

# ASSESSING THE RELIABILITY OF A PHYSICS-BASED MODEL FOR THE CONVECTIVE DRYING OF YACÓN (*Smallanthus sonchifolius*)



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# Yacón?



# MOTIVATION



## COMPOSITION

Yacón is rich in **water** and soluble **fiber**, mainly FOS and inulin.

## PROCESSING

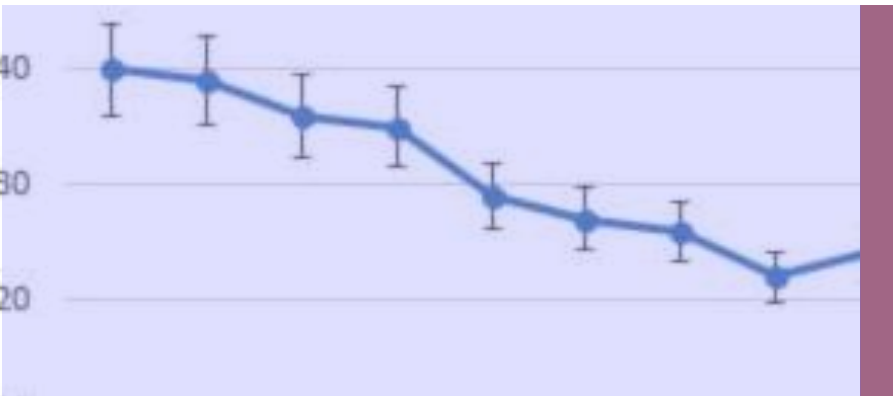
Drying and pretreatments can **hydrolyze** the fiber into simple sugars.

## WHAT CAN BE DONE?

# SPECIFIC OBJECTIVES

**1**  
Estimate what cannot be  
measured directly without  
disturbing the drying process

**2**  
Verify how susceptible the  
model is to parameter changes



# PROJECT STAGES

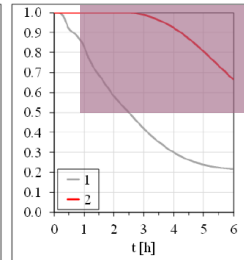
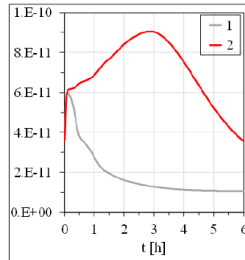
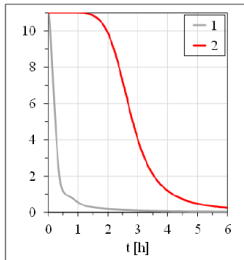
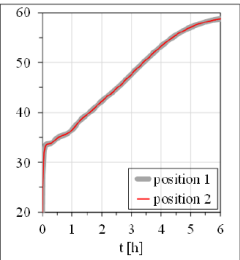
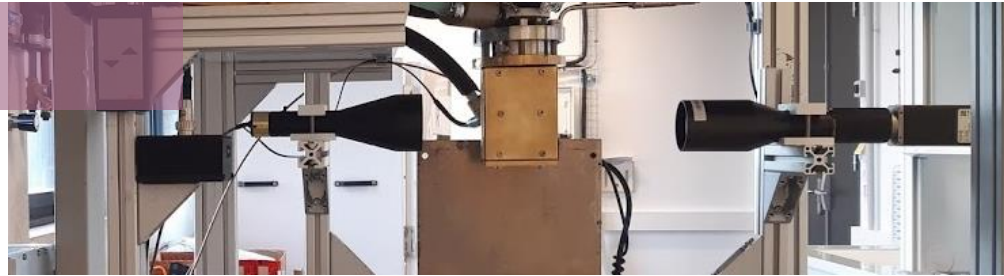


## STAGE 1

**Pilot-scale** drying experiments  
Preliminary characterization

## STAGE 2

**Laboratory-scale** drying experiments  
Further characterization



## STAGE 3

**Modeling** and validation



# PROJECT STAGES

## STAGE 1

Pilot-scale drying experiments  
Preliminary characterization

## STAGE 2

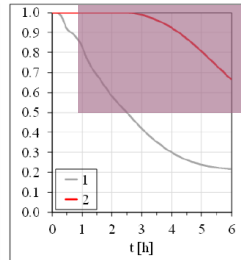
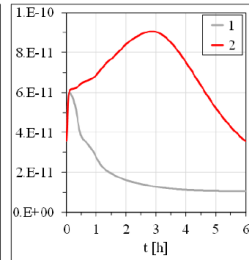
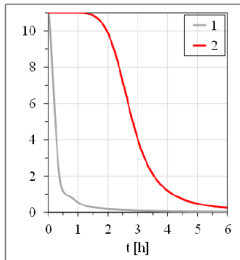
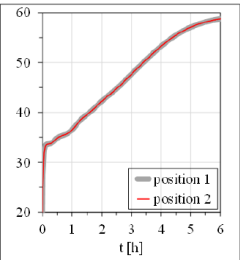
Laboratory-scale drying experiments  
Further characterization

