Modelling of the resistance to compression of dehulled & intact rapeseed under unidirectional pressure.

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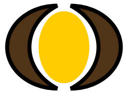
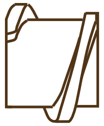
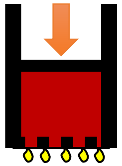
The challenge of mechanical cold extraction of dehulled seeds

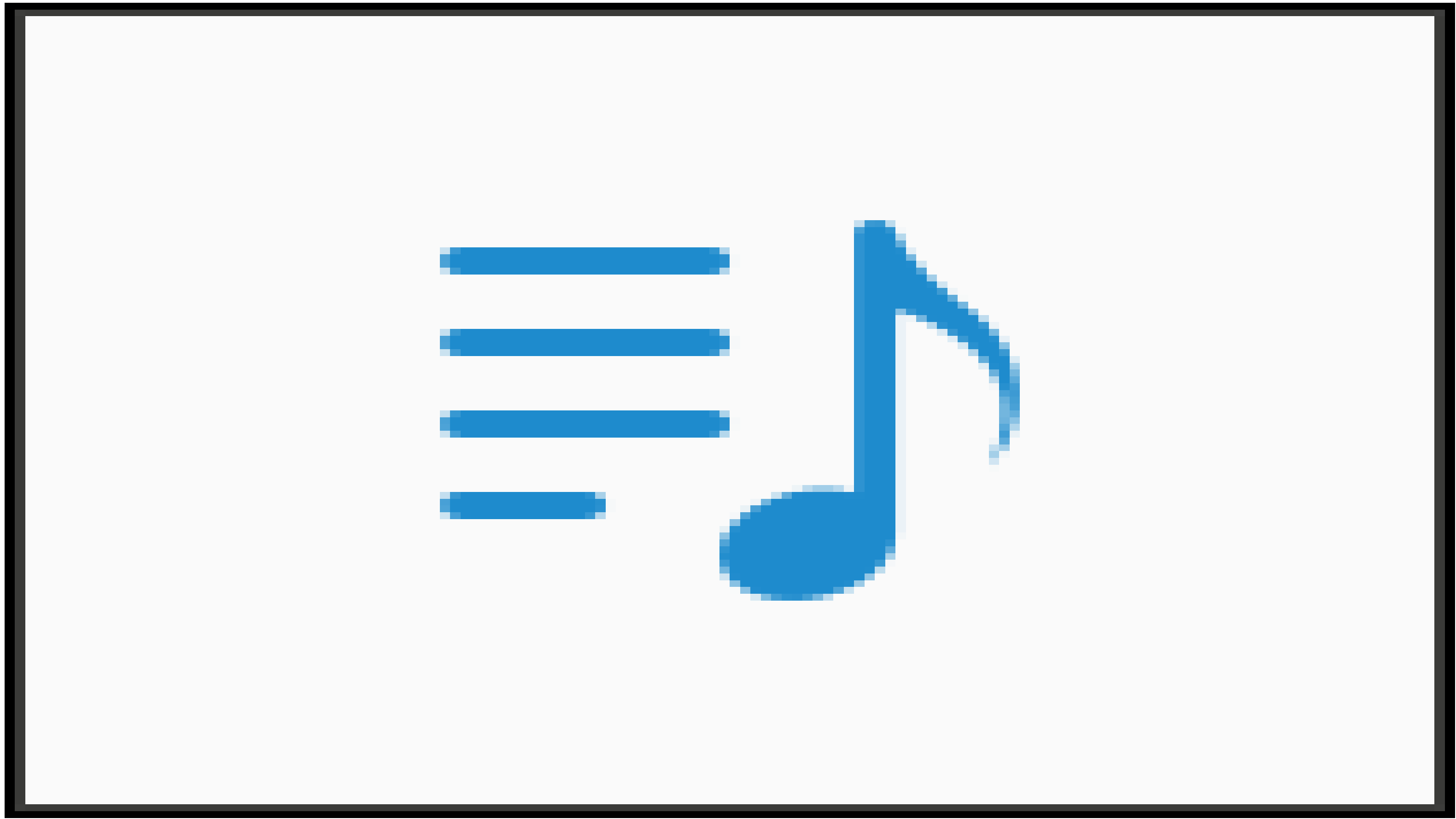




Without hulls, it becomes difficult to operate the presses:

- The cake out-flow becomes slow
- Oil yield decreases
- Total throughput falls sharply because rotational speed has to be reduced to maintain extraction performance





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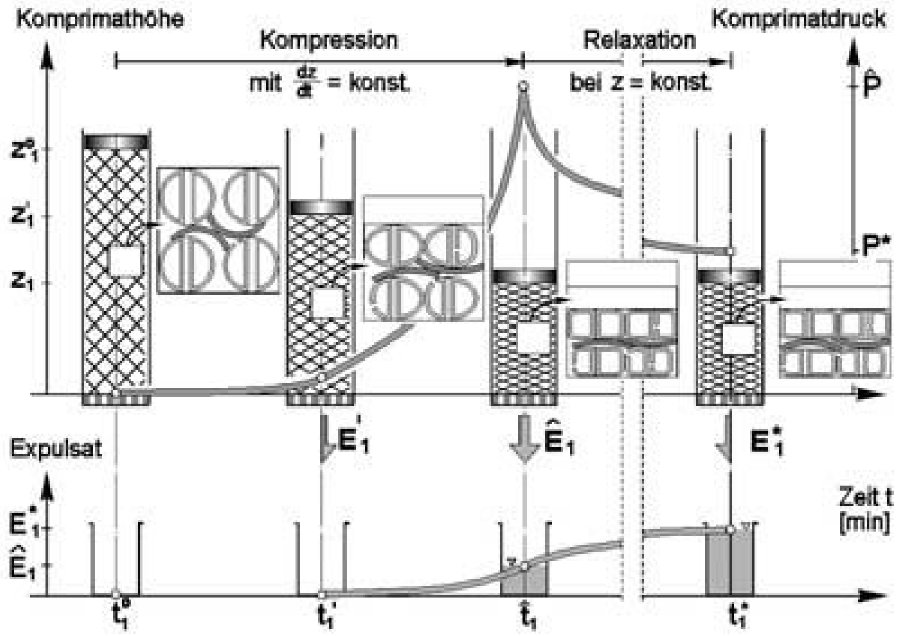
Current state of knowledge

