Third International Conference **CONSOLFOOD**2020

Advances in Solar Thermal Food Processing

22-23-24 January 2020

INSTITUTE OF ENGINEERING; UNIVERSITY OF ALGARVE; CAMPUS DA PENHA; FARO-PORTUGAL

SOLAR DRYING OF NOPAL (*Opuntia ficus-indica*) USING DIRECT TECHNOLOGIES

Luis Humberto Huerta Medina, Beatriz Castillo Téllez, Rachid Marzoug y Margarita Castillo Téllez

UNIVERSIDAD DE GUADALAJARA
CENTRO UNIVERSITARIO DEL NORTE

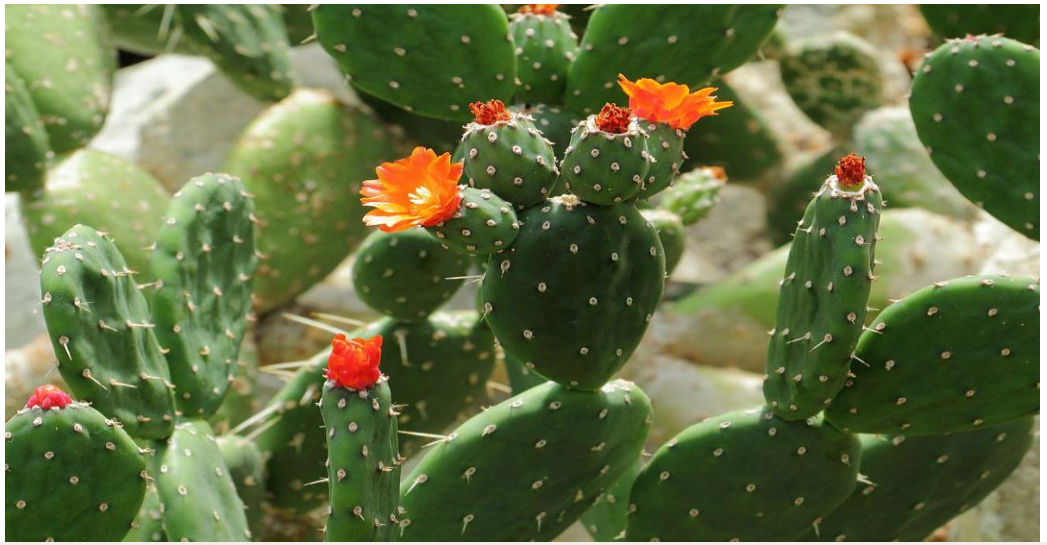
WASTE OF NOPAL IN MEXICO

Why is food wasted?

- About 1.3 billion tons of food produced worldwide is wasted each year.
- The main reason is because food cannot be preserved

THE NOPAL

The nopal is a Mexican plant that belongs to the family of cacti.



Used since pre-Hispanic period and has different uses from gastronomy to medicinal.

BENEFITS

As a food

- Versatility in consumption: Fresh: Various tasty preparations
- Powder, (sweets, breads, tortillas, biscuits, toast)
- Fruit, (sweets, jams and jellies)

As a medicine

- Lowering blood sugar levels
- Prevents the development of osteoporosis
- Provides calcium, protein, iron and carbohydrates
- Cholesterol
- Obesity control
- Controls gastritis

