Processing High Oil Content Seeds in Continuous Screw Presses

J.A. WARD, Engineering Director, Simon-Rosedowns, Hull, England

ABSTRACT

This paper covers a range of oilseeds from rapeseed to copra–including groundnuts, cocoa beans, and palmkernels–and gives a very brief definition of screw press operation and its terminology. Screw press operation and its essential similarity to that of the hydraulic stroking press are discussed, including an outline of the functions of the various worm assembly stages and how they are basically achieved and essential objectives which must be met as meal passes along the barrel. Also covered are radial and axial pressure gradients within the machine and their effect on processing of high oil content seeds; rates of pressure buildup within the press and their effect on various different high oil content seeds; and materials of construction. Finally, the effect of seed pretreatment cooking and fines handling on the operation of a screw press on various seeds and essential differences between high pressure pressing and pre-pressing for solvent extraction are discussed.

INTRODUCTION

The seeds accepted as "high oil content seeds" include copra and palmkernels at the hard, fibrous end of the range all the way to groundnuts and sunflower meats at the "soft" end of the range. To keep it to a reasonable length, the paper is confined to some specific aspects of the screw press itself, with reference being made to copra and groundnuts representing two extremes of high oil content seed types. Then we will look at the particular processing techniques of copra and groundnuts. Other high oil content seed processing will be briefly discussed.

THE SCREW PRESS IN OILSEED PROCESSING

If we are first to look specifically at the screw press, we must briefly define the two ways in which it is used to expel oil from oilseeds: first, as a high-pressure operation to low residual oil contents; second, as a pre-press operation prior to solvent extraction or, rarely nowadays, prior to high pressure expelling. Figure 1 shows these two operations as simple flow diagrams. In both cases, the four stages which influence pressing efficiency are: (a) seed preparation, (b) cooking, (c) screw pressing, and (d) separation of solids from expelled oil and return to cooker/screw press.

Unless all four steps are properly done, good results will not be obtained. It is seldom possible to correct fully one bad step, no matter how well the other three operations are performed. For example, a good result from high-pressure pressing of copra is nearly impossible unless adequate drying of the meal is done in the cooking stage; bad solids separation and filtering of expelled groundnut oil can throw a complete operation out of gear.

What is correct in seed preparation and cooking for high pressure operation is not always suitable for the same seed when pre-pressing. When high pressure pressing, the objective is to obtain the maximum value of oil and cake leaving the press consistent with capacity and running costs. In a pre-press operation, the overall objective remains the same but is based on the output of both press and extractor. Often in pre-press operations the degree of rolling is increased and the degree of cooking reduced, sometimes to the detriment of the pressing operation, so that an ultimate superior solvent extraction of the presscake is achieved.

It must be realized also that a screw pressing operation is ultimately self-defeating. The oil in the seed is contained in sacs or fibrous capillaries. The application of pressure causes the capillaries to be reduced in volume and the oil to be expelled, but by the same effect the capillaries are narrowed, sheared, and eventually sealed by the application of increasing pressure. This puts a practical limit, even with all four operations ideally performed, on the lowest residual oil content obtained by a high pressure screw press.

Similarly on a pre-press operation the limit to which the oil-in-cake figure is reduced should be watched. While a low-oil cake is good for solvent/meal ratios and hence for distillation plant efficiency, this can be wiped out by impermeable cake granules or by having to reduce or flake the cake so that the whole extractor bed is itself impermeable. Anyone who has tried to extract 6% oil groundnut cake to a low residual will know what this means.

Hence, in the following discussion on the screw press itself, the place in an overall process must be kept in mind.

Brief Description and Terminology

A screw press is little more than an overgrown mincing machine with a drained barrel. In a simple form, an oilseed screw press has a horizontal main wormshaft which carries the "worm assembly." The worm assembly most commonly comprises a series of hardened or hard-faced "worm sections" spaced apart by hardened or hard-faced "distance pieces." In certain cases, the worm assembly is formed integrally with the shaft and subsequently hard-faced; this is a "solid" assembly.