Raβ thesis (mechanical extraction of dehulled OSR in piston press):

- **Oil drainage** in the press cake related to kinetic of compression.
  - ➢ A constant compression leads to degraded permeability
  - ➢ Evolutive compression with relaxations period can prevent the loss of permeability
- Effect of the rheological behaviour of the material too complex for being modelled (small changes in the parameters can lead to huge variations in the compression kinetics).
- Hulls are playing a role in maintaining the cake permeability during compression



Material and methods

Unidirectional micropress :

Universal Mecmesin bench

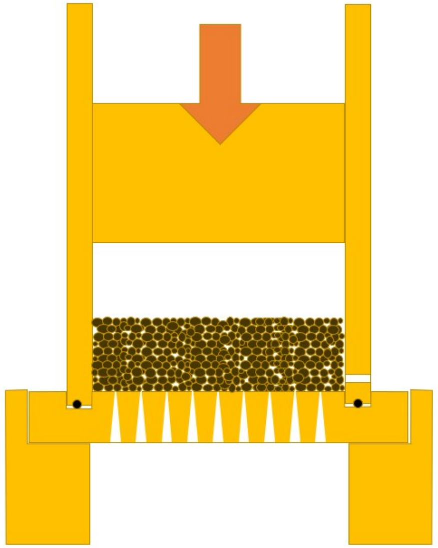
- Fine measure of the piston displacement piston (µm)
- Force up to 50 kN

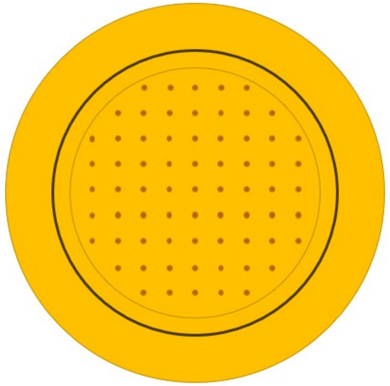
Cell of compression

- diameter 40 mm
- Filtering bottom plate
- Temperature regulation
- Pressure max 350 bar

Mass of material : 15 g

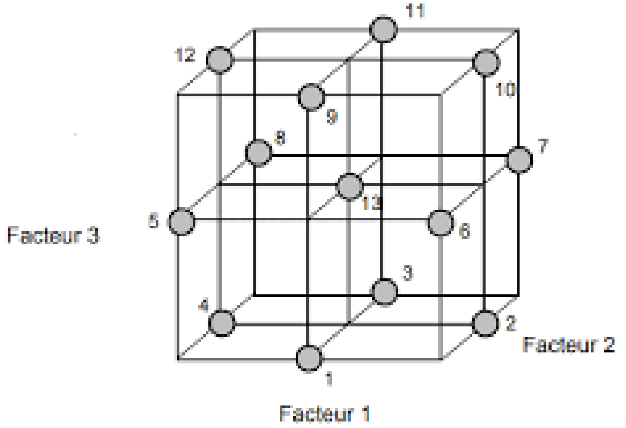
Stainless steel filtering cloth at the bottom of the cell for avoidance of material extrusion ~ 80 µm





Study of dehulled rapeseed compressibility

- Box Bhenkem experimental design
  - Piston speeds: 0.1, 40 et 80 mm/min
  - Water content: 5, 7 et 9%
  - Temperatures: 30, 65 et 100°C
- Conditions :
  - Comparison between hulled and non-hulled seeds
  - 3 or 4 repetition of the central point
  - Observed variable: force on the piston → Stress (bar) = f(Strain)
  - Strain = rate of compression = (initial height - actual height) / Initial Height



Explaining the compressive behaviour of rapeseed by the material plasticity

A question of permeability

Modelling the strain x stress curves

The use of a model enabled the irregularities on the curve to be smoothed out:

