Modeling alpha-galactosides behavior during cowpea soaking-cooking for nutritional optimization

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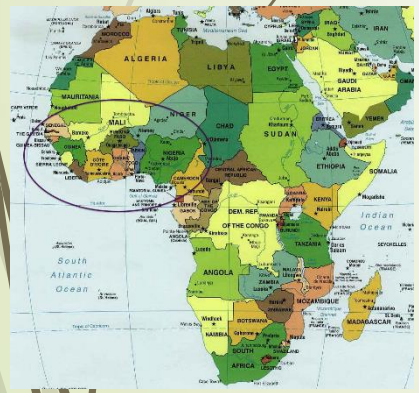
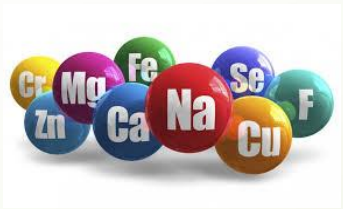
What is cowpea ?

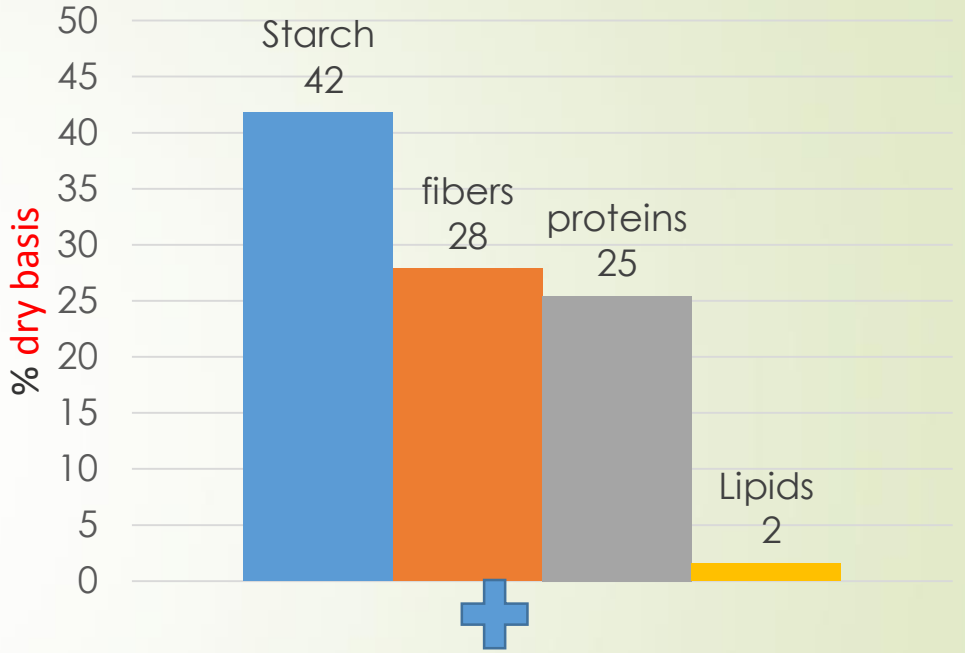


Legume (Bean) cropped and consumed in West Africa (*Wankoun* cultivar)

