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QUALITY OF VEGETABLE OIL FROM A SMALL-SCALE EXTRACTION PLANT

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SUMMARY:

The University of Idaho has developed an automated plant using a press of 40 kg/hr capacity. 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. This processing plant is an important part of the total vegetable oil program at the University of Idaho.

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QUALITY OF VEGETABLE OIL FROM A SMALL-SCALE EXTRACTION PLANT

C.L. Peterson and J. Thompson *

Abstract

University of Idaho seed processing research is 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. The press, preheater, cake removal auger, and oil transfer pump are tied into a central panel where energy use is measured and the process controlled. 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 hours or more. It is then pumped through a filtering system and stored ready to be used as an engine fuel. The plant has processed over 11,000 kg of seed with an average extraction efficiency of 78 percent.

Introduction

Extraction of oil from vegetable oil crops has been the subject of intense 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 percent 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/hr capacity (Figure 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, has been constructed locally.

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 extraction it also:

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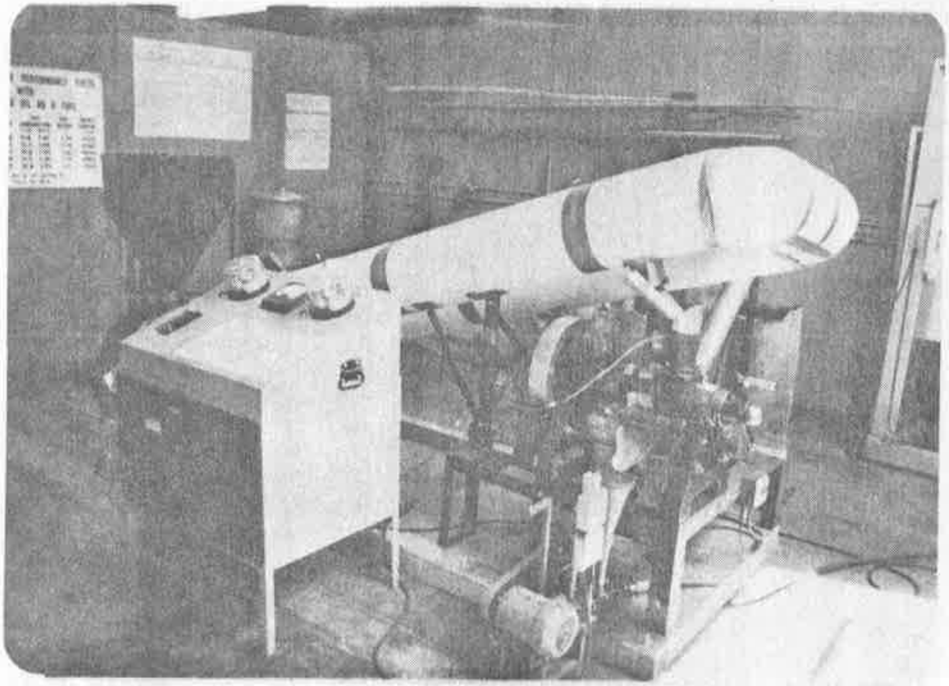

Figure 1. The University of Idaho Small-Scale Extraction Plant.

1. Provides all of the oil used in the engine testing program.
2. Provides all of the meal used in the animal industries nutrition studies.
3. Is used for long term storage studies with meal, oil, and oil seeds.
4. Provides data used by Agricultural Economics on cost budgets for on-farm processing plants.
5. Is used with the breeding program to supply oil samples, meal samples and extraction data on experimental varieties. A recent study compared 4 varieties of safflower, 2 winter rape varieties, and one sunflower variety. Significant differences existed in every category and demonstrated the value of the plant as a research tool.
6. Has been used to provide modest amounts of oil to other research programs not associated with the University of Idaho and to test for oil extraction for other products including peanuts, millet, and dog fennel (weedseed).

Review of Literature

Extraction of vegetable oils for food and industrial markets is a common practice, carried on successfully in many locations with a variety of vegetable oil sources. Nearly all previous extraction data reported has been concerned with large scale processing in plants operated by highly technical professionals. The concept of extracting oil by pressure with a screwpress is well known as are the various associated processes (Anjou, 1971; Beach, 1975; Norris, 1982).

