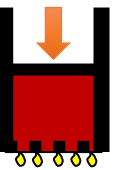


# Modelling of the resistance to compression of dehulled & whole rapeseed under unidirectional pressure



Sylvie Dauguet <sup>1</sup>

Florian Rousseau <sup>1</sup> 

Patrick Carré <sup>1</sup>

Raphaëlle Savoie <sup>2</sup>

<sup>1</sup> Terres Inovia, Pessac, France

<sup>2</sup> ENSMAC, Pessac, France



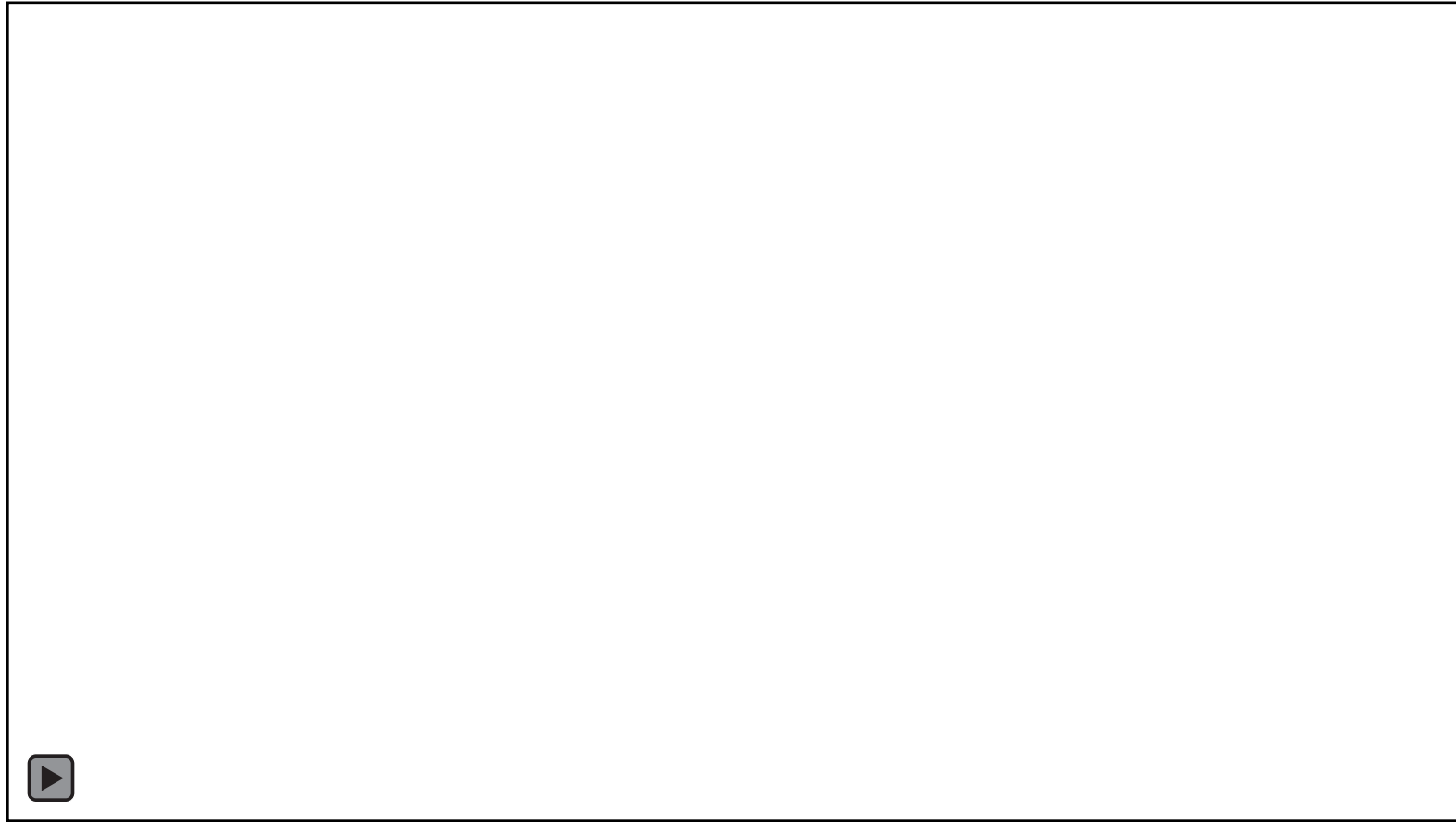
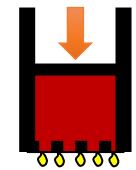
# The challenge of mechanical cold extraction of dehulled seeds