Vitamins

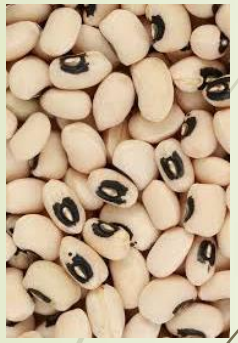


Minerals



Anti-nutrients:
Alpha-galactosides
Phytate

The soaking-cooking process



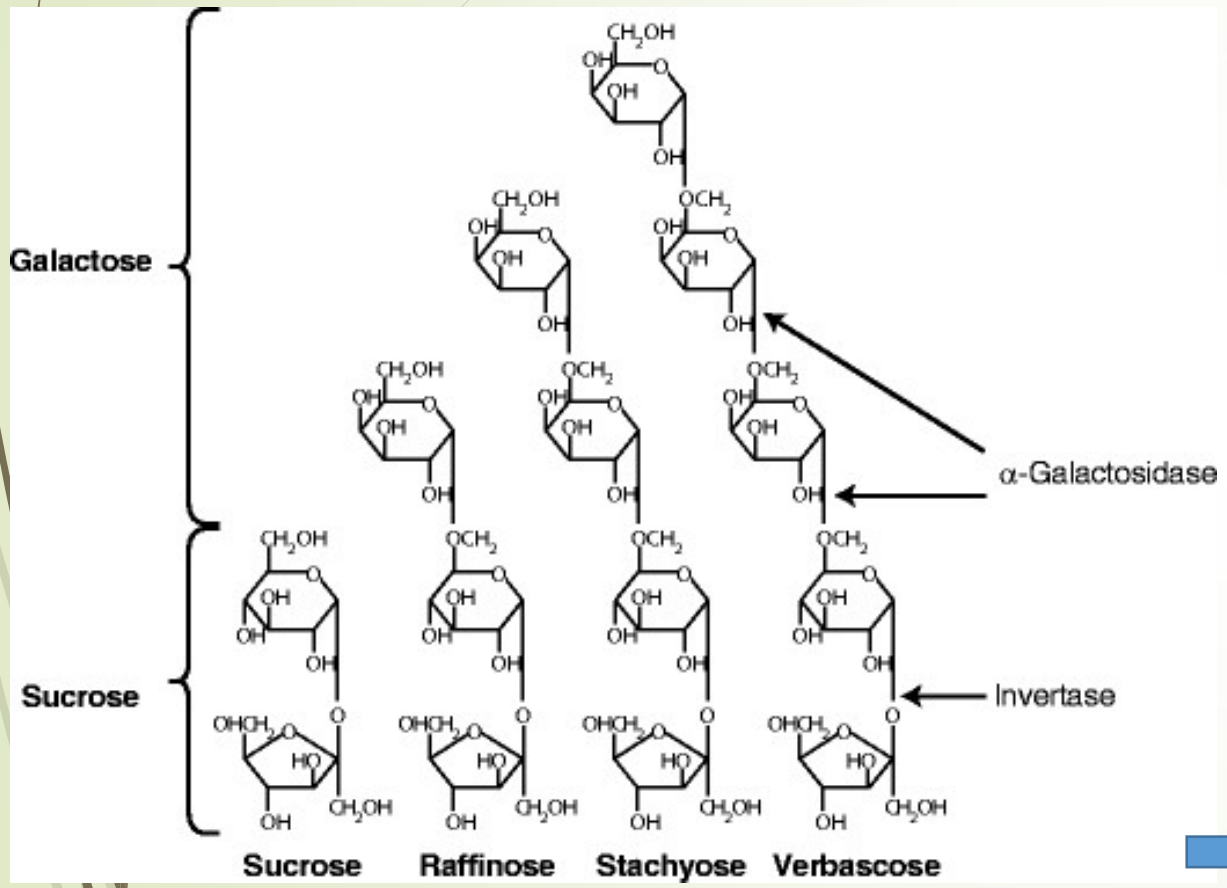
And
/
Or

Soaking (1 night)

Cooking (25min if previously soaked or 1h if not)

Soaking-cooking conditions strongly impact the nutritional and antinutritional content of cowpea seed

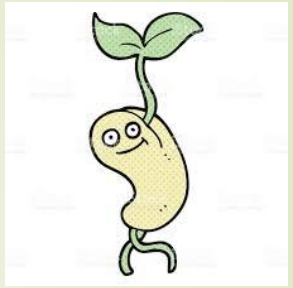
Alpha-galactosides: definition

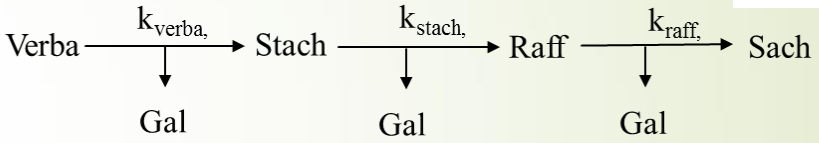


0,4 % 3,8 % 0,5 %

Wankoun (% dry basis)

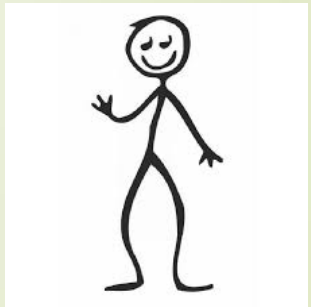
Functionalities in the seed:
-Prevent water losses
-Energy storage for germination





Adverse human effects:
-intestinal disorders
-flatulence problems

Soaking-cooking process can be optimized to reduce cowpea alpha-galactoside content

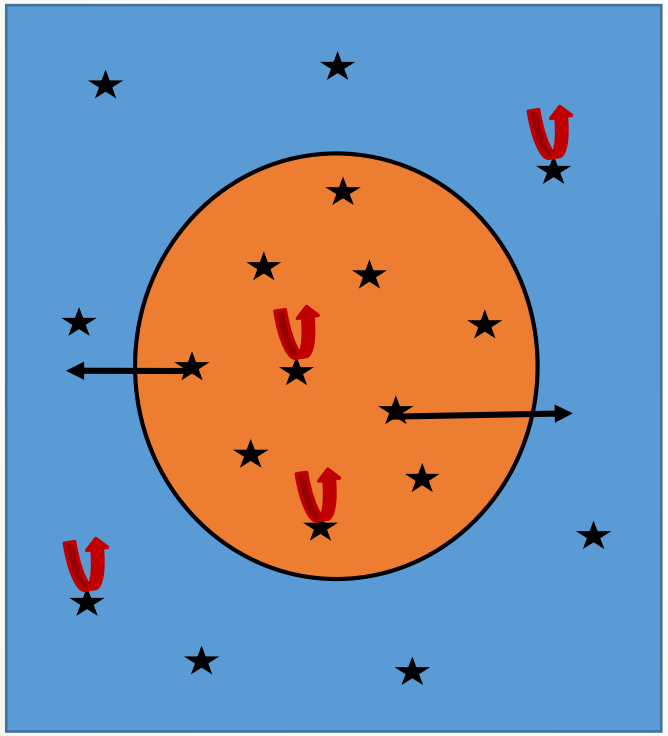


Objectives of the study

★ Alpha-galactosides :
-Raffinose
-Stachyose
-Verbascose

→ Diffusion:
Apparent diffusivity
D ($m^2.s^{-1}$)
$J=-\rho \times D \times$ [α-gal]

