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Prediction of solar cooking dynamic conditions effects on different vegetables quality parameters

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FARO-PORTUGAL

Solar cooking

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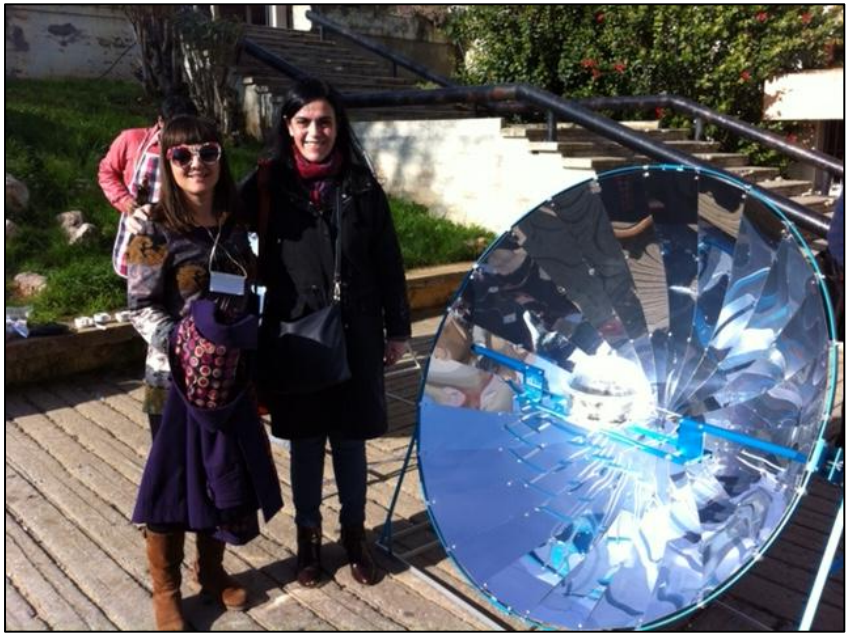
- Many advantages
- Difficult to predict cooking time for the non-experienced user
- Impact on quality ?



Objectives

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- ✓ Study the thermal performance of two cookers:
  - ✧ *Box type*
  - ✧ *Parabolic*
- ✓ Preliminary study on influencing variables
- ✓ Theoretical estimation of solar cooking impact on vegetables quality

Materials & Methods

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→ Thermal performance:

- Box type (Suntaste)
- Parabolic type (**TFCFL 1.5m Diameter**)
- time required for heating a known quantity of water up to the boiling point
- solar radiation intensity logger (TRIX-8 model)
- temperature logger (PCE SPM1)

black plastic pot with 700mL

black aluminum pot with 2500mL

Materials & Methods

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- Porto at 41.176598N latitude and - 8,605593W longitude
- 4 weeks between March and April 2019, for a total of 40 water time-temperature profile recorded inside box and parabolic solar cooker
- average environmental temperature of 21,4°C and the average solar radiation intensity of 952,72 W/m^2

black plastic pot with 700mL

black aluminum pot with 2500mL

Materials & Methods

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- Data analysis - modified Gompertz model

$$T_w = \alpha \exp\left[-exp\left(\frac{kmax\ e}{\alpha}(\lambda - t) + 1\right)\right]$$

T_w	water temperature
t	time
kmax	maximum heating rate
λ	delay time
α	maximum temperature reached

Materials & Methods

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→ Impact on quality:

Product	Quality parameter	Type of kinetics	Tref	Ea (Kj mol^{-1})	k (min^{-1})	Reference
Cow pea *(Vigna catjang L.)*	Folic acid	1st order	80	15,74	0,0043	Nisha et al. (2005)
Potato *(Solanum tuberosum L.)*	Texture	1st order	80		0,0243	Nisha et al. (2006)
Tomato puree *(Lycopersicon esculentum L.)*	Colour (a/a0)	1st order	80	27,44	0,0012	Nisha et al. (2011)
Potato	Ascorbic acid	1st order	80	60	0,0317	B. Jobe et al. (2016)
Red cabbage *(Brassica oleracea)*	Glucoraphanin 4-hydroxyglucobrassicin 4-methoxyglucobrassicin	1st order	110	177 58 115	0,0115 0,0547 0,0487	K.Oerlemans et al., (2006)
Broccoli *(Brassica olearacea var. italica)*	Sensory evaluation: texture colour	0 order	80	 84,2 69,2	 0,2 0,2	Goncalves et al., (2009)