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

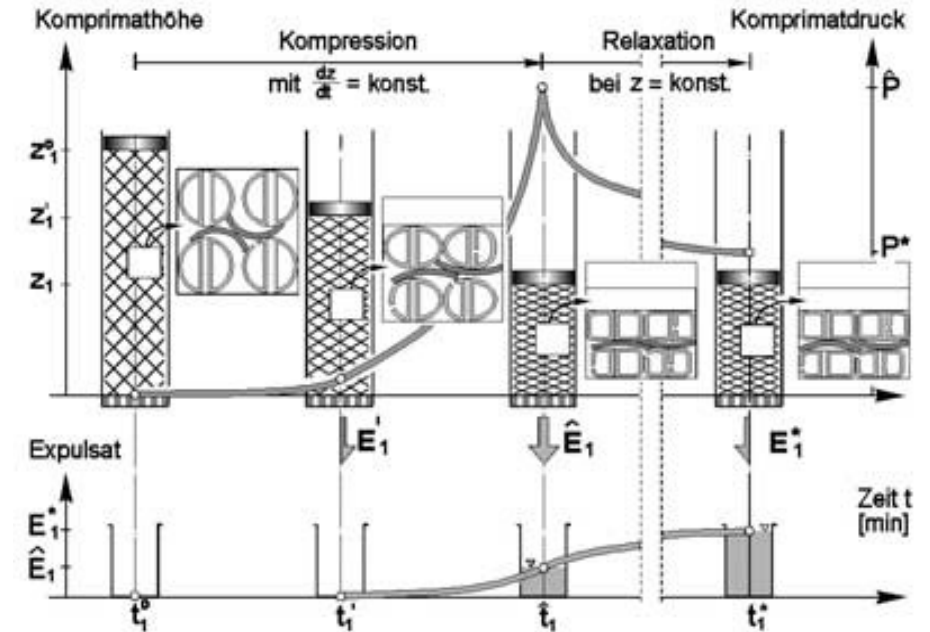
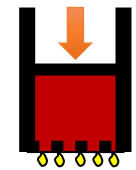


# Current state of knowledge



**Raß 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 play a role** in maintaining the cake **permeability** during compression



# Material and methods



**Unidirectional micropress :**  
**Universal Mecmesin bench**

- Fine measure of the piston displacement piston ( $\mu\text{m}$ )
- Force up to 50 kN

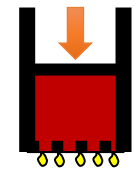
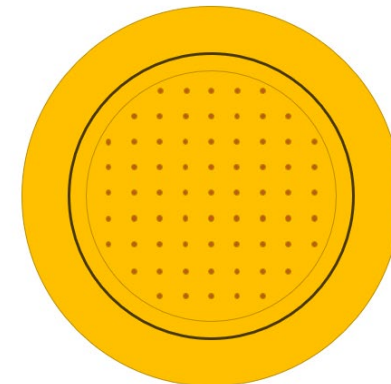
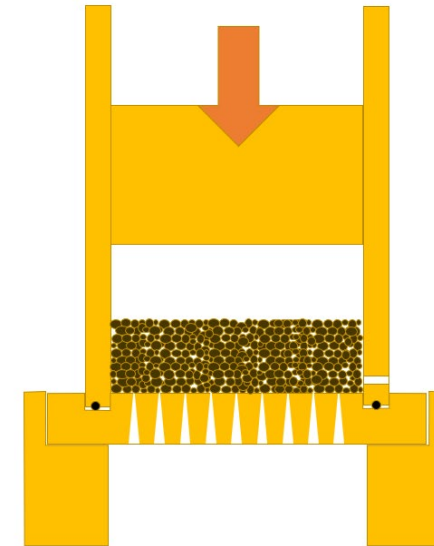
**Cell of compression**

- 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  $\sim 80 \mu\text{m}$



# Study of dehulled rapeseed compressibility

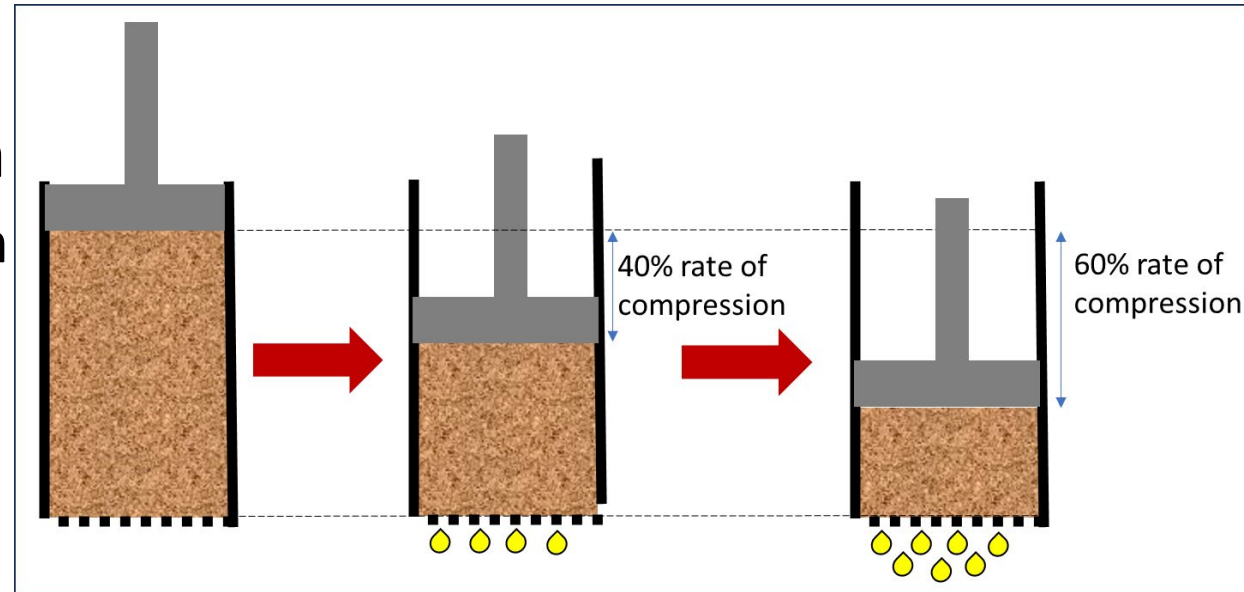
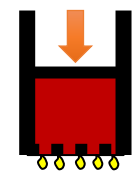


- Box Bhenkem experimental design
  - Piston speeds: 0.1, 40 et 80 mm/min
  - Water content: 5, 7 et 9%
  - Temperatures: 30, 65 et 100°C