Rapeseed, the most promising fuel oil in the Pacific Northwest, is characterized by small seed size and high oil content. Anjou (1972) suggests the hulls are important to act as supporting material during extraction which increases oil yield but lowers feeding value. Some authors prefer crushing of the seed before pressing, whereas, Beach (1975) has the opinion that "cracking prior to flaking is unnecessary and redundant." Beach says the objective is to roll to a flake thickness of 0.2 mm with 0.25 to 0.30 mm the maximum thickness tolerable.

There is general agreement on the following discussion of screwpress operation (Anjou, 1972; Beach, 1975; Norris, 1982).

The mechanical screwpress has five elements: the main worm shaft and worm, drainage barrel, choke mechanism, motor transmission and bearings, and the loading system.

The press is designed to exceed a pressure of 1,000-1,400 kg/cm^2 on the seed and should reduce the oil content from 42-45 percent in whole seed to 14 or 15 percent in the processed meal. Power requirements are approximately 1 kw per metric ton of daily capacity. Cooking temperatures range from 77°C to 105°C with hold-up times of 15-20 minutes. Longer times promote protein degradation. 80°C is the minimum temperature for myrosinase inactivation. Most plants today use a mild pressing operation in which approximately half or more of the oil is removed avoiding high pressure. The remainder of the oil is solvent extracted.

Crude rapeseed oil has small amounts of phosphatide called "gums" and free fatty acids which should be removed by hydrating with steam or hot water.

Filtration is ordinarily achieved by settling and then forcing through a plate and frame filter system.

Cooking is done to breakdown oil cells, coagulate protein to facilitate oil separation, reduce affinity of oil for solid surfaces, insolubilize phosphatides, increase fluidity of oil, destruct 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.

Anjou (1972) reports that the quality of both oil and meal are markedly affected by the method of cooking. The protein of the meal is often extensively denatured in the cooker, which improves feeding value, but too much heating can cause losses in amino acids. Lysine, an essential amino acid is the most heat sensitive. Overcooking darkens the oil and increases refining loss. Heat treating can also lower the oxidation stability of the oil, which would affect storage life and the amount of anti-oxident additives needed for both oil and meal. Free fatty acid content of the oil is also affected by temperature, moisture, and hold-up time.

Straight screwpressing has the advantages of simplicity and lower investment costs and the disadvantages of high power consumption, wear, and tear on equipment, residual oil in meal and high temperatures.

Information on the operation of small scale plants is much less available. While the basic theory is the same, more problems with quality control, efficiencies and handling and storage of seed, oil and cake are inevitable. Personnel have less training and equipment must be manufactured as inexpensively and simply as possible.

Simon-Rosedowns (1981), Anderson International (1981), and Chuo Boeki Goshi Kaisha (1981) all have bulletins describing processing equipment. The smallest is about 40 kg per hour capacity. Seed preheaters and some handling equipment are also described. Research papers or data 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) in a special report for the American Chemical Society state 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 system are as follows: The raw product is screened as it is being dumped into a holding bin of 100 kg capacity. The holding bin sits directly over the pre-heater 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. Heat is provided by 4 - 750 watt 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 four magnets arranged to remove any metal scraps it might contain. This has proved to be a necessary precaution. The feed auger is controlled through the central panel utilizing a photo cell and related circuitry to keep the press hopper full. The press, a screw type, 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 small 76 mm auger and collected in bags to be distributed to animal scientists for feeding purposes. The oil flows into a funnel shaped catch that feeds into a squeeze pump, controlled with a washing machine type liquid level switch. From there it is transferred to a holding tank and allowed to settle for a few days. The oil is forced through a 3-stage filter unit consisting of a recleanable pre-filter, 20 micron and then 4-5 micron throw away final filters. Finally the oil is stored in drums ready to be used in the engine testing phase of the program.

