Auld, J. C. Thompson
MEMBER
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ABSTRACT

UNIVERSITY of Idaho seed processing research in centered about a CeCoCo oil expeller. A seed preheater-auger, seed bin, meal auger, and oil pump have been constructed to complete the system, which is automated and instrumented. Extracted oil weight, meal weight, process temperature, and input energy are all recorded during operation. The oil is transferred to tanks where it settles for 48 h or more. It is then pumped through a filtering system and stored ready to be used as an engine fuel. The equipment has processed over 11,000 kg of seed with an average extraction efficiency of 78%. Winter rape, safflower, and sunflower have been the principle crops used in the study.

INTRODUCTION

Interest in the feasibility of farmer owned and operated vegetable oil expression facilities prompted this study. The research is one part of a project concerning the use of a vegetable oil as an alternative fuel for the diesel engines used in agricultural production.

Extraction of oil from vegetable oil crops has been the subject of study by many researchers. Equipment and techniques for extracting the oil by both mechanical and solvent methods are well known. Equipment is commercially available from several sources. Recent interest in using vegetable oils such as from rape, safflower, sunflower and peanuts, all of which have from 40 to 45% oil content, has stimulated an interest in a small extraction plant which could be used on one farm or by individuals in a small cooperative. Not many of these small scale presses are known to be in operation in the U.S., although two particular machines have been actively promoted for this use. While the general techniques of operating a large plant are well known by engineers and scientists, the practical problems encountered with the efficient operation of a small press are not well documented.

The University of Idaho has developed an automated plant using a press of 40 kg/h capacity (Fig. 1). A seed preheater-auger, seed bin, meal auger, oil pump, oil storage, and oil filtration equipment complete the system. The plant is automated and instrumented. The press, preheater, oil filtering system, and auger are tied into a central panel where energy use is measured and the process controlled. Most of the equipment, with the exception of the screwpress, was constructed locally.

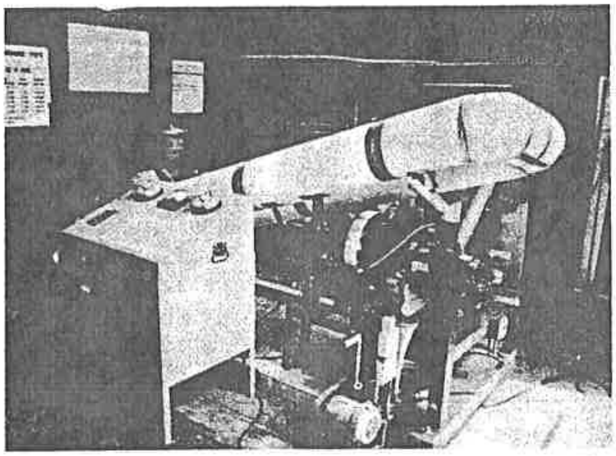

Fig. 1—The University of Idaho small-scale expression equipment.

This automated processing plant is an important part of the total vegetable oil program at the University of Idaho. In addition to providing valuable data on small scale screwpress expression, it also is used to:

1. Provide all of the oil used in the engine testing program.
2. Provide all of the meal used in the animal industries nutrition studies.
3. Process the meal, oil, and oil seeds used for long term storage studies.
4. Provide data used by Agricultural Economics on cost budgets for on-farm processing plants.
5. Supply oil samples, meal samples, and extraction data on experimental varieties in the breeding program.
6. Provide modest amounts of oil to other research programs not associated with the University of Idaho and to test for oil expression for other products including peanuts, millet, and dog fennel (weedseed).
7. Provide information on the feasibility of on-farm oil expression for growers.

REVIEW OF LITERATURE

Extraction of vegetable oils for food and industrial markets is a common practice, carried on successfully in many locations from a variety of vegetable oil sources. Nearly all extraction data reported has been concerned with large scale processing in plants operated by highly technical professionals. The concept of expressing oil by pressure with a screwpress is well known as are the various associated processes (Anjou, 1972; Beach, 1975; Norris, 1981). There is general agreement on the fundamentals of screwpress operation.