## • Conditions :

- Comparison between hulled and non-hulled seeds
- 3 or 4 repetitions of the central point
- **Observed variable: force on the piston → Stress (bar) = f(Strain)**
- **Strain = rate of compression = (initial height - actual height) / Initial Height**

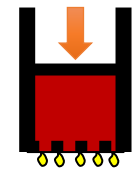




# Explaining the compressibility of rapeseed by the material plasticity



**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



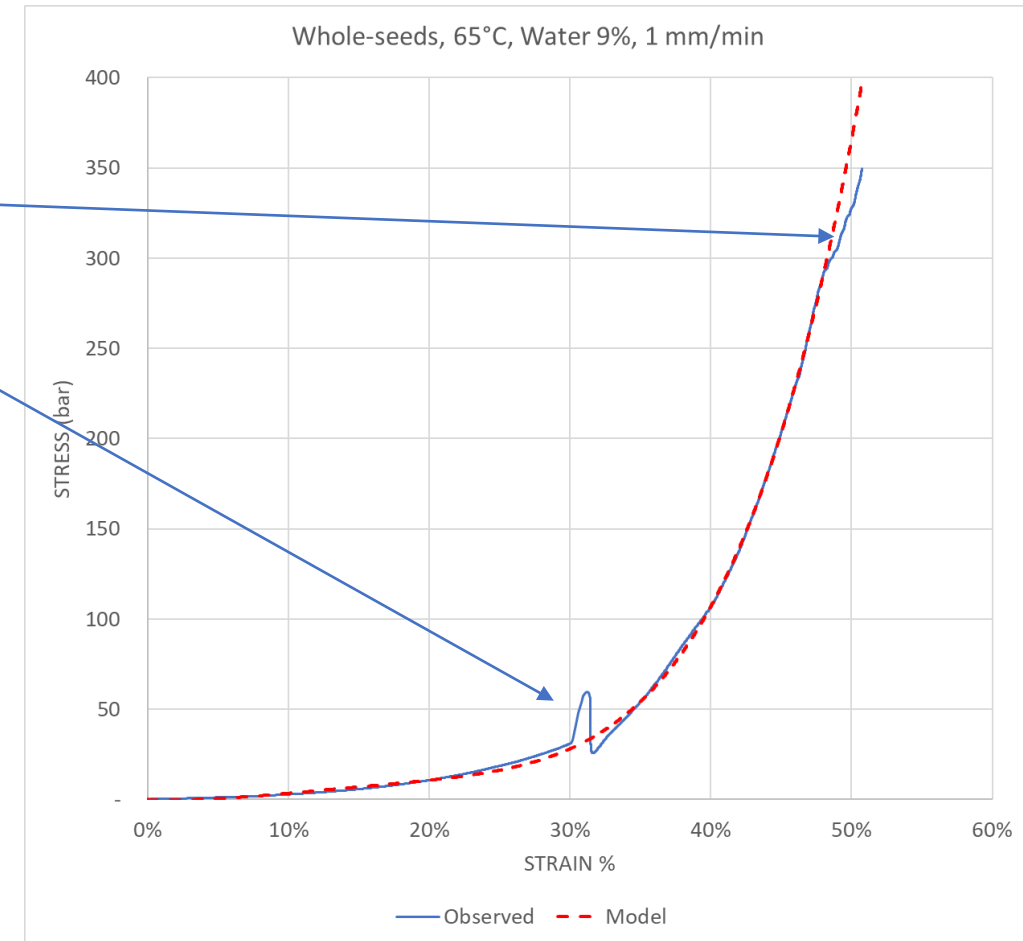
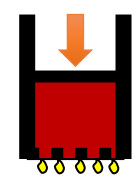
The model that fitted the observations well was

$$\text{Stress} = a \cdot \tan(bx)^c + dx$$

With:

a, b, c, d = adjusted constant

x = strain (rate of compression)