## STAGE 3

Modeling and validation



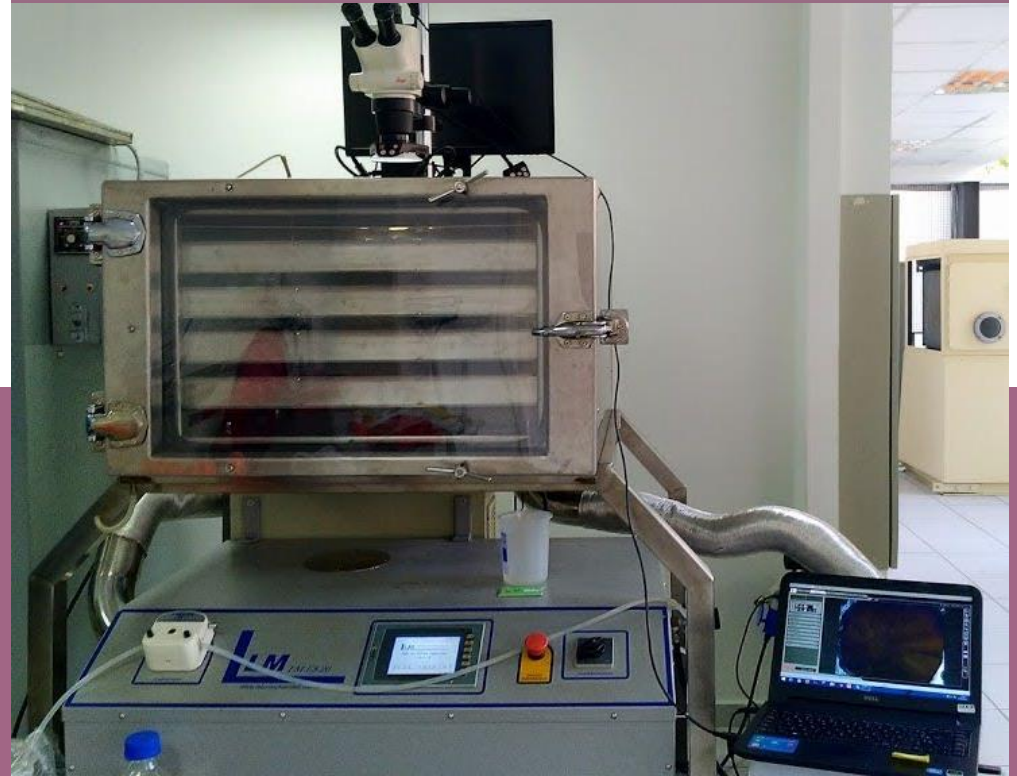
*you are here*



# EXECUTION



# PREVIOUS EXPERIMENTAL WORK





# PREVIOUS EXPERIMENTAL WORK

## Drying conditions:

50 °C, 20 % RH

50 °C, 30 % RH

60 °C, 20 % RH

60 °C, 30 % RH

1 Shaping



2 Blanching



3 Positioning



4 Drying



# PREVIOUS EXPERIMENTAL WORK

## Drying conditions:

50 °C, 20 % RH

50 °C, 30 % RH

60 °C, 20 % RH

60 °C, 30 % RH

1 Shaping



2 Blanching



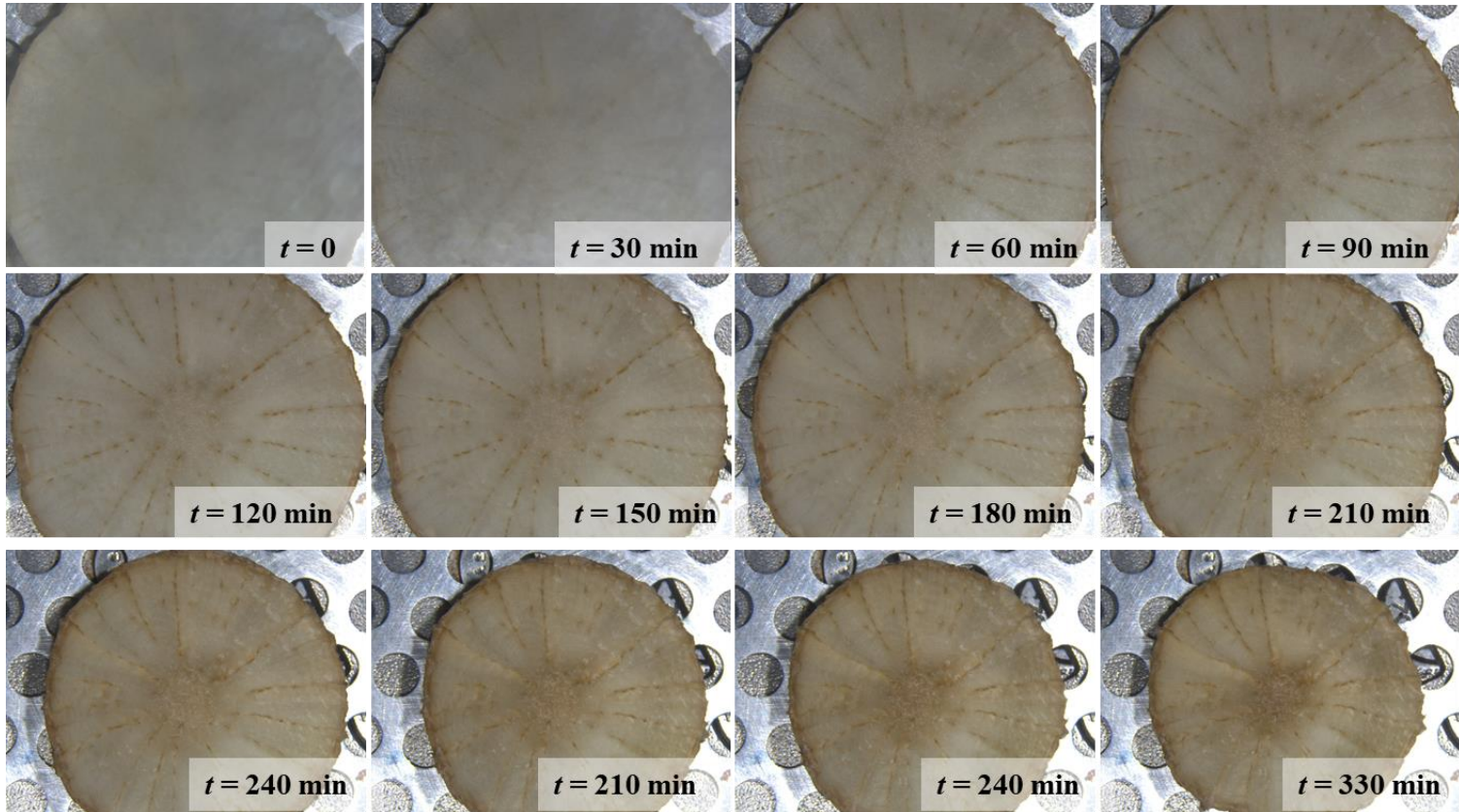
3 Positioning



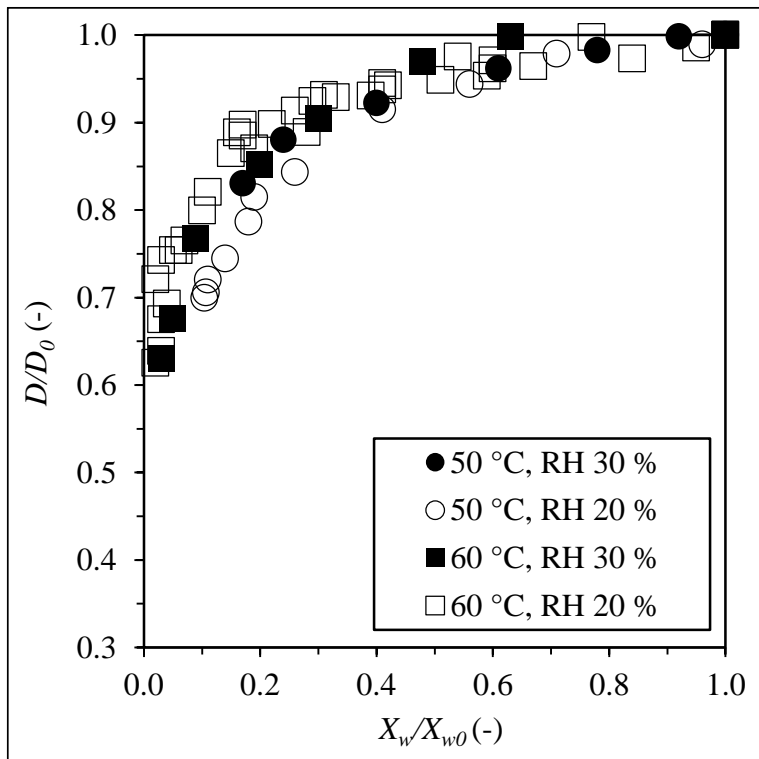
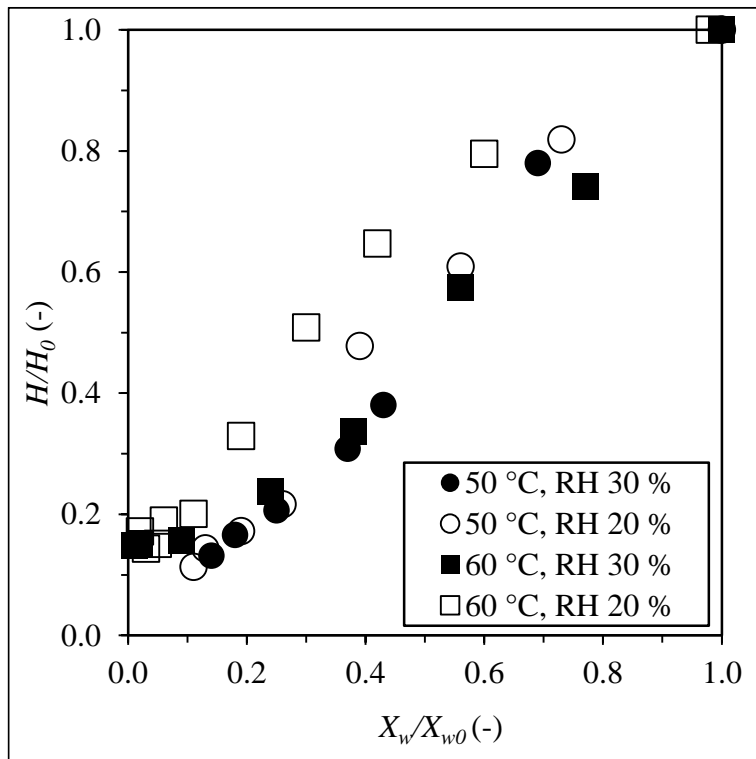
4 Drying