Degradation :
Rate constant k (s^{-1})
$k_{(\alpha\text{-gal})} \times$[α-gal]



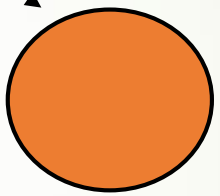
Cowpea soaking-cooking

- To determine through model adjustment the apparent diffusivities and rate constants of α-gal depending on conditions (*T*, *t*,…) thanks to a model

- To determine with the adjusted model optimal processing pathways to reduce α-galactoside consumption

Method

Soaking-cooking conditions :
30/60/95°C with a 4:1
water-to-seed ratio (m/m)



Seed freeze-drying +
grinding

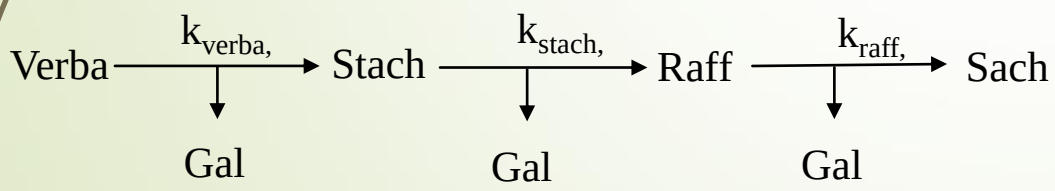
Soaking water

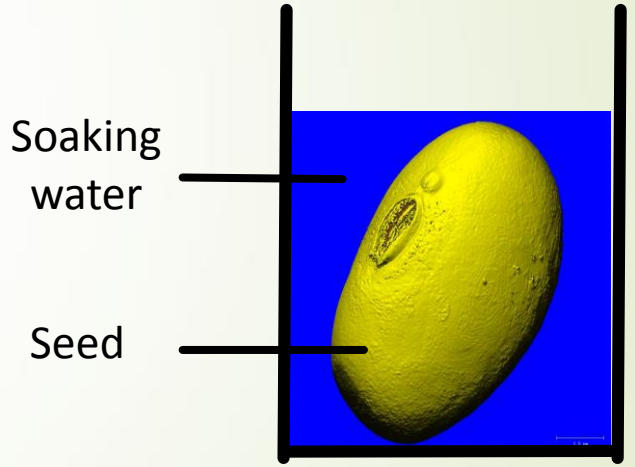
Extraction 80%
ethanol at 80 °C

COMSOL
Model + Matlab
Optimization

Model assumptions

- Single cowpea seed with 2D axi-symmetric properties
- Two homogeneous compartments (seed and soaking water being dynamically absorbed)
- Water transport, without seed deformation
- No thermal degradation
- First-order kinetics (rate constants k (s^{-1})):





- Alpha-galactosides diffusivities ($m^2.s^{-1}$) identified applying Fick's law

Governing equations (PDE coefficient mode)

Seeds

$$\frac{\partial[Verba]}{\partial t} - \nabla.\left(D_{Verba}\nabla[Verba]\right) = -k_{verba,\Omega}[Verba]$$

$$\frac{\partial[Stach]}{\partial t} - \nabla\left(D_{Stach}\nabla[Stach]\right) = k_{verba,\Omega}[Verba] - k_{stach,\Omega}[Stach]$$

$$\frac{\partial[Raffi]}{\partial t} - \nabla\left(D_{Raffi}\nabla[Raffi]\right) = k_{stach,\Omega}[Stach] - k_{raffi,\Omega}[Raffi]$$

Water

$$V_{SW}\frac{\partial[Verba]}{\partial t} = J_{Verba}(t) - k_{verba,\Omega}[Verba]V_{SW}$$

