Evidence of a speed dependent critical pressure for the mechanical extraction for high-oil and low-fiber matrices

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CONTEXT & OBJECTIVES

It is well known in the profession that fully dehulled materials like sunflower kernels, dehulled peanuts, cotton kernels, walnuts, jatropha are difficult material for mechanical extraction.

In the same time, the food industry has to cope with the demand for less animal proteins and a growing reprobation for the so-called "ultra-processed food" in which are falling proteins isolates and concentrates. In this context, meals from mechanically extracted dehulled oilseeds could play a role, providing protein rich foodstuff considered as minimally processed. The aim of this work was to contribute to understanding the poor performance of screw-presses with these high-oil and low fiber materials for enabling the production of protein meals with high nutritional value.

The usual explanation given for the poor performances of screw presses is the lack of friction caused by the absence of the fibrous envelopes of the seeds. This hypothesis is based on the observation of lower temperature for dehulled material than in non-hulled seeds during screw pressing of both materials.

This work aims at supporting an alternative hypothesis based on the behavior of these matrices during unidirectional compression at constant speed. This hypothesis postulate that dehulled material is more resistant to filtration.

If confirmed, this hypothesis could lead to strongly different recommendations for the design of screw presses. Lack of friction could be compensated the research of mean to increase the pressure in the presses while the filtration resistance hypothesis would lead to solution aiming at reducing the pressure in the first sections of the press for not exceeding the filtration capacity of the material.

MATERIAL AND METHOD

Sunflower

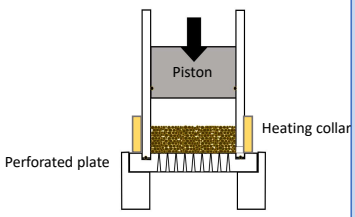
Kernels were obtained from a confection batch (Flanquart, France), un-hulled achenes from a commercial batch of oleaginous sunflower.
Moisture of achene and kernels: 4%
Fat content: kernels 57%, un-hulled 45%

Protocol

1. Adjust the moisture content of the material at 4%
2. Weight with an accuracy of 0.01 g 15 g of material
3. Place the material in the press cylinder, pre-position the piston in the cylinder
4. Warm the press and the seeds at 65°C during 25 min
5. Run the test at desired piston speed (0.1mm/min < v < 20mm/min)
6. Determine the serration point on the curves

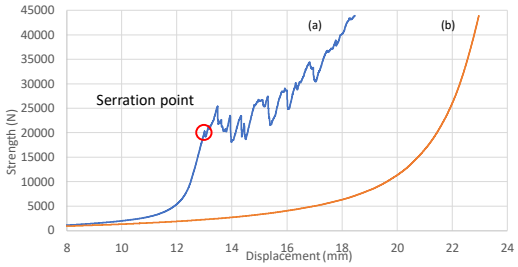
Compression study

Compression study were carried out with a bench top universal testing machine Mecmesin Omnitest 50.
The bench measure the force exerted by a piston on the compression cell as a function of the piston displacement.
The force gauge has a capacity of 50kN and an accuracy of 0.5%. The displacement is measured with a precision of 1 µm. The data are monitored by a software (Vectorpro) which was recording 50 positions by second.

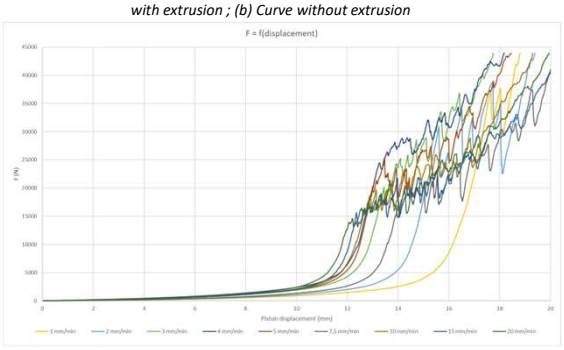


Compression cell was a 40 mm hollow cylinder in which a piston of the same diameter can slide. The piston was connected to the mobile arm of the tester via the force gauge. At the bottom of the cylinder a plate perforated by 69 holes of 0.88 mm on the intern side and 2 mm on the downward side. A circular resistor controlled by an electronic regulator was heating the cell at the desired temperature.

RESULTS



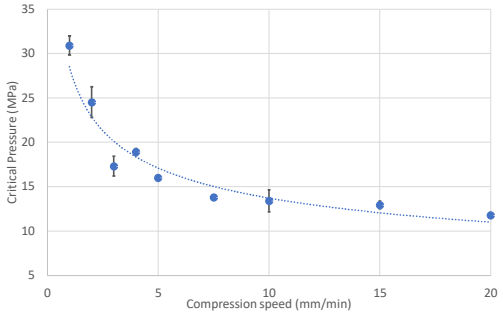
Example of curves obtained with unidirectional compression; (a) Curve with extrusion ; (b) Curve without extrusion



Comparison of compression curves at different speeds for sunflower kernels

Remarks:

- No extrusion was observed with kernels at speeds below 1 mm/min)
- No extrusion for unshelled sunflower in the range of speeds studied
- Increasing the compression speed decreases the minimal pressure for extrusion



Evolution of critical pressure as a function of compression speed

DISCUSSION

The serration effect is a manifestation of the loss of solid material through the perforations of the compression modulus. When it occurs, the pressure stops its exponential rise and fluctuates accordingly to the volume of material expelled from the modulus. When the solid remains in the modulus, the rise of the pressure follow a quasi-linear slope corresponding to the expelling of the air and then the oil which can easily flow outward. If the material offer little filtration resistance, the curve bends upward when the oil content in the cake reaches a level where the rearrangement of solids material becomes limiting and requires more and more pressure for small displacement. In principle, the speed of compression shouldn't change the rate of volume reduction where this change occurs. On the contrary, the figures above clearly demonstrate a speed dependence of the compression rate where the inflexion appears and the pressure at which the serration effect is observed. These observations are evidencing that filtration resistance is the main driver of the pressure change during the compression of sunflower kernels.

The pressure rises because the oil flow is limited by the cake porosity. It depends on the speed because higher compression speed requires higher flow rate in a limited channels network just as an increase in car traffic causes traffic jams on a road network.

Moreover, it is also possible that higher pressure could lead to the collapse in part of the capillary network reinforcing the filtration resistance.

The critical pressure at which extrusion of solid material occurs varies with the oil content in the cake. Higher oil residues leads to lower pressure. In non-hulled seeds, the fibrous material reduces the filtration resistance and prevents the collapse of the capillary network.

Conclusion: This works is a strong evidence that filtration resistance is probably the main driver in the poor performances of mechanical oil extraction of highly dehulled oleaginous material. Screw presses should be designed for maintaining a gentle compression during the first steps of extraction instead of looking to generate higher pressure.