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UNDERSTANDING SOLVENT EXTRACTION OF VEGETABLE OILS

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PREFACE

This paper is one of a series published by Volunteers in Technical Assistance to provide an introduction to specific state-of-the-art technologies of interest to people in developing countries. The papers are intended to be used as guidelines to help people choose technologies that are suitable to their situations. They are not intended to provide construction or implementation details. People are urged to contact VITA or a similar organization for further information and technical assistance if they find that a particular technology seems to meet their needs.

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UNDERSTANDING SOLVENT EXTRACTION OF VEGETABLE OILS

By VITA Volunteer Nathan Kessler

I. INTRODUCTION

Oil is extracted from seeds, beans, and nuts for use as cooking or salad oil; as an ingredient in paint, cosmetics, and soap; and even as fuel.

Historically, such oils have been extracted by wrapping seeds(*) in cloth, and then using devices operated by stones and levers to exert pressure on them.

An improved form of mechanical device, which allowed considerably more pressure to be exerted, involves the use of hydraulically operated rams: a simple, hand-operated cylinder pump is used to press flat plates or hollow cages attached to the hydraulic ram against a fixed-position ram.

This type of press developed into a motorized hydraulic pump system that pressed the seed bag and then released a press cake(**).

The next improvement in extracting oil was the screw press or expeller. Screw presses use an electric motor to rotate a heavy iron shaft, which has flights, or worms built into it to push the seeds through a narrow opening. The pressure of forcing the seed mass through this slot releases part of the oil, which comes out through tiny slits in a metal barrel fitted around the rotating shaft. Expellers have a continuous flow of seed through the machine in contrast to the hydraulic system described above, which uses small, individual packages or batches of seed. To release as much oil as possible, the seeds must be dried to rather low moisture content and exposure to high temperature causes darkening of the oil. It also causes some scorching or

(*) The term seed, or seeds, will be used in this report to include all seeds, beans, and nuts from which oil can be extracted.

(**) Terms in boldface are defined in the glossary at the end of this paper.

overheating of the meal. The meal contains protein which, if undamaged, may be used for either human food, soy flour for example, or animal feed such as soybean meal.

Because most press or expeller processes overheat the meal and leave too much of the high value oil in the seed cakes, methods of extracting the oil with solvents were developed. Seeds (like soybeans) with low oil content are processed by solvent methods alone. In other cases, presses are used first to extract part of the oil; then solvents extract the oil that remains in the seeds.

Because of their efficiency, processes employing solvents to extract vegetable oils in large quantities are in wide use, and solvent extraction equipment is readily available commercially. The basic technology of solvent extraction is simple, but great care should be taken in deciding whether and where it can be used.

Solvent extraction of vegetable oils, which recovers more oil than earlier methods and leaves more usable meal, begins to be economically attractive where large quantities of seed can be processed (at least 200 tons per day for continuous-feed processes); where storage, transportation, power, water, and solvent supply are adequate; and where occupational safety and training standards can be enforced. There are solvent extraction plants with capacities of up to 4,000 tons per day.

II. OPERATING PRINCIPLES

Solvent extraction is simple in principle, but complex in operation. See Figure 1.

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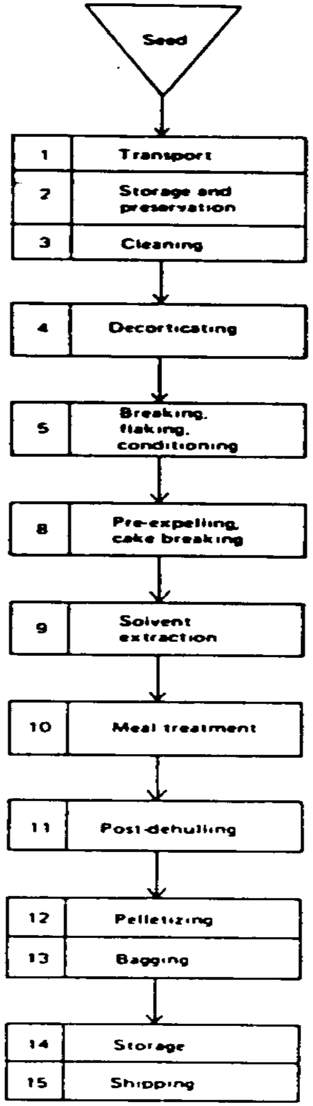

Figure 1. Oil-seed processing: general flow chart

Source: <u>Guidelines for the Establishment and Operation of Vegatable Oil Factories</u>, United Nations Industrial Development Organization, 1977.