Kinetics of quality changes due to isothermal water cooking

Materials & Methods

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- Four factor evaluation – two-level full factorial design

		Factors			
		F1	**F2**	**F3**	**F4**
		Solar Radiation (W/m²)	**Solar cooker type**	***k*** **(min⁻¹)**	***Ea*** **(Kj/mol)**
min	-1	810	Box	0,0009	10
max	1	1045,5	Parabolic	0,02	200

Results & Discussion

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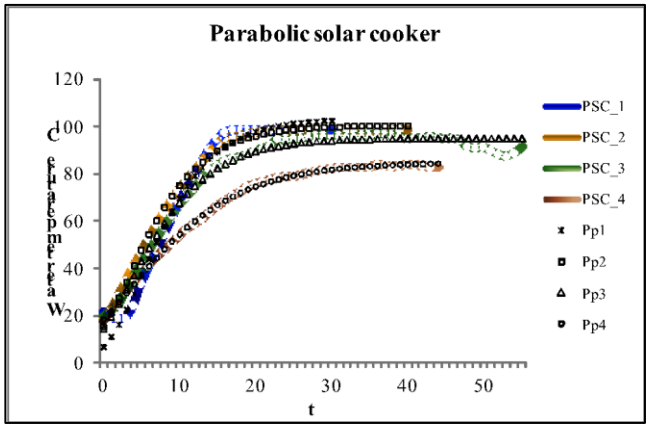
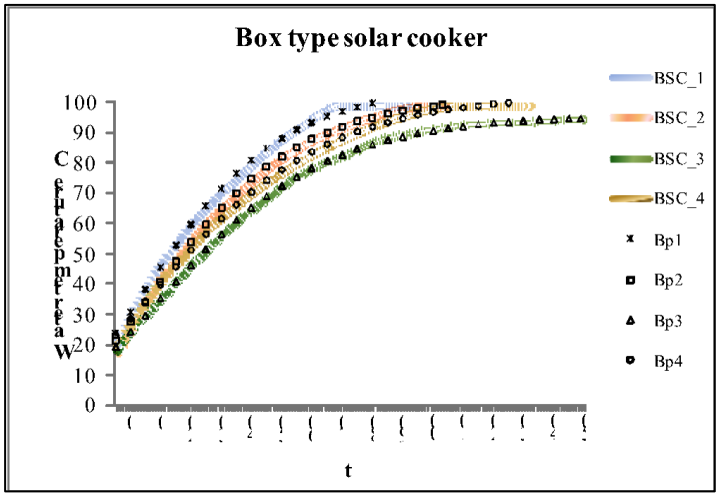
→ Thermal performance:

Examples of comparison between time-temperature profiles recorded in different days and water temperature predicted data





Results & Discussion

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T_w	water temperature
t	time
kmax	maximum heating rate
λ	delay time
α	maximum temperature reached

Parabolic

	PSC model parameters			
	α	***kmax***	***λ***	**R²**
Pp1	103,36	7,343	0,011	0,9971
Pp2	100,42	6,895	-1,949	0,9997
Pp3	95,067	5,997	-2,174	0,9991
Pp4	84,88	3,856	-4,653	0,9999

Box

	BSC model parameters			
	α	***kmax***	***λ***	**R²**
Bp1	105,5	1,489	-15,65	0,9997
Bp2	102,6	1,336	-15,54	0,9999
Bp3	95,99	1,118	-16,589	1
Bp4	102,72	1,151	-19,74	0,9999

Results & Discussion

$$T_w = \alpha \exp\left[-exp\left(\frac{kmax\ e}{\alpha}(\lambda - t) + 1\right)\right]$$

T_w	water temperature
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- solar cooking is an uncontrolled process
- changes in ambient temperature, wind speed and solar radiation intensity can significantly alter the cooking time