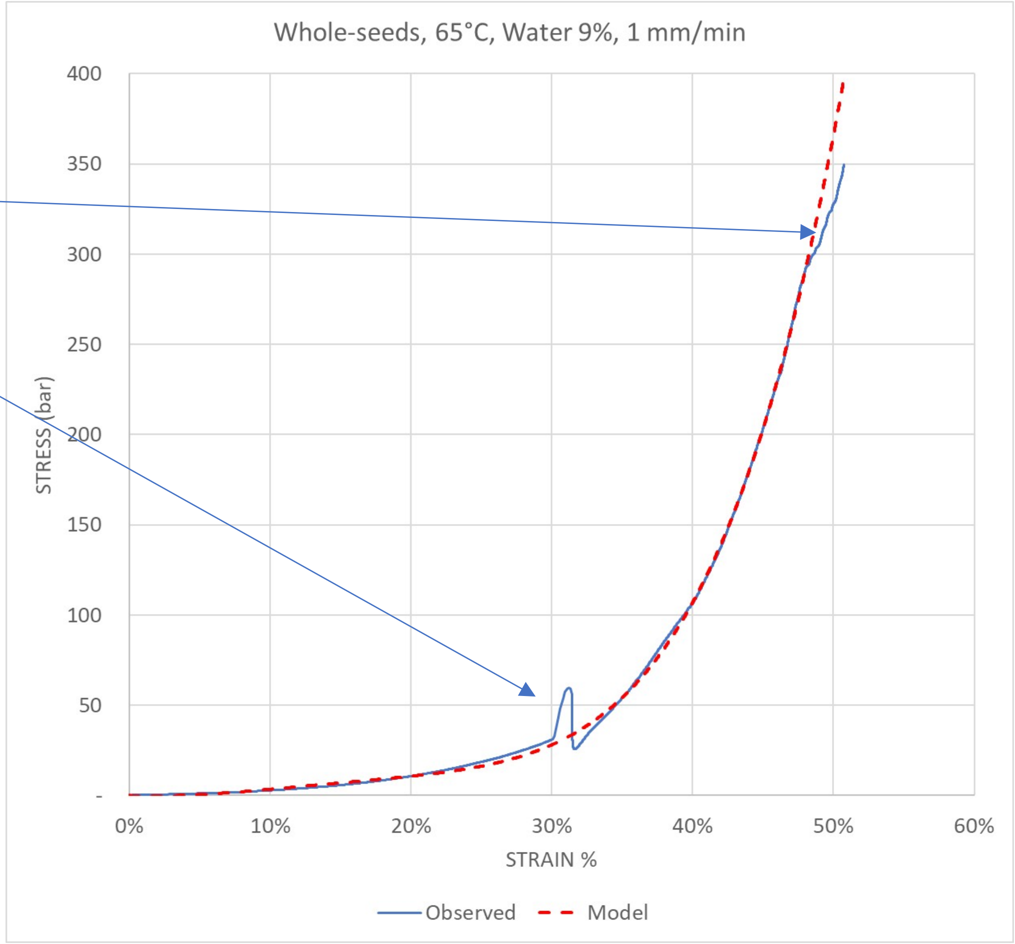
- Extrusion of material through the filtering bottom
- Mechanical defect of the machine

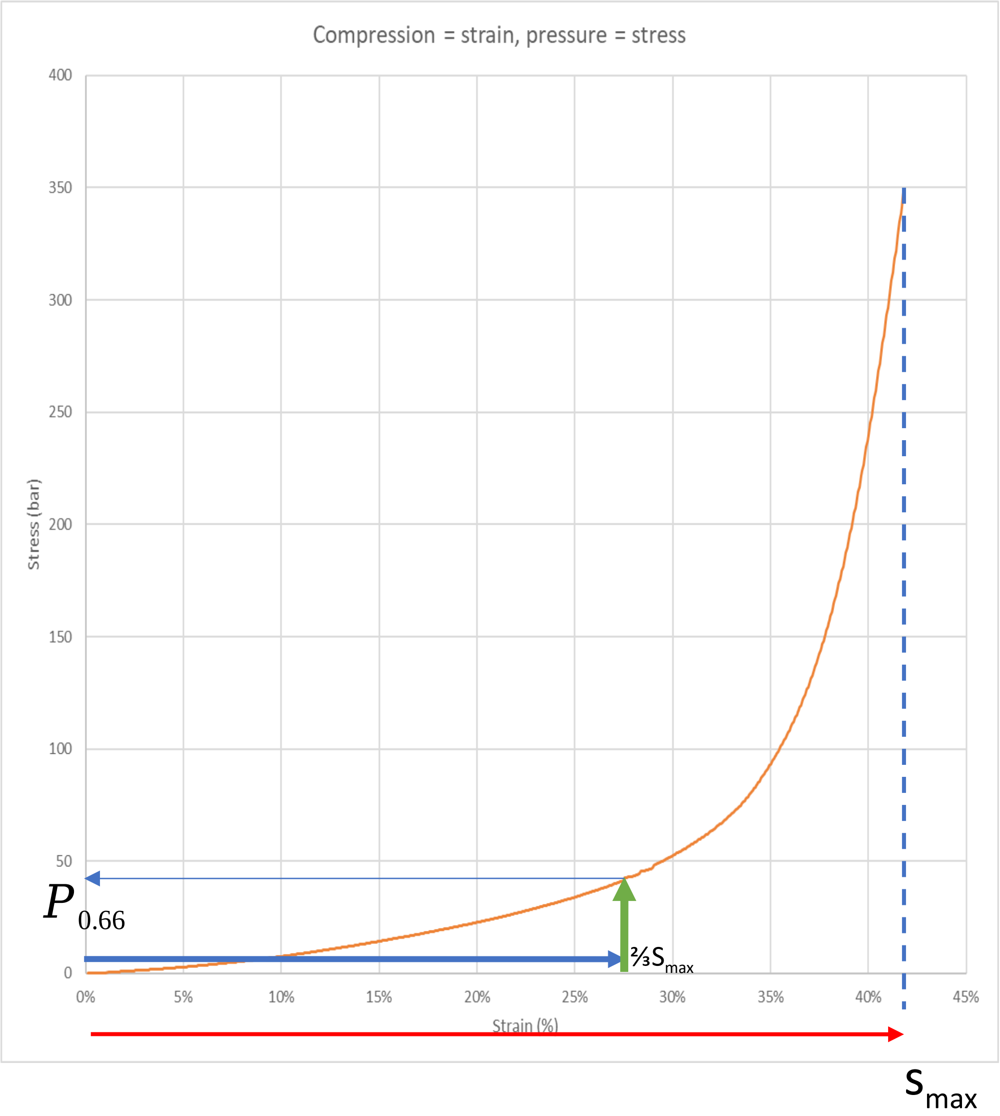
The model that fitted the observations well was

With:

a, b, c, d = adjusted constant

= strain (rate of compression)





A simple way to summarise the information contained in the curves

Simplification →

- Maximum strain (**S_{max}**) : strain at 350 bar

  Higher strain = more volume reduction

- Pressure at 66 % of Smax$_x$ (**$P_{0.66}$**)

  = Resistance of the cake at 66 % of the piston stroke

Wanted :

S_{max} highest possible value

$P_{0.66}$ Lowest possible value

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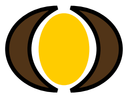
Modelling

