



Broccoli waste valorization through solar energy

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Broccoli (*Brassica oleracea* L. var. *Italica*)

- Popular worldwide:
dietary potential, organoleptic properties, easy production
- Florets are known from its health benefits
- Source of many phytochemical compounds:
including phenolic compounds and vitamins with antioxidant capacity
- Reduce the risk of different degenerative and chronic diseases:
including cancer, cardiovascular and diabetes



Adding Value to Broccoli Stems



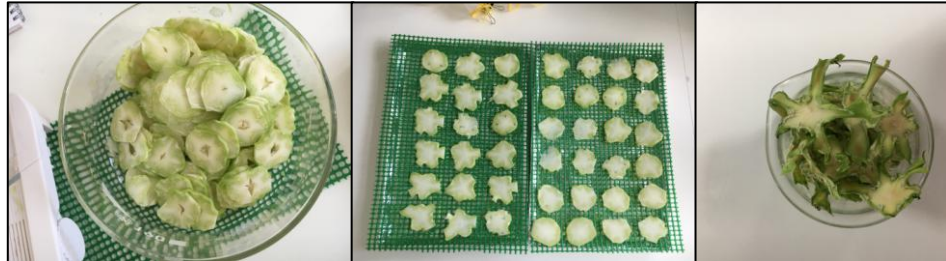
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- Stalks are usually discarded:
for feed or fertilizer
- Stalks can have larger antioxidant capacity than florets
- Stalks should be not seen as a byproduct - reduce food waste



Adding Value to Broccoli Stems

- Development of new food products
- Using appropriate technologies
- Dehydration of broccoli stem slices



- ✓ Add value to broccoli stalks using different drying conditions:
 - ✧ *Convective*
 - ✧ *Laboratory*
 - ✧ *Solar*
- ✓ Study drying kinetics
- ✓ Evaluate the impact on quality:
 - ✧ *Physical: shape/size and colour*
 - ✧ *total phenolics and antioxidant activity*

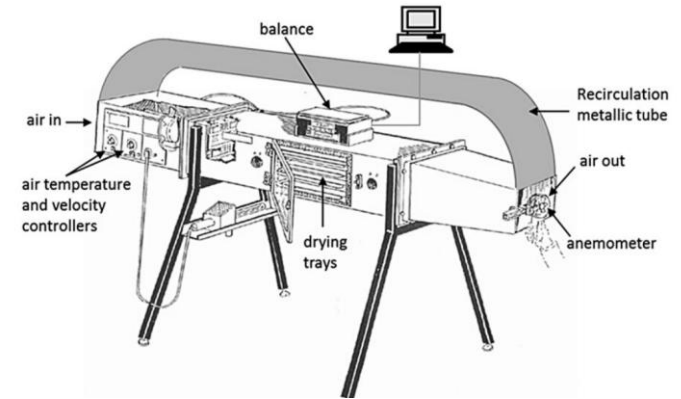


Materials & Methods

- Slices of 2 mm



- Drying at 50, 60 and 70°C; 1,2 m/s
– tray dried (Armfield UOP8, Ringwood, England)



- Drying at 50-60°C; 0,03 m/s
– laboratory (Excalibur 9-tray)



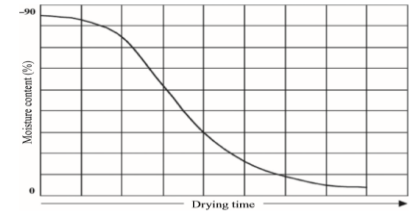
- Solar drying
– (Sunflair 48.3 x 39.4 x 5.1 cm)



- Model drying kinetics for convective experiments

$$\frac{X-X_e}{X_0-X_e} = \exp(-k \cdot t^n) \quad \text{Page model}$$

$$k = k_{ref} \exp \left[-\frac{E_a}{R} \left(\frac{1}{T} - \frac{1}{T_{ref}} \right) \right]$$