Results & Discussion

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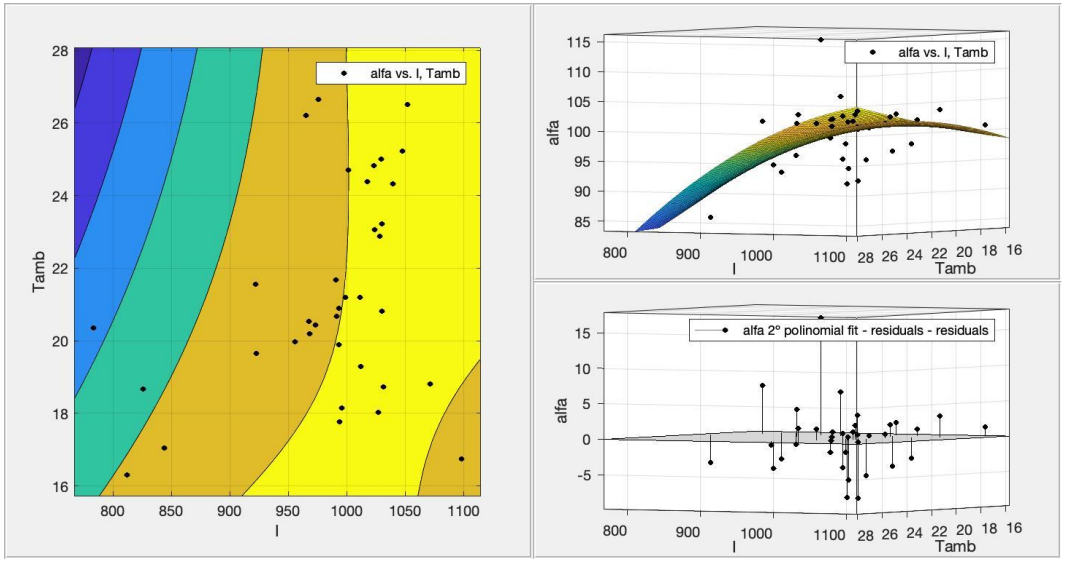
Contour plot, 3D graph and residual analysis of **Parabolic Solar Cooker** α estimated values plotted versus ambient temperature T_{amb} and solar radiation intensity (I)



α maximum temperature reached

Results & Discussion

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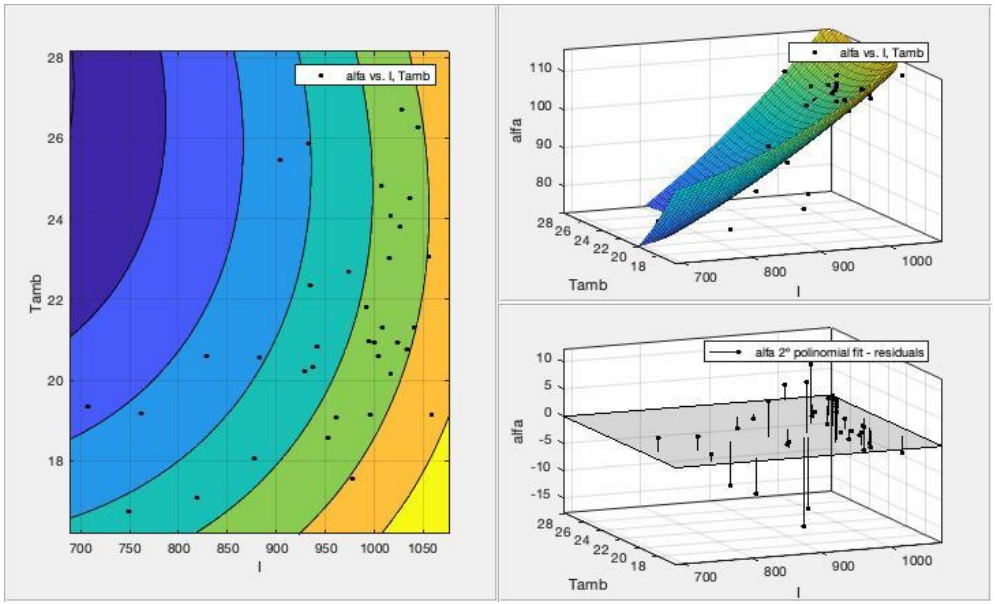
Contour plot, 3D graph and residual analysis of **Box Solar Cooker** α estimated values plotted versus ambient temperature T_{amb} and solar radiation intensity (I)