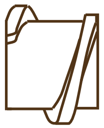


69.9

With

H : 0 for dehulled, 1 for whole seeds

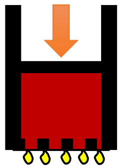
W: water content(g/100g)



(mm/min)

Adj-R^2 = 0.886

F-statistic 40.12 on 6 and 24 DF, P-value 2.35 10^{-11}



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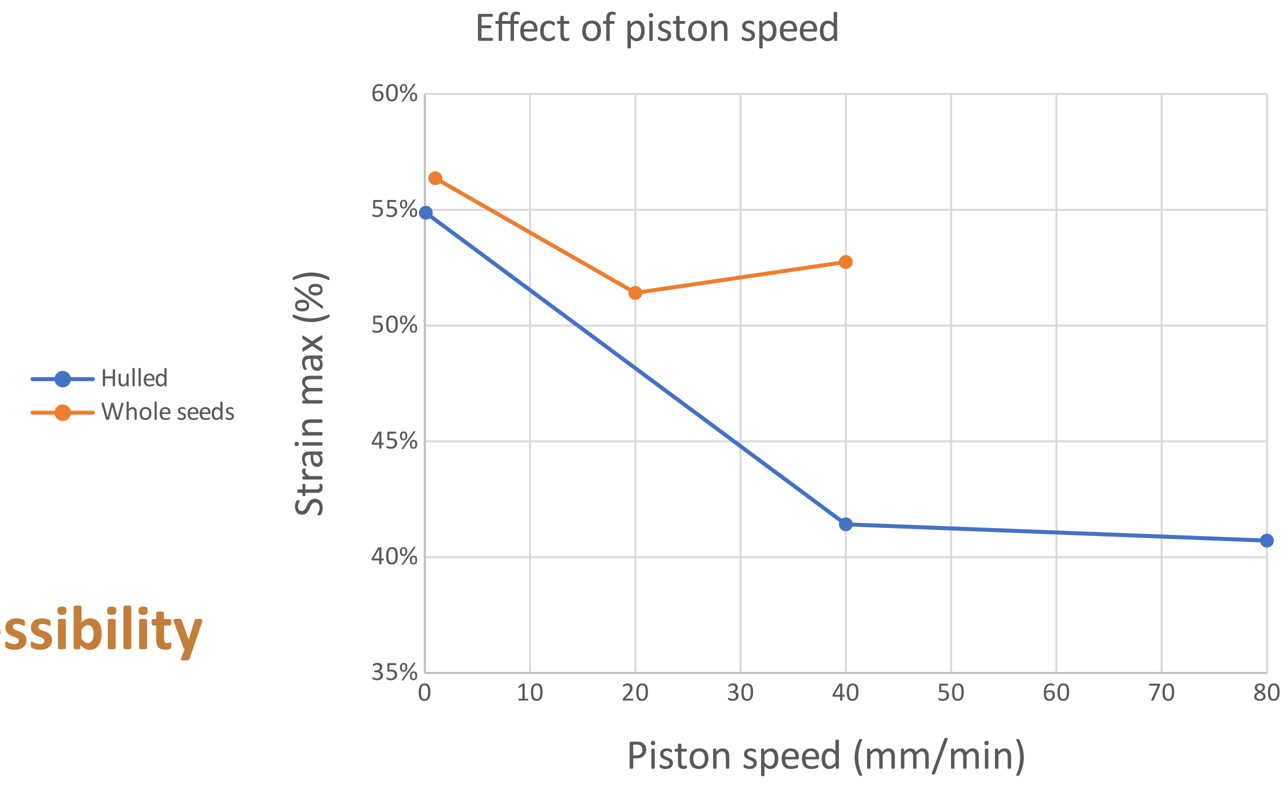