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 per L. Thus far, materials used in the cleanable pre-filters have not had a sufficiently small mesh size to extend significantly the life of the final 4-5 micron filter. Additional materials including metallic and plastic materials of smaller sieve sizes will be tested. Final filter life as determined by pressure drop through the filter and total cost of filtration per liter of oil are the evaluation criteria.

Extracted oil weight, meal weight, process temperatures, and input energy are all recorded during operation. The system requires a very minimum of supervision, however, a person collecting data has been with the system during all of its operation thus far. The plant has processed 11,370 kg of seed and produced over 4,000 liters of oil in 250 hours of operation. An average extraction efficiency of 78 percent has been obtained to date. Sediment in the oil has averaged only 1 percent, the oil left in the meal has been 15.3 percent. The power required for the total system has been 0.16 kw-hr/L. A summary of the data is shown in Table 1.

Table 1. 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 (%)	Oil in Meal (%)	Solids in Oil (%)	Power Require. (kw-hr/L)	Total Processing Time (hrs)
11372	4226	4330	37.2	78.0	45.0	15.0	1.1	0.16	250

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 in the seed such as metal or rock. If the tapered end of the scroll becomes scored the efficiency of the press is drastically reduced. After about 1400 L of oil had been produced this problem was encountered. Precautions were taken, such as screening the seed and incorporating a magnetic metal trap. These measures were felt to have 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 has been processed with good success, giving an overall efficiency of nearly 85 percent. 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 - 0.30 extra cost per liter of oil is incurred to replace or rebuild the screw.

Data Collection and Analysis

In order to obtain an accurate materials balance, the weight of the seed input is measured against the weights of the products out. An electronic scale was used to take accurate weight measurements. The oil weight was determined with a calibrated digital counter which records revolutions of a squeeze tube transfer pump. Seed and meal samples were taken at regular intervals and oil content measured on a Newport Nuclear Magnetic Resonance Analyzer (NMR). These values were used to calculate press efficiency. Oil samples were also evaluated for sediment using filtration and drying methods and for fatty acid content with a gas chromatograph. Temperature at various locations on the preheater and press were measured using thermocouples. Power requirements were tabulated with amp and watt meters.The meal was evaluated for suitability as a livestock feed by the Animal Sciences Department.

Seed Types Processed

Three oil seed crops selected because of their adaptability to the Pacific Northwest, have been processed in the press. In addition, peanuts from Georgia at the request of USDA personnel, 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 5,600 kg/ha have been achieved in experimental trials. It's production benefits other crops in a cereal-legume rotation by reducing the build-up of pathogens and insects. It has been grown in the Palouse of Northern Idaho since about 1938. The majority of the seed processed here has been Winter Rape seed of the Dwarf Essex variety. It is easily processed, has a high oil content, and is locally available. The extraction percentage has been very good (80-88%). The oil flows out clean (1% solids) and the cake is dry and easy to handle. The disadvantages of rape are its high content of erucic acid and glucosinolates leaving the meal somewhat toxic. The oil is also quite viscous causing flowability 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 can be developed. The safflower has a tough hull and requires more power than the other seeds as can been seen in Table 2. The majority of it has been fairly trashy and leaves a high sediment percentage in the oil. The cake is very coarse but high in protein and fiber making it a good feed supplement.

Sunflower. Native to North America, most of the sunflower raised in the U.S. are produced in the Dakotas, Minnesota and Texas. However, two oil-types were evaluated in Northern Idaho with favorable results. Traditionally sunflower seed is hulled prior to a pressing operation, however due to availability and cost, the seeds could not be hulled and were processed as is. Some difficulty was experienced in pressing 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%, see Table 2.

Table 2. Crop/Cultivar Experiment (Summary)

Seed Type	Seed In (kg)	Oil Out (kg)	Oil Out (L)	Oil Eff. (%)	Press Eff. (%)	Oil In Seed (%)	Oil In Meal (%)	Solids In Oil (%)	Power Require. (kw-hr/L)	Proc Time/Mg (hrs)
Saffl.	364	100	106	27	75	36.2	13.2	2.7	0.17	16.5
Sunfl.	91	32	36	35	69	44.4	16.1	2.9	0.13	16.8
W. Rape	182	67	74	37	85	43.7	13.7	.95	0.08	22.5

Peanut. The Southern Agricultural Energy center at Tifton, Georgia provided 45 kg of raw, shelled peanuts to be evaluated 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 percent up to 88 percent 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 extraction 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 percent oil, but a very disagreeable odor made extraction quite objectionable.