α maximum temperature reached

Results & Discussion

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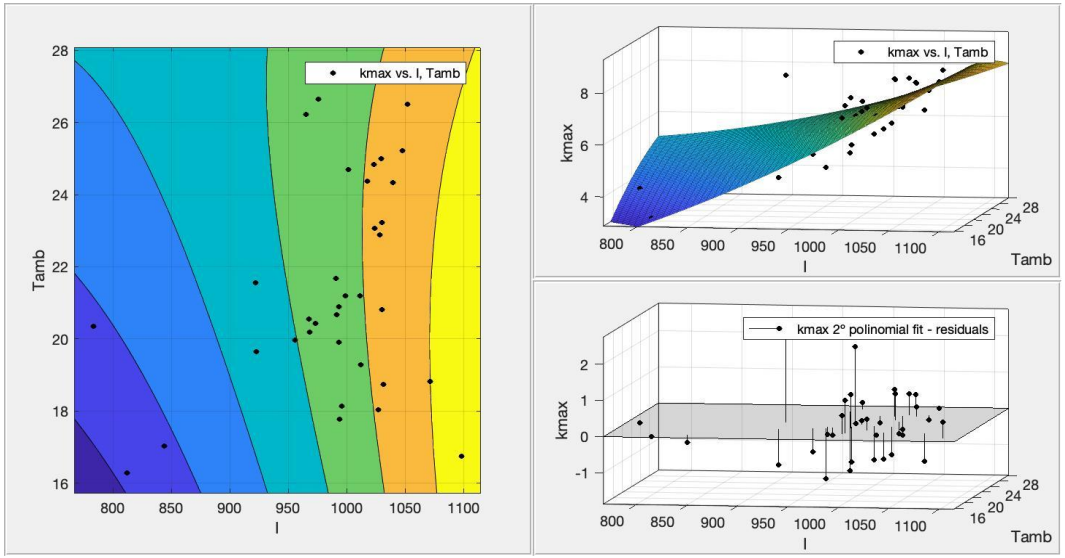
Contour plot, 3D graph and residual analysis of **Parabolic Solar Cooker** *kmax* estimated values plotted versus ambient temperature T_{amb} and solar radiation intensity (I)