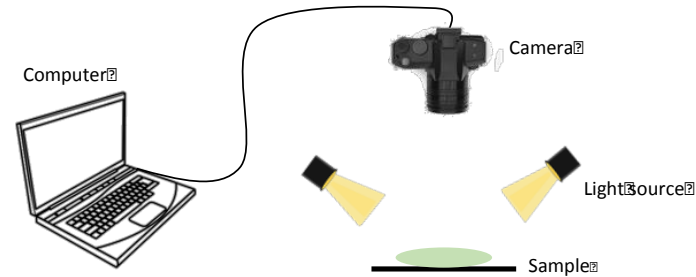
- Extrapolation, by integration, to predict laboratory and solar drying behavior

- Shape, size and color evaluation by image analysis

$$C = C_0 \exp^{-kt} \quad \frac{C - C_{eq}}{C_0 - C_{eq}} = \exp [-k t]$$

$$TCD = \alpha \exp \left[-\exp \left(\frac{K_{max} e}{\alpha} \right) \cdot (\lambda - T) + 1 \right]$$

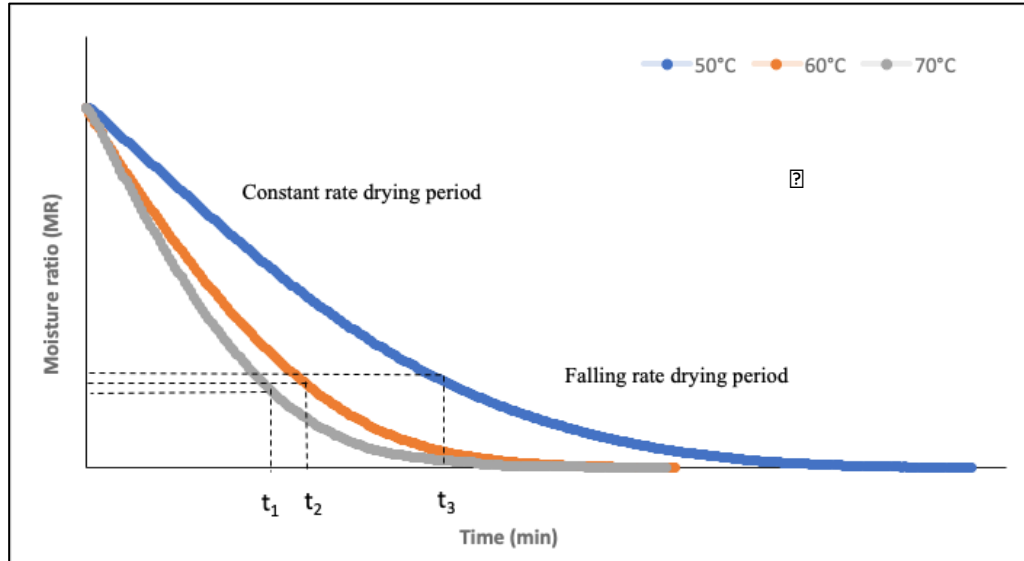
$$k = k_{ref} \exp \left[-\frac{E_a}{R} \left(\frac{1}{T} - \frac{1}{T_{ref}} \right) \right]$$



- Total phenolic compounds
- Total antioxidant activity

Results and Discussion

- Convective drying



Page model equation coefficients

Equation coefficients		
T	k (min ⁻¹)	n
50°C	0.00232	1.35343
60°C	0.00491	1.34120
70°C	0.00485	1.36661

Global model:

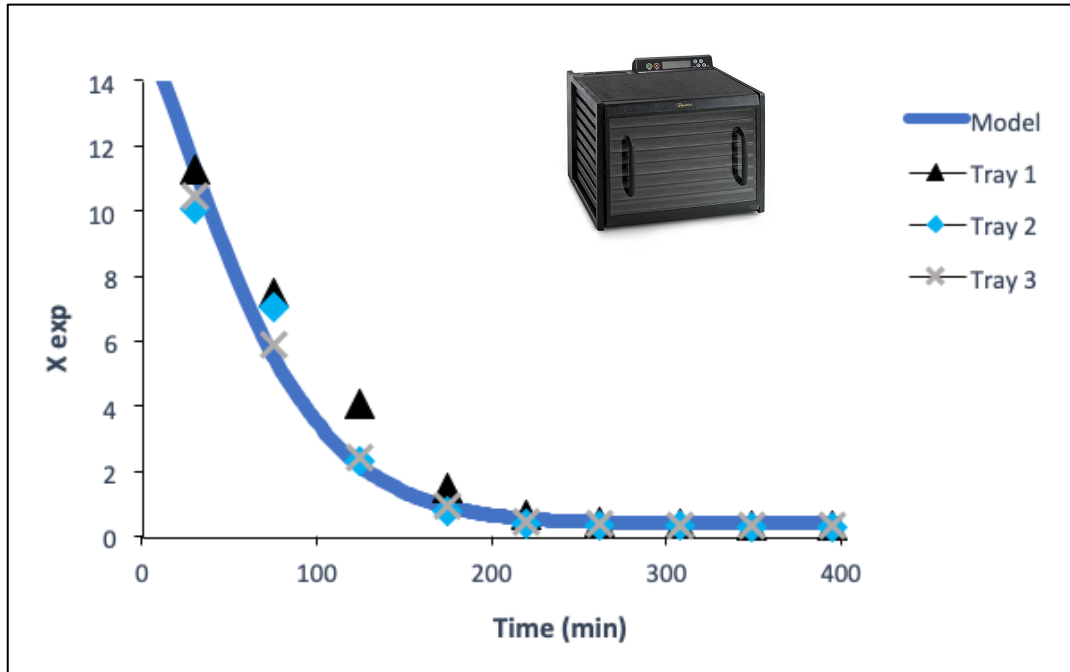
$$k_{60^{\circ}\text{C}} = 0,004 \text{ min}^{-1}$$