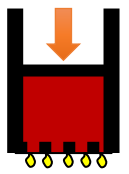


# A simple way to summarise the information contained in the curves

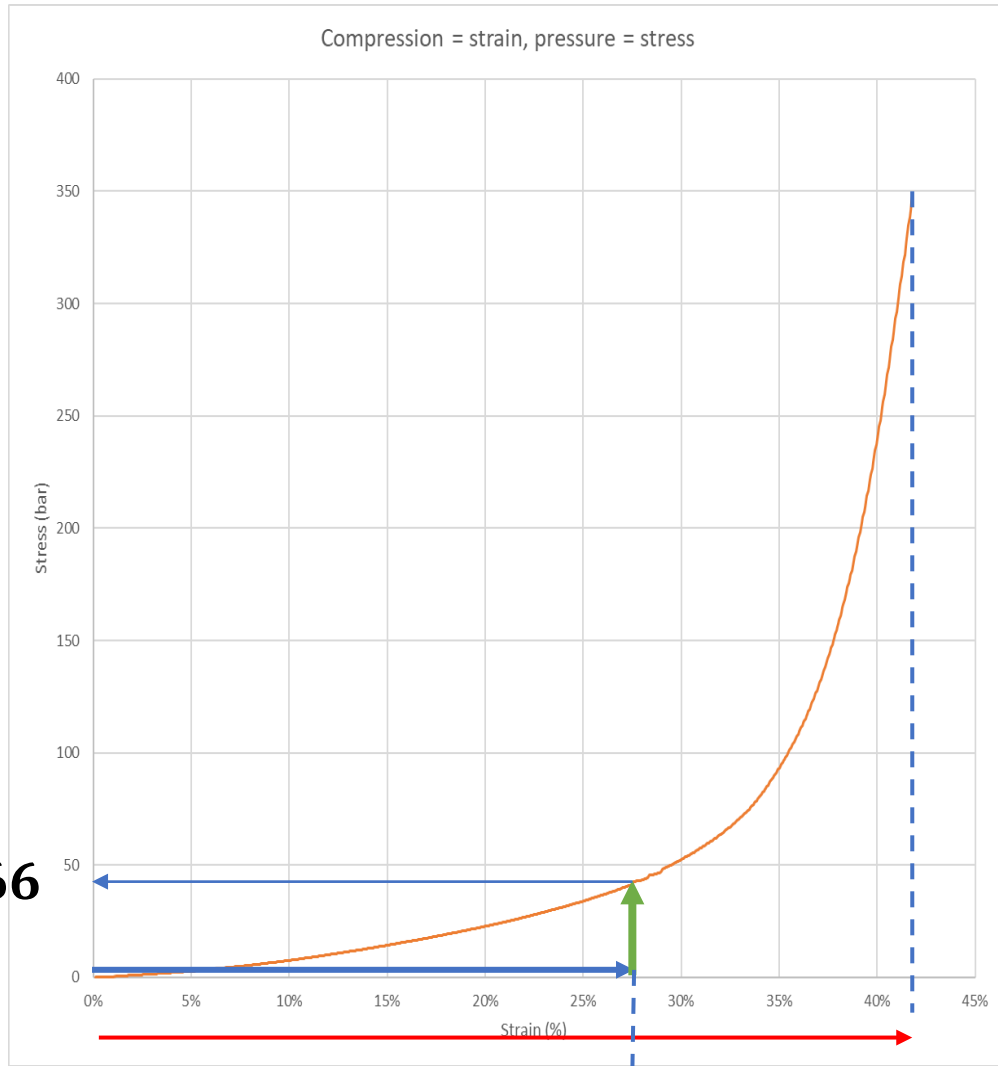


Simplification →

- Maximum strain ( $S_{max}$ ) : strain at 350 bar  
Higher strain = more volume reduction
- Pressure at 66 % of  $S_{max}$  ( $P_{0.66}$ )  
= Resistance of the cake at 66 % of the piston stroke



**Wanted :**  
 $S_{max}$  highest possible value  
 $P_{0.66}$  Lowest possible value



$P_{0.66}$

$\frac{2}{3}S_{max}$        $\frac{8}{8}S_{max}$

# Modelling $S_{max}$



$$S_{max} = 69.9 + 0.77H - 2.11W - 0.70S_p + 0.004S_p^2 + 0.25HS_p + 0.03WS_p$$

With

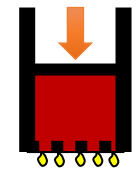
H : 0 for dehulled, 1 for whole seeds

W: water content(g/100g)

$S_p$ : speed of piston displacement (mm/min)

Adj-R<sup>2</sup> = 0.886

F-statistic 40.12 on 6 and 24 DF, P-value 2.35 10<sup>-11</sup>



# Modelling $S_{max}$



$$S_{max} = 69.9 + 0.77H - 2.11W - 0.70S_p + 0.004S_p^2 + 0.25HS_p + 0.03WS_p$$

With

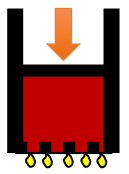
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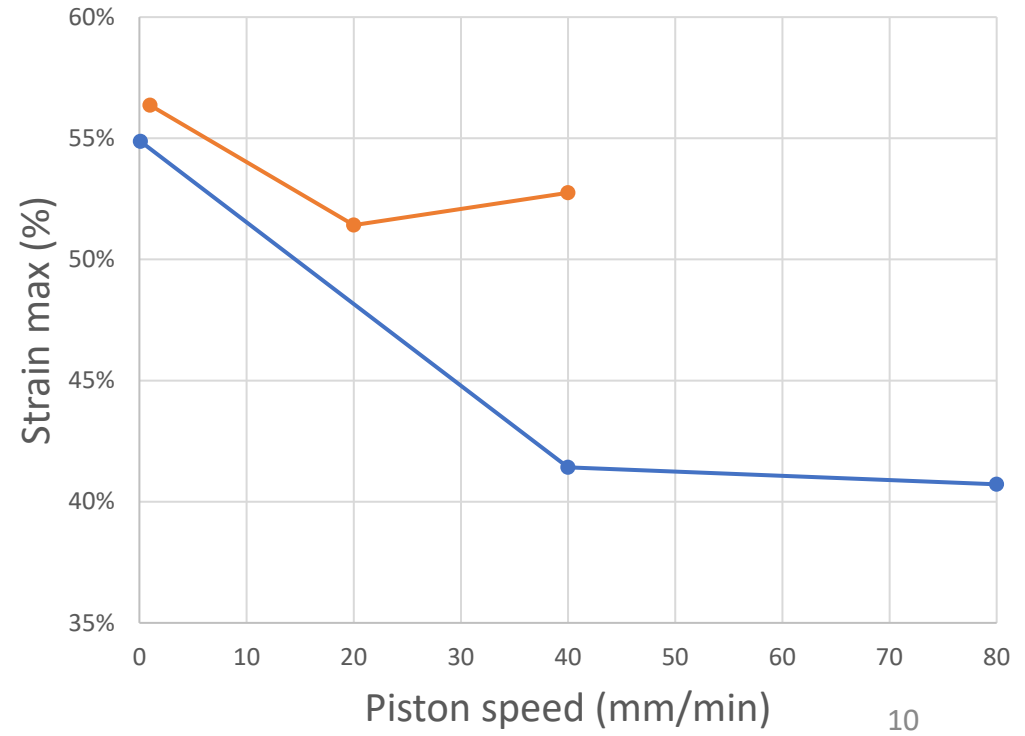
F-statistic 40.12 on 6 and 24 DF, P-value 2.35 10<sup>-11</sup>