# SHRINKAGE

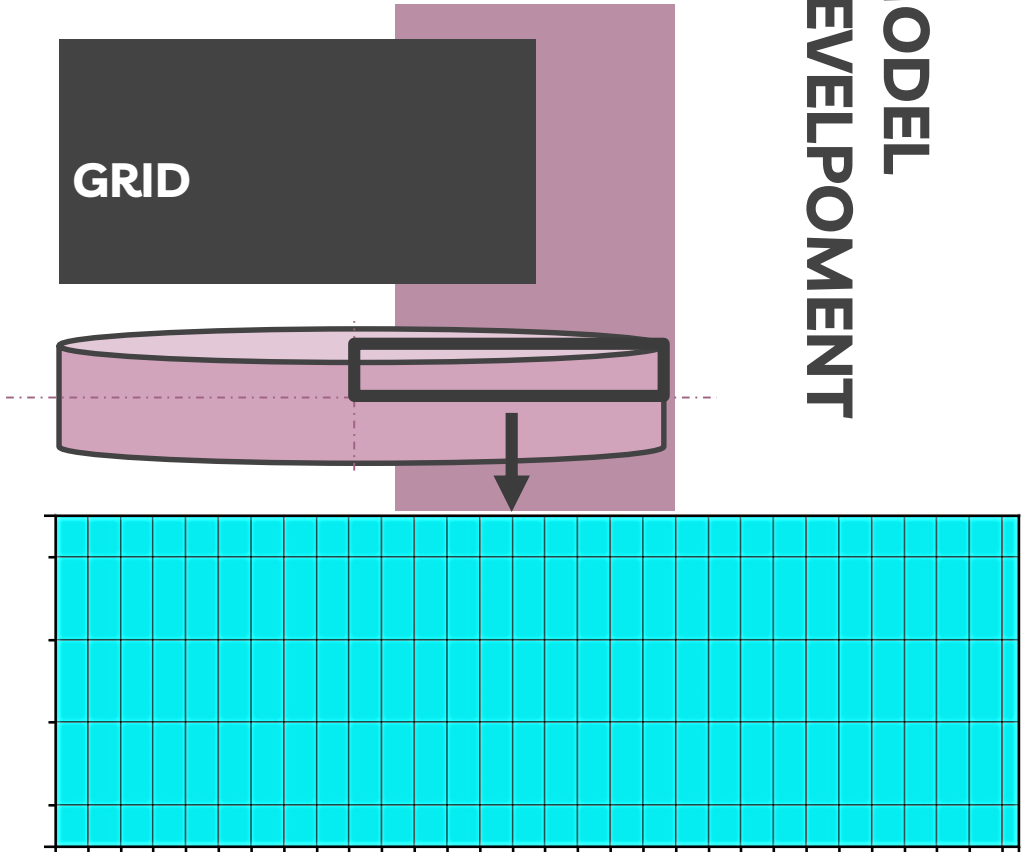


# SHRINKAGE





# MODEL DEVELOPMENT

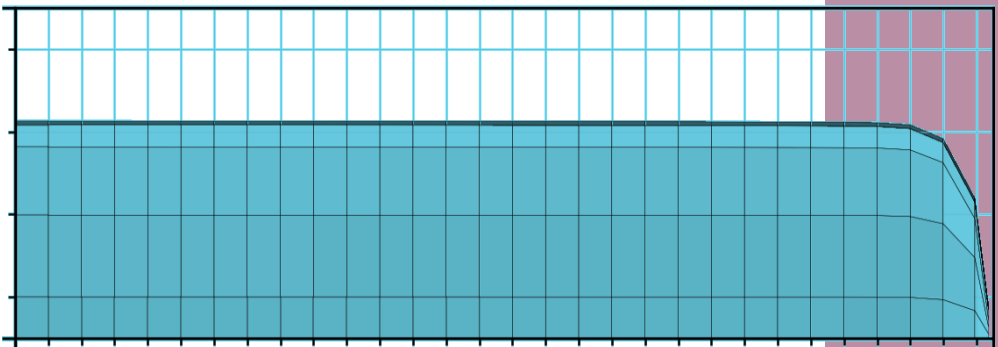
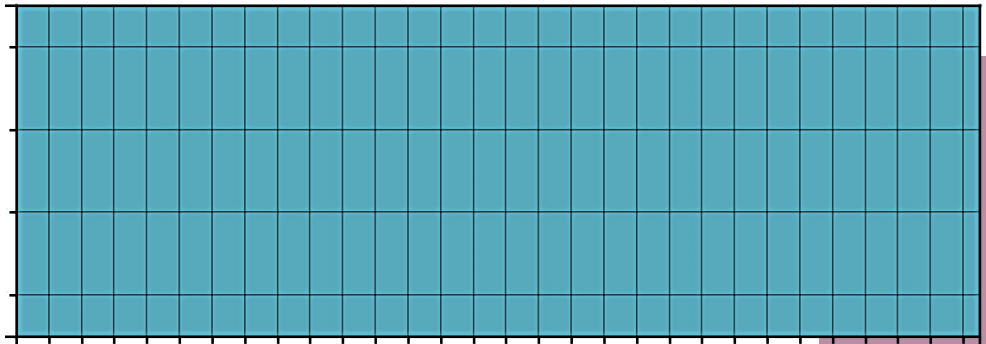


# EMPIRICAL BASIS





# MODEL DEVELOPMENT



# APPROACH & HYPOTHESES



## SHRINKAGE IS IMPORTANT!

Yacón loses up to 90% in volume when dried.



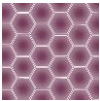
## SIMPLIFIED GEOMETRY

Described with experimental data in different directions.



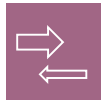
## VARIABLE DIFFUSIVITY

Large variations in moisture are described by the Maroulis et al. (2001) model. [7]



## POROSITY IS IGNORED

Based on empirical data



## WATER MOVES, SOLIDS DON'T

Water follows moisture gradient, solids stay in their cells



## COUPLED HEAT & MASS TRANSFER

Energy transfers occurs due to conduction inside the matrix and due to convection on the surface.