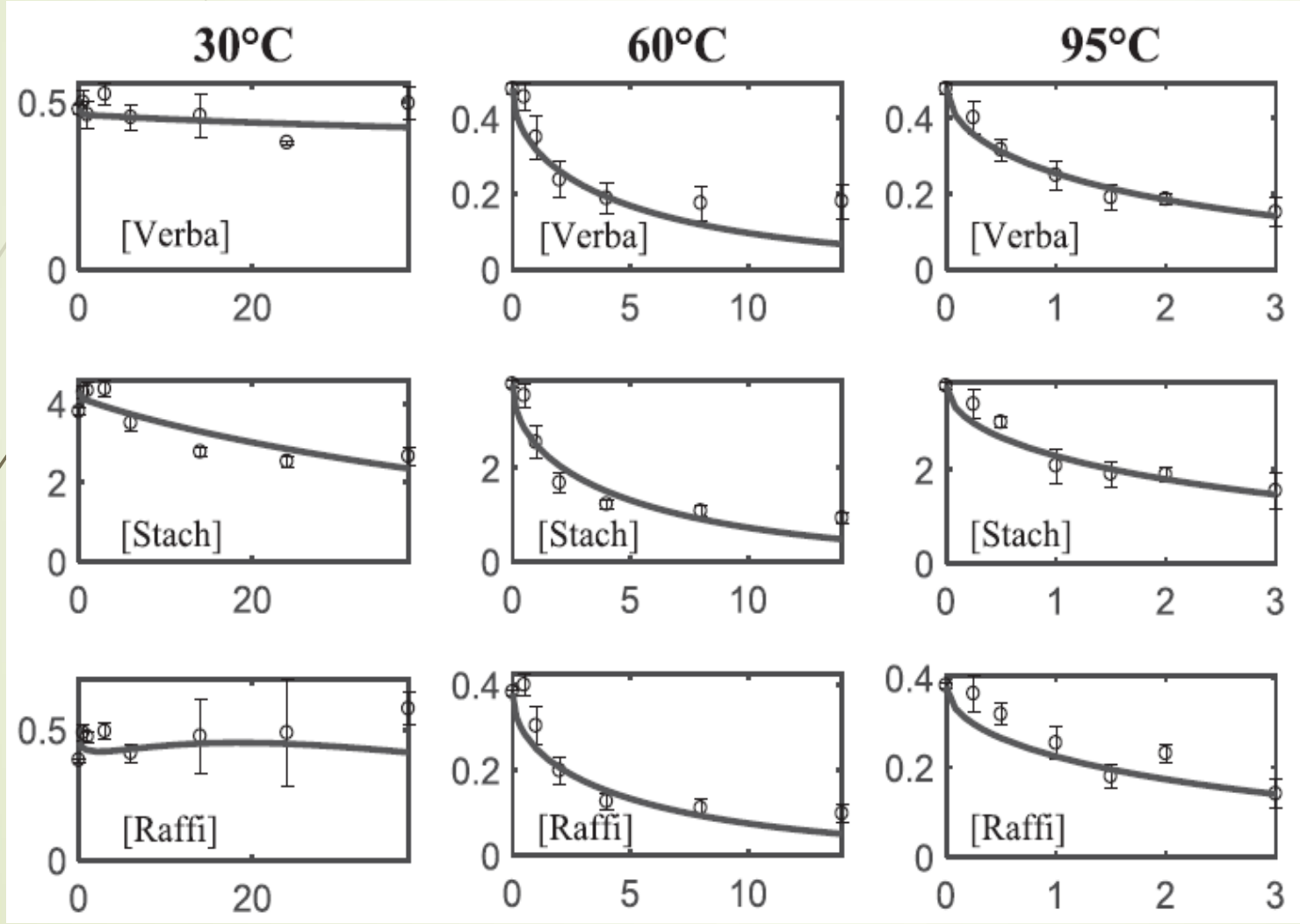
$$V_{SW}\frac{\partial[Stach]}{\partial t} = J_{Stach}(t) + k_{verba,\Omega}[Verba]V_B - k_{stach,\Omega}[Stach]V_{SW}$$

$$V_{SW}\frac{\partial[Raffi]}{\partial t} = J_{Raffi}(t) + k_{stach,\Omega}[Stach]V_B - k_{raffi,\Omega}[Raffi]V_{SW}$$

-Simultaneous identification of 9 model parameters with 95% confidence intervals applying Monte Carlo method