The seed is prepared by being cracked into chips. These chips are warmed and passed through smooth flaking rolls. The flaking rolls flatten the chips into paper-thin, flat flakes. The thin flakes can then be treated with solvent, which dissolves or washes the oil out of them. Solvents that boil at fairly low temperatures (65'C) are used so that the solvent can be readily removed from. both the oil and the flakes. Solvent extraction recovers almost all the oil, leaving only one percent or less oil in the flakes.

Unfortunately, most solvents are dangerous to handle, more so than gasoline.

They burn or explode very readily. Therefore, the equipment that extracts the oil and removes the solvent must be airtight and leakproof, and all motors and electrical switches, lights, etc. must be specially designed as vapor-explosion-proof (Class I-D). No matches, no smoking, and no cutting torches, welders grinders, or other heat-producing or spark-producing devices can be permitted where such solvents are used. Careless exposure to sources of fire or sparks (including engines of trucks driven too close to extraction plants) have caused disastrous explosions.

Attempts to find solvents that are not explosive and are economical to use have not yet succeeded. Chlorinated hydrocarbons such as trichloroethylene worked well but were found to create a poisonous by-product in the extracted meal. Solvent extraction plants built in 1950 using trichloroethylene had to be discarded or converted to the commonly used explosive solvent, hexane. Today, all commercial oilseed extraction plants utilize hexane or a similar solvent.

III. DESIGN VARIATIONS

Like pressing, solvent extraction can be done with equipment that processes the oilseed in batches, or with equipment that processes it continuously. A continuous extractor is not considered economically practical unless it processes at least 200 tons per day.

BATCH SOLVENT EXTRACTION

Batch solvent extraction is likely to be the appropriate method if you plan to process less than 200 tons of seed per day, but enough to yield oil in commercial quanitities.

Very few batch plants are in use in the United States today. A batch solvent extraction plant can be as simple as an enclosed steel tank with a false bottom made of screen or metal slats. The flakes are dropped into the tank, where they lie on the false bottom. The tank inlet is closed, and solvent is pumped into flood the bed of flaked oilseed. The solvent is allowed to contact the seed for 10 to 20 minutes; then the drain valve at the bottom (under the false bottom) is opened to complete the extraction.

After the final extract has been fully drained, steam is introduced into the bottom of the extractor. This evaporates the solvent out of the flakes. This combination of steam and solvent is piped as vapor into a condenser that contains water-cooled tubes. The solvent is lighter than water, so it is readily freed of water by standing in a tank from which water is decanted, or

overflowed. The flakes now are nearly solvent free, but are wet from the steam treatment. They are conveyed out of the extractor to a steam-heated dryer to reduce the moisture to about 12 percent for best storage quality.
Most of the washes, or miscellas, are saved and reused on a later batch. However, fresh, oil-free solvent must be used for the final wash of a batch. And the first, oiliest miscella is pumped to a steam-heated, tubular evaporator, which boils most of the solvent out of the mixture, recovering solvent for reuse. The oil then goes to a vacuum stripper, where it is heated to about 100'C and steamed as it passes down through a series of steel baffles or a column of stoneware rings or saddles. The purpose is to expose every portion of the oil to steam, which is needed to remove the last 5 to 10 percent of the solvent from the oil.

CONTINUOUS SOLVENT EXTRACTION

Continuous extractors use conveyors inside vapor-tight housings. The conveyor may be an endless metal mesh belt or a series of sieve-bottom buckets attached to a traveling chain.

Another style uses vertical columns filled with solvent. Flakes are continuously fed at the top and removed from the bottom by a vertical mass-flow elevator. Fresh solvent enters at the bottom, and oily miscella overflows from the top. Still another style uses a rotating carousel arrangement of the extraction baskets or buckets as in the Rotocel: this French Oil Mill Machinergy Company stationary extractor rotates the inlet and outlet assembly above and below stationary sieve-bottom baskets.

In all of these extractors, flaked seeds are conveyed continously into the extractor through a vapor lock or seal which prevents solvent vapors from escaping out of the extractor into the flake conveyor. The flakes are sprayed or wet with miscella as they enter the extractor, and receive several washes with successively more dilute (less oily) miscella. These miscellas drain down through the flakes and through the sieve bottom or belt into pans, which drain into pumps. The pumps transfer the miscella to the next state, from less oily to more oily flakes. In this continuous countercurrent, the oldest solvent miscella (the solvent miscella with the highest oil content), contacts the fresh incoming flakes. The final wash uses oil-free hexane. The flakes are then drained (10 to 15 minutes), and dropped from the belt or the basket into a spent-flake hopper.