# DESCRIBING THE WATER DIFFUSIVITY

$$D_w\{X_w, T\} = \frac{1}{1 + X_w} D_{w,dry}\{T\} + \frac{X_w}{1 + X_w} D_{w,wet}\{T\}$$

$$D_{w,dry}\{T\} = D_{dry} \exp\left(-\frac{E_{dry}}{R} \left(\frac{1}{T} - \frac{1}{T_{ref}}\right)\right)$$

$$D_{w,wet}\{T\} = D_{wet} \exp\left(-\frac{E_{wet}}{R} \left(\frac{1}{T} - \frac{1}{T_{ref}}\right)\right) .$$

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# OTHER ASSUMPTIONS

## Initial values

Slice temperature	20 °C
Slice water content	11 kg water/ kg dry matter
Slice half-height	0.0035 m
Slice radius	0.02 m

## Dry matter properties

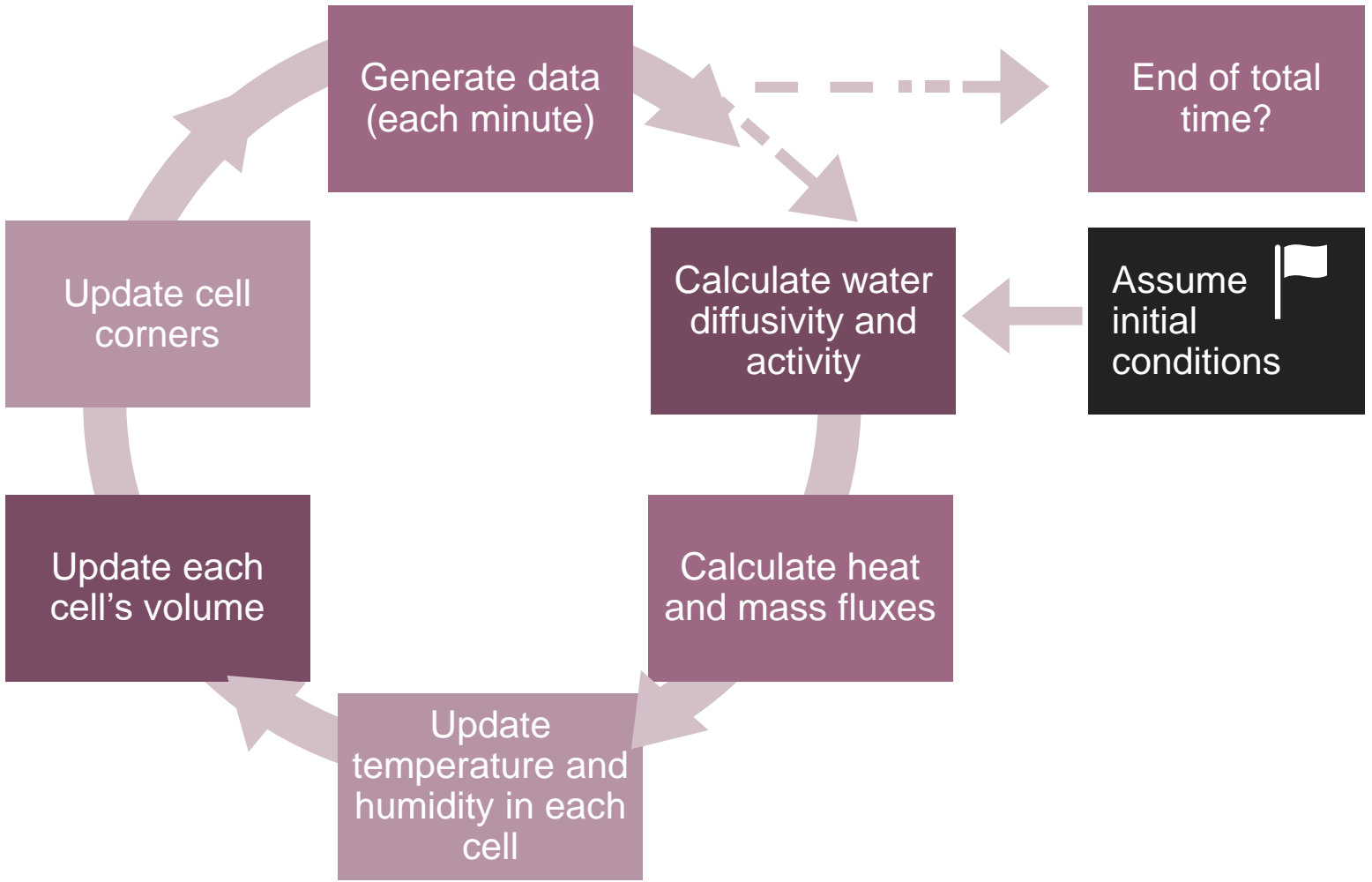
Density	1590 kg/m <sup>3</sup>
Heat capacity	1620 J/kg K
Thermal conductivity	0.250W/m K

## Discretization

Mesh	J=5 lines; l=30 columns
Timestep	0.01 s



# ALGORITHM



A background image featuring a laptop on the left displaying a bar chart with values 200, 280, 400, 410, and 470. Below the laptop is a printed document with a pie chart and a pen. The word 'RESULTS' is overlaid in a white box on a purple background.

# RESULTS

# SIMULATION

## System

Windows 10 Enterprise v.20H2, 64-bit

Intel® Core™ i5-6600 CPU @ 3.30 GHz  
16.0 GB RAM

## Environment

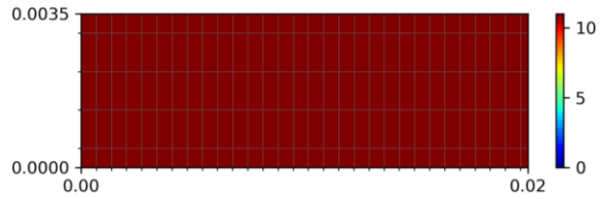
Spyder (Python 3.7.6)