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The authors are: C. L. PETERSON, Professor, Agricultural Engineering Dept., D. L. AULD, Professor, Plant, Soil, and Entomological Science Dept., and J. C. THOMPSON, Scientific Aide, Agricultural Engineering Dept., University of Idaho, Moscow.

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The mechanical screwpress has five elements: the main worm shaft and worm, drainage barrel, choke mechanism, motor transmission and bearings, and the loading system. These elements are designed to exceed a pressure of 137 MPa on the seed and should reduce the oil content from 42 to 45% in whole seed to 14 or 15% in the processed meal. Power requirements are approximately 1 kW/Mg of daily capacity. Cooking temperatures range from 77 °C to 105 °C with hold-up times of 15 to 20 min. Longer times promote protein degradation. A minimum temperature of 80 °C is required for myrosinase inactivation. Most plants use a mild pressing operation in which approximately half of the oil is removed avoiding high pressure. The remainder of the oil is solvent extracted.

Screwpressing is a less complex process and has lower investment costs than solvent extraction. The disadvantages are high power consumption, wear, equipment maintenance, residual oil in meal, and high temperatures.

Rapeseed, the most promising fuel oil in the Pacific Northwest, is characterized by small seed size and high oil content. Anjou (1972) suggested the hulls were important to act as supporting material during expression which increased oil yield but lowered feeding value. Some authors prefer crushing of the seed before pressing, whereas, Beach (1975) had the opinion that "cracking prior to flaking was unnecessary and redundant." Beach said the objective was to roll to a flake thickness of 0.2 mm with 0.25 to 0.30 mm the maximum thickness tolerable. Filtration is ordinarily achieved by settling and then forcing the oil through a plate and frame filter system.

Cooking of oilseeds prior to expression is done to break down oil cells, coagulate protein to facilitate oil separation, reduce affinity of oil for solid surfaces, insolubilize phosphatides, increase fluidity of oil, destroy molds and bacteria, and inactivate the enzyme, myrosinase. The latter is essential for oil and meal to be free of hydrolysis products from the glucosinolates.

Considerable data concerning the operation of large commerical plants can be found in the literature, however, information on the operation of small scale plants is much less available. While the basic theory of operation is the same, more problems with quality control, efficiency, and handling and storage of seed, oil and cake are inevitable. Equipment for small scale plants must be manufactured as inexpensively and simply as possible to be economically feasible. Another element is that operating personnel have less training. These factors point to a need for detailed information on the operation of small scale expression equipment.

Manufacturers Simon-Rosedowns (1981), Anderson International (1980), and Chuo Boeki Goshi Kaisha (1981) all have bulletins describing their processing equipment. The smallest has about 40 kg/h capacity. Seed preheaters and some handling equipment are also described.

Research papers on the operation of small units, the range of oil quality expected, and economics of scale could not be found in the recent literature. Morgan and Schultz (1981) stated that "simple, low-cost extraction equipment is needed." They further state that "the literature in key technical areas—oil seed agronomy, oil extraction and conversion, and diesel utilization—is incomplete, especially for less well-known species."

UNIVERSITY OF IDAHO SMALL SCALE PROCESSING PLANT

The flow of materials and operation of the sytem are as follows: The raw product is screened to remove foreign material as it is being dumped into a 100 kg capacity holding bin. The holding bin sits directly over the preheater-auger. On its way to the press, the seed is heated by conduction through the inner and outer walls of a special auger to temperatures ranging from 30 to 60 °C (Fig. 2). Heat is provided by four, 750 W strip heaters in a closed forced air system controlled by two thermostats and protected by a memory limit switch. Before the seed enters the press, it passes over a series of