From here a mass-flow conveyor lifts the still solvent-wet flakes (containing 35 percent moisture) and delivers them into a desolventizer-toaster. This is a steam-jacketed vessel, usually a vertical set of kettles with gates that allow the flakes to fall from one kettle into the next below while being treated with direct steam. The lower kettles act as dryers to bring the moisture content down to proper levels. Air is drawn to cool the dried hot flakes, either in the lower part of the same vessel or in a separate meal cooler. As in the batch extractor system, the solvent vapors flow to a condenser with water-cooled tubes, and the liquid solvent is separated from the water by decanting.

An older form of desolventizer employs a series of steam-jacketed

paddle conveyors to evaporate most of the solvent. The partially desolventized flakes then crop into a larger conveyor, into which direct steam is blown, removing the rest of the solvent. This form of desolventization was improved by using super-heated hexane vapor to quickly remove most of the solvent. This first step is followed by a steam treatment. However, neither of these methods cooks soybean flakes thoroughly enough to eliminate trypsin inhibitors. For this reason, if the flakes are going to be fed to nonruminant animals, a cooking or toasting stage has to be added: the flakes are heated to about 125"C, reducing their moisture to 18 percent or less. When the flakes are intended for human consumption, this step is not necessary, since they will be cooked before being eaten.

Solvent in continuous systems is evaporated and recovered from the miscella in the same way as in batch systems. However, when solvent is removed from the flakes by the desolventizer-toaster method, the hot vapors from the toaster can be used as the heat source in the first-stage miscella evaporator. This results in important energy savings.

For seed very high in oil, such as cottonseed groundnut or peanut, or sunflower, low-pressure expellers are ususally used to remove part of the oil at reduced cost. This is follwed by flaking and solvent extraction as described above. this pre-pressing is important in cottonseed also because it reduces the antinutritional gossypol material left in the meal. Figure 2 illustrates

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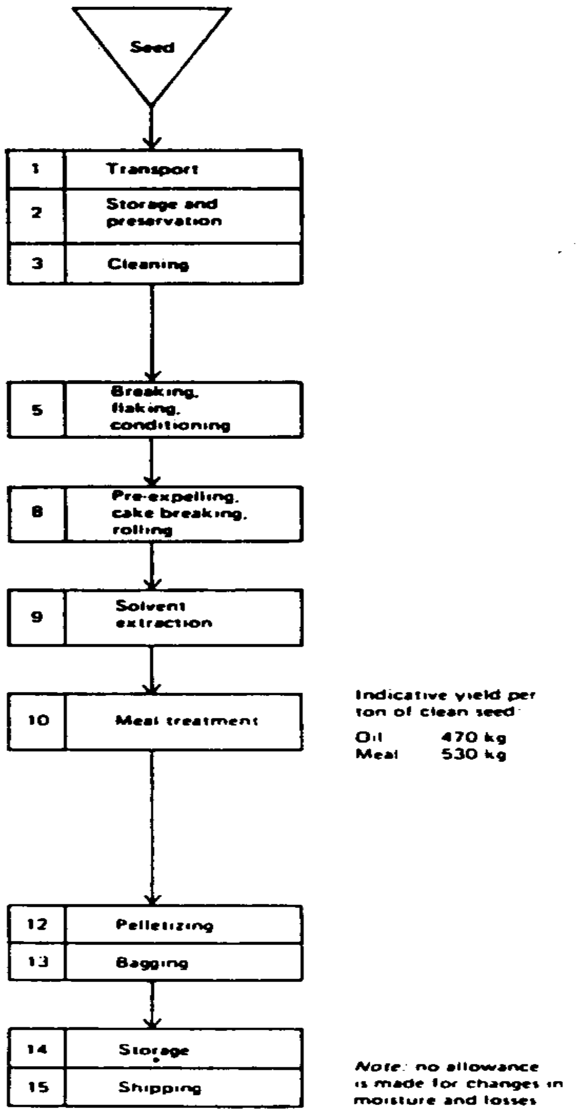

Figure 2. Sesame seed processing

Source: Guidelines for the Establishment and Operation of Vegetable Oil Factories, United Nations Industrial Development Organization, 1977.

the process for sesame seed processing.

IV. FACTORS TO CONSIDER IN PLANNING AN OIL EXTRACTION SYSTEM

Solvent extraction of vegetable oils should be seen as part of a technological and economic system that includes far more than the extraction plant itself. Factors affecting the operation of a solvent extraction plant include: potential markets; nature, timeing, size, and reliability of seed and solvent supply; adequacy and reliability of power, water, and transportation, and of maintenance and storage facilities; and ability to find and train personnel and rigorously enforce safety standards. Table 1 gives inforamtion about some of these requirements.