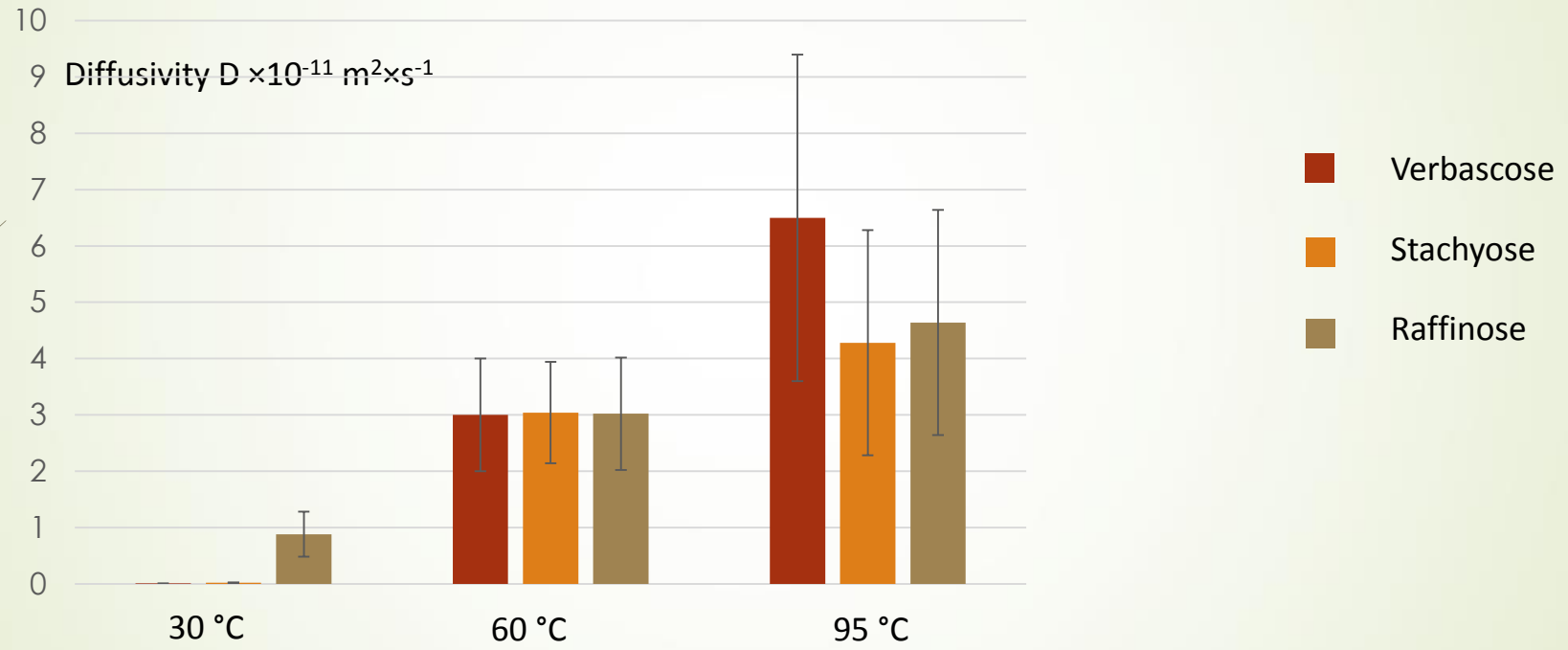
-Optimization by minimizing the determinant of covariance matrix (Livelink for Matlab® coupled with COMSOL v5.2a)

Model Adjustements (in the seed)