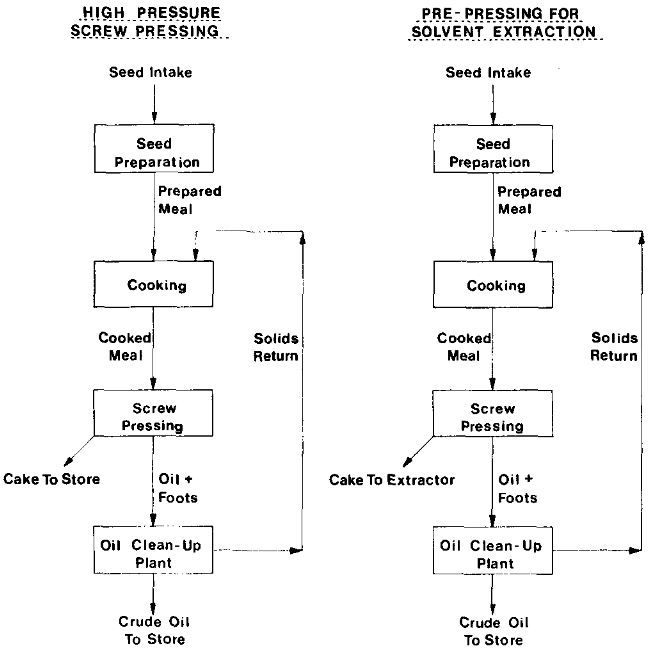

FIG. 1. Flow diagrams.

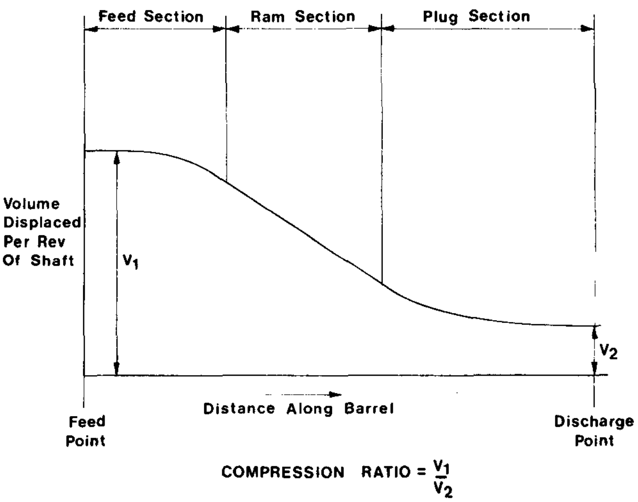

FIG. 2. Compression curve.

The wormshaft revolves within a "barrel" or "cage" which normally consists of axially placed "lining bars" or "barrel bars" contained within substantial frames split on the vertical or horizontal planes. The two halves of the cage are held together by "clamping frames." The lining bars are locked into the cage frames and spaced apart by shims or "spacers." "Knife bars" clamped between the half cages have projecting "nibs" into distance-piece sections of the shaft to assist in preventing meal rotation.

Most screw presses have "feed gear," a means of ramming meal into the press, and "choke gear," a means of adjusting the cake thickness.

The configuration of the worm sections is such that the volume displacement at the feed end of the press is considerably greater than at the discharge end. Hence, as material is conveyed from feed end to discharge end, it is subjected to increasing pressure, and oil is expelled through the slots between the cage lining bars. "Foots" are the solid particles expelled with the oil. "Cake" is the de-oiled material discharged from the press.

The "compression ratio" of a press is simply volume displaced per revolution at feed end divided by volume displaced per revolution at discharge end. The compression curve of a press is a plot of volume displacement to a base of length along the barrel, shown in Figure 2. The significance of the compression ratio and the compression curve are discussed later; they basically provide a means of comparison between one assembly and another for one particular press.

Action of a Screw Press

To visualize how a screw press works, it can be best likened to an ordinary hydraulic stroking press. A column or plug of compressed meal is formed along the discharge end of the barrel, the equivalent of the hydraulic presshead, which remains the same length, under stable operating conditions, new cake being formed at the inner end of the column as cake is expelled from the choke gear. Against the frictional resistance of this plug, fresh meal is rammed by the action of the feed worms; this is the equivalent of the hydraulic press ram. This likeness to a hydraulic stroking press checks out in practical operation.