kmax maximum heating rate

Results & Discussion

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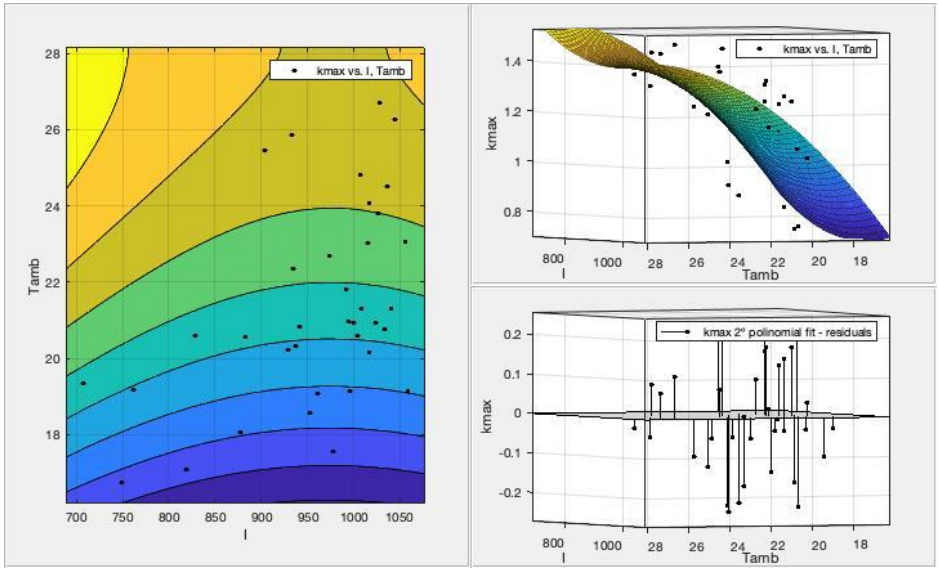
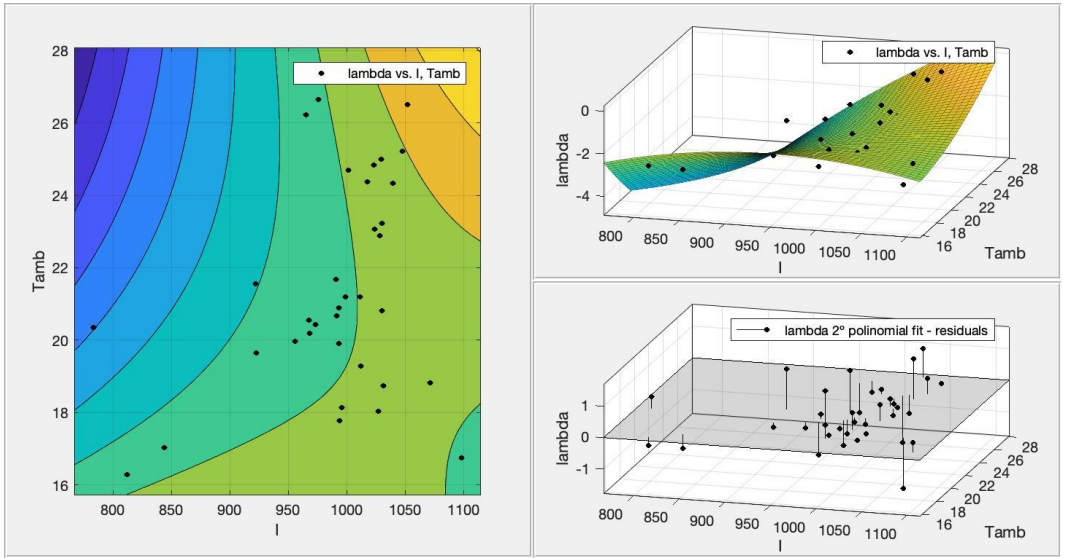


kmax maximum heating rate

Results & Discussion

Contour plot, 3D graph and residual analysis of **Parabolic Solar Cooker** λ estimated values plotted versus ambient temperature T_{amb} and solar radiation intensity (I)



λ delay time

Results & Discussion

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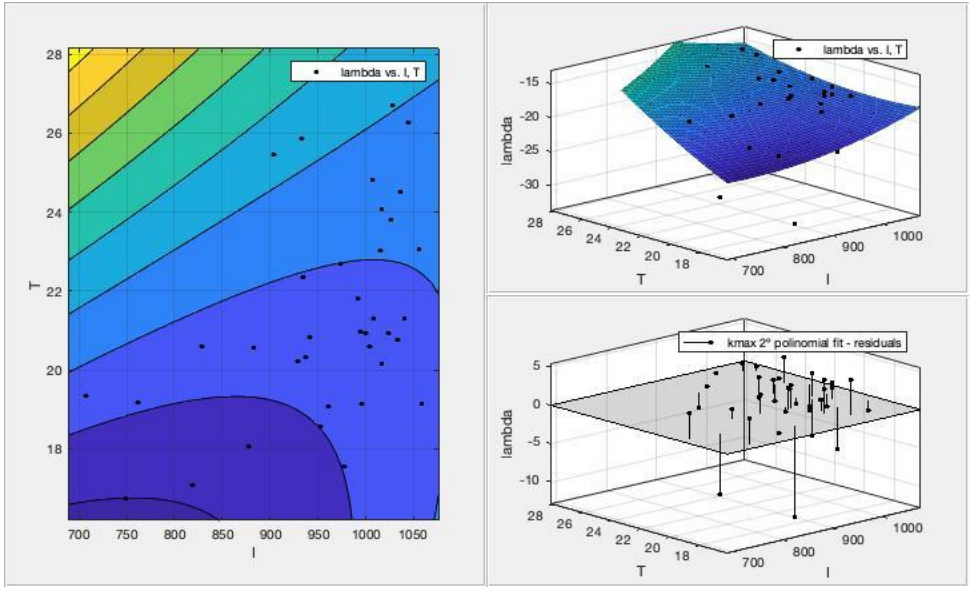
Contour plot, 3D graph and residual analysis of **Box Solar Cooker** λ estimated values plotted versus ambient temperature T_{amb} and solar radiation intensity (I)



