Mechanical Extraction

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ABSTRACT

The mechanical screw press was the principal means of extracting vegetable oilseeds in the United States from the 1930s through the 1940s and 1950s. Then the utilization of solvent extraction cut drastically into their use for full extraction, but created a great demand for screw presses for pre-pressing of high oil content seeds for solvent extraction. However, use of the screw press for full extraction has been increasing over the years in the less developed countries, and is the main modern machine utilized for some products such as palm fruit. Today ever larger and more efficient machines are being developed for full extraction and pre-pressing of vegetable oilseeds and fruits.

There have been three eras in the extraction of vegetable oils from the various oil-bearing seeds, nuts and fruits, namely hydraulic pressing, continuous screw pressing and solvent extraction. At the time of my entry into the oil seed extraction field in 1945, the last of the hydraulic oil mills were being built in the U.S.A., and the use of screw presses was at its maximum. Several solvent extraction plants had been built just prior to the start of World War II, and after the war this type of plant began to take over the soybean extraction industry. However, the use of screw presses continued to expand in the cottonseed field up to the end of the 1950's. Today in the U.S.A., the solvent extraction process predominates in the extraction of vegetable oils. There are still many screw press mills operating in the U.S.A. in 1978 on the full extraction of cottonseed, soybeans, peanuts, corn germ, sunflower seed, walnuts and various other seeds. The largest use of screw presses in our country today is as prepresses of high oil content seeds prior to solvent extraction.

In the world as a whole, there are still many screw press mills being built every year for the full extraction of the seeds mentioned above and for copra, palm fruit, palm kernels, rape seed, sesame seed, etc. In fact, screw pressing is the preferred process in many areas and most likely will be for decades to come because of its basic simplicity. Indeed there are many seeds or fruits that do not lend themselves to solvent extraction.

In considering continuous screw pressing, it is necessary to examine fully a typical screw press oil mill. First the seed to be extracted must be accumulated and stored in sufficient volume to insure continuous, uninterrupted runs. It must be stored in such a manner to insure that its quality is preserved. It must be cleaned of trash, sand and any contaminants that will adversely affect the quality of the oil and meal and/or cause excessive wear of the mill's machinery. The accomplishment of this will vary considerably from one oil-bearing material to another, and I won't go into details on how that is done in this paper. It is good practice to have good quality clean raw material at the outset of any extraction operation. From this point on, we have two paths that are frequently followed. One is to take a seed or nut with the hulls or husks intact and extract the oil from this; the other is to do a good job of decorticating. Most manufacturers of screw presses recommend proper decorticating, which permits a more efficient extraction of oil, a higher capacity of presses, a minimal wear on the high pressure screw press and the production of a high protein cake, which is generally a more desirable meal for the mixed feed industry–where most meals are utilized.

Generally we would consider that the mechanical pressing of oil-bearing materials begins with the rolling of the seed or the mastication of the fruit (i.e., copra) in a suitable machine to rupture a substantial percentage of the oil cell walls of the seed or nut. This is of maximum importance in the efficient extraction of cottonseed meats where five high stands of rolls are most usually used. The proper rolling also insures a uniform flake that can be cooked and conditioned properly and a higher quality oil.

The next step is cooking/conditioning. The majority of screw press oil mills the world over use stack cookers employing steam jacketed bottoms, a slow turning vertical stirring shaft with properly designed sweeps to mix the rolled meats, turn them over uniformly, scrape the hot cooker bottom to prevent scorching and insure uniform feeding down through the kettles of the cooker. It is quite uniformly acclaimed throughout the industry that the meats should be cooked with a high moisture content for approximately twenty min, with a minimum of evaporation and a temperature of about 87C. This insures that the action of the enzymes that increase the FFA of the oil will be stopped and rupturing of the oil cell walls will be completed. It is also at this point that the liquid proteins are coagulated, and various toxic substances such as free gossypol are bound. The balance of the decks of the stack cooker are used to dehydrate the meats to the proper moisture for best extraction and to raise the temperature to that most desirable for pressing. A common situation might find a meat of 8% moisture and ambient temperature being introduced into the top of the cooker. The moisture might be increased to 10% by water spray in the top kettle. Then the cooked conditioned meat might come from the cooker after 55 min in the device at a temperature of 115 C and a moisture content of 2.2%.