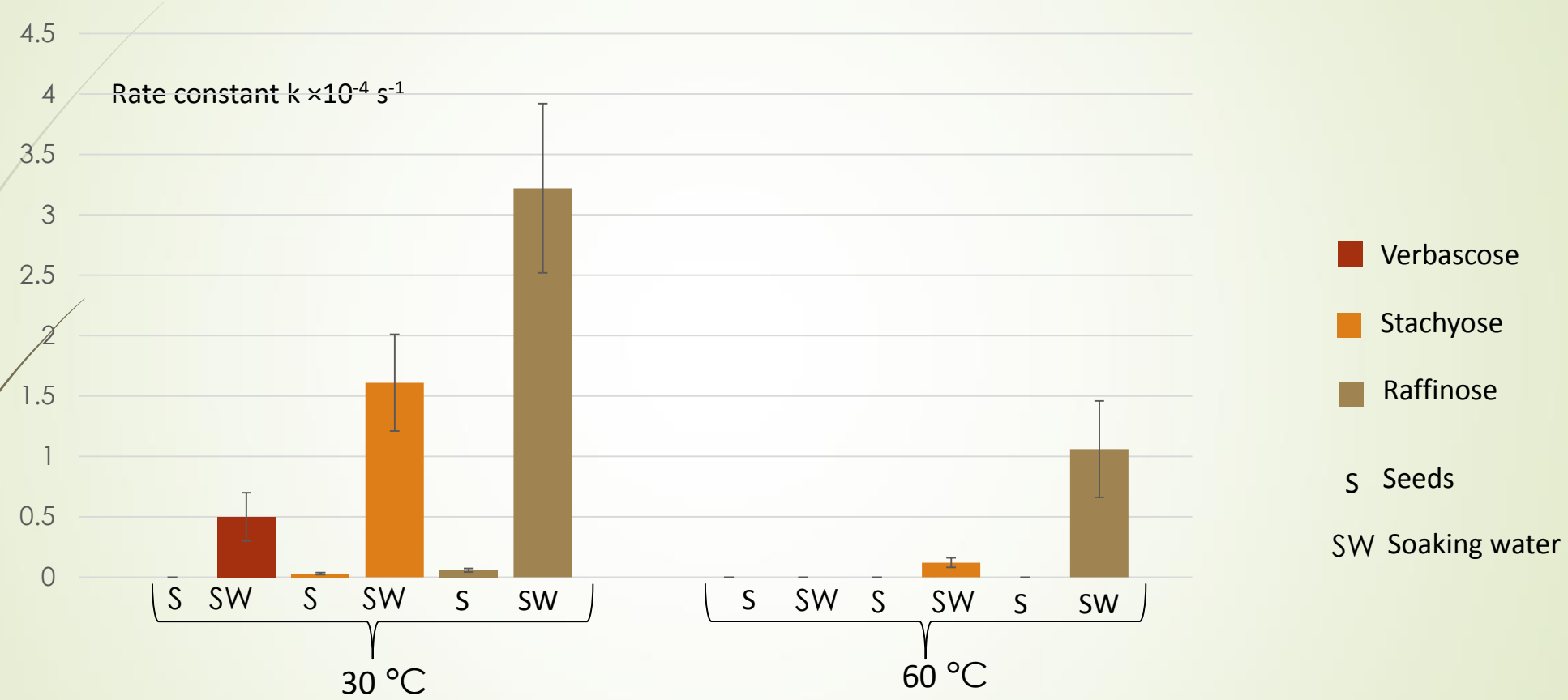
RMSE in cowpea seed lower than 10%

Evolution of alpha-galactoside apparent diffusivities depending on *T*°C



- At 30°C, diffusion is negligible
- Strong temperature effect on alpha-galactosides apparent diffusivities (D↑ when T ↑)
- D↑ when MM ↑ at lower temperature (30°C)

Results : evolution of alpha-galactoside rate constants

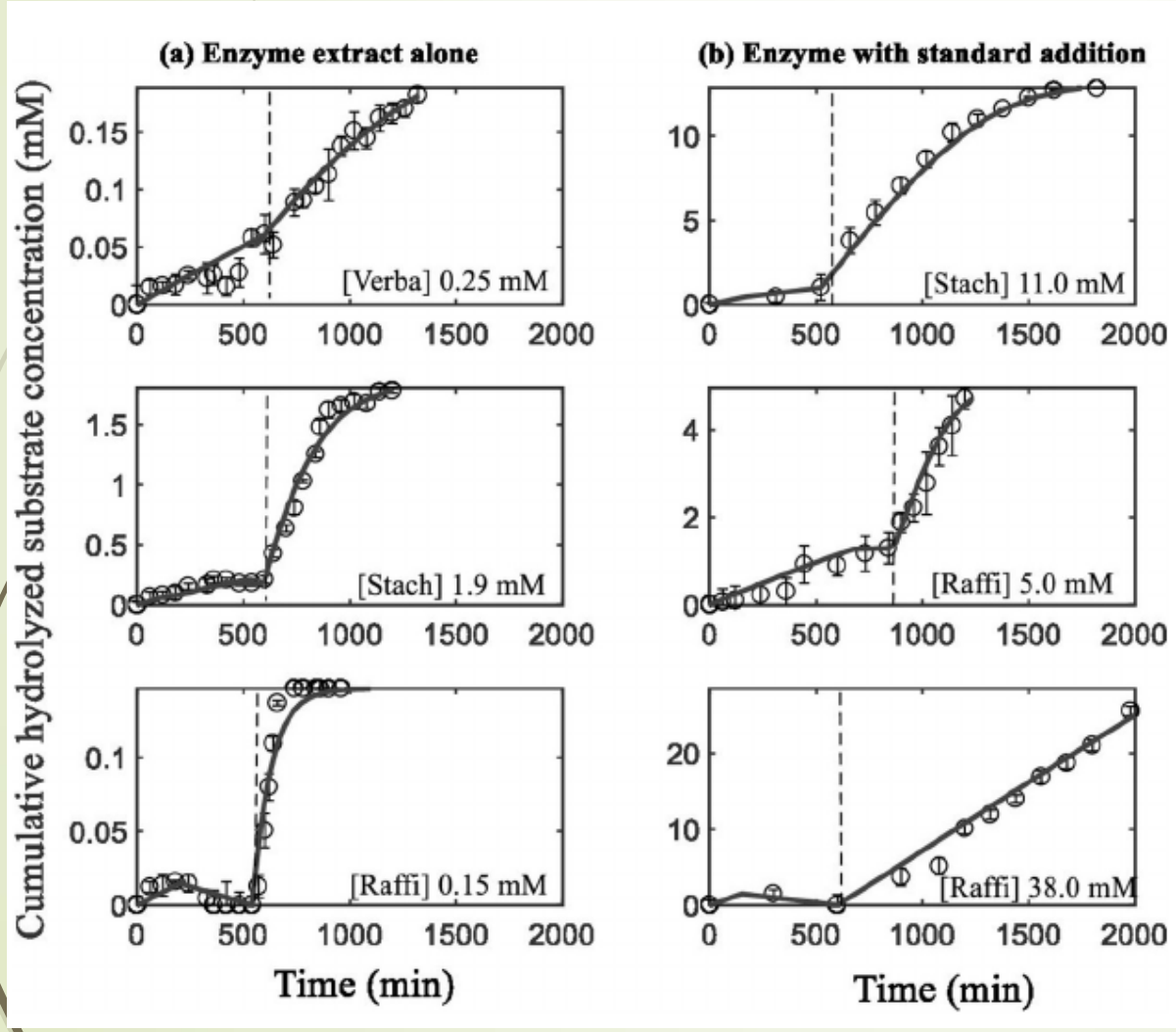


k >> in the soaking water than in the seed

k ↓ when T ↑ due to the alpha-galactosidase optimal temperature (35°C) (Dey & Pridham, 1969)

k ↓ when MM ↑ : consistent with their respective Michaelis constants : Km (raff)=4,8mM and Km (stach)=13 mM (Alani et al., 1989)