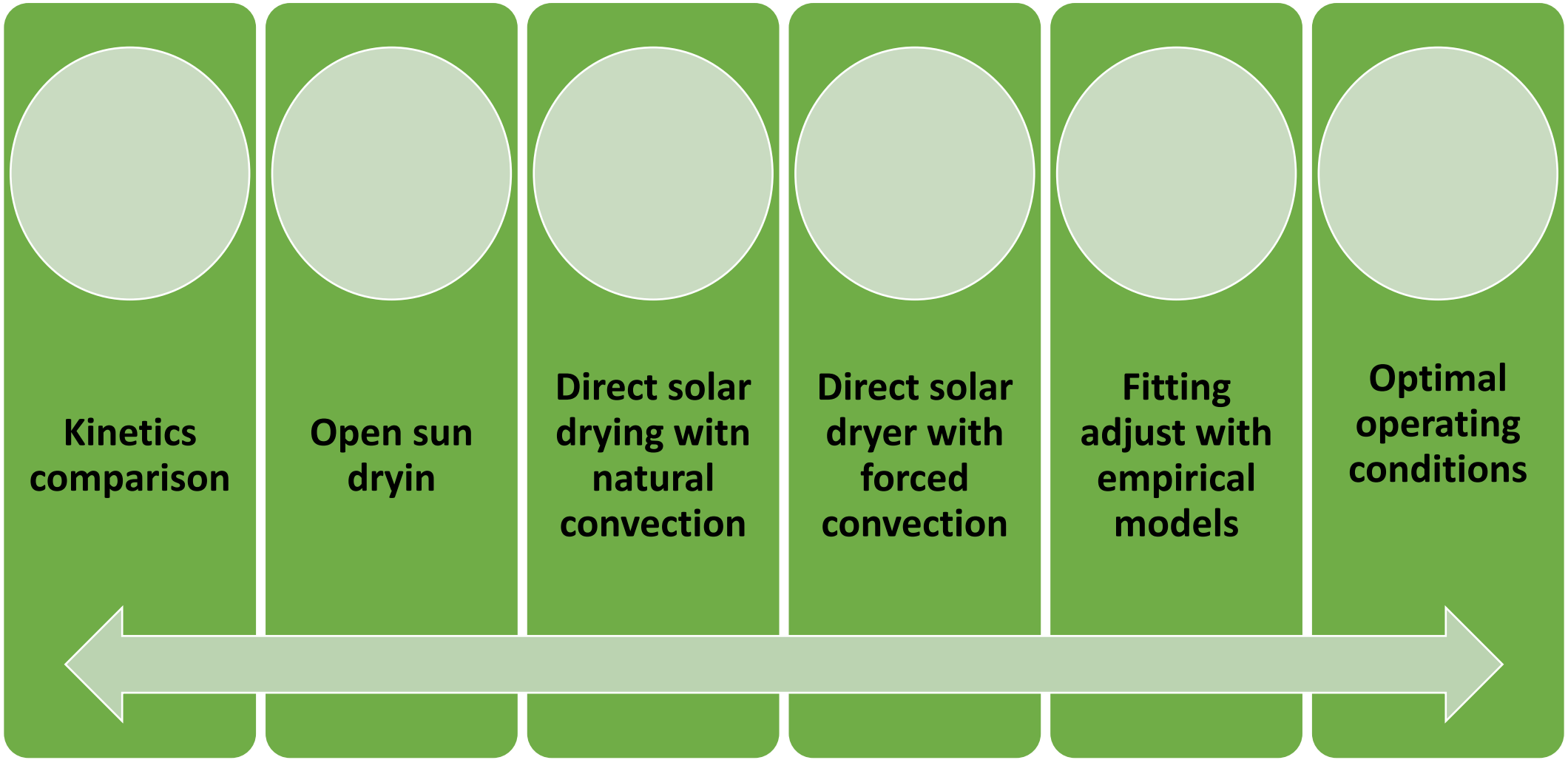
NOPAL DRYING POTENTIAL

377 species
104 grow in Mexico, 60 endemic Mexico
The Nopal has generated adaptive strategies
Can survive long droughts
They grow in arid and semi-arid regions
More than 45% of the Mexican territory has this condition

TECHNOLOGIES USED

EXPERIMENTAL WORK

UNIVERSIDAD DE GUADALAJARA
CENTRO UNIVERSITARIO DEL NORTE



MATERIAL AND PROCESS

100 g de nopal was cut into pieces

Dipped into a water-sodium choride for 20 min

Placed in tray into the dryer

OPEN-SUN DRYING

The product already cut, was placed in a container and directly exposed to the sun's rays Times were also measured, humidity humidity, until they reached the result