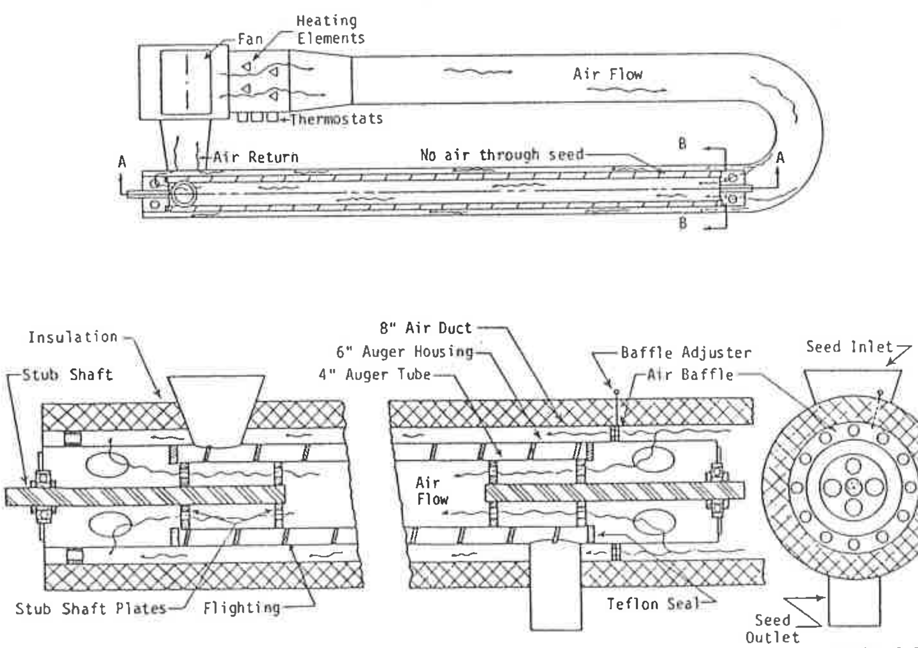

Fig. 2—Schematic of the preheater-auger.

four magnets to remove any metal scraps. The feed auger is controlled through the central panel utilizing a photo cell and related circuitry to keep the press hopper full. The screw press is presently adjusted by hand. The scroll moves in or out with respect to a tapered end bushing and is gaged by the oil flow and the thickness and consistency of the cake. The meal is carried away by a 76 mm auger and collected in bags. The oil flows into a funnel shaped catch-basin that feeds into a squeeze pump. The pump is controlled with a liquid level switch. From there the oil is transferred to a holding tank and allowed to settle for a minimum of 48 h. The oil is then pumped through a 3-stage filter consisting of a recleanable pre-filter, a 20 μm and then a 4 to 5 μm throw away filter.

Finally the oil is stored in drums.

The existing filtration system is technically adequate to provide oil of high enough quality for use in diesel engine tests. However, the cost of the throw-away filters is 2.5 to 3 cents/L. Thus far, materials used in cleanable pre-filters have not had a sufficiently small mesh size to extend significantly the life of the final 4 to 5 μm filter.

Extracted oil weight, meal weight, process temperatures, and input energy are all recorded during the pressing operation. The system requires little supervision; however, a person collecting data has been present during all of its operation. The plant has processed 11.4 Mg of seed and produced over 4 kL of oil in 250 h of operation. An average extraction efficiency of 78% has been obtained to date. Sediment in the oil has averaged 1%. The oil left in the meal has averaged 15.3%. The energy required for the total system has been 0.58 MJ/L. A summary of the data is shown in Table 1.

MAINTENANCE

The operation of the "New Type 52" CeCoCo press is quite simple and requires very little routine maintenance. However, the screw arrangement is vulnerable to foreign material such as metal or rock in the seed. If the tapered end of the scroll becomes scored, the efficiency of the press is drastically reduced. This problem was encountered after about 1400 L of oil had been produced. Precautions were taken, such as screening the seed and incorporating a magnetic metal trap. These measures eliminated particles contaminating the seed, but the problem persisted. Further investigation revealed a worn bushing on the drive end of the scroll allowing it to score against the tapered end ring when adjusted for optimal oil expression. The bushing and shaft were then refitted to true alignment. During the interim, various methods of rebuilding the screw and tapered end ring were explored. The ring was first rebuilt with brass, then a steel insert and finally a spray powder hard facing technique. None of these methods worked satisfactorily. The auger, made of manganese steel, responded well to the spray powder build-up and a turning and polishing operation. The end ring was then bored out to the base cast iron and the resulting combination has worked well. Since these problems have been corrected, over 5.5 Mg of seed have been processed with good success, giving an overall oil expression efficiency of nearly 85%. New parts will be evaluated against the rebuilt parts to gage the effectiveness of the technique.

It should be noted that if the screw fails during the processing of one Mg of seed, $0.20 tp $0.30 extra cost per liter of oil is incurred to replace or rebuild the screw.