$$E_a = 34,5 \text{ kJ/mol}$$

$$n = 1,33$$

Results and Discussion

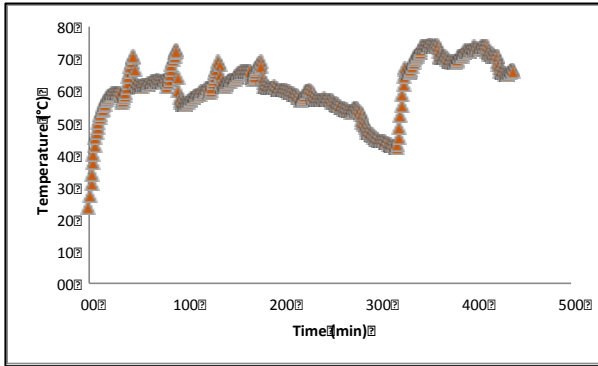
- Laboratory drying



Predicted vs Experimental

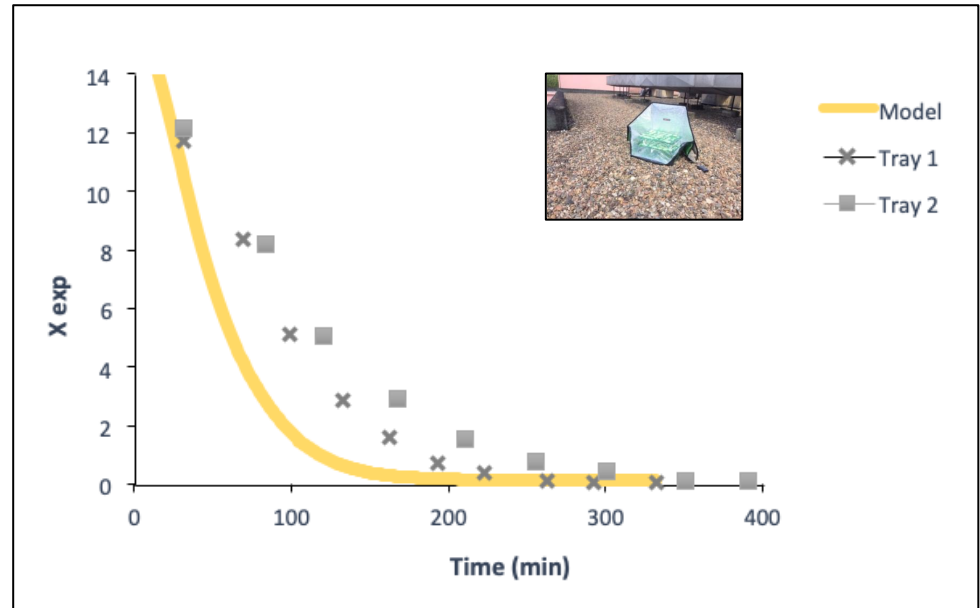
Results and Discussion