Table 1. Estimated Requirements for Solvent Extraction of Vegetable Oils

Required per ton of seed processed	Units	Batch processing	Continuous processing
Steam	kilograms	700	280
Power	kilowatt hours	45	55
Water	cubic meters	14	12
Solvent	kilograms	5	4
Labor	person hours	0.8	0.5

Source: Ernesto Bernadini, "Batch and Continuous Solvent Extraction" Journal of the American Oil Chemists' Society 53 (Hybe 1976): 278.

SIZE OF OPERATION

The size of the operation is the most important factor in determining wich kind of process will be used.

For intermediate-scale operations (operations that process up to 200 tons per day), the choice is between batch solvent extraction and expeller (pressure extroaction) systems. Batch solvent extraction systems operate more slowly and less efficiently, are more labor intensive and dangerous, and use greater quantities of solvent than properly designed continuous systems do. Because of these drawbacks, expellers are usually preferred for installations too small for continuous solvent systems. However, there are instances when expeller extraction is not suitable for a small operation; in those cases, batch solvent extraction may be the only practical way to proceed.

Continuous solvent extraction should be considered only for systems that will treat 200 tons or more of seed per day.

SITE AND DESIGN

Solvent extraction plants are complex systems that must be carefully engineered for safety because of their special hazards. Because of the danger of explosion, solvent extraction plants need to be located a safe distance away from populous areas, and to be designed by experienced engineers. Installation of a plant without such engineering of details is a dangerous error.

COST

The cost of solvent extraction plants is much higher than the cost of expeller extraction plants, usually about double. However, since a solvent plant recovers a greater proportion of the oil, it may still be the economically wiser choice. For example, solvent extraction should recover about 40 kilograms more oil per ton from dry soybeans than expeller extraction would.

PRODUCT QUALITY

Not only does solvent extraction yeild more oil, it avoids the overheating of the oil and meal that often occurs with expeller extraction. Solvent-extracted meal can be toasted to optimum food or feed quality.

PERSONNEL AND SAFETY

It takes less labor but more sophisticiation to maintain and operate a solvent extraction plant than to maintain and operate an expeller plant. Two people per shift are required for the former, compared to three for the latter. The dangers of solvent explosion make tightly controlled procedures necessary. Workers must be trained to have a wholesome fear of exposure to the solvent and of solvent leakage.

RELIABILITY OF THROUGHPUT

For continuous solvent installations especially, it is essential to be able to depend on a steady throughput. Unscheduled interruptions of production, or discontinuities because of the inability to transport the finished product, for example, mean that seed will pile up somewhere and possibly spoil, expecially if stroage arrangements are insufficient. Unanticipated interruptions of seed supply may cause buyers of oil and meal to turn to more reliable sources. Both batch solvent and expeller operations are less vulnerable to the effects of such interruptions than continuous solvent operations are.

INTENDED USE OF THE OIL

Since crude oil is usually refined before being used as food, it is necessary to have a crude oil refinery that can handle the volume of oil produced by the extraction plant. Food oil refineries are more complicated to operate and more expensive in equipment costs than solvent extraction plants are. For nonfood uses, such as drying oil, a refinery is not necessary.

GLOSSARY

Expeller A kind of screw press (see below)

Flakes Thin, flat pieces of seed or press cake (see below) prepared for solvent treatment.

Flights Also termed worms--the screw threads in an Expeller or screw press.

Miscella Also termed wash--the liquid, containing oil and solvent, drained after application of solvent to flaked seeds.

Press cake Seed residue left after pressing.

Screw press A press that uses a screw to guide and force seeds through a narrow opening.

Trypsin Inhibitors Enzymes that prevent the breaking down of proteins.

Wash Also termed miscella--the liquid, containing oil and solvent, drained after application of solvent to flaked seeds.

Worms In a screw press the screw threads, or flights, that guide and force seeds through a narrow opening.

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United Nations Industrial Development Organization. Guidelines for the Establishment and Operation of Vegetable Oil Factories, 1977.

SUPPLIERS AND MANUFACTURERS

Sources of equipment and engineering of a complete plant include:

French Oil Mill Machinery Co.
Piqua, Ohio 45356
USA

Extraction technology:

DeSmet SA
Avenue Prince Baudouin 265
B-2520 EDEGEM ANVERS
BELGIQUE

Crown Iron Works
1229 Tyler Street, East
Minneapolis, Minnesota 55440

USA

Blaw-Knox Food & Chemical Equipment Company
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Buffalo, New York 14240 USA

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Rome, Italy

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