EXPERIMENTAL METHODS

UNIVERSIDAD DE GUADALAJARA
CENTRO UNIVERSITARIO DEL NORTE

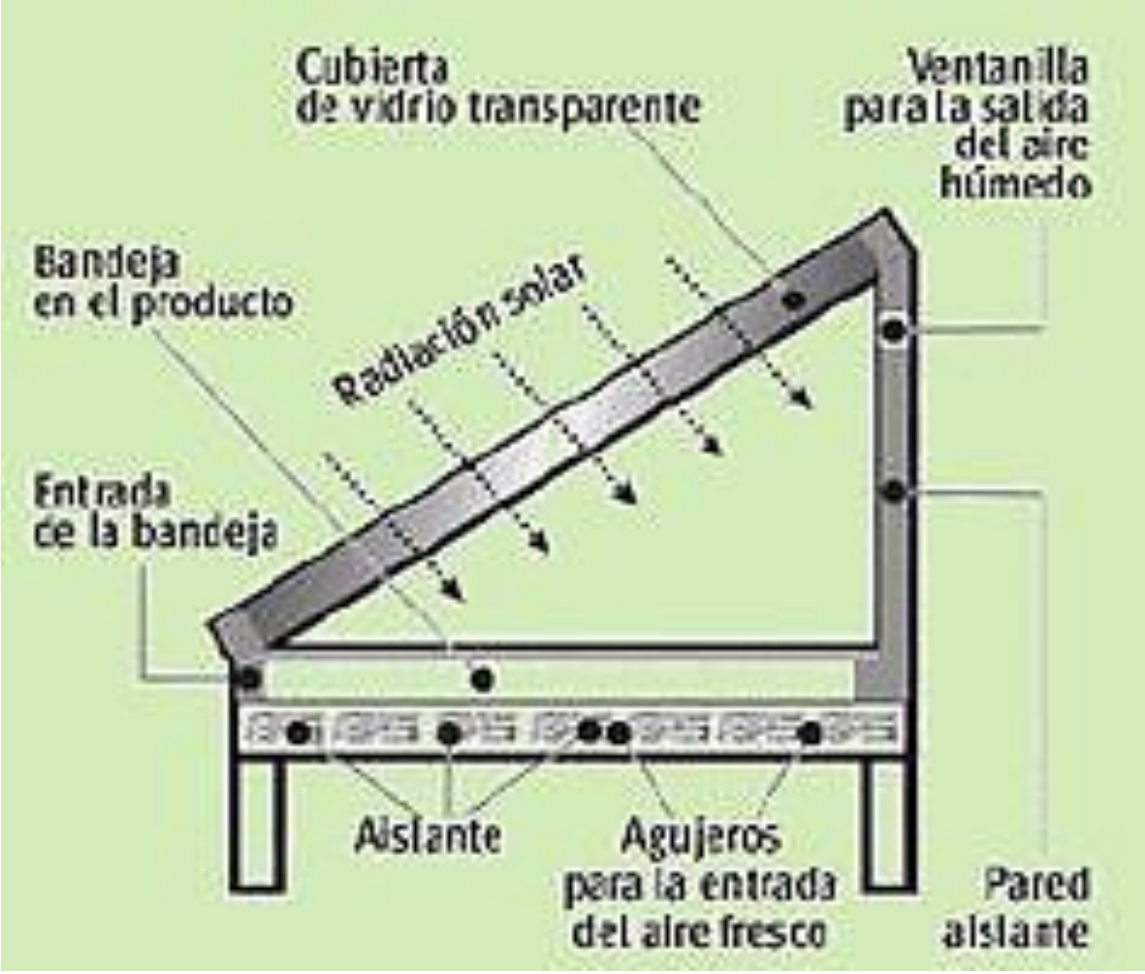
Direct solar drying

- Transparent plastic gabinet, surface 0.5 m^2.
- Lower perforations Circulation and extraction of hot and humid air.
- Natural air circulation or forced convection They were measured: indoor temperature, weight loss in samples, solar irradiance, relative humidity.
- Fan with a maximum air speed of 2 m/s.