Higher speeds → lower compressibility

Modelling

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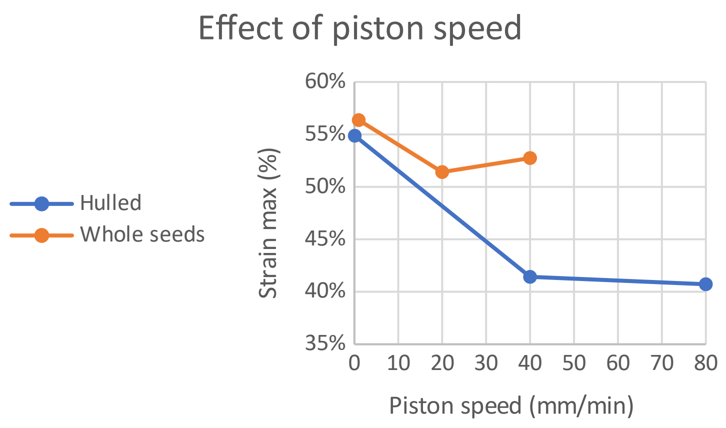
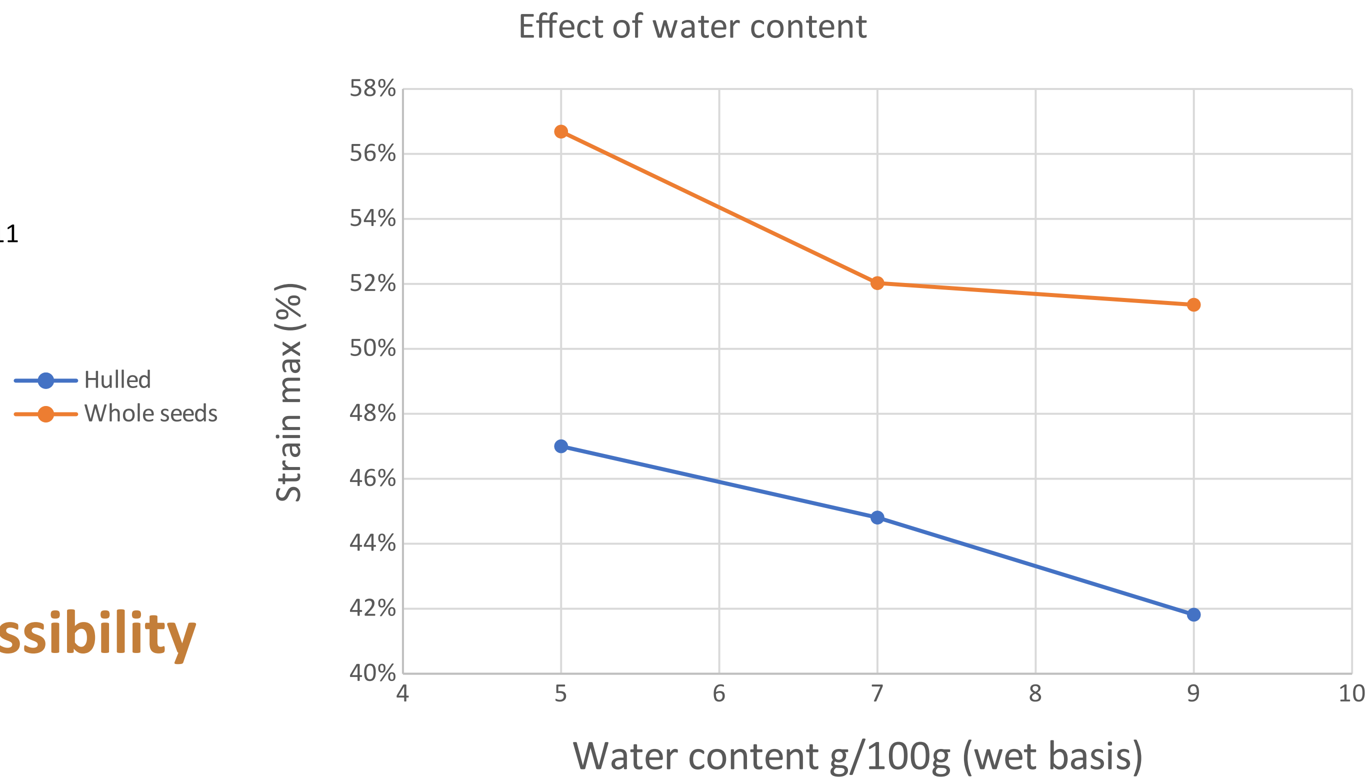
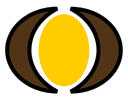


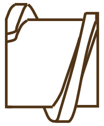


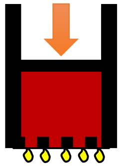
More water
Hulled seeds
→ **lower compressibility**