## Runtime

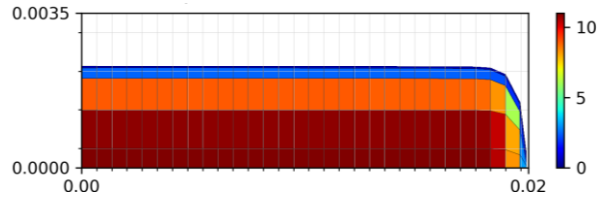
$1.81 \cdot 10^4$  s

# WATER CONTENT

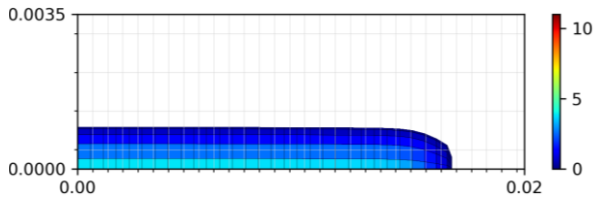
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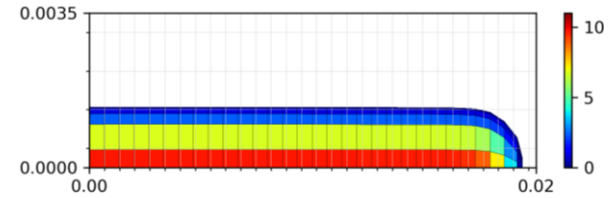
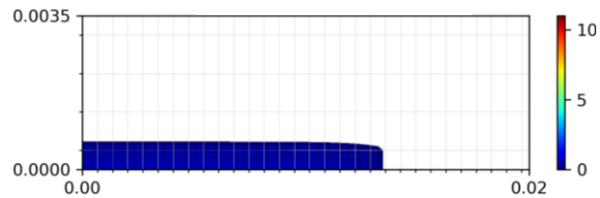
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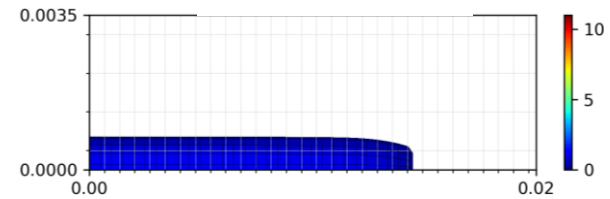
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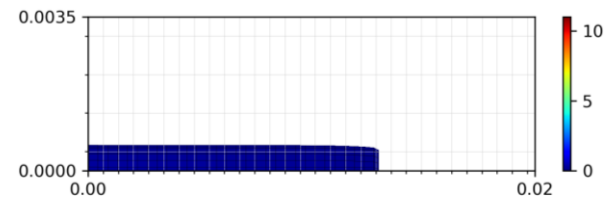
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$t = 2h$



$t = 4h$

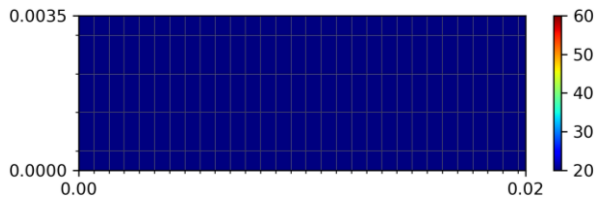


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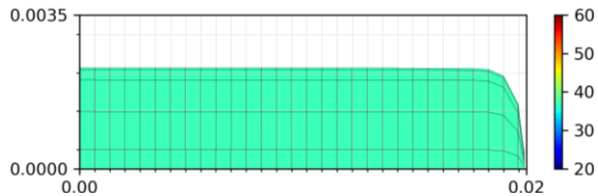


# TEMPERATURE

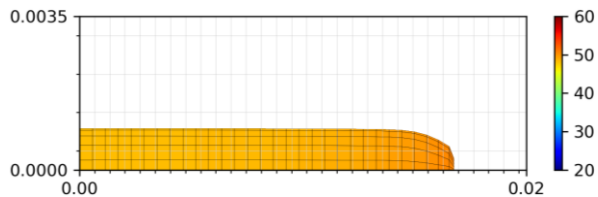
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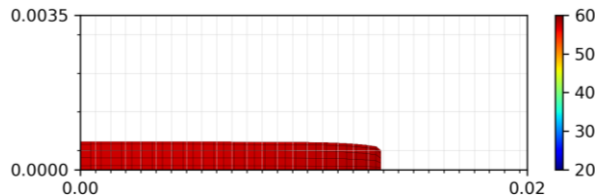
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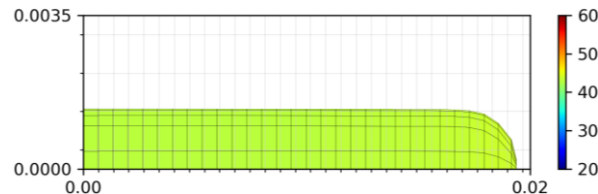
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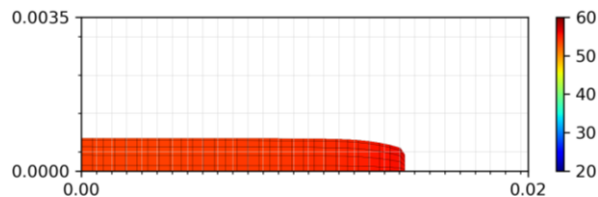
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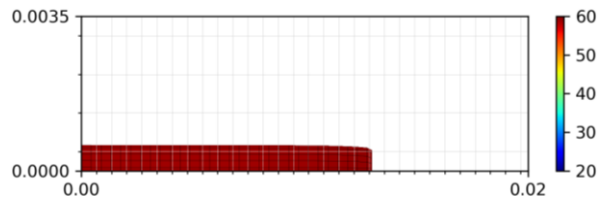
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$t = 4h$

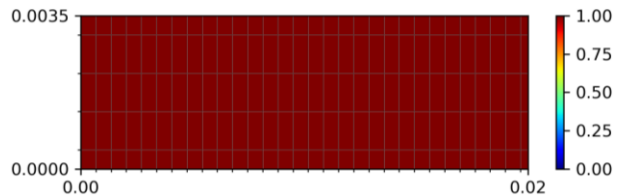


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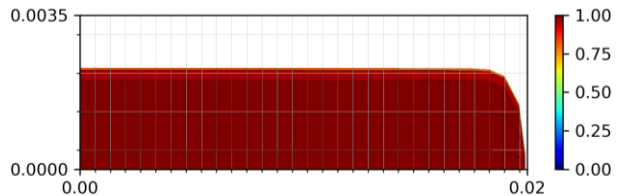


# WATER ACTIVITY

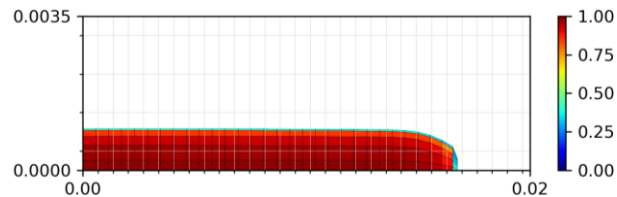
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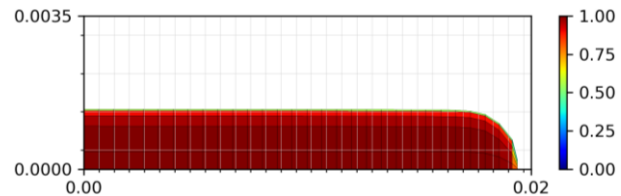
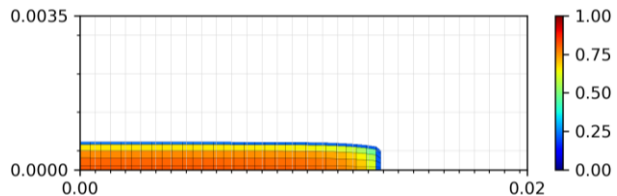
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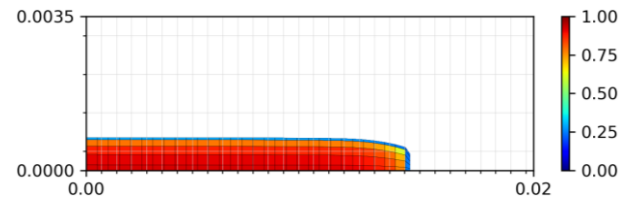
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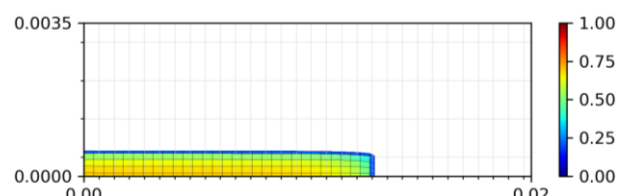
$t = 5h$