Referring again to Figure 2, the typical shape of a compression curve is shown. For convenience, it can be split up into three sections: the feed section, the ram section, and the plug section. Radial pressures generated in a screw press can be measured fairly easily using strain gauges, and Figure 3 shows the general shape of the radial pressure curve along a screwpress barrel. The maximum radial pressure is generated at the feed end of the compressed plug. The axial pressure is more difficult to measure, but its curve follows

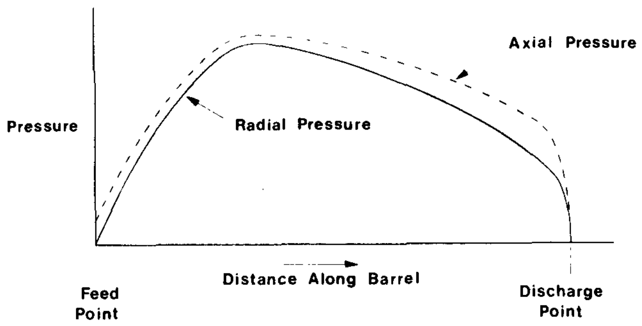

FIG. 3. Radial pressures in screw press barrel.

that of the radial pressure up to the beginning of the plug where hydraulic conditions obtain in the press barrel; the fall off in pressure towards the discharge end is less marked. It is certain that there is a pressure gradient towards both ends of the press.

We can now look in more detail at the specific areas of the press.

Feed Gear Design Considerations

The pressure gradient towards the feed end is troublesome inasmuch as expelled oil will flow countercurrent to the meal along this gradient. This can be verified quite simply by stopping a press on load and quickly extracting samples along the barrel. In the immediate feed area of a high pressure press on groundnuts, for example, the meal has a higher oil content than that being fed to the press. Added to the tendency for high-oil seeds to "oil-up" at the feed end of the press is the fact that a quantity of air has to be expelled before the meal is compacted. It is essential, therefore, to locate drainage area close to the feed end of a press to ensure that oil and air can be expelled as rapidly as possible. I am of the opinion that the location of feed-end drainage is of much greater importance than the quantity.

The second problem generated by the pressure gradient towards the feed end is that the press is self choking unless it is capable of getting a "bite" on the meal to feed it forward. The design of the feed end has to be such that this back pressure is dissipated. The effect of having to feed meal forward against a rapidly increasing pressure causes the meal to slip and rotate with the screw.

Under ideal circumstances, the flow of material along the wormshaft should be purely axial. In this case, the compression ratio of the worm assembly would be quite low. For example, 100 lb of groundnuts fed to the press at 33 lb/ft^3 would produce 55 lb of cake at a voidless density of 80 lb/ft^3 in a high pressure operation. Hence, volume at feed divided by volume at discharge equals 4.3, which is the theoretical compression ratio. In actual fact, ratios of the order of 10:1 are used, the difference representing the degree of slip or rotation of meal with the shaft. Tests with radioactive isotopes have confirmed what is to be expected; i.e., the greater part of the slip and rotation occur at the feed end of the shaft.

The reticulated effect produced by the lining bars, the knife bar nibs, and other means (such as the knife wheel rotated by the feed worm) attempt to reduce rotation to the minimum.

At the feed end of the press, the crunch problem is generated by the fact that, just at the point where the maximum volume displacement is needed, increasing the pitch of the worm causes a greater component of the force applied by the worm flight to cause rotation. This is shown diagrammatically in Figure 4.