● Hulled  
● Whole seeds

Higher speeds → lower compressibility

Effect of piston speed



# Modelling $S_{max}$



$$S_{max} = 69.9 + 0,77H - 2.11W - 0.70S_p + 0.004S_p^2 + 0.25HS_p + 0.03WS_p$$

With

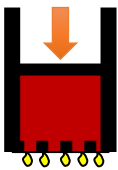
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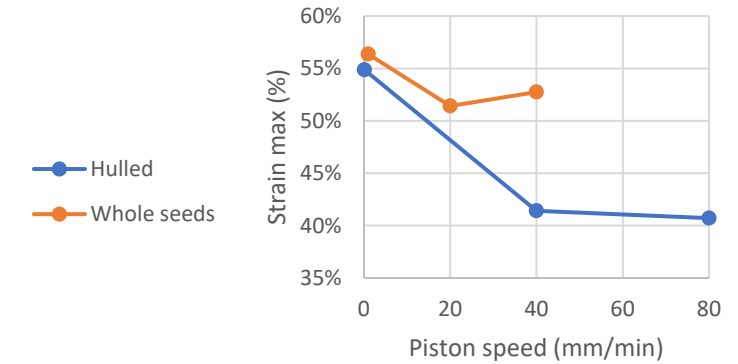
F-statistic 40.12 on 6 and 24 DF, P-value 2.35 10<sup>-11</sup>



