

Extrusion and oilseed processing

Expanders to prepare solvent extraction

Expanders are in use to prepare oil bearing materials ahead of solvent extraction since 1965. These apparatus improve the capacity of extractors by increasing the density of the flakes and improving the oil extractability by decreasing the defect of milling.

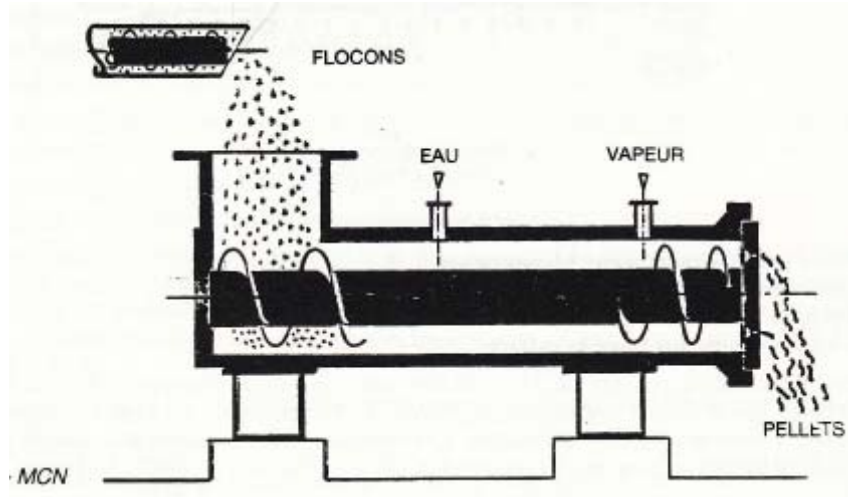


Figure 1: Schema of principle of an expander

Expanders are large extruders having a relatively simple design. They consist of a heavy duty, constant pitch, constant flight depth, interrupted flight (cuts) screw within a barrel. Bolts extend from the barrel wall into the “cuts” between the flights to shear the product as the screw turns. Most of the back pressure is provided by the die plate. Water and steam injection are made into the barrel to add water and heat to the processed material. ¹

In the case of soybean, the water content of the pellets is increased of 2 points and the temperature of the collets exiting the dies is 80-85°C. By air cooling, the moisture is reduced to normal values.

Collets from expander compared to flakes have several improved characteristics:

- **Micro-porosity:** hexane penetration is enhanced thanks to the expanded structure of the collets due to the flashing of the steam at the exit of the dies. This micro-porosity improves the extraction of oil allowing a better recovery.
- **Macro-porosity:** the shape of the collets let more room available for the solvent circulation avoiding the formation of areas where the solvent has a poor penetration. Moreover, the macro-porosity decreases the solvent hold up after extraction (20-23 % vs 30 % with flakes).
- **Homogeneity:** according to the nature of the seeds, the flakes can be more or less crumbly when collets are stable in shape, allowing a better percolation of the solvent
- **Density:** collets have a density of 0.56 versus 0.36 for soy flakes.
- **Solidity:** collets are not destroyed during transports when flakes can be turned in fines if shacked by chutes and chocks.

With soybean, the daily capacity of the oil mill can be increased up to 50 % ².

¹ American Soybean Association – Developing the potential usefulness expanders in soybean processing – Report of a Food protein Research – Texas A&M University System Dec 15, 1989

² Laisné J. L’huilerie moderne, arts et techniques – ed Compagnie Française Pour le Développement des Fibres Textiles, Paris, 1984

According to Lusas et al.³, the extrusion of soybean flakes in expander can destroy the activity of the enzyme which is responsible of the loss of the capacity of lecithin to form micelles in presence of water. This enzyme is the D phospholipase which cut the molecule between the phosphorus group and the polar group (choline, serine, ...). The remaining phospholipid is phosphatidic acid which is not hydratable and requires a conditioning of the crude oil with phosphoric acid before the degumming. Another consequence of this loss of ability to form micelles is higher concentration in calcium and magnesium in crude oil after water degumming. These ions are decreasing the oxidative stability of oils by forming salts with phosphatidic acid.

In the case of direct extraction of the flakes, the normal loss of hydratable phospholipids is around 50 %. 10-15 seconds in the expander are sufficient to deactivate the D phospholipase,.