- Solar drying



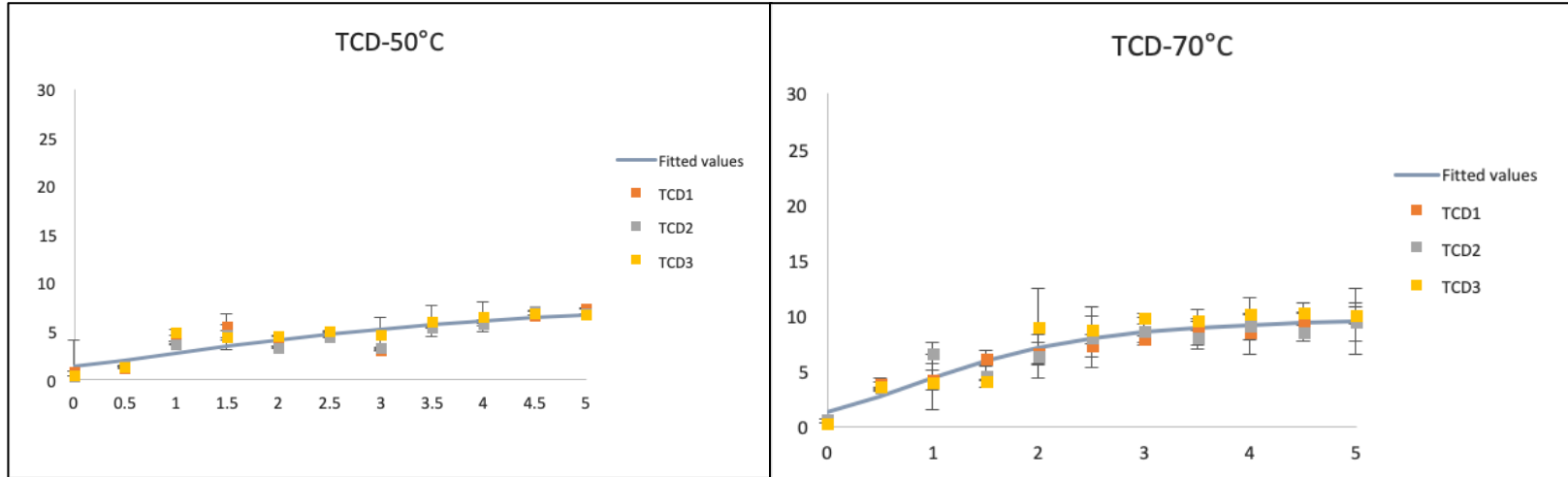
Predicted vs Experimental

Equilibrium moisture content
not constant



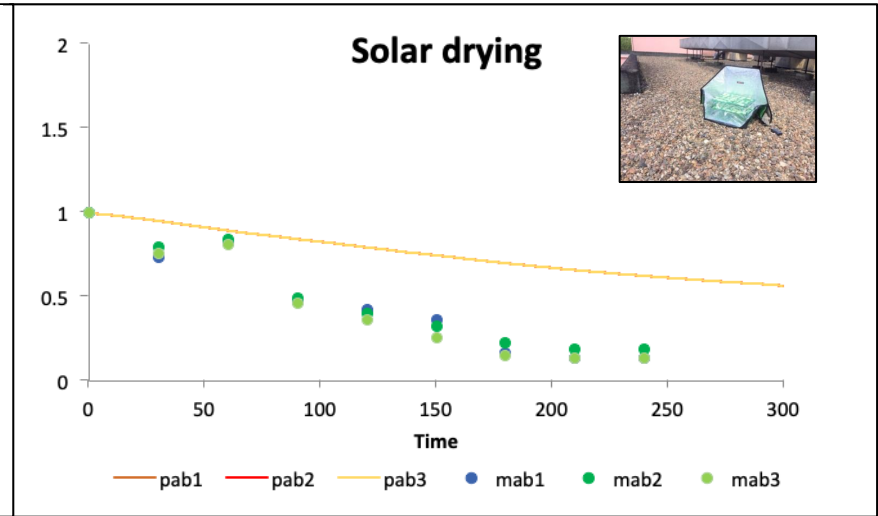
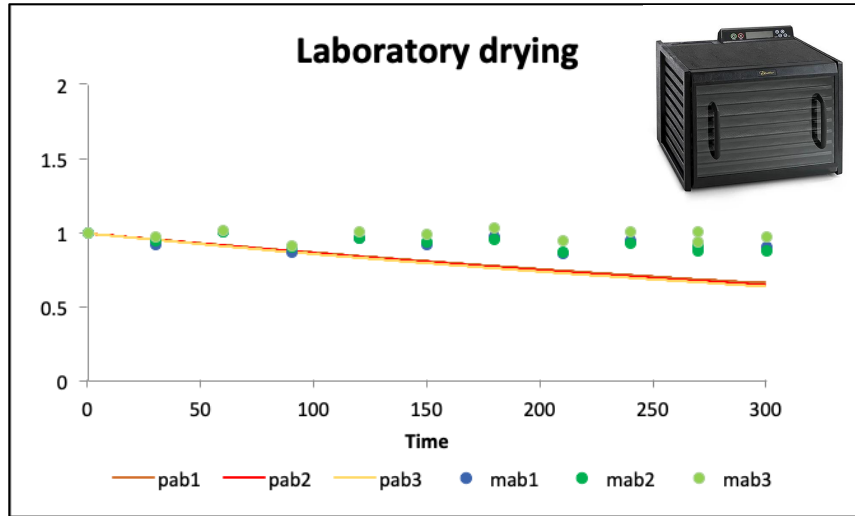
Results and Discussion