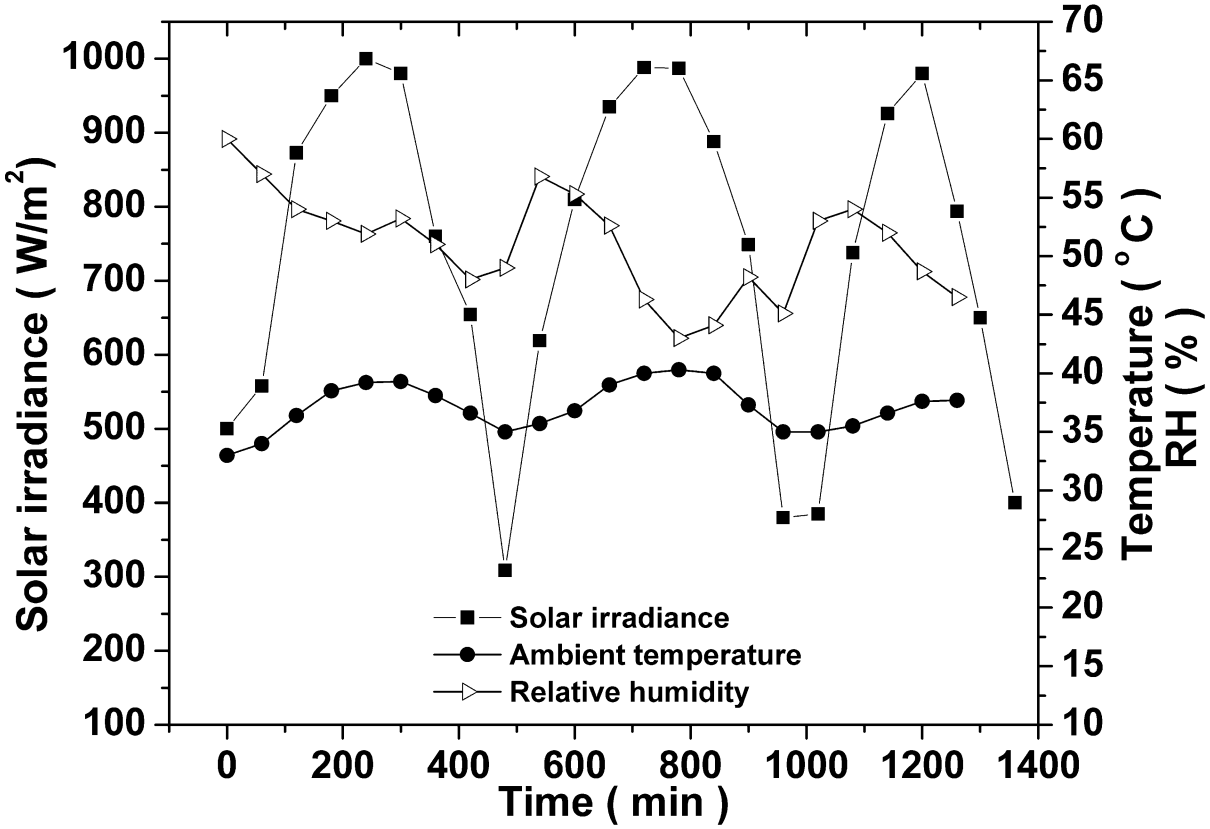
Figura 1 a) Secador solar directo con convección forzada y b) Secado a cielo abierto