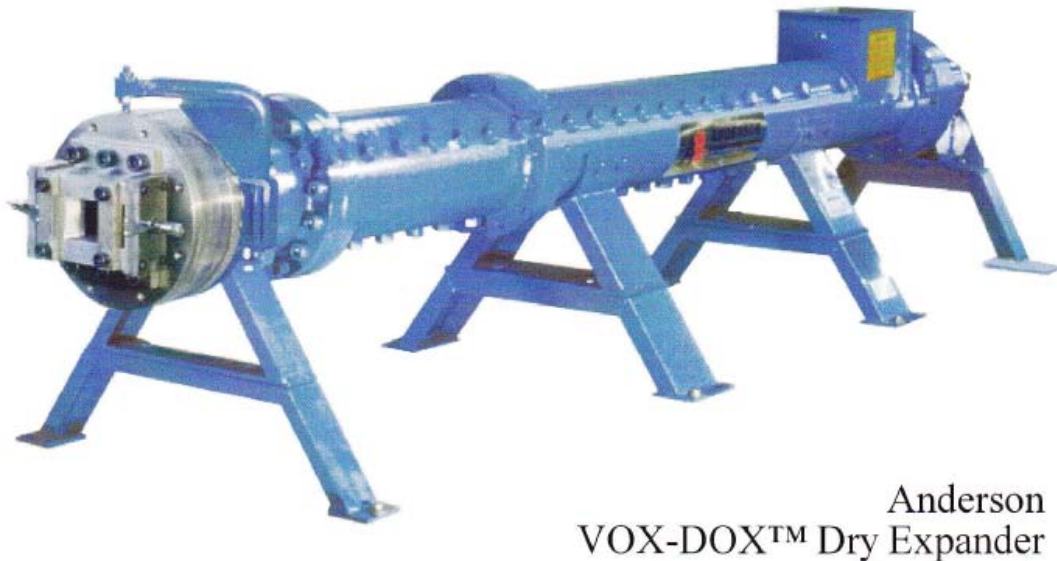


Figure 2: Anderson soybean expander

Expander have been adapted to oil rich seeds that cannot be extruded in a closed barrel apparatus because under the pressure carried out at the dies level, oil is expressed and moves back to the feeding area and disturbs the functioning.

Drainage cage have been positioned on expanders close to the dies plate in order to give an outlet to this oil (fig. 3). According to Williams⁴ of the Anderson Cie, such an expander can work rapeseed flakes and produce deoiled collets having 25-30 % of oil content. These figures are much higher than pre-press cake (18-22 %) but the goal of the expander is not oil production but shaping collets for extraction. Industrial test were carried out in Europe but they were not satisfactory and expander are not in use for the preparation of rapeseed and sunflower which are pre-pressed and in some case pelletised.

Most cottonseed meal produced in the U.S. today is manufactured using solvent extraction. This method utilizing an expander helps to increase production efficiency as well as binding much of the free gossypol found in cottonseed meal.⁵ Gossypol is an antinutritional polyphenolic pigment found in cottonseed which has anti-nutritional properties when free. Expanders increase the value of the meal for animal feeding.

³ Lusas E.W., Watkins L.R., Rhee K.C. Separation of fats and oils by solvent extraction and non traditional methods. Proceeding of world conference on edible oil and fats processing – Basic principles of modern practices. DR Erikson, ed., American Oil Chemist's Society, Champaign, IL may 1990.

⁴ Williams M. Expander to improve extractibility – Inform, 1990, Vol 1, n°11 pp 959-963