Particularly on soft seeds, simply increasing the barrel diameter at the feed end is not a solution inasmuch as the shoulders generated where the barrel diameter is reduced give an equally damaging choking effect. Reductions in

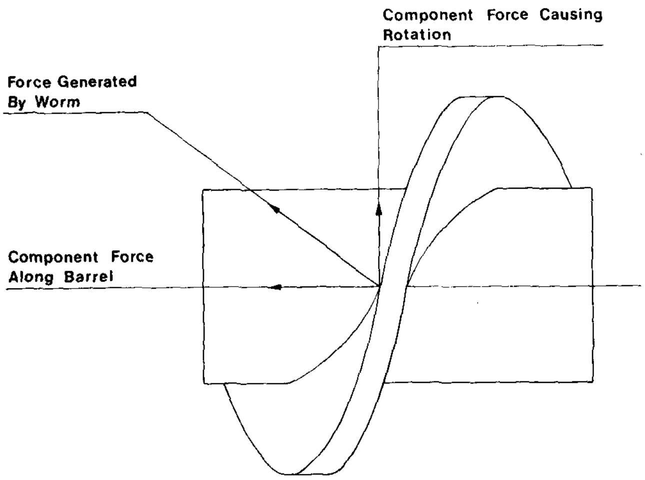

FIG. 4. Directions of force in expeller barrel.

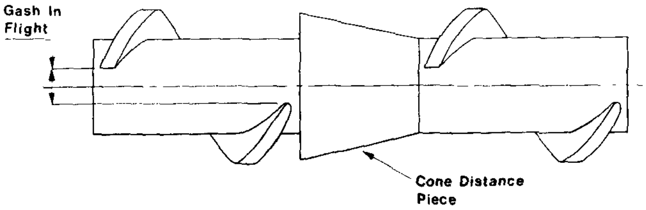

FIG. 5. Design showing cone distance piece.

barrel diameter should be made as far down the barrel as possible.

Hence, the feed end of the press handling a high oil content seed must fulfill the job of overcoming the back pressure plus the seed to move a sufficient volume of meal forward with a minimum of rotation and provide properly located drainage for the expelled oil and air.

To achieve this objective, Rosedowns uses the side feed conveyor and the twin intermeshing feedworms, Anderson uses the high speed vertical shaft, and FOMMCO uses the high-speed "quill" feedworm.

Discharge End Design

The forward thrust of the feed gear is balanced by the frictional resistance of the compressed plug along the discharge end of the press. Very often the discharge worms of a press have the same volume displacement, giving the normal flat end to the volume displacement curve.

It is reasonably obvious that the wider the worms are spaced along the discharge end of the press, the greater is the resistance of the plug inasmuch as each individual worm must generate a higher axial thrust to move the column of meal into the next worm along the assembly. Hence, on soft seeds the discharge end has wide-spaced worms whereas a hard seed will have close-spaced worms. The resistance of the plug may be effectively increased by using "cone" distance pieces, shown in Figure 5, commonly used for groundnuts.

Materials of construction of the press are vital in determining the suitability of the discharge end configuration. For copra and palmkernels, it is essential to have a worm assembly and cage lining bar material with a low friction coefficient if stable operation of a press is to be attained. Hence, Stellite-faced items are nearly standard for these seeds. It is important to bear in mind that the wormshaft must rotate within the compressed column; consequently, to reduce the tendency for the meal to rotate, it is desirable that a low-friction shaft be used in conjunction with higher friction bars for the softer range of seeds.

Worm sections along the pressure and discharge sections of the press are invariably made so that the flight does not wrap round more than ca. 320°. This leaves an axial "gash" in the flight (Fig. 5) which enables compressed meal to slide through the worm in either direction relative to the velocity generated by the pitch of the worm. This enables pressures over a group of worm sections to be balanced and considerably reduces the tendency for meal to "lock" in individual sections and rotate with the shaft.

It is common practice to stagger by 180° the gashes in successive worms to reduce the bending of the shaft caused by the shock generated as the gash rotates past the knife bars.

Choke Gear

The effect of the choke gear on press performance is, to my mind, much overated. It certainly can be used in a minor way to affect the plug along the discharge end, but its influence is too little and too late to correct an incorrect worm assembly. It is useful to assist in the starting and stopping of a machine, and it can be used to produce a cake of a required thickness for process or marketing reasons. The choke gear of a pre-press should produce a cake with a surface that permits easy percolation of the solvent.