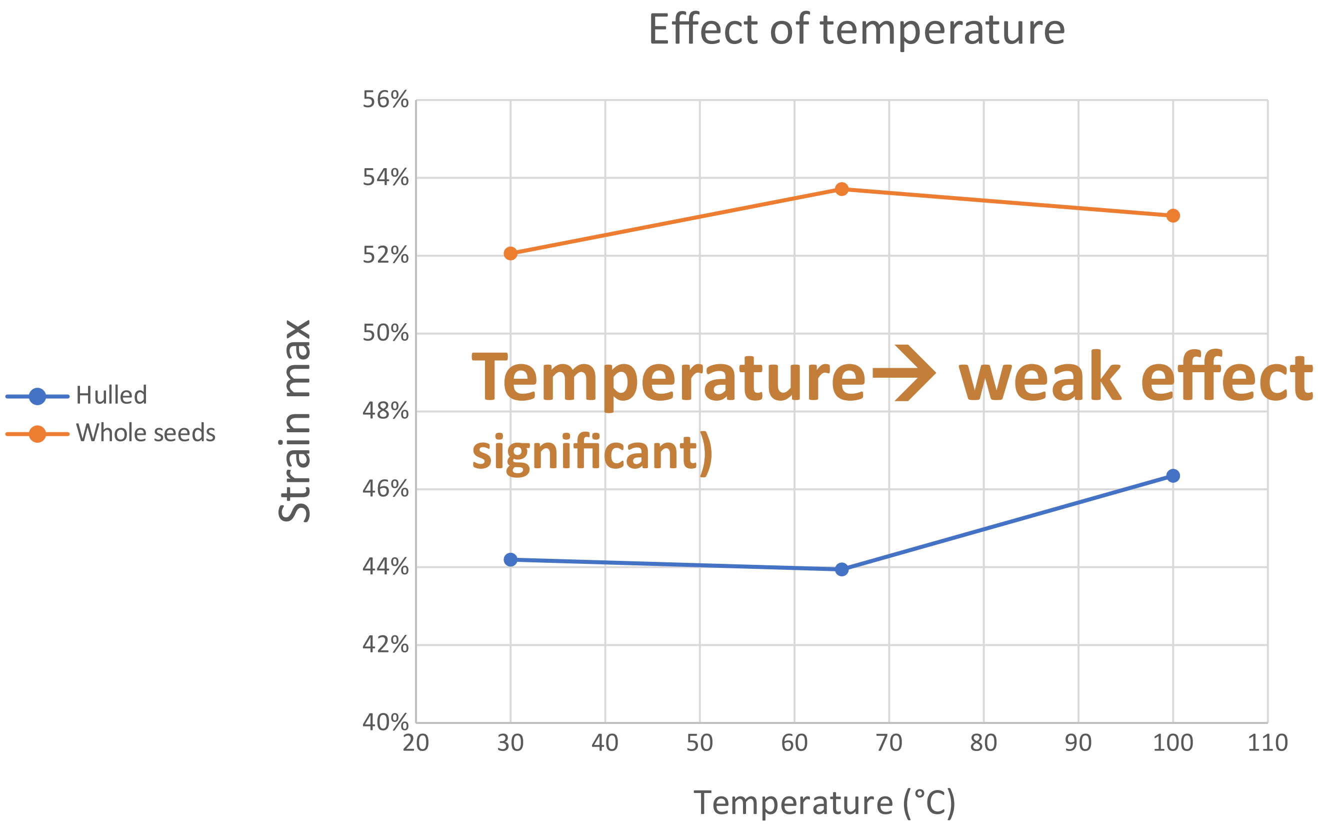
Modelling

69.9

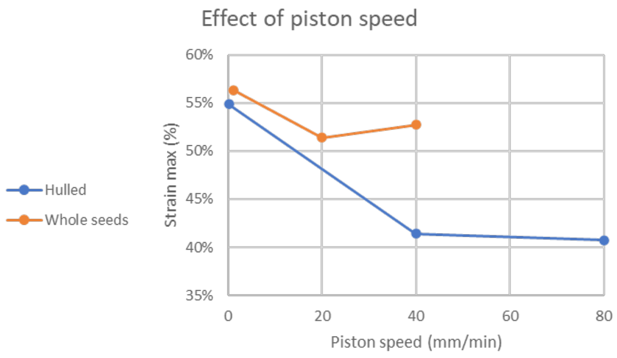


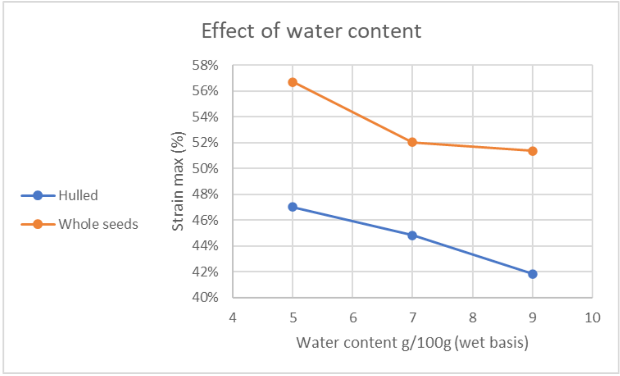






Temperature→ weak effect (not statistically significant)





With

H : 0 for dehulled, 1 for whole seeds

W: water content(g/100g)

(mm/min)

Adj-R^2 = 0,886

F-statistic 40,12 on 6 and 24 DF, P-value 2,35 10^{-11}

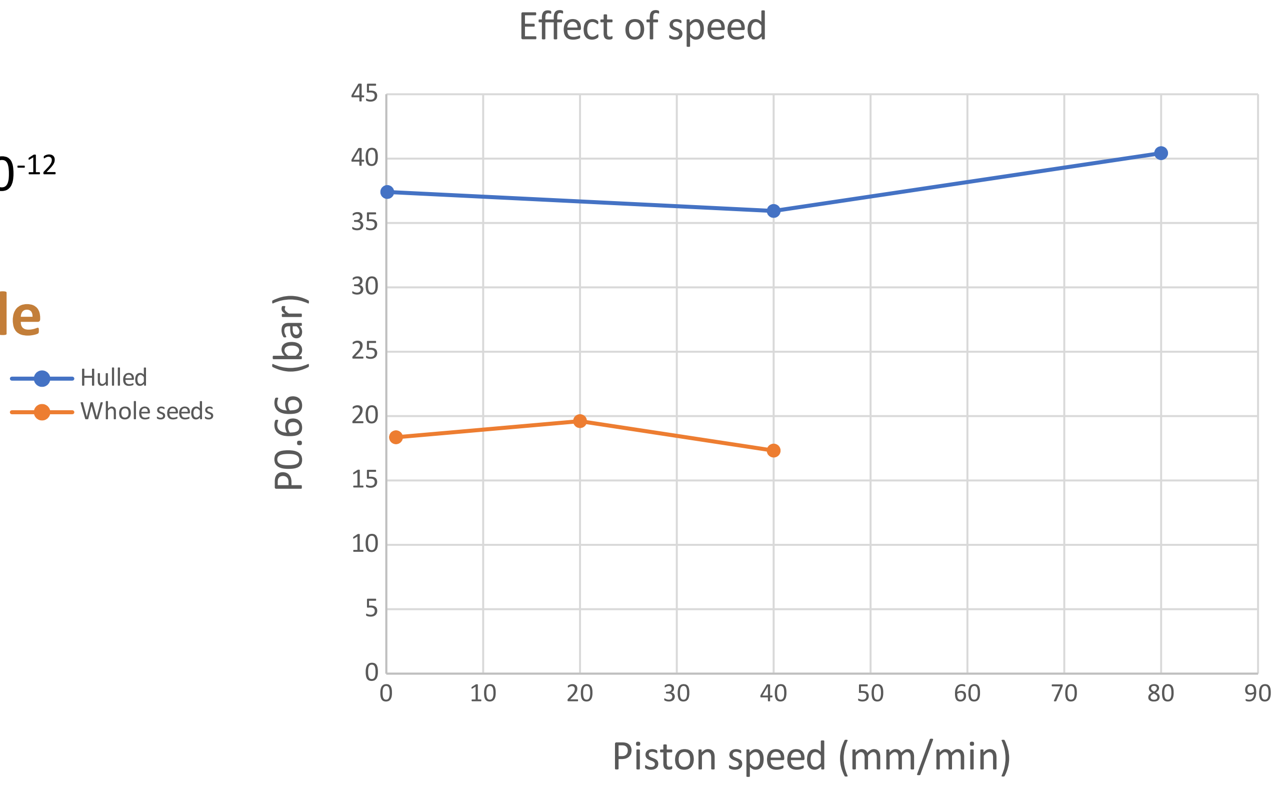
Modelling

99 HW

With
H : 0 for dehulled, 1 for whole seeds
W: water content(g/100g)