The third step would be pressing of the oil-bearing material in the screw press. To attain efficient pressing it is absolutely essential that the first two steps are done well, that the cooker be uniformly loaded and stabilized at all times. The screw press itself can take many forms to accomplish a like end, and since I represent perhaps the leading company in the world designing and manufacturing screw presses, I will confine my descriptions to the French Oil Mill Machinery Company screw presses. Essentially the screw press is a screw of increasing root diameter and decreasing pitch revolving in a cylindrical drainage cage. The screw is rotated by a gear box containing gears, shafts and bearings to which is affixed an electric motor. At the discharge end of the rotating screw shaft is a variable orifice to make fine adjustments of the back pressure against the discharging cake.

Specifically the screw press must have an inlet hopper. A variable speed feeder feeds the properly cooked and conditioned oil-bearing material to this hopper at a constant rate. In the French Oil press the vertical hopper has an inner rotating lining revolving past a fixed scraper. The purpose of this is to prevent bridge-overs or blockages of the somtimes sticky meats, which would interfere with an efficient pressing action. The meats fall into a fast rotating "feed screw," which introduces the meats into the pressing cage. In our press this feed screw is a continuation of the main pressing shaft, rotating on the same axis as the main shaft so as to pack the meats in at a uniform rate. This method eliminates or expels the entrapped air and squeezes out the easy to remove oil. In practice this feed screw might be turning at a speed of 122 rpm, and the interaction of the back pressure tends to cause the meats to rotate with the feed screw. This is largely prevented by the employment of a "starwheel," which is a self-indexing wheel turned by the action of the worm flight on the star wheel. This star wheel gives a positive feed action to the feed screw. The partially de-oiled meats are pushed into the low pressure end of the main pressing shaft which might be turning at 42 rpm. If the feed screw has a 4.5 in. pitch and the hub diameter is 5.25 in. with the screw turning in a 7 in. diameter cage, the screw would move 73.4 cubic in. each revolution. At 122 rpm this would be 8955 cubic in. per minute. The first worm of the low pressure end of the main pressing shaft normally would have a hub diameter of 5.25 in. and a pitch of 6 in. The carrying capacity is 101 cubic in. per revolution and 4,241 cubic in. per min. One can see right away that we have a compression ratio of 2.11:1 at the very beginning of the shaft and cage. It is essential that this pressure area be surrounded by drainage bars with adequate spacings between them to provide sufficient hydaulic drainage for the easy to remove oil that is under relatively low pressure. The following worm normally would have a pitch of 4.5 in. and the same hub diameter of 5.25 in., giving it a carrying capacity of 73.4 cubic in. per revolution or 3083 cubic in. per minute, further increasing the pressure. A well designed shaft arrangement will bring the pressure up at a uniform rate by having a series of worms of increasing hub diameters with a reduction in pitch. The total compression ratio in this section might be 6:1 as far as the contribution of the worms. However, there are additional factors at work. The work flights are spaced by collars which permit the intrusion of breaker bar lugs into the shaft space. These lugs or knives are necessary to prevent the rotation of the compressed mass of oil-bearing material from rotating with the shaft. These collars are of variable lengths, say from 1.5 in. to 6 in., and for many seeds are tapered. In other words, the diameter increases on the collars as the compressed meats pass over them. Therefore, these factors are at work compressing the oil-bearing material: the decreasing carrying capacity of the worm shaft thru reduction in speed and pitch, the increase in hub diameter, the utilization of collars, straight or tapered, of varying lengths and, very importantly, the case friction of the cage bars that form the drainage cage as the compressed material is pushed through it. The worms in the final high pressure section of the worm arrangement will go up to a hub diameter of 6 11/16 in. with a carrying capacity of 11.73 cubic in. per revolution and an overall capacity of 493 cubic in. per min. Thus, the overall compression ratio of the shaft would be 18:1. These last worms are repeated perhaps six times with ever longer or ever increasing diameter-tapered collars to maintain the high pressure over a long period of time. The maximum pressure attained in a screw press has been measured at 16,000 psi. Of course, a variable size orifice is provided around the discharge end to fix the thickness of the discharging cake and to give a final control on the back pressure. The compression of a shaft is variable due to the use of individual worms and collars that can be assembled in any desired order on a plain keyed shaft. Generally one would have to consider a lower compression or less severe shaft arrangement for a low content oil seed and a high compression or severe shaft arrangement for a high oil seed. Of course, here one must also consider the structure of the product being pressed. A peanut has very little fiber if all hulls are removed, and the back pressure due to the friction of the fiber would be minimal. However, copra has considerable fiber after most of the oil is pressed out, and a considerable back pressure is contributed from the action of this fiber as it is pressed thru the cage.