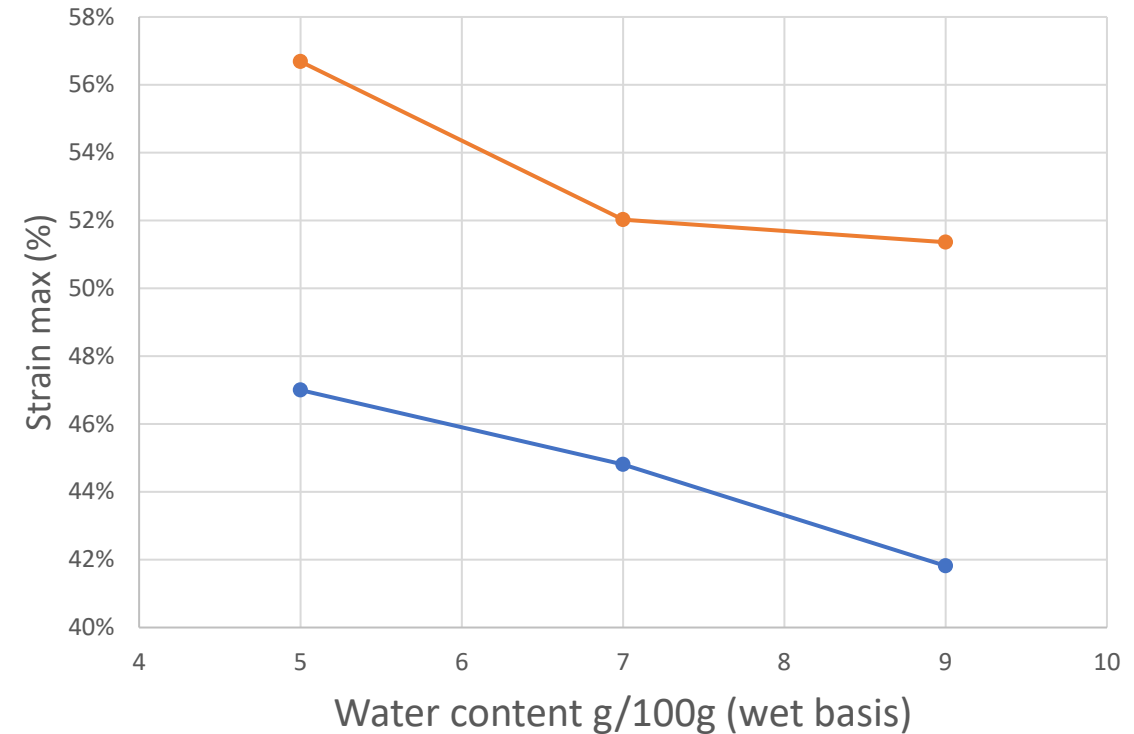
● Hulled  
● Whole seeds

More water  
Hulled seeds } → lower compressibility

Effect of piston speed



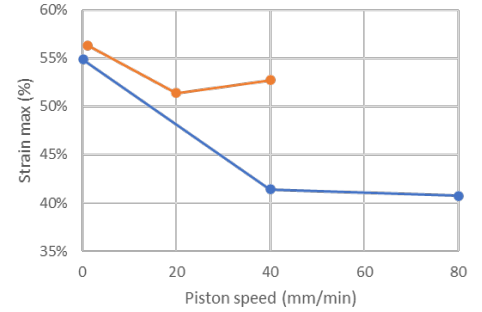
Effect of water content



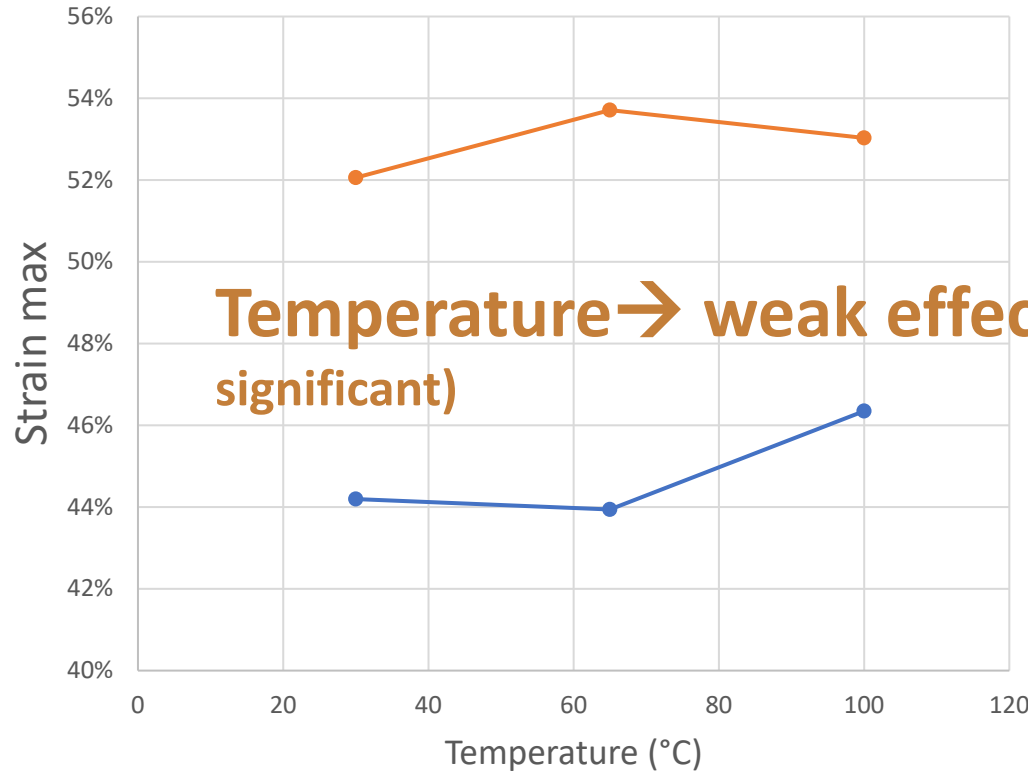
# Modelling $S_{max}$

$$S_{max} = 69.9 + 0,77H - 2.11W - 0.70S_p + 0.004S_p^2 + 0.25HS_p + 0.03WS_p$$

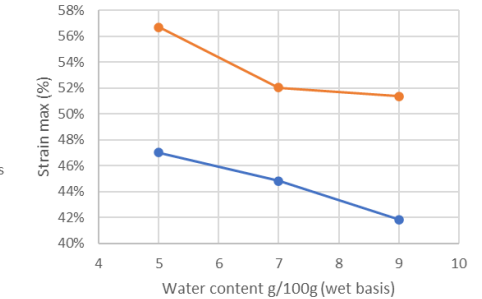
Effect of piston speed



Effect of temperature



Effect of water content



With

H : 0 for dehulled, 1 for whole seeds

W: water content(g/100g)

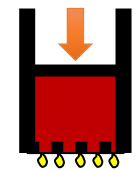
$S_p$ : speed of piston displacement (mm/min)

Adj-R<sup>2</sup> = 0,886

F-statistic 40,12 on 6 and 24 DF, P-value 2,35 10<sup>-11</sup>



● Hulled  
● Whole seeds



# Modelling P<sub>0,66</sub>

$$P_{0.66} = 99 - 35.2H - 6.81W - 0.2T + 2.4HW$$



With

H : 0 for dehulled, 1 for whole seeds

W: water content(g/100g)

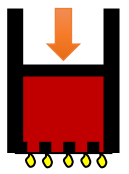
T: temperature (°C)

Adj-R<sup>2</sup> = 0.879

F-statistic 55.69 on 4 and 26 DF, P-value 2.24 10<sup>-12</sup>



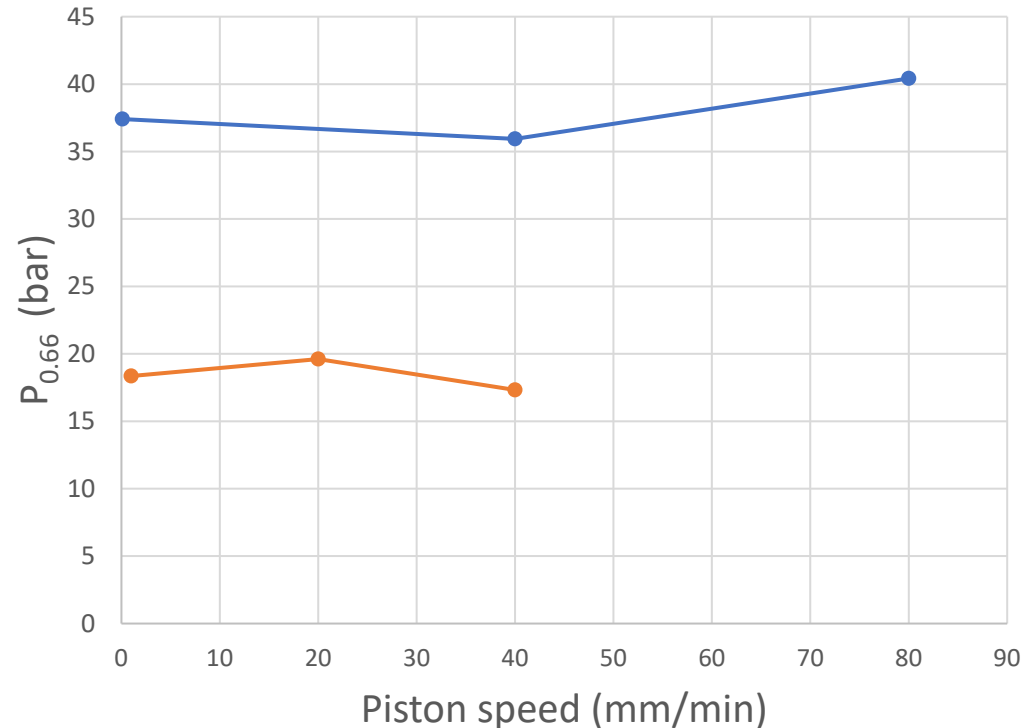
Large difference between hulled and whole seeds → lower P<sub>66</sub> for whole seeds