CABINET-TYPE SOLAR DRYER

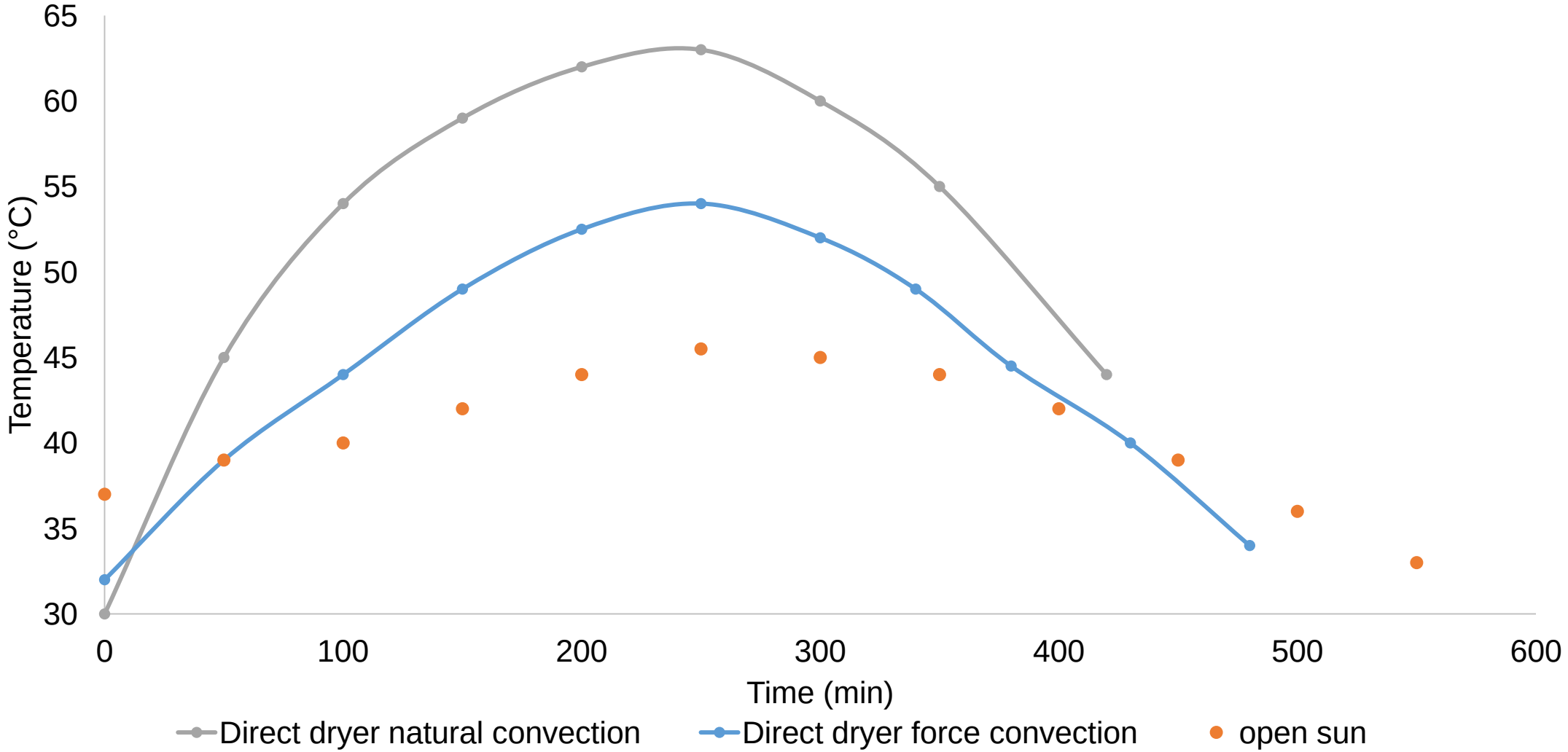
- A clear plastic solar dryer, with an area of 0.5m^2
- The cabinet has a surface that absorbs solar radiation directly into the drying chamber.
- The side and bottom parts have perforations to make it easier to circulate moisture.