$t = 2h$



$t = 4h$

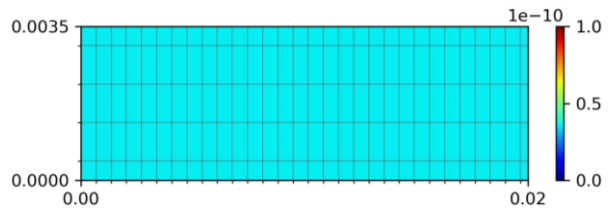


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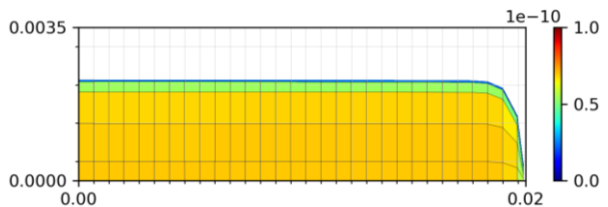


# WATER DIFFUSIVITY

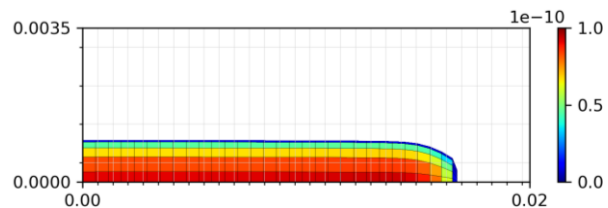
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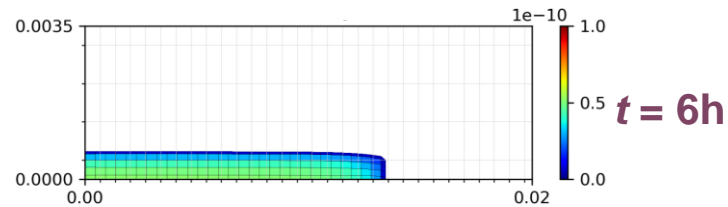
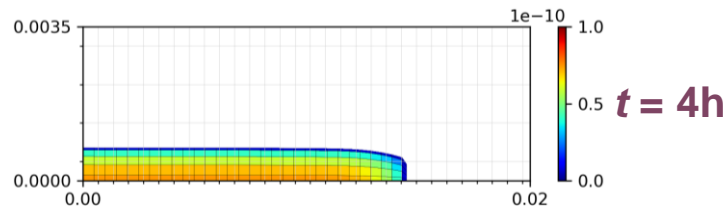
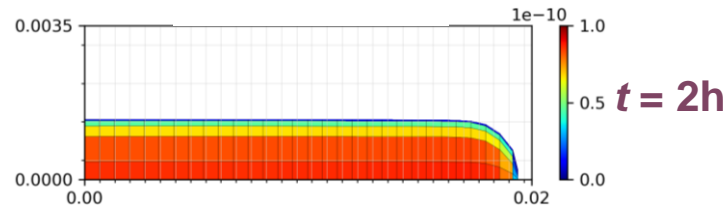
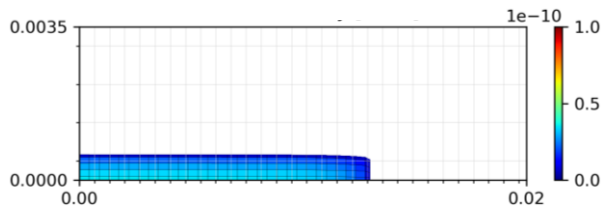
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$t = 3h$

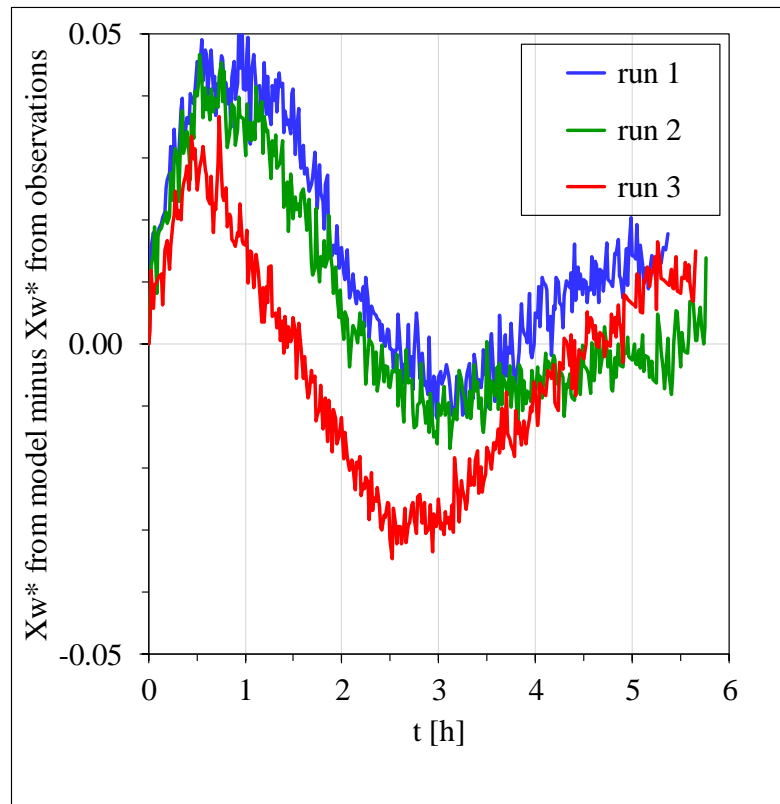
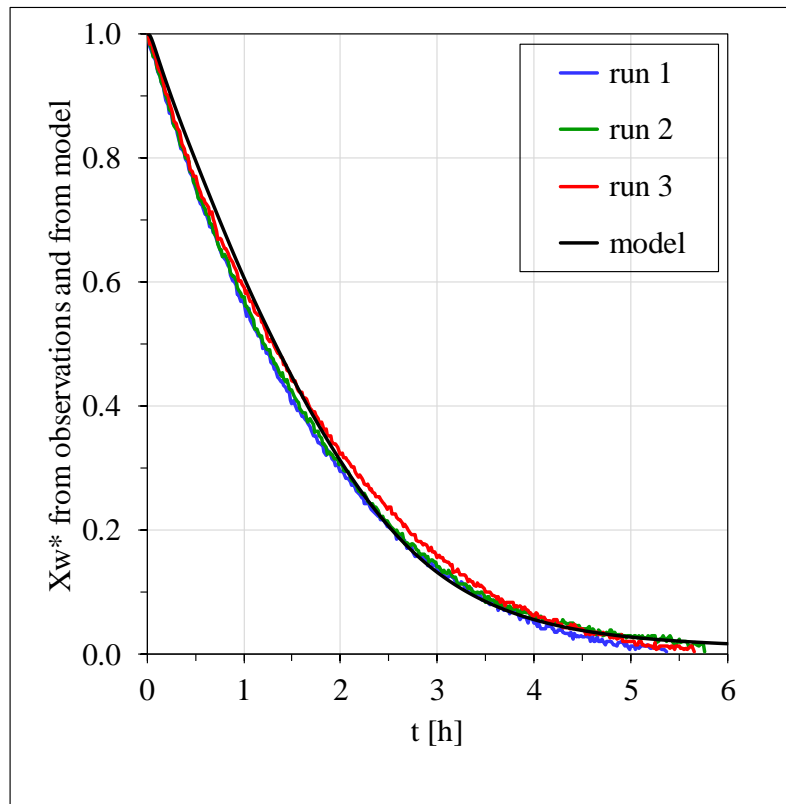