One must consider that the design of pressing worms is a compromise of many factors. First the worm acts as a conveyor, and the axial movement through the cage is to be considered. However, as the oil-bearing material is compressed, the radial pressure against the cage bars and the desired movement of the oil radially to the bars and through the drainage slots is a factor. The rotational factor contributed by the friction of the worm flight and worm body adds to the compression and shearing action, but this must be counteracted by the interruptions in the flight, into which are placed the collars and breaker bar lugs. In practice it is accepted that the best worms will have a flight that wraps somthing less than the full 360 degrees, perhaps 345 to 350 degrees, or an interrruption of about one in. or less This, of course, permits back flow cake and oil which is a useful factor in pressing. The intense pressures attained and the presence of fibers, proteins and abrasive foreign materials makes it necessary to build the worm of a highly abrasion resistant material of a given frictional component. Normally steel worms are overlaid with hardcoating materials of given types for given oil-bearing materials. When the flights wear down, throughput is reduced. Also, as the tips of flights round off due to wear, the axial push of the flight is reduced, and the radial push is increased to the point that excessive solid material tends to be pushed through the screen bars. Collars, especially taper collars, wear down also, decreasing their contribution to the proper back pressure, and they are hard faced and must be maintained. It is obvious that the action of the worm shaft generates considerable heat. This can readily be seen when one looks at cake being discharged from the press. Normally the inside of a piece of cake will be darker and somewhat ironed or glazed over. For this reason, water cooling of the shaft is utilized to dissipate the excess heat, to make a bright cake and to increase pressing efficiency.

The cages of most screw presses are lined with screen bars 11 in. long, ½ in. wide and one in. thick. They are usually case hardened, tool steel to give the proper rupture resistance or strength, and hard enough on the exterior to resist abrasion. These bars are spaced with spacers to provide adequate drainage of the oil. One would normally expect wide drainage slots of perhaps .030 in. or more at the low pressure end gradually being reduced to perhaps .005 in at the discharge end. It is part of the normal operation for a certain amount of meal or cake fines to be pressed out with the oil. This is normally called "foots," and is readily removed in proper screening devices and filters. But if one has an insufficient cook/conditioning operation, great quantities of "foots" can be pressed out with the oil resulting in too great an amount of workback and a very inefficient pressing operation. Conversely it is possible to have insufficient drainage in a cage to the extent that the oil cannot readily get out. Then the oil may pass through with the cake, or it might migrate back to the feed section and make a muddy loblolly at the feed screw preventing feed to the press. Usually approximate spacings can be utilized for any given shaft arrangement and oil bearing material, but it is always necessary to experiment with greater or lesser drainage to attain the optimum spacing for a particular seed at any given location and time. Sometimes hard faced screen bars are used in place of the less expensive case hardened, but here the friction contribution of the cage often is upset, letting the pressed material slide through too easily, and oil content of cake rises to too high a level. Of course, one must realize that this cage friction generates considerable heat. On all of our full press screw presses we employ water-cooled cages to insure bright cake and to increase the efficiency of extraction. It has often been observed that upon cooling a cage inadvertently left operating for a shift or more with no cooling water, the amperage increased about 10% on the main motor, and the extraction improved by .25% to .33% in oil left in cake. In the proper operation of water-cooled cages and shafts, it is always best to utilize a soft water system through the screw press and heat exchanger, and a hard water system through the cooling tower and the heat exchanger. For least generation of "foots," it is always best to have the bevel of the screen bar face the rotation of the shaft, resulting in a surface on the inside surface of the cage like a shingled roof. Screen bars tend to stair step, and the sharp edges should always be away from the rotation of the shaft.