- Impact on quality - *colour*



Results and Discussion

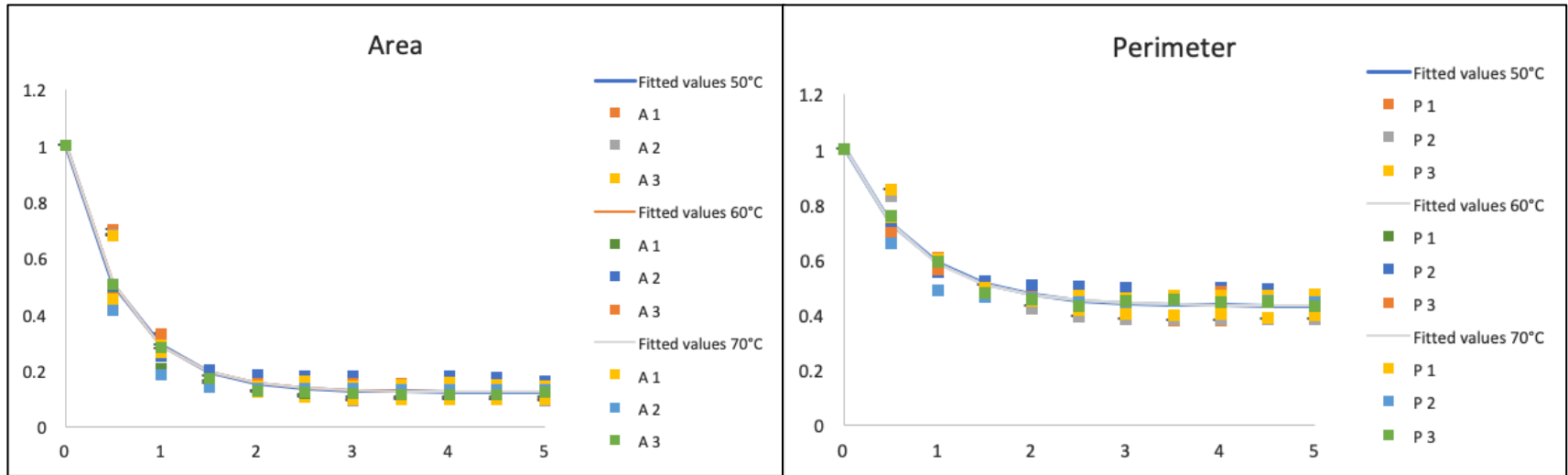
- Impact on quality - *colour*



Predicted vs Experimental

Results and Discussion

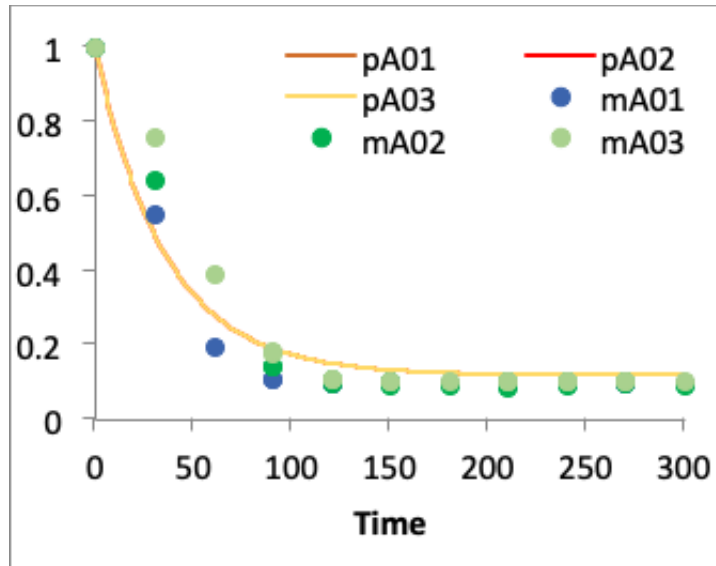
- Impact on quality – *area & perimeter*