Speed → not statistically significant

● Hulled  
● Whole seeds

Effect of speed



# Modelling $P_{0,66}$

$$P_{0,66} = 99 - 35.2H - 6.81W - 0.2T + 2.4HW$$

With

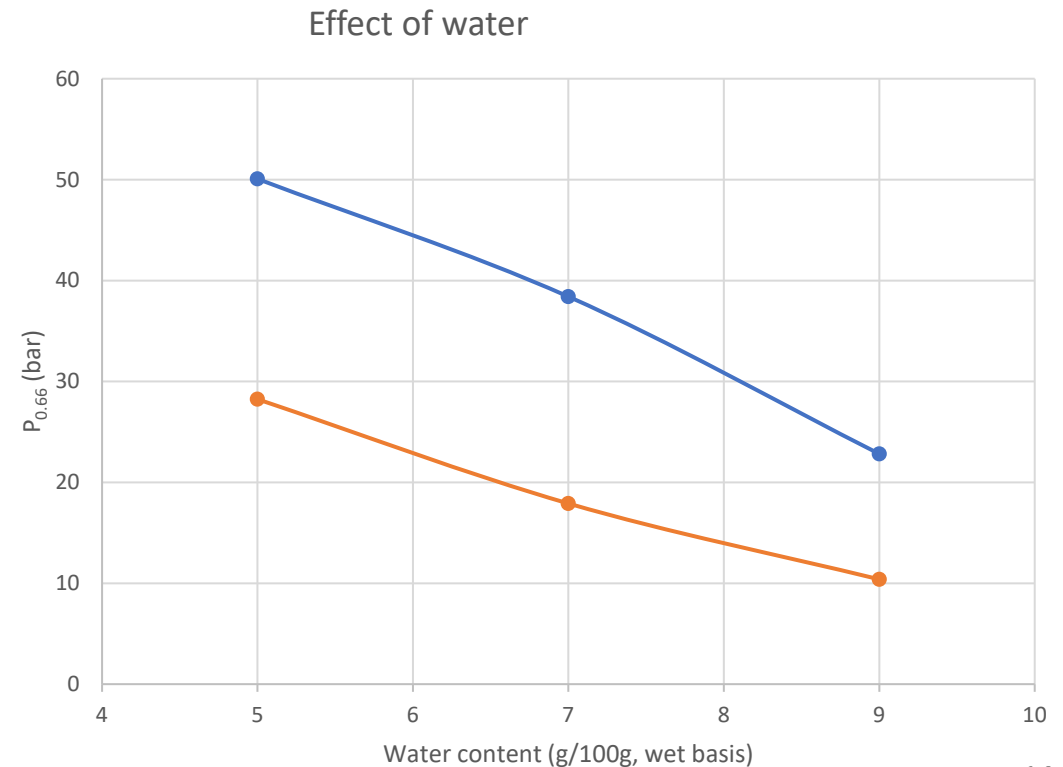
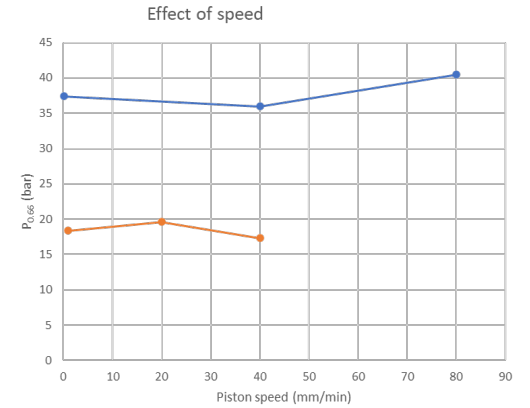
H : 0 for dehulled, 1 for whole seeds

W: water content(g/100g)

T: temperature (°C)