Michaelian parameter model adjustment



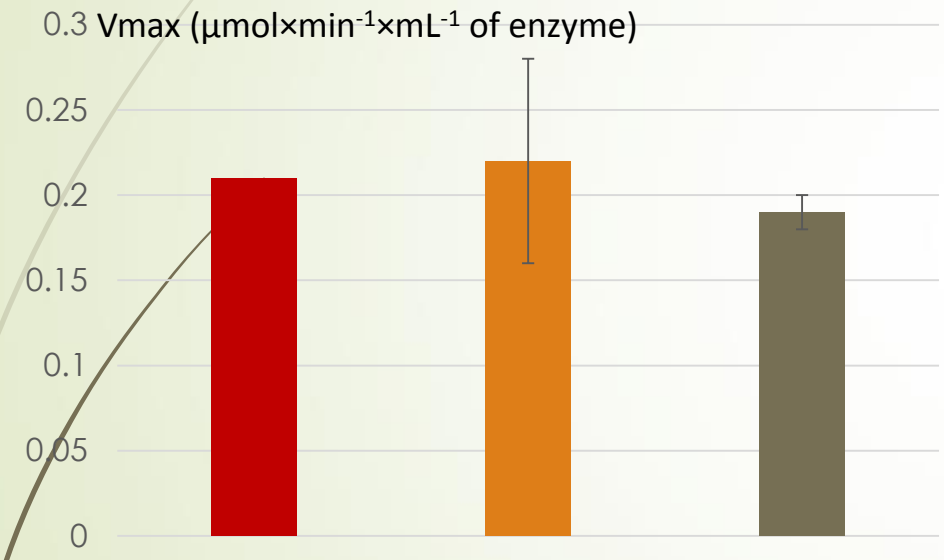
First-order kinetic approach : v=k[S]

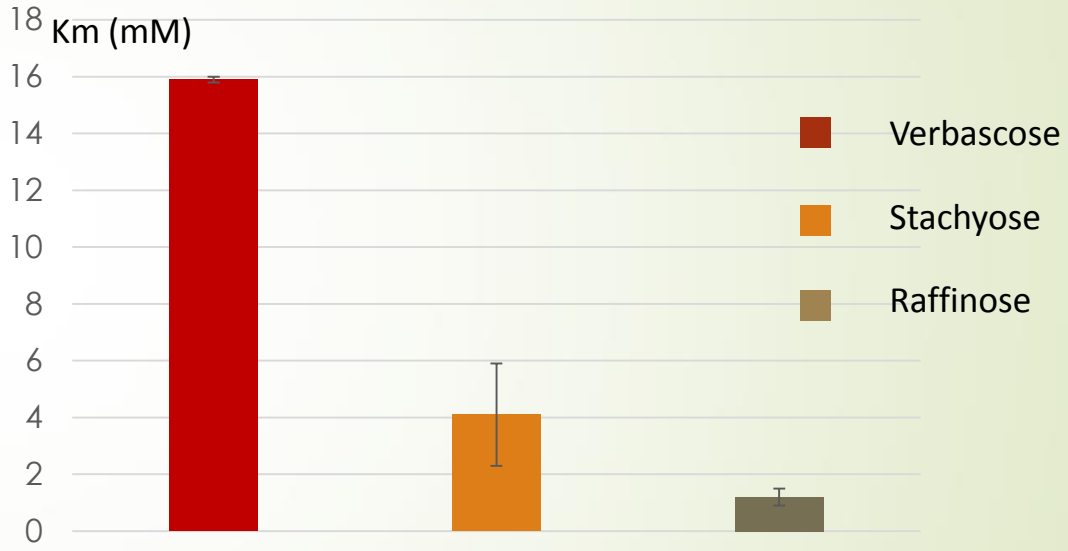
Michaelian approach : $v = \frac{v_{max}[S]}{K_m + [S]}$

Good fitting results

10-hour lag phase !!