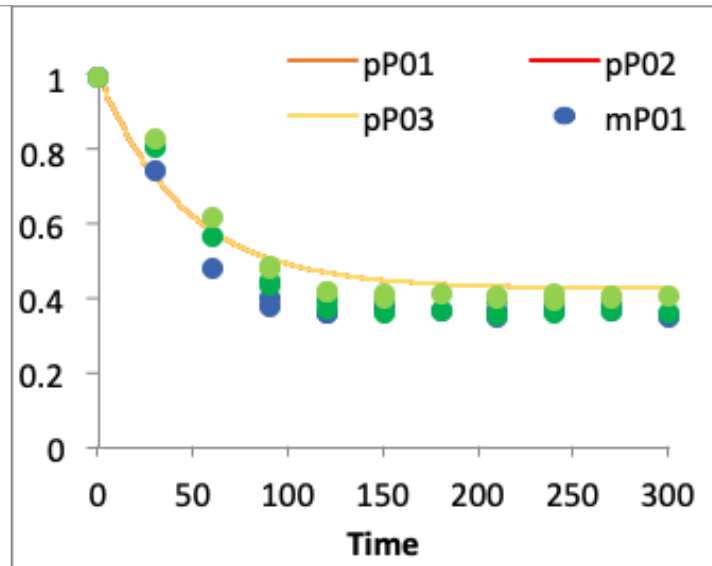
Results and Discussion

- Impact on quality - *area & perimeter*

Area



Perimeter

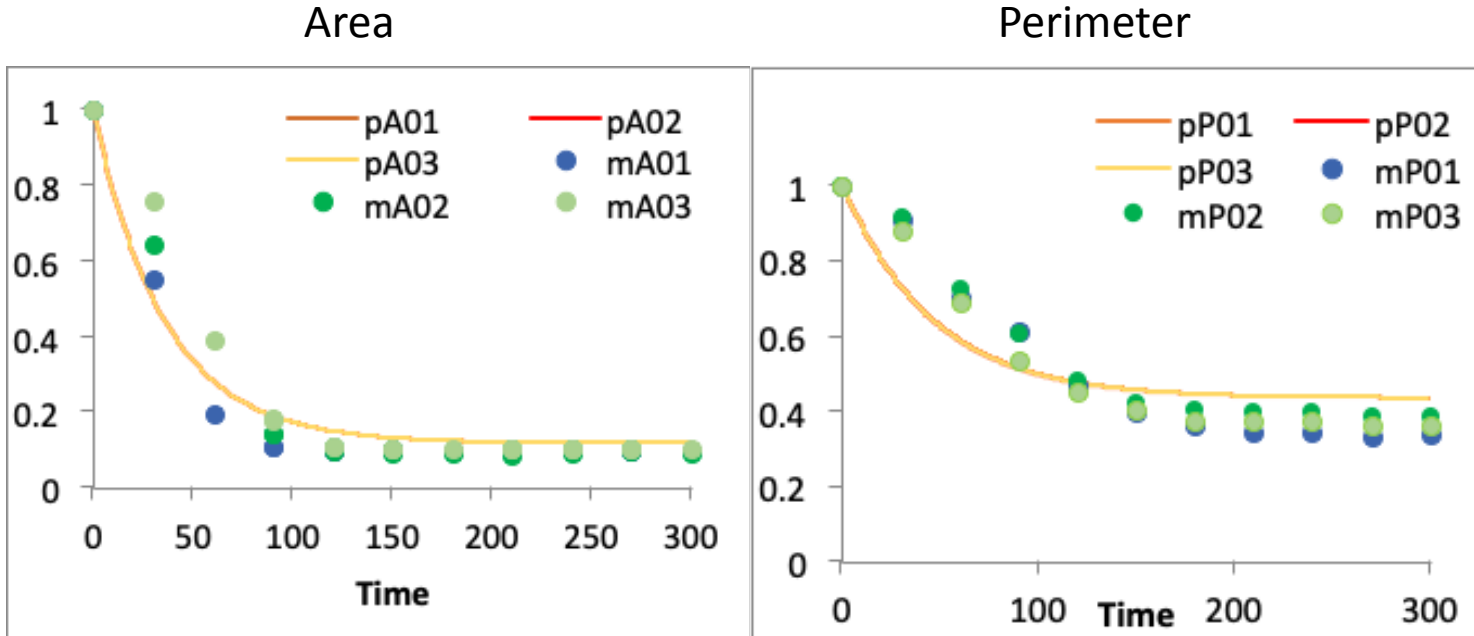


Predicted vs
Experimental

For laboratory
drying

Results and Discussion

- Impact on quality - *area & perimeter*

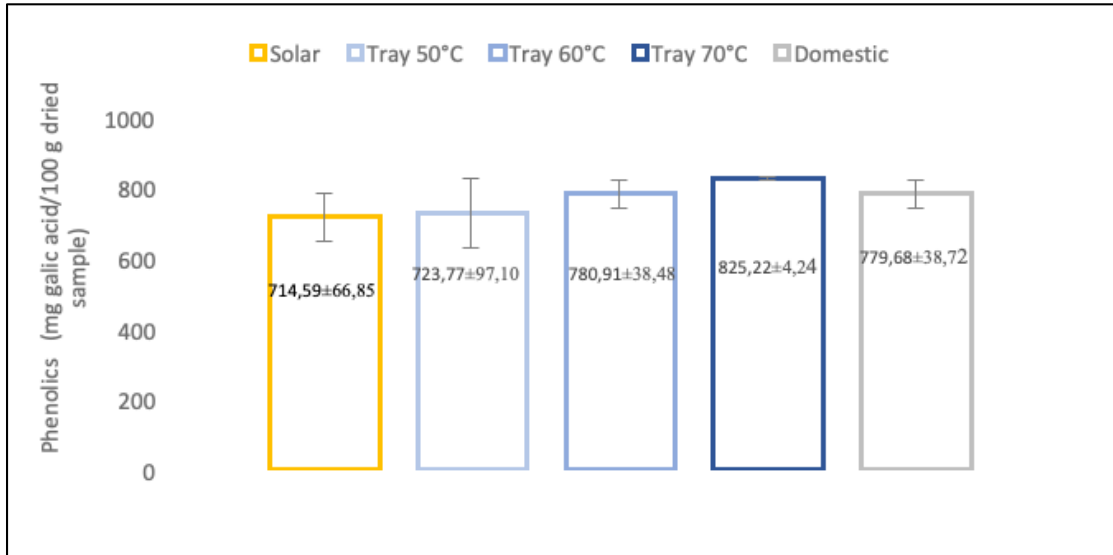


Predicted vs
Experimental

For Solar
drying

Results and Discussion

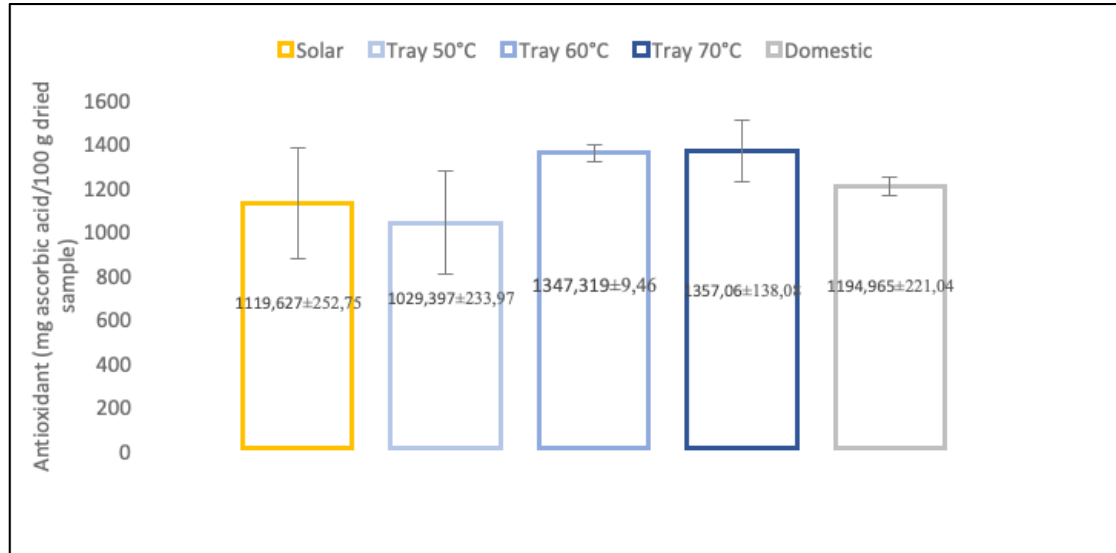
- Impact on quality – *total phenolic compounds*



samples presented a similar total phenolic value ($p>0.05$).

Results and Discussion

- Impact on quality – *total antioxidant activity*



samples presented a similar total antioxidant activity ($p>0.05$).

→ For drying:

- Page model, with Arrhenius behavior, was able to fit well convective drying experiments
- Model was able to predict laboratory drying results
- For solar drying the equilibrium moisture content has to be included in the model

→ For quality:

- Quality changes were modeled under isothermal conditions
- Models predicted well the behavior under laboratory conditions
- For solar drying models predicted well area and perimeter changes

→ For quality:

- No significant changes for total phenolic compounds among samples dried in convective, laboratory or solar drying
- Similar conclusion for antioxidant activity of dried broccoli stem slices



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