The choke gear, in modifying the resistance of the plug, can increase load on a screw press, but essentially the load on a press should be controlled by the rate of feed. This means that a screw press running at a fixed speed has one ideal capacity, and therefore a press or group of presses fixes plant capacity. While this is usually acceptable on an oilseed duty, in other processes (rubber de-watering, for example) the adjustment of press load by the choke gear has to be accepted.

PROCESSING HIGH OIL CONTENT SEEDS

The greatest common problem to all high oil content seeds is that one is seldom able ideally to prepare and cook the seed for screw pressing without freeing too much oil and generating problems at the feed end of the press.

For good order, perhaps we should define more closely the purposes of seed preparation and cooking.

Seed preparation consists essentially of cleaning, decortication where necessary, and reduction. Proper cleaning is essential to reduce wear in rolls and presses; even small quantities of sand or stones in a feed to a high pressure press can generate maintenance and downtime problems.

There is an argument against cleaning which can be put by a processor. Take the case of a 100 TPD high pressure groundnut mill. It is probable that 1-2 TPD of sand and shell is removed by efficient cleaning. This would normally appear in the cake, and chances are that the fiber and silica sand limits would not be reached. Hence, the processor is losing something between $175 and $350 per day in lost cake revenue, besides having the running costs of the cleaner and the disposal of the dirt to deal with. Hence, there can be a situation where reducing the wear by, say, 75% is not economically sound. But you can't have your cake and eat it!

Reduction of the seed consists of grinding or passing through breaker rolls followed by milling the seed through flaking rolls of five-high AA rolls. The purpose of reducing the seed is to break down or weaken the oil cell walls to the point where the oil is available to be expelled.

In general terms, cooking the seed serves the following purposes: (a) completes breaking down of oil cells; (b) lowers viscosity of oil to be expelled; (c) coagulates protein in the meal; (d) adjusts moisture content of the meal to the optimum level for pressing (since moisture in the meal acts as a lubricant in the press barrel, the final stage of cooking is normally a drying operation); (e) sterilizes the seed, i.e., destroys enzyme action and prevents the growth of mold and bacteria; (f) detoxifies undesirable seed constituents (gossypol in cottonseed, for example); and (g) fixes certain phosphatides in the cake to lower the subsequent refining loss.

The physical characteristics of the seed dictate the degree of preparation and cooking which are tolerable or necessary. Let us look in some detail at the stages of processing of copra and groundnuts.

Copra (High Pressure Pressing)

Cleaning: Since copra is very irregular in size, only sand is removed. For sun-dried copra (not now very common), it is advisable to use a rotary screen to ensure that the half cups are turned over.

Coarse grinding: This reduces the half cups to pieces about 20 mm square and is normally done in a swing-hammer grinder without a screen or grid.

Fine grinding or breaking: This reduces the broken copra to pass 8 mesh. The quality of copra is extremely variable depending on its source. Good quality brittle copra can be handled perfectly well in grinders of the swing hammer type. "Rubbery" copra is more difficult to grind since oil is freed in grinding which blinds the screen. Breaker rolls two or three pair high are much better for poor quality copra; the coarse grinding stage can be incorporated as an extra pair of toothed rolls on the breaker roll stand.

Cooking: It is necessary to reduce the moisture content as low as possible. A moisture content of 1½% to the press should be aimed for at a temperature range 115-120 C to the press. Oil flavor is particularly important on copra, and it may be necessary to reduce feed temperature on poor quality material. No water or open steam addition is normally needed in copra cookers, but a good aspiration system, capable of fire control, is needed.