⁵ <http://www.cottonseed.com/publications/feedproductsguide.asp>

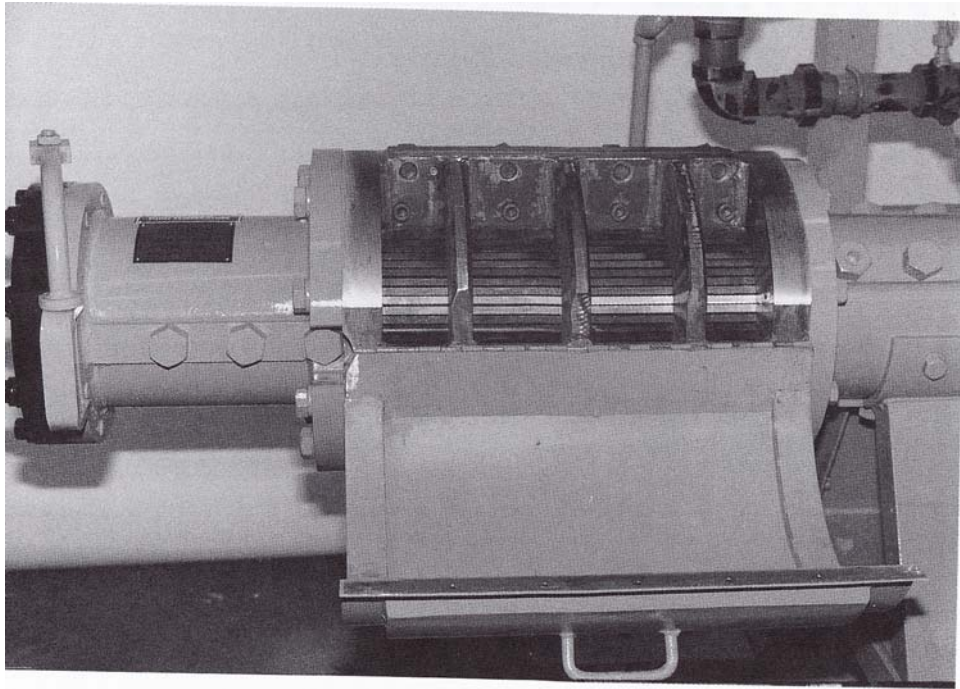


Figure 3: A deoiling cage on the barrel of an expander.

Expander to prepare expelling

The Anderson Company includes expander in their process for mechanical extraction of oilseeds (fig.4).

According to their commercial documents, the presence of expander saves around 30 % of the power necessary to produce cakes at 6 % of oil residues. On the second hand, this documentation does not provide information about the consumption of heat for conditioning and drying.

The role of expander before expeller is to increase the press capacity by comparison with normal conditioning (flaking, cooking). The capacity of the presses can be doubled thanks to the mechanical preparation done by the expander. Little information is available to explain these data but one can guess that the mechanical preparation achieves a good destabilization of the oil bodies inside the cells and decreasing the oil content of the material entering in the expeller is likely to improve its efficiency.

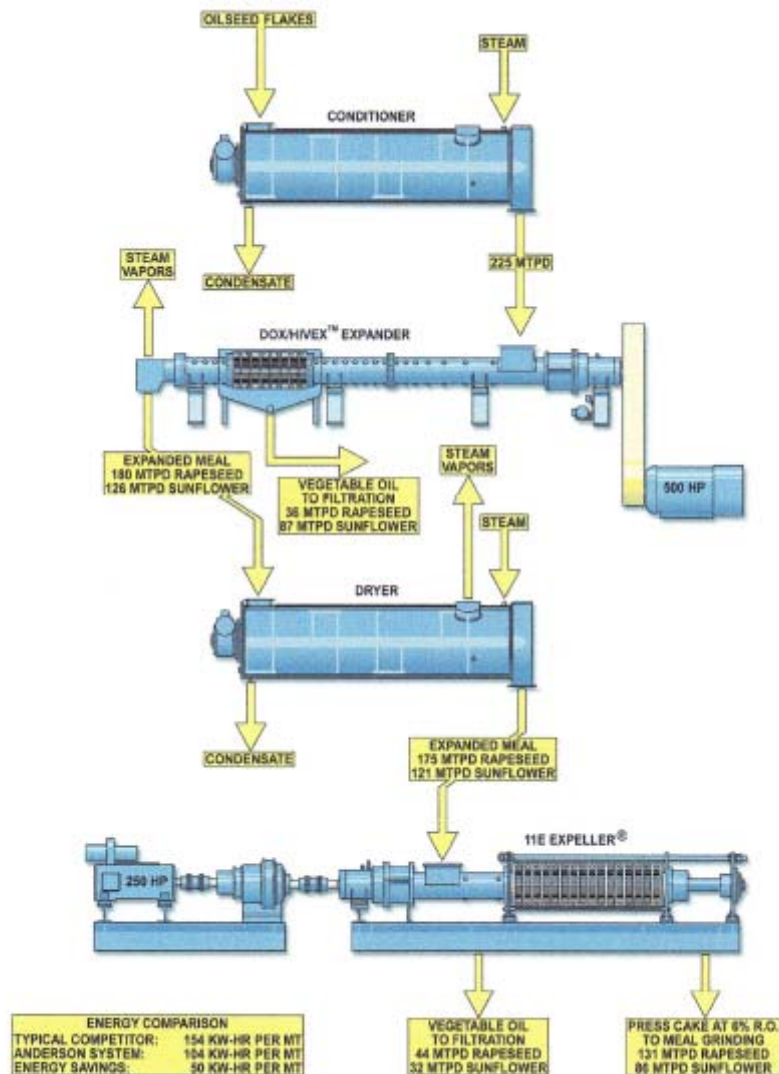


Figure 4: Mechanical extraction of oil enhanced by expanders

Extruders

Compared to expanders, extruders used in other fields of oilseed processing have shorter barrel, higher rotating speed and involve greater energy transfer to the processed material.