$t = 5h$



# ABSOLUTE ERROR

Tair = 60°C and RHair = 20%

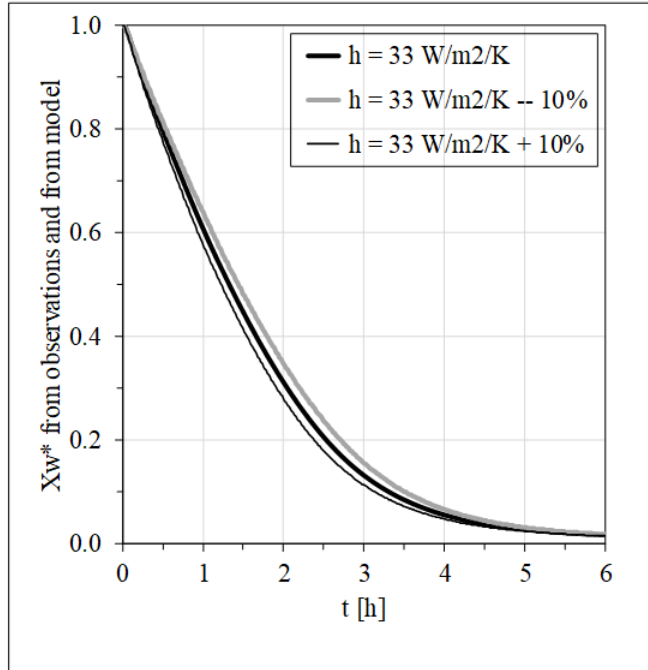


# SENSITIVITY TESTS

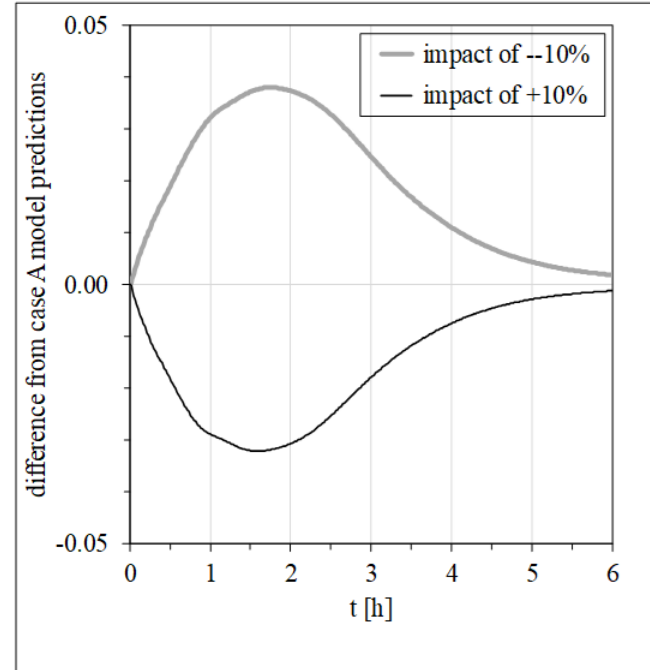
Simulation	$T_{air}$ (°C)	$RH_{air}$ (%)	$h$ (W/m <sup>2</sup> K)	Mesh (Jxl)	Timestep (s)	$X_w(t=6h, \text{average})$ (kg/kg dry matter)	RMSE(-)
A	60	20	33	5 X 30	0.01	0.173	$1.96 \cdot 10^{-2}$
B	60	20	33-10%	5 X 30	0.01	0.193	$3.50 \cdot 10^{-2}$
C	60	20	33+10%	5 X 30	0.01	0.160	$2.22 \cdot 10^{-2}$
D	60	20	33	4 X 24	0.01	0.171	$1.91 \cdot 10^{-2}$
E	60	20	33	6 X 36	0.01	0.175	$1.99 \cdot 10^{-2}$
F	60	20	33	5 X 30	0.01 / 5	0.173	$1.96 \cdot 10^{-2}$
G	60	20	33	5 X 30	0.01 X 5	0.202	$1.90 \cdot 10^{-2}$
H	60	30	37	5 X 30	0.01	0.192	$4.17 \cdot 10^{-2}$
I	50	20	31	5 X 30	0.01	0.376	$2.76 \cdot 10^{-2}$
J	50	30	35	5 X 30	0.01	0.407	$3.18 \cdot 10^{-2}$

# SENSITIVITY TESTS

cases A, B and C (sensitivity to heat transfer coeff.)

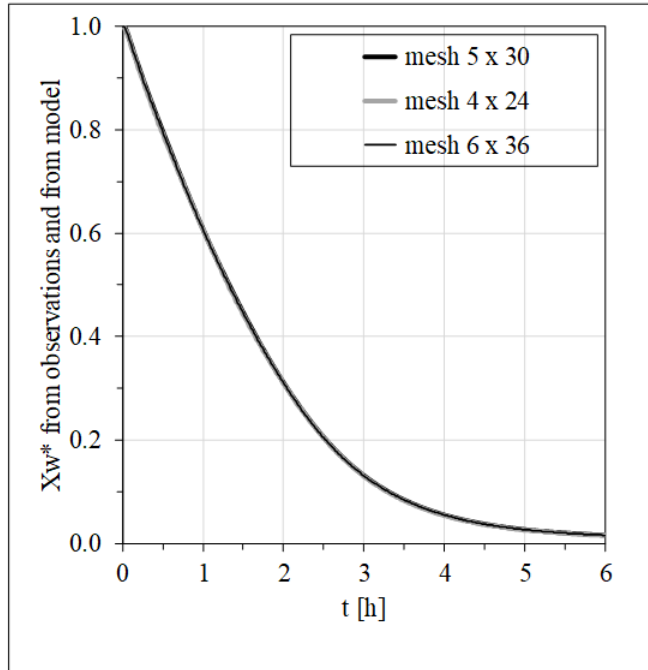


cases A, B and C (sensitivity to heat transfer coeff.)

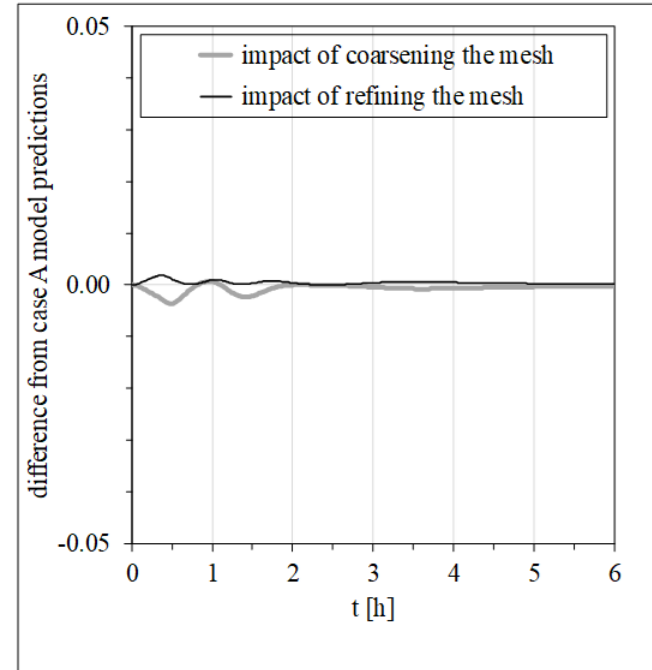


# SENSITIVITY TESTS

cases A, D and E (sensitivity to mesh resolution)