Some screw presses have as many as three gear boxes containing bearings and lubricants. We employ one gear box containing all thrust bearings, shafts, gears, oil seals, etc. A well designed gear box should have a continuous service factor well over 1.0, 1½ to 2 service factors being most desirable. B-10 bearing life should never be less than 30,000 hr, and fiber stress on shafts should be kept to less than 60,000 psi to insure decades of trouble free service. Heavy duty screw presses have employed extra heavy bolts to hold the two halves of the cages together. Recently we have perfected and patented heavy duty clamps for this purpose. This greatly reduces the time required to open and close a heavy cage. Our screw presses employ special flange mounted main drive motors with a built in jack, permitting easy and quick change of motor pinions when it is desirable to change the speed of the main shaft.

All in all, the present day heavy duty full press screw press will extract the oil from up to 50 tons per day of oil-bearing seeds or nuts, leaving from 3½ to 4½% oil in cake. Just last week I visited an oil mill in Mississippi operating two D88 screw presses on peanuts. They were single pressing 50 tons of kernels each per 24 hr day to 3% oil left in cake pulling 150 H.P.

We make smaller presses, down to 75 HP and 25 tons per day capacity, and larger presses with 10¼ in. diameter cages and 300 HP Main motors, and capacities up to 100 tons per day single pressing.

Of course, we all are aware of the great numbers of solvent extraction plants in our industry. We have built several hundred such plants ranging from less than 100 tons per day capacity up through 3,000 tons per day capacity. This type of extraction is most efficient on a seed like soybeans. But there are many high oil content seeds that create problems in a solvent plant. Early in the development of solvent extraction plants we converted existing full press screw presses to prepressing. Experience has taught us that the prepress capacity of a conventional full press screw press is ca. double that of its full pressing capacity. Changes in speeds and shaft arrangement are desireable to reach full potential of a conventional press.

It is necessary to consider briefly what we are trying to do with a full press screw press vs. a prepress screw press. In the full press machine we must have optimum rolling and cooking to be sure all oil cells possible are broken and that the oil to be recovered is fully available for the severe pressure of the press. All the oil possible to recover must be taken out in the press and the cake generally is ground or pelletized for feed mixers. In pre-pressing we are only going to remove a portion of the oil. The actual objective is to change the composition of the high oil content seed from a state where the oil holds the fibers together to a state where the fibers are brought into contact with one another and will support the meal when the oil is washed out with solvent. In a way, the pressing action is a densifying process. While rolling and cooking are still valuable aides, they are nowhere near so critical as in full pressing. Pressures within the screw press are much less, power required is less, and the wear on pressing worms and screen bars is a small fraction of what it is in full pressing. But the cooking/conditioning and the worm arrangements are important to insure the proper physical state of the pre-pressed cake. The cake cannot be pressed too much or it will seal out the solvent. It is necessary to have a porous cake that is readily permeable with the solvent being used and still be dense enough or have a solid enough structure not to disintegrate into fines when the oil is removed.

In recent years we have developed a family of large capacity prepress screw presses such as the B-2100's and H2-6600's. These machines have single speed shafts rotating in cages of 10¼ in. and 14 in. inside diameter. The B series are equipped with foot mounted motors of 150, 200, and 250 H.P. and are prepressing over 200 tons per day of cottonseed meats, whole seed basis, up to 150-165 tons per day of copra, corn germ (wet process), rape seed, flax seed at 125 tons per day, etc. The H series come equipped with 500 or 600 HP main drive motors and pre-press up to 350 tons per day of safflower or flaxseed and up to 400 tons per day of wet process corn germ.

Here again we have something new in that many processors have a great aversion to rolling a seed that is being prepressed. If a prepress does not do a thorough job of rupturing whole seeds or meats, the extraction in the solvent plant suffers. To help alleviate this condition we have made available special patented notched worms that increase the milling action within the screw press. This takes horsepower and generates heat, but it seems to be of genuine value in several installations. While I have earlier mentioned that the pressures generated in pre-pressing are less than in full pressing, we must be conscious of the fact that in large diameter presses, with large throughputs, and putting in 200, 250, 500, or 600 HP, tremendous torques and linear thrusts are generated. A machine of these high capabilities must be well designed to stand up to the service you require of your oil mill machinery.

We are manufacturing another type of screw press today for a field untouched by North American manufacturers. This is the low pressure screw press for palm fruit. Here we have large diameter (18 in) perforated screen cages containing a special shaft designed to press out palm oil without rupturing palm kernels. The horsepower utilized is low and the speeds are very slow by any of the standards for other oil-bearing material.