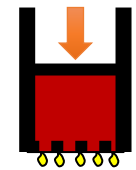
Adj-R<sup>2</sup> = 0,879

F-statistic 55,69 on 4 and 26 DF, P-value 2,24 10<sup>-12</sup>



**Effect of water → Strong effect**

● Hulled  
● Whole seeds



# Modelling $P_{0,66}$

$$P_{0,66} = 99 - 35.2H - 6.81W - 0.2T + 2.4HW$$

With

H : 0 for dehulled, 1 for whole seeds

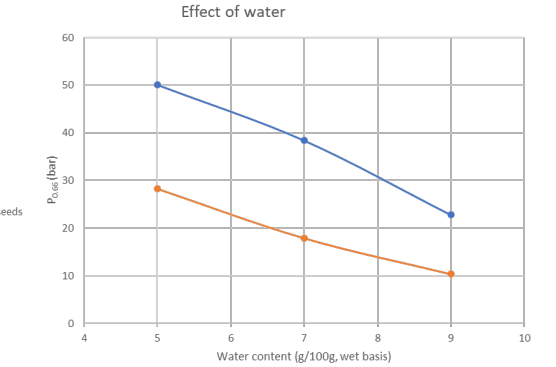
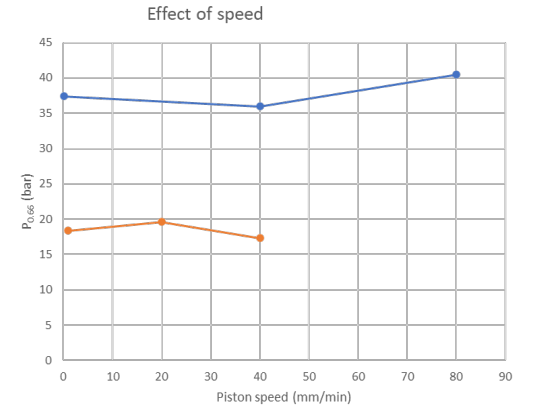
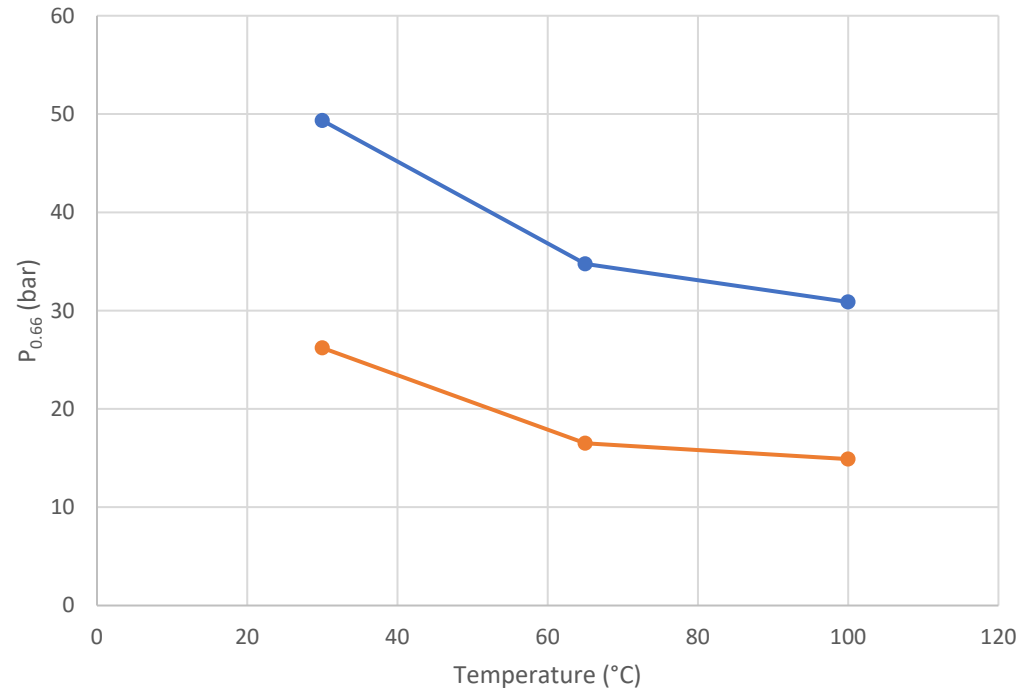
W: water content(g/100g)

T: temperature (°C)

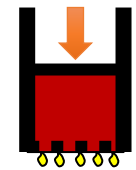
Adj-R<sup>2</sup> = 0,879

F-statistic 55,69 on 4 and 26 DF, P-value 2.24 10<sup>-12</sup>

Effect of temperature



**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.

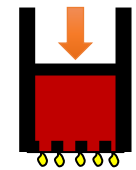
→ A matrix that is easier to deform might seem at first sight to be easier to compress (?)




# Interpretation

Great convergence with Raß 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.



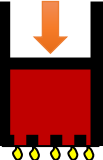
# Conclusion

 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).

## Practical implications for screw presses

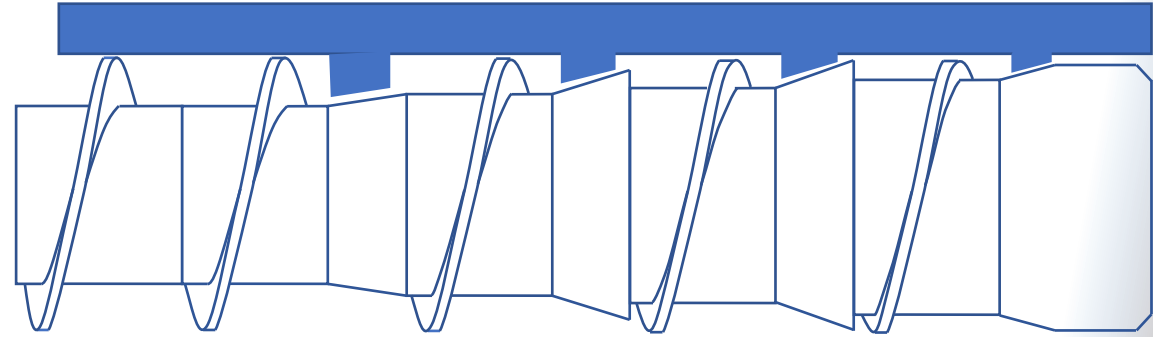
 1/ Reduce the speed of compression in the zone of first compression:

- 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





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Thank you for your kind  
attention