TABLE 1. EXPRESSION PROCESS DATA FOR TOTAL SEED PROCESSED 7/8/81 TO 4/9/82 (WINTER RAPE REPRESENTS 90% OF TOTAL)

Seed in, kg	Oil out, kg	Oil out, L	Oil ext., %	Press eff., %	Oil in seed, %
11372	4226	4330	37.2	78.0	45.0

Oil in meal, %	Solids in oil, %	Energy used, MJ/L	Total processing time, h
15.0	1.1	0.58	250

PROCEDURE

Thoughout the operation of the expeller, accurate weights have been kept of seed input, meal, output, and oil. Oil weight was determined with a calibrated digital counter which recorded revolutions of a squeeze tube transfer pump. Seed and meal samples were taken at regular intervals and the oil content was measured on a Newport Nuclear Magnetic Resonance Analyzer. These values were used to calculate press efficiency. Oil samples were evaluated for sediment using filtration and drying methods and for fatty acid content with a gas chromatograph. The temperature at various locations in the preheater and press were measured using thermocouples. Power requirements were tabulated with watt-meters. The meal was evaluated for suitability as a livestock feed by the Animal Sciences Department, Thomas et al., (1982).

SEED TYPES PROCESSED

Three oil seed crops, winter rape, safflower, and sunflower, were selected because of their adaptability to the Pacific Northwest. In addition, peanuts from Georgia and a few other minor crops have also been processed.

Rape: Winter Rape is currently produced on less than 3,000 ha in northern Idaho. Seed yields in excess of 5.6 Mg/ha have been achieved in experimental trials, Auld et al. (1981). Production of winter rape benefits other crops in a cereal-legume rotation by reducing the build-up of pathogens and insects. Winter Rape has been grown in the Palouse of Northern Idaho since 1938. The majority of the seed processed with the equipment described in this paper has been Winter Rape seed of the Dwarf Essex variety. It is easily processed, has a high oil content, and is locally available. The expression percentage has been very good (80 to 88%). The oil flows out clean (1% solids) and the cake is dry and easy to handle. The disadvantage of rape is its high content of erucic acid and glucosinolates which makes the meal toxic. The oil is also quite viscous causing flow problems under cold conditions.

Safflower: An oilseed crop grown in Arizona, California, Montana, and North Dakota, safflower was found to be adapted to the dryland areas of northern Idaho and could be raised commercially if suitable markets were developed, Auld et al. (1981). Safflower seed has a tough hull and requires more power than the other seeds as can be seen in Table 2. The majority of the seed has been fairly trashy and leaves a high sediment in

TABLE 2. A COMPARISON OF EXPRESSION DATA FOR SAFFLOWER, SUNFLOWER, AND WINTER RAPE.

Seed type	Seed in, kg	Oil out kg	Oil out L	Oil eff., %	Press eff., %
Safflower	364	100	106	27	75
Sunflower	91	32	36	35	69
Winter rape	182	67	74	37	85

Seed type	Oil in seed, %	Oil in meal, %	Solids in oil, %	Power require., MJ/L	Proc time/Mg, h
Safflower	36.2	13.2	2.7	0.61	16.5
Sunflower	44.4	16.1	2.9	0.47	16.8
Winter rape	43.7	13.7	0.95	0.29	22.5

the oil. The cake is very coarse but high in protein (24%) and fiber making it a good feed supplement.

Sunflower: Native to North America, most of the sunflowers raised in the U.S. are produced in the Dakotas, Minnesota, and Texas. However, two oil-types were evaluted in Northern Idaho with favorable results, Auld et al. (1981). Traditionally, sunflower seed is hulled prior to a pressing operation. However, due to availability and cost of dehulled seeds, the seeds were processed as is. The sunflower seeds were the most difficult to process as the seed would back up in the chamber. The slick hulls seemed to be causing the problem. Extraction efficiency was the lowest of the seeds evaluated, averaging about 70% (Table 2).