λ delay time

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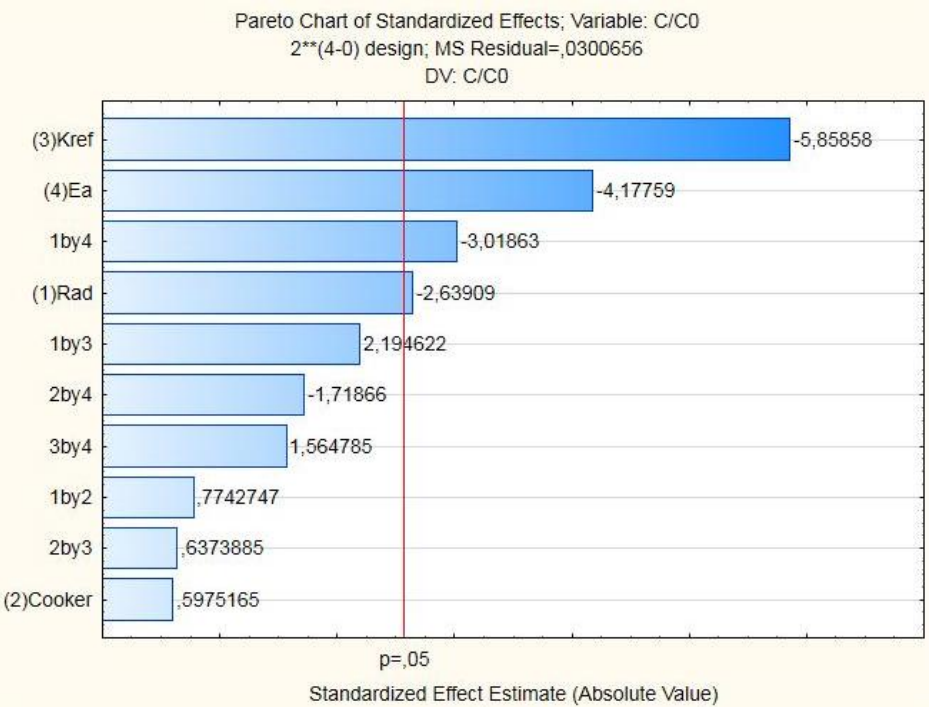
→ Impact on quality:

Solar radiation (W/m^2)	Solar cooker type	k (min^{-1})	Ea (kJ/mol)	C/C_0
1	1	1	1	1,16E-33
1	1	1	-1	0,52
1	1	-1	1	0,0329
1	1	-1	-1	0,97
1	-1	1	1	4,083E-66
1	-1	1	-1	0,13
1	-1	-1	1	0,0011
1	-1	-1	-1	0,91
-1	1	1	1	0,0044
-1	1	1	-1	0,42
-1	1	-1	1	0,78
-1	1	-1	-1	0,96
-1	-1	1	1	0,27
-1	-1	1	-1	0,11
-1	-1	-1	1	0,94
-1	-1	-1	-1	0,91

Results & Discussion



Main effects:

kref
Ea
solar radiation intensity

Conclusions

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- ✓ This was an exploratory study
- ✓ Quality retention during solar cooking depends mainly on the vegetable quality parameter considered: rate constant and activation energy of the quality change
- ✓ Effect of the radiation was also identified
- ✓ Important to explore how different radiation profiles can affect the quality of food during solar cooking, considering also different location or year season

Contact

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