Table 3. Georgia Peanut Experiment Trial.

Temp °C	Seed In (kg)	Oil Out (kg)	(L)	Oil Ext. (%)	Press Eff. (%)	Oil In Seed (%)	Oil In Meal (%)	Power Require. (kw-hr/l)
22	9.1	0.4	7.27	4.7	11	41.0	40.5	0.22
40	9.1	2.3	0.45	25.0	61	41.0	21.3	0.24
60	18.2	6.5	1.17	36.0	88	41.0	8.5	0.36

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 expulsion. The soft meal was forced through the cage bars similar to the trial with cold peanuts.

Discussion

Several types of information have been obtained with the press. These include an oil extraction versus temperature experiment with winter rape, data on power requirements and extraction efficiency at various time periods in the life of the plant, and a crop and cultivar processing experiment.

Oil Extraction Versus Temperature.

Most sources advocate heating the seed to 75-120°C and holding it for 30-60 minutes to increase efficiency. Early studies with the University of Idaho press concentrated on drawing a correlation between oil extraction and temperature, however the preheater was found to be inadequate to attain temperatures above 85°C. It was found that temperature had very little affect on oil extraction. In fact, a slightly negative correlation was found (Figure 2). There does seem to be an optimum temperature within the present working range. If seed temperature is held at 40°C the press temperature will stabilize at 55-60°C. Oil flow and cake consistency are very good at this point. As the press temperature approaches 70°C the oil flow drops off and is reflected in the cake. Similarily until the press reaches a temperature of about 50°C operation is somewhat sluggish. Plans for the immediate future call for building a cooker capable of reaching the 120°C range in order to experiment with the recommended temperature.

Data at Various Time Intervals.

Table 4 gives data collected during four time periods during the life of the press. The initial set was taken when everything was fairly new including the operator, and experiments were being designed and methodology worked out. Second was a period of mechanical problems discussed earlier. The efficiency dropped and much oil was lost in the cake. After the problems were corrected, trials were conducted with favorable results. The latest period reflects good operation during production of over 2500 L of rape oil for use in the upcoming engine endurance trials.

Table 4. Data Representing Various Time Periods of Plant Operation.

Dates	Seed In (kg)	Oil Out		Oil Ext. (%)	Press Eff. (%)	Comments
		(kg)	(L)			
7/8/81-8/20/81	3610	1249	1369	34.0	75.2	Initial Break
8/20/81-11/23/81	1385	366	401.6	26.5	57.5	Mech. Problems
11/23/81-1/12/81	636	191	212.0	39.9	77.2	Crop/Cultivar Exp.
1/12/82-4/9/82	5739	2356	2584.4	41.1	86.3	Mech. Problems Solved

Seed Type and Cultivar Processing Experiment.

A recent study in cooperation with the Plant and Soil Science Department was performed on four varities of safflower, two varities of winter rape, and one varity of sunflower. A summary of the data appears in Table 2. The experiment involved running 5 - 18 kg samples of each variety through the press and collecting the data for a materials balance analysis as well as time, temperature, and power 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.

Table 5. Crop/Cultivar Processing Experiment.

	OIL CONTENT		
	Whole Seed (%)	Meal (%)	Extraction (%)[1]
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 EXTRACTION

	kg/Mg	L/Mg	time/Mg (hrs/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

POWER REQUIREMENT

	kw-hr/hr	kw-hr/Mg	kw-hr/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.

[1] Percent of oil in whole seed that was extracted.

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 plant 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 per liter of oil range from 0.5 to 1.00 dollars. The economic balance of using the oil for fuel vs. selling it on the open market is obviously unfavorable at current diesel fuel prices, however as the availability of fossil fuels diminish and if prices continue to rise, the economics may 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.

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