Peanut: The USDA Southern Agricultural Energy center at Tifton, GA provided 45 kg of raw, shelled peanuts to be evaluted in the plant. Tests were made under three temperature conditions, and extraction was found to be very temperature dependent. The seeds were run at room temperature, preheated to 40 °C and finally preheated to 60 °C. Results appear in Table 3. Preheating the nuts increased the extraction efficiency from about 11% up to 88% compared to room temperature processing. The cold seeds, being fairly soft, were forced out through the cage bars when close adjustment was made. Backing off the screw then caused all of the material to be forced past the end ring with little or no oil extracted. When the seeds were preheated to 60 °C, expression proceeded smoothly with high efficiency and a hard dry cake.

Other: Millet and dog fennel have also been tried in small quantities. The oil content of the millet was very low and would not flow through the press without clogging. The dog fennel did yield about 17% oil, but a very disagreeable odor made expression quite objectionable.

An attempt was also made to rerun some wet (high oil content) rape seed meal obtained from operating the press when the scroll was damaged. The consistency of the meal did not lend itself to oil expression. The soft meal was forced through the cage bars similar to the trial with cold peanuts.

TABLE 3. GEORGIA PEANUT EXPERIMENT.

Temp. °C	Seed in, kg	Oil out, kg	Oil out, L	Oil ext., %	Press eff., %	Oil in seed, %	Oil in meal, %	Energy use, MJ/L
22	9.1	0.4	7.27	4.7	11	41.0	40.5	0.79
40	9.1	2.3	0.45	25.0	61	41.0	21.3	0.86
60	18.2	6.5	1.17	36.0	88	41.0	8.5	1.30

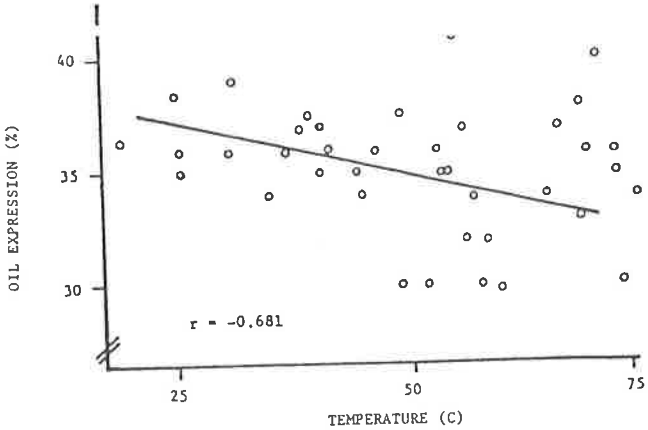

Fig. 3—Oil expression vs. temperature with winter rape seed.

DISCUSSION

Several types of information have been obtained with this press. These include an oil expression versus temperature experiment with winter rape, data on power requirements and expression efficiency at various chronological periods of equipment operation, and a crop and cultivar processing experiment. Each of these will be discussed in relationship to factors important to press operation.

Oil Expression Versus Temperature For Winter Rape.

Most sources advocate heating the seed to 75 to 120 °C and holding it for 30 to 60 min. to increase efficiency. Early studies with the University of Idaho press concentrated on drawing a correlation between oil expression and temperature. The preheater was found to be inadequate to attain temperature above 85 °C, so the highest temperatures used were below those suggested in the literature. It was found that temperature had very little affect on oil expression with winter rape seeds. In fact, a slightly negative correlation was found (Fig. 3). There did seem to be an optimum temperature within the present working range. If seed temperature was held at 40 °C, the press temperature would stabilize at 55 to 60 °C. Oil flow and cake consistency were very good at that point. As the press temperature approached 70 °C, the oil flow dropped off and was reflected in the cake. Similarly, until the press reached a temperature of about 50 °C, the operation was somewhat sluggish. Plans for the immediate future call for building a cooker capable of reaching 120 °C in order to experiment with the recommended temperature.

Press Power Requirements and Expression Efficiency.

Table 4 shows the data collected during four time periods during the life of the press. The initial data were taken when everything was fairly new, including the operator. Experiments were still being designed and methodology developed. Second was a period of

TABLE 4. POWER REQUIREMENTS AND EXPRESSION EFFICIENCY DURING FOUR PHASES OF EQUIPMENT OPERATION.