Screw pressing: (a) The screw press should be Stellite-faced on both pressure worms and cage linings. (b) Barrel drainage slots must be wide at the feed end of the press to allow the large quantity of oil to be drained as rapidly as possible. (c) Since copra forms a fibrous drainage matrix within the press barrel, the quantity of foots produced is not high if the seed is properly cooked. (d) Shaft cooling is necessary to prevent burning of the cake on the shaft side. The rubbing velocity is considerably greater on the shaft side, hence the tendency to burn is much greater. (e) Cage cooling, by water jacket or cooled oil spray, improves oil flavor and becomes more essential as the power of the press is increased, say above 100 HP. (f) The load on the discharge worms is great. This generates problems in the strength of these items, which is not helped by the accelerated corrosion which can occur. Solid shafts are an obvious answer, but these are mechanically weak after Stellite facing. A commonly employed compromise solution is to produce "combined" assembly items where a group of up to four worms and distance pieces are produced as a single unit. (g) With the present range of high pressure presses on the market, a "falling feed," i.e., a metered feed, to the press would be normal. Hence, the press would be loaded up to the safe allowable amperage on the press motor. Some safety relay system is therefore an advantage.

Copra (Pre-Pressing for Solvent Extraction)

Variations from high pressure pressing are: (a) The fine grinding is taken further, either by allowing more grinder/breaker roll capacity or by rolling the meal after grinding. (b) Using low meal levels, the cooking is eased to give 105-110 C to the press at 3-4% moisture. The finer grinding tends to free oil in the cooker, hence the grinding and cooking stages must be balanced to eliminate this problem. The finer grinding plus the higher moisture cake are necessary for good extraction. (c) The press loading is not nearly so severe as for high pressure pressing, but the same broad principles apply.

Groundnuts (High Pressure Pressing)

Cleaning: Groundnuts, although a "soft" seed, are very abrasive due to the sand and shell fiber they contain. Good cleaning on an aspirated, de-stoning cleaner is essential if wear on the press is to be kept low.

Preparation: Each half of a groundnut is virtually one oil cell. Any breaking of the seed is certain to free oil in the cooker, yet such a stage is really necessary. Opinions differ, but mine is firmly that groundnuts should not be broken prior to high pressure pressing.

Cooking: (a) Overstirring groundnuts in the cooker must be avoided; hence, meal levels should be kept low—the cooker should only be filled to the degree required. (b) Theoretically, one should be able to coagulate the protein in the seed, but this is practically near impossible since the addition of the necessary water in the top ring of the cooker causes the seed to break down into something resembling mud. (c) There is a definite maximum feed temperature to the press, which I would put at 115 C. (d) Although differing based on seed type, a moisture content of 3½-4½% to the press should be the target. (e) Pressing is normally improved by injecting live steam into the bottom ring of the cooker. Since the meal in the bottom ring is above 100 C and the injected steam is superheated, there is little chance of the moisture content being increased. I must confess that the function of the injected steam has no logical explanation, and I would welcome comment.

Screw pressing: (a) With such a low friction coefficient, groundnuts are difficult to press. Hardened bars with Stellite-faced worm assembly probably represent the best combination. (b) The sheer strength of the seed is low, so the rate of pressure build-up must be gradual. Hence, low shaft speeds and a long-barrelled machine are preferred. (c) Shaft and barrel cooling are debatable needs, but there is some sound argument in saying that the plasticity of the meal is reduced by cooling; hence, a higher plug resistance is achieved. (d) The load taken by the press is low; hence, the machine will invariably take a full feed. Great care should be taken not to use the feed gear too fiercely on groundnuts; otherwise the amount of foots produced, normally heavy, is increased to crippling proportions. In other words, excess feed above a certain point appears only as foots pushed through the bars. (e) Oil clean-up is of enormous importance since returned foots and filter cake represent a severe unbalancing effect on screw pressing. A uniform return of dry foots and filter cake is essential. Ideally, foots should be returned directly to the press, but practically this is not possible inasmuch as feed rates become erratic and press load is inconsistent. In a single press installation, returning foots and filter cake to the bottom stage of the cooker is an effective compromise.

Groundnuts (Pre-Pressing for Solvent Extraction)

The variations from high pressure expelling are not great and concern again the breaking and cooking of the seed.

There is a much greater argument to coarsely break the nuts for pre-pressing—say, into quarters or eighths. This produces a more easily extractable cake, without large pieces of whole nut embedded in it. Cooking is usually eased so that a temperature of about 105 C to the press is used. Some operators trickle water directly into the feed spout of the press with the meal to give a more stable pre-press operation, but I suspect this causes some oil filtration problems.