Adj-R^2 = 0.879
F-statistic 55.69 on 4 and 26 DF, P-value 2.24 10^{-12}

Large difference between hulled and whole seeds → lower P66 for whole seeds



Speed → not statistically significant

Modelling

99 HW

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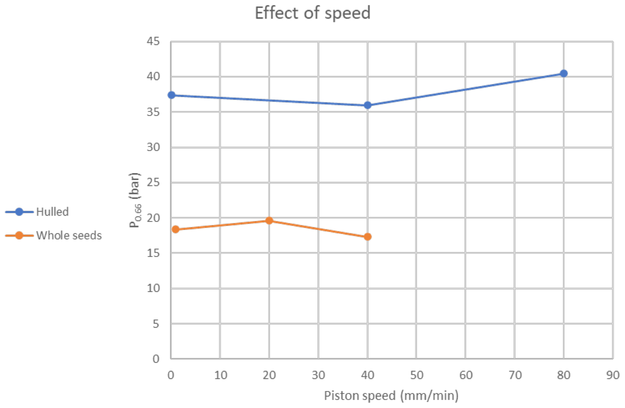
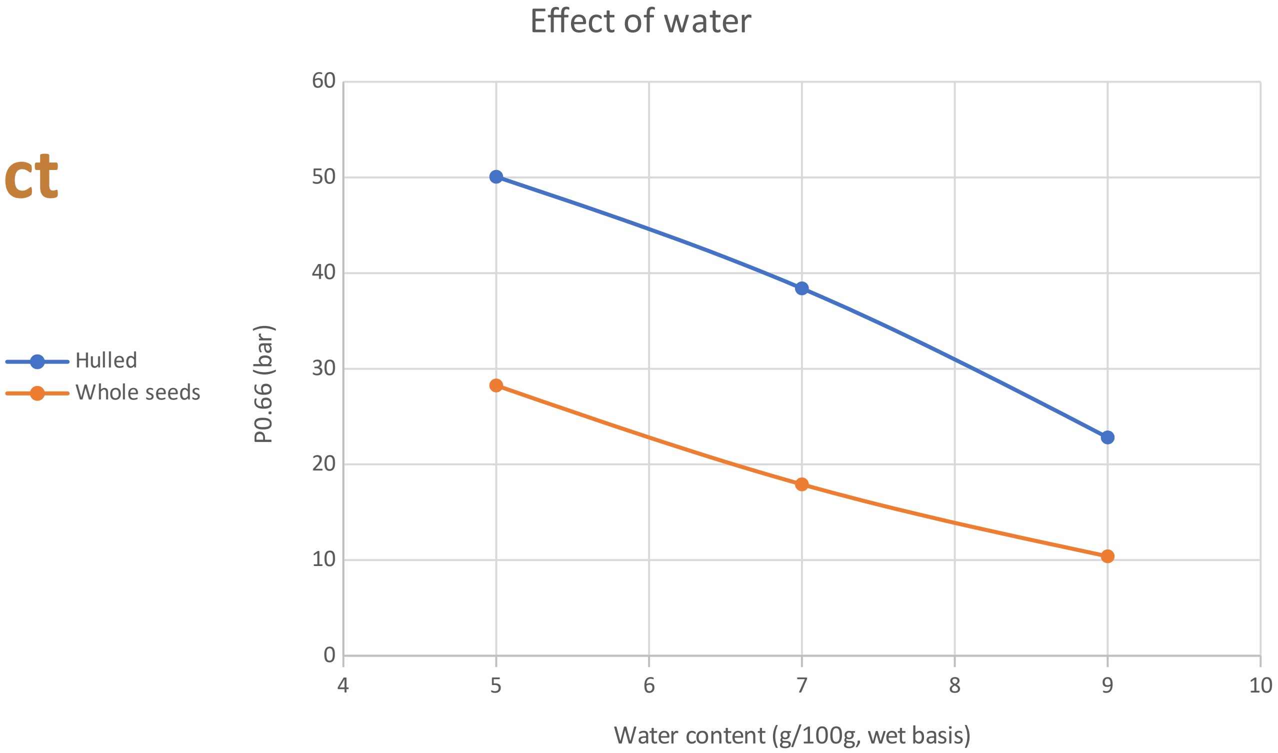


Effect of water→ Strong effect



Modelling

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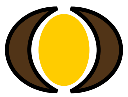

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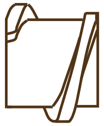