Extrusion cooking has been developed for full fat soybean processing. Soybean contains several thermo-labile anti-nutritional factors like trypsin inhibitor factor which decrease the feeding value of the soybean.

- Lectins (hemagglutinin) are proteins that have the ability to cause aggregation of the red blood cells. These molecules have two binding sites that can form bridges with carbohydrates coating membrane of red blood cells. In the normal feed digestion, these proteins are losing their function at the stomach pH.
- Trypsin inhibitors⁶ (TI): when raw soybean is given to some young animal, some growth depletion is observed. The protein combines with trypsin, a proteolysis enzyme, so that once

⁶ Snyder H.E., Kwon T.W. Soybean utilization, Avi Book, Pb. Van Nostrand Reinold Company, New York, USA, 1987

the enzyme has cleaved the protein, the remnants parts of the protein instead of breaking apart remain bound to the enzyme which becomes inactive. In consequence, the pancreas must produce more trypsin to overcome that deficit of activity at the point that pancreas hypertrophy generates a growing trouble.

- Lipoxigenase: these enzymes are involved in the apparition of bad flavors of soy-products for human food. They are promoting the oxidization of the polyunsaturated fatty acids and promote rancid flavors in derivates of soymilk.

Heat treatments can modify the three-dimensional structure of the protein and destroy their biological functionality. Trypsin inhibitors (TI) are known to require the higher temperature for this deactivation. The heat treatment is a combination of temperature and duration. The higher is the temperature the shorter the residence time. With a temperature of 100°C, 6-8 mn duration is necessary to reach a 80 % deactivation.

The monitoring of that temperature and duration must be done with good accuracy because excessive heating decreases the proteins digestibility thanks to the formation of bonds between proteins and reducing sugars.

In the regular soybean processing, it is during the desolventization of the meal that a toasting treatment is done. In the bottom of the desolventizer, meal is treated by direct steam resulting in strong moisture content (20-22%) then its temperature is brought to 105-110°C during 10-12 mn and the meal is cooled and dried.

When directly used as feed, soybean must be treated in order to deactivate TI. Several means are available to carry out that treatment but the most popular one is extrusion. To get a satisfactory decrease of TI a temperature of 150 °C must be reached

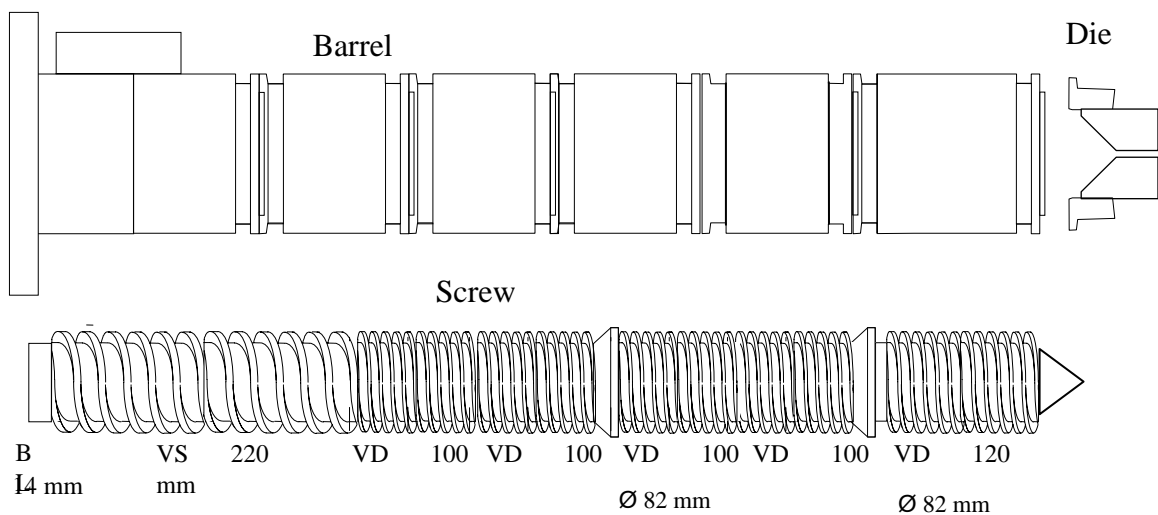


Figure 5: Screw and barrel profile of a single screw extruder.