Dates	Seed in, kg	Oil out, kg	Oil out, L	Oil ext., %	Press eff., %	Comments
7/8/81-8/20/81	3610	1249	1369	34.0	75.2	Initial break-in
8/20/81-11/23/81	1385	366	401	26.5	57.5	Mech. problems
11/23/81-1/12/81	636	191	212	39.9	77.2	Crop/cultivar exp.
1/12/82-4/9/82	5739	2356	2584	41.1	86.3	Mech. prob. solved

operation where mechanical problems were being worked out as discussed earlier. In this phase, the efficiency dropped and considerable oil was lost in the cake. After the problems were corrected, trials were conducted with favorable results. The last period reflected good operation during production of over 2500 L of rape oil.

Seed Type and Cultivar Processing Experiment.

A recent study in cooperation with the Plant and Soil Science Department was performed on four varieties of safflower, two varieties of winter rape, and one variety of sunflower. A summary of the data appears in Table 2. The experiment involved running five, 18 kg samples of each variety through the press and collecting the data for a materials balance analysis as well as time, temperature, and energy data. This information appears on Table 5. Note that significant differences exist between crops and between cultivars within crops showing the usefulness of the system in agronomic studies.

CONCLUSIONS AND RECOMMENDATIONS

One of the objectives of this phase of the energy project at the University of Idaho was to demonstrate the feasibility of a farmer owned and operated vegetable oil plant that would provide a high percentage of liquid fuels needed for crop production. The equipment described in this paper has proved to be a workable system readily adaptable to most farm operations in the Pacific Northwest. Initial investment costs are estimated at $10,000, and production costs range from $0.50 to $1.00/L of oil. The economic balance of using the oil for fuel versus selling it on the open market is obviously unfavorable at current (1983) diesel fuel prices. However, as the availability of fossil fuels diminish and prices rise, the economics could swing in favor of vegetable oil to power U.S. agriculture. It has also been suggested that if plants were established, they could provide oil for existing oil markets with the option of switching the production to fuel use in time of emergency. For additional discussion of the economics of small scale extraction, refer to McIntosh et al. (1982).

TABLE 5. A COMPARISON OF OIL EXPRESSION EFFICIENCY AND POWER REQUIREMENTS FOR TWO CULTIVARS OF WINTER RAPE, THREE CULTIVARS OF SAFFLOWER, AND ONE CULTIVAR OF SUNFLOWER.

	Oil content		
	Whole seed (%)	Meal (%)	Expression (%)†
Safflower			
S-208	35.9 e*	14.0 bc*	73.5 bc*
S-112	36.4 e	12.5 c	76.5 b
UC-1	36.7 e	10.3 d	75.0 b
S-541	38.8 d	12.7 c	75.5 b
Winter rape			
Dwarf Essex	45.9 a	14.4 b	83.4 a
Sidal	41.5 c	13.0 bc	86.5 a
Sunflower			
Hybrid 894	44.4 b	16.1 a	69.9 c

			Oil expression	
	kg/Mg	L/Mg	(h/Mg)	sediment (%)
Safflower				
S-208	262 f*	282.5	16.6 bc*	6.95 a*
S-112	275 e	295.8	16.2 bc	2.91 bc
UC-1	272 e	296.7	16.0 bc	2.52 bcd
S-541	290 d	311.7	17.3 bc	2.58 bcd
Winter rape				
Dwarf Essex	380 a	417.7	18.4 b	1.01 cd
Sidal	358 b	388.9	15.3 c	0.89 d
Sunflower				
Hybrid 894	308 c	334.6	22.5 a	2.91 b

	Energy requirement		
	MJ/h	MJ/Mg	MJ/L
Safflower			
S-208	2.98 a*	49.6 a*	0.174
S-112	3.06 a	49.4 ab	0.166
UC-1	3.00 a	49.5 ab	0.166
S-541	2.92 a	50.6 a	0.161
Winter rape			
Dwarf Essex	1.82 c	33.3 c	0.079
Sidal	2.20 b	33.7 c	0.087
Sunflower			
Hybrid 894	2.02 bc	43.4 b	0.129

* Means within a column not followed by the same letter differ at the 0.05 level of probability by Duncan's multiple range test. Each data point represents the average of five replications, 18 kg per sample.
† Percent of oil in whole seed that was extracted.

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