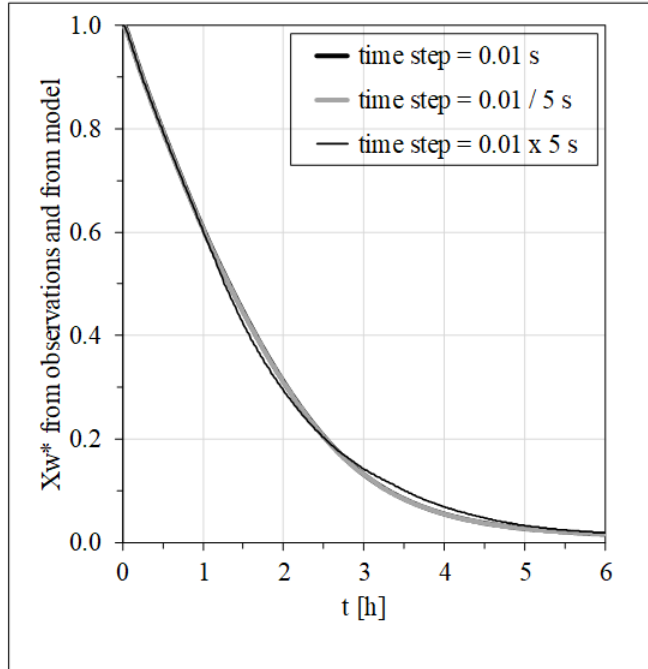


cases A, D and E (sensitivity to mesh resolution)

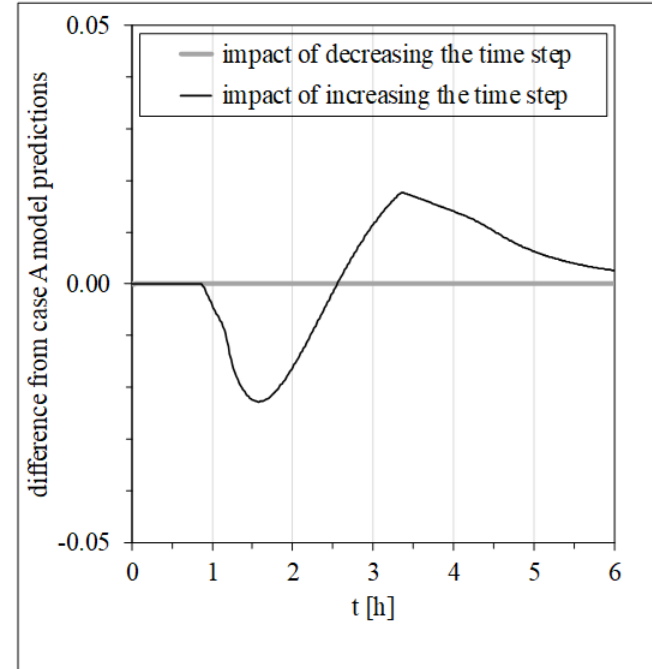


# SENSITIVITY TESTS

cases A, F and G (sensitivity to time step)



cases A, F and G (sensitivity to time step)





**IN  
CLOSING**



## FINAL NOTES

These results represent the first efforts in displaying how the water **diffusivity** and water **activity** evolve throughout a food **matrix** exposed to convective drying.

Special attention must be given to the **final hours** of drying.

Refining the **timestep** or **mesh** would not give significantly better results, but a larger timestep is not recommended.

Our model is particularly **sensitive** to variations in the **heat transfer coefficient**.

## REFERENCES

- [1] Seminario, J., Valderrama, M., & Romero, J. (2004). Variabilidad morfológica y distribución geográfica del yacón, *Smallanthus sonchifolius* (Poepp. & Endl.) H. Robinson, en el norte peruano. *Arnaldoa : revista del Herbario HAO.*, 11(1), 139–160.
- [2] Santana, I., & Cardoso, M. H. (2008). Raíz tuberosa de yacón (*Smallanthus sonchifolius*): Potencialidade de cultivo, aspectos tecnológicos e nutricionais. *Ciencia Rural*, 38(3), 898–905. <https://doi.org/10.1590/S0103-84782008000300050>
- [3] Hermann, M., Freire, I., & Pazos, C. (1998). Compositional Diversity of the Yacón Storage Root. CIP Program Report, 425–432.
- [4] Hermann, M., & Heller, J. (1997). Andean roots and tubers: Ahípa, arracacha, maca and yacón. Promoting the conservation and use of underutilized and neglected crops. 21. Roma: Institute of Plant Genetics and Crop Plant Research.

## **(some more) REFERENCES**

[5] Ribeiro, J. D. A. (2008). Estudos químico e bioquímico do yacon (*Smallanthus sonchifolius*) in natura e processado e influência do seu consumo sobre níveis glicêmicos. Universidade Federal de Lavras.

[6] Scher, C. F., Rios, A. O., & Noreña, C. P. Z. (2009). Hot air drying of yacon (*Smallanthus sonchifolius*) and its effect on sugar concentrations. *International Journal of Food Science and Technology*, 44(11), 2169–2175. <https://doi.org/10.1111/j.1365-2621.2009.02056.x>

[7] Maroulis, Z.B., Saravacos, G.D., Panagiotou, N.M., Krokida, M.K.: Moisture diffusivity data compilation for foodstuffs: Effect of material moisture content and temperature. *International Journal of Food Properties* 4, 225–237 (2001). <https://doi.org/10.1081/JFP-100105189>

## IMAGE CREDITS

Slide template by Slidesgo

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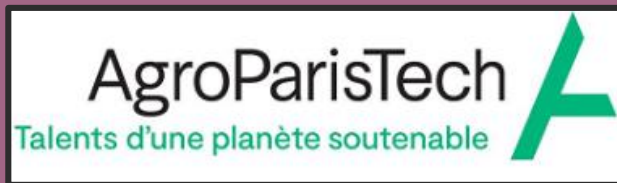
Images by Wayhomestudio and Pressfoto in Freepik; Vlad Bagacian on Pexel, and Fimbee.com

[1] <https://g1.globo.com/sp/presidente-prudente-regiao/blog/nutricao-pratica/post/voce-conhece-batata-yacon.html>

[2] <http://www.ksbig.com.br/produtos/batata-yacon>

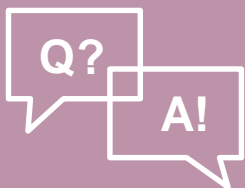
[3] [https://produto.mercadolivre.com.br/MLB-1905948962-batata-yacon-1-kg-livre-de-agrotoxicos-\\_JM#&gid=1&pid=1](https://produto.mercadolivre.com.br/MLB-1905948962-batata-yacon-1-kg-livre-de-agrotoxicos-_JM#&gid=1&pid=1)

[4] <https://www.cultivariable.com/instructions/andean-roots-tubers/how-to-grow-yacon/>



# ACKNOWLEDGEMENTS

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**OR**

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