Michaelian parameters for each considered alpha-galactoside

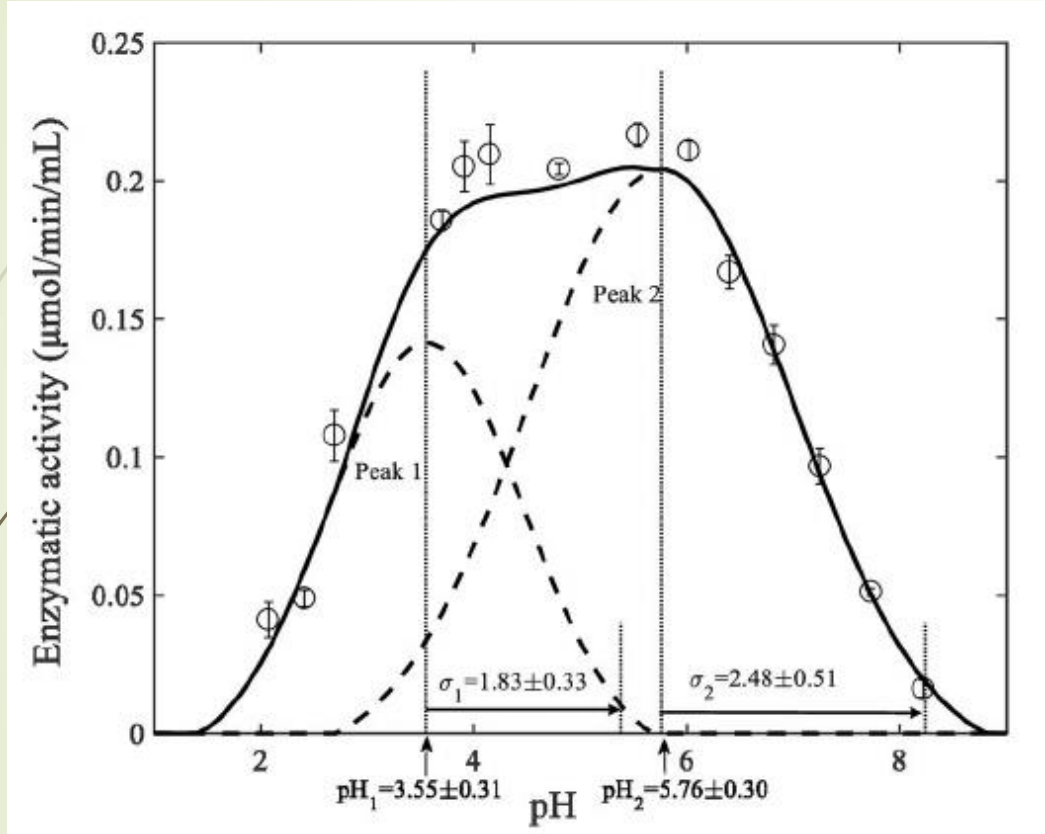




Vmax similar for the three alpha-galactosides

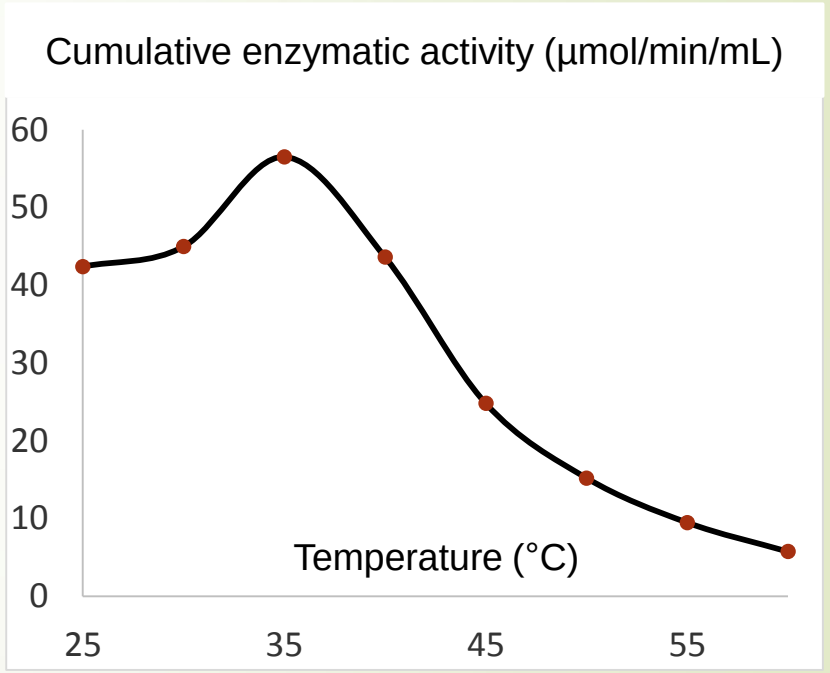
Km ↓ when MM ↑ FAIRE UNE PHRASE
(MM à traduire en anglais)

Optimization of alpha-galactosidase activity



-Two peaks corresponding to the optimal pH for the two isoforms of alpha-galactosidase enzyme

-Optimal pH=5.8



-Optimal temperature T = 35°C for 12h of soaking.

Conclusion & perspectives

-Model revealing contrasted behaviour of cowpea seed alpha-galactosides in the context osf soaking-cooking process

-Diffusion enhanced by temperature contrary to enzymatic degradation

-Enzymatic degradation is more intense for alpha-galactosides having low molar weight

-Model practical use: Alpha-galactosides consumption can be limited using a first presoaking step at 30°C, pH=5,8 for time longer than 10h ETRE PLUS PRECIS SUR LE TEMPS TREMPAGE

Perspective :

- Integrate the Michaelis-Menten law (enzymatic degradation) in the alpha-galactoside Comsol finite-element model

Thank you for your attention

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