The typical extruder for soybean cooking has a length / diameter ration of 6-8. The nose of the screw has conical shape and the die is mounted on a threaded insert allowing the adjustment of the space between the screw nose and the die. Restriction rings help to increase the mechanical shearing and compression of the raw material. The energy necessary to make that treatment is in the 80-100 kWh range. Beyond the reduction of TI, it improves the oil availability for young animals resulting in better conversion of feed.

Further improvements of this technique have been done in order to minimize the electricity consumption by preconditioning with direct steam. In this case, the beans are coarsely broken, and then they are introduced in a maturing tank where direct steam is injected before being extruded at a moisture content of about 15-20 %.

In 1987, Nelson and al⁷. published an article in which they described a new process to produce expeller cake of soybean using dry extrusion as preparation to expelling. Coarsely ground whole seeds are extruded in way allowing a rise of the temperature up to 135°C and directly pressed. Such an extrusion greatly improved the throughput of the expeller. Oil recovery of 70 % was reached in a single pass in a pilot scale press. The cake has 6 % of oil residues and a 90 % deactivation of TI activity. Expelled oil quality was satisfactory. Further investigations⁸, showed that compared to solvent extraction, extruded expelled oil had less free fatty acids, lower peroxide value and lower phosphorus content while tocopherols content was slightly enhanced.

According to Said⁹, this process requires low capital investment and enable the profitability of small scale oil mill located near to the production areas and can answer to the identity preservation demand of the market. In its paper, this author present a set of economical data stemming from the experience of a 9 000 t / year capacity plant crushing cottonseeds in USA. The production cost is evaluated at \$31/t, the production gives 125 kg of oil and 875 kg of meal generating a net profit of \$25 by ton. The capital cost of that unit was \$400 000.

In a study published on 2001, Wang and Johnson¹⁰ indicate that they were 74 plants using the extrusion-expelling process in North America in spring 1999 (capacity 5-20 metric ton / day). The total capacity of these plant remains low compared to the regular processing but it concerns niche market generating more added value than large industry per unit of crushed seeds. In this article, the authors propose a simplified refining allowing better income for small crushers.

In France the CETIOM ran a study about this process in order to propose a way to deoil soybeans produced in traced conditions to feed quality broiler. This study¹¹ confirmed the interest of the technique but found no industrial concretization because of the progressive disinterest of growers for soybean in France.

Conclusion

Extrusion is largely used in both South and North America to prepare raw material to extraction, principally in the case of soybeans. This technique remains poorly used to process Europeans crops like rapeseed and sunflower. Although some trials have been done to introduce this practice for rapeseed which is considered as difficult to crush, no real application is done in Europe.

The technical reasons that explain this difference of attitude in front of extrusion are not clear and because expander does not belong to the set of equipment supplied by European equipment providers it could be a simple question of culture. At the place where Americans employ expanders, Europeans have put pellet presses which do not provide the same mechanical work. Experiments at the pilot scale could help to check whether extrusion could enhance rapeseed oil extraction in the same way that the use of expander enhanced soybean oil extraction.

⁷ Nelson A.I., Wijeratne W.B., Yeh S.W., Wei T.M. and Wei L.S. – Dry extrusion as an aid to mechanical expelling of oil from soybeans, 1987, J.A.O.C.S. vol 64, n°9, pp1341-1347.

⁸ Hill S.E., Characterization and oxidatio stability of mechanically expelled soybean oil, MS thesis, University of Illinois, Urbana, IL 1990.

⁹ Said N.W., Dry extrusion – mechanical expelling. 1998, INFORM, vol 9,N°2, pp139-144

¹⁰ Wang T. and Johnson L.A. – Natural reffining of extruded-expelled soybean oils having various fatty acid compositions. 2001, J.A.O.C.S. vol 78, n°5, pp461-466

¹¹ Quinsac A., L'extrusion-pression, procédé adapté à la trituration de graines de soja pour les filières aviaires locales tracées, Journée de la Recherche Avicole, St Malo - 30 mars 2005 - Poster