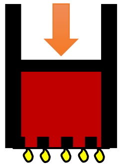

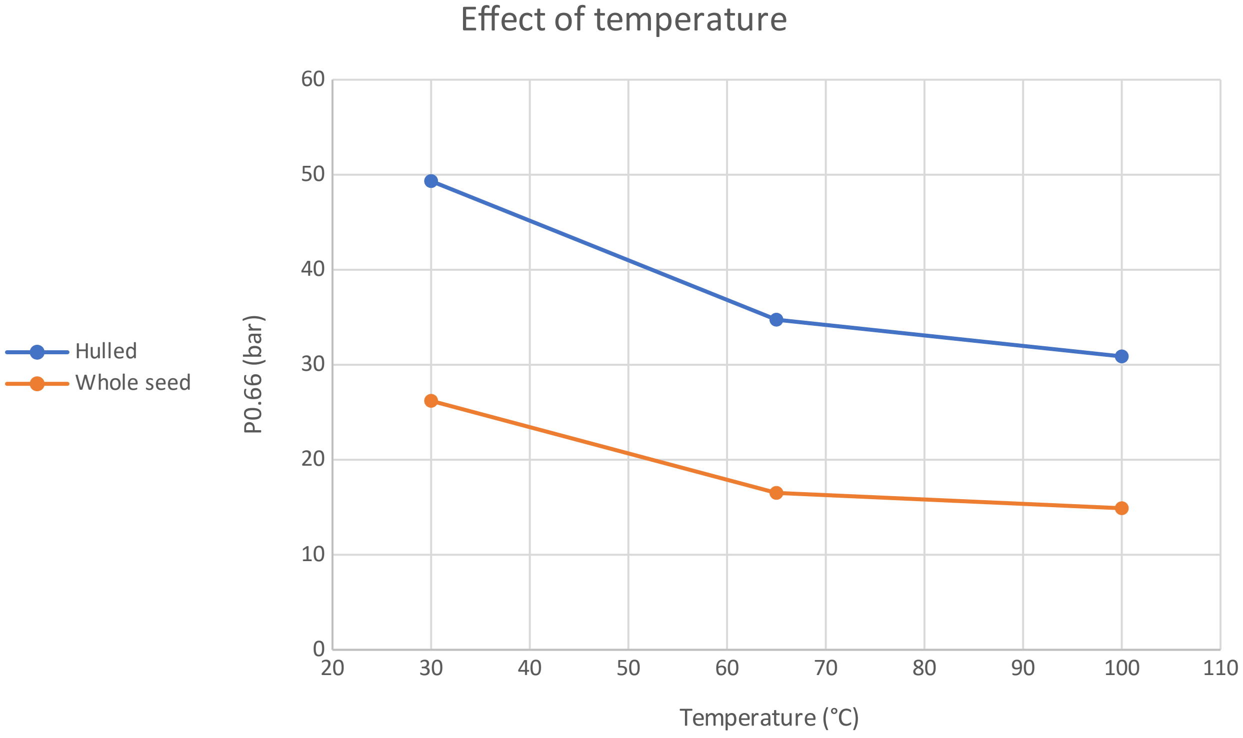

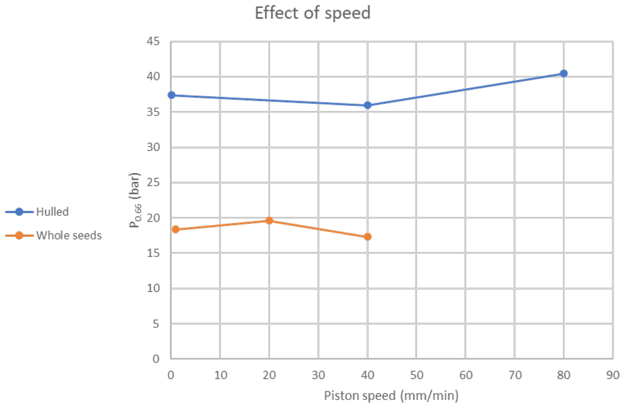

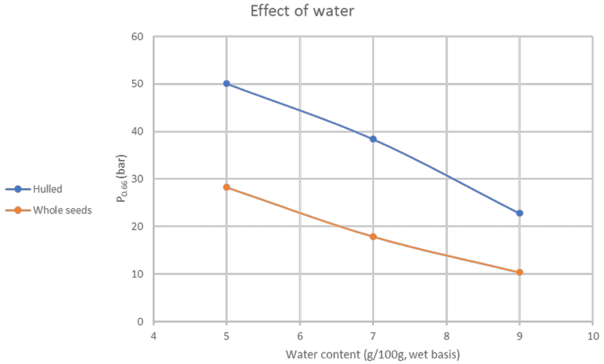

Temperature→ effect more important for low values

Main results

- **Dehulling** leads to poor compressibility except at low speed
- Increasing the **water** content reduces $P_{0.66}$ and S_{max}
- **Temperature** is neutral on S_{max} but reduces $P_{0.66}$

Given that hulling, higher water content and higher temperatures lead to higher cake plasticity, these results may seem counter-intuitive.

→ A matrix that is easier to deform might seem at first sight to be easier to compress (?)

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Interpretation

Great convergence with Raβ works :

- The main driver of compressibility is the permeability of the cake
    - **Hulls** bring resilience to capillaries and delay collapse under compression forces
    - **Water** increases plasticity and decreases the capillaries resilience
    - High **speed of compression** leads higher pressure in the cake and faster capillaries collapse
    - **Temperature** has a positive effect on drainage by reducing the oil viscosity but a negative one by increasing the plasticity of the solid residues in the cake.

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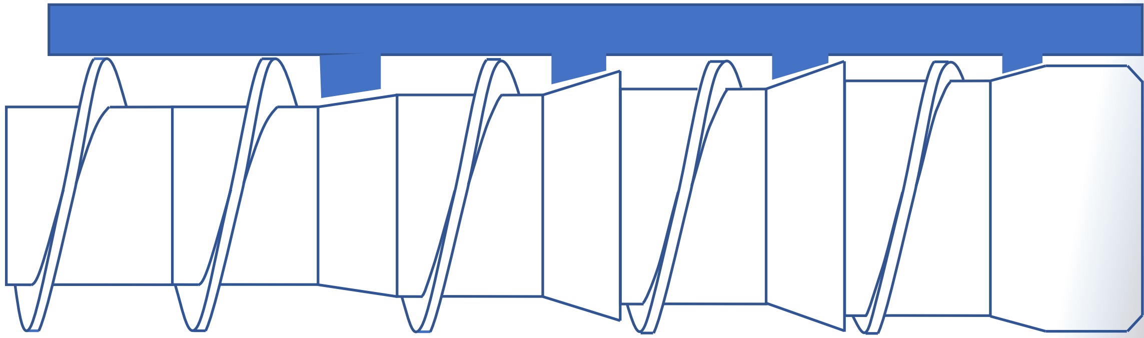
Conclusion

Emergence of a credible theory to explain the difficulty of oil extraction by mechanical pressing in low-fibre matrices (maintaining the capillary network under compressive stress).



<u>Practical implications for screw presses</u>

1/ Reduce the speed of compression in the zone of first compression:

- High pressure is counterproductive
- Reduce screw rotation speed
- Design of progressive and moderate compression screw geometry

2/ Best conditions ➔ low water content and temperature trade-off between oil viscosity and cake plasticity.

3/ Facilitate oil flow at low pressure → Porosity of the cage

4/ Regenerate porosity in the cake when passing through the cone rings