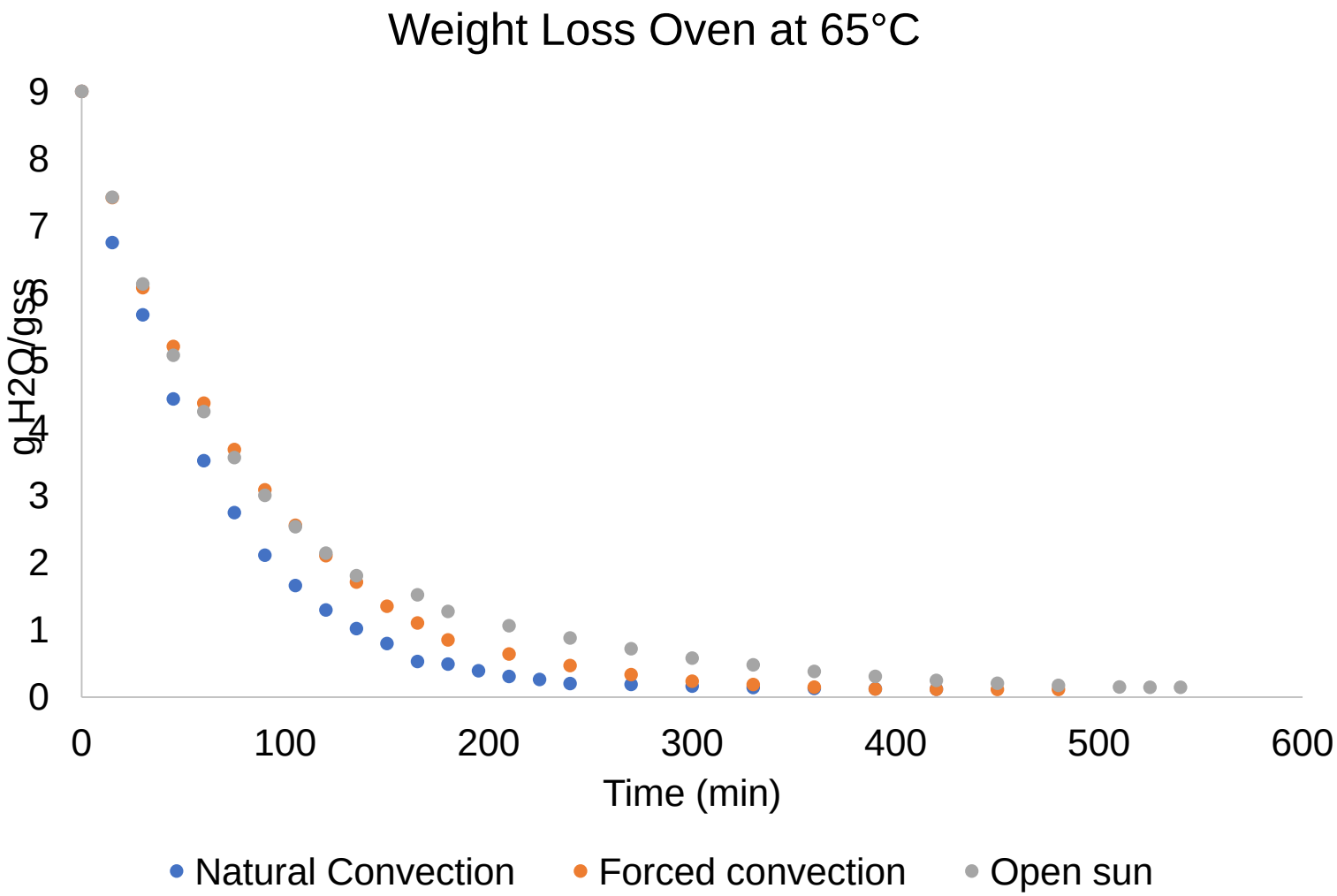
CLIMATIC PARAMETERS DURING TEST



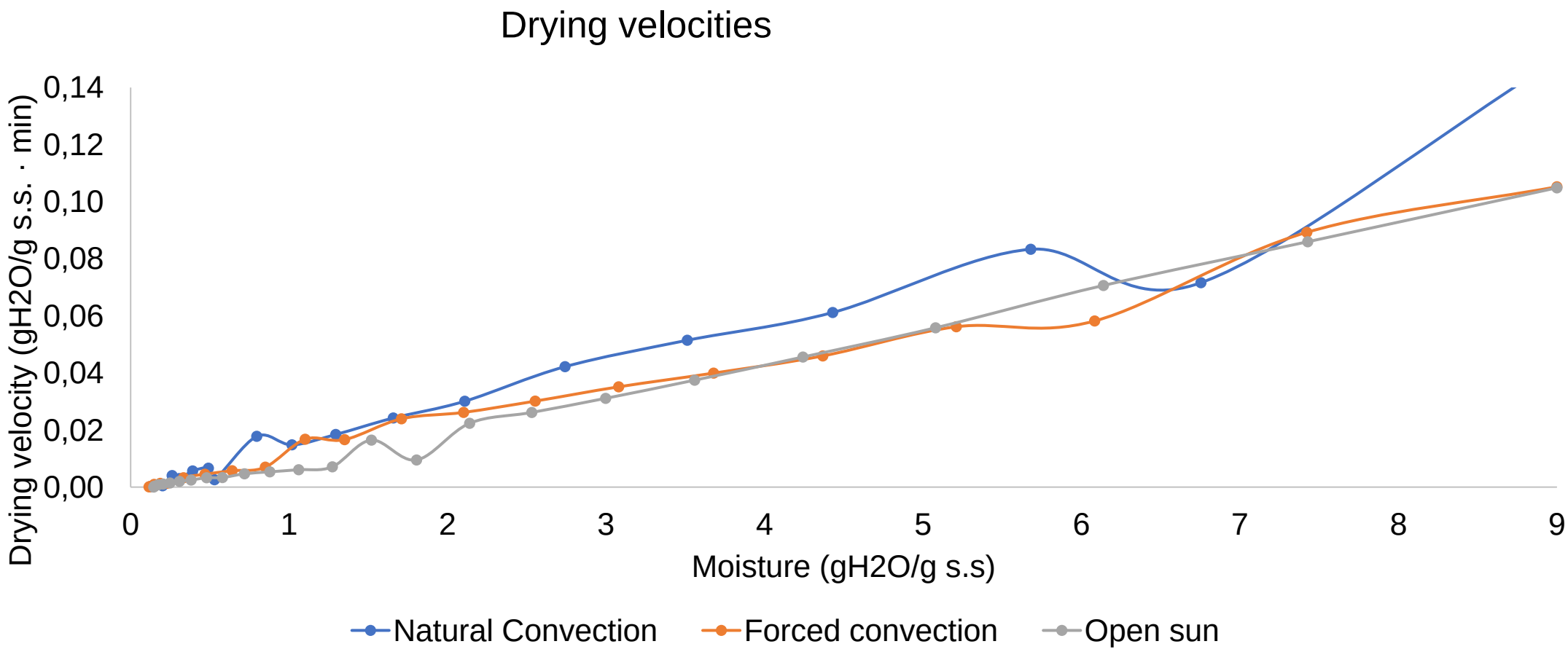
TEMPERATURES REACHED DURING TEST



RESULTS


Weight Loss Oven at 65°C
9
8
7
6
5
4
3
2
1
0
gH2O/gss
0
100
200
300
400
500
600
Time (min)
Natural Convection
Forced convection
Open sun

DRYING VELOCITIES NOPAL DRYING



Modelo	Ecuación	Referencia
Newton	MR = exp(-kt)	(Tunde 2011)
Page	MR = exp(-ktn)	(Page 1949)
Page modificado	MR = exp(-(kt)n)	(Diamante et al., 1993)
Henderson and Pabis	MR = a exp(-kt)	(Henderson and Pabis 1961)
Logarítmico	MR = a exp(-kt) + c	(Togrul and Pehlivan 2002)
Dos términos	MR = a exp(-k0t) + b exp(-k1t)	(Kouaa et al., 2009)
Dos términos Exponencial	MR = a exp(-kt) + (1-a)	(Sharaf-Eldeen et al., 1980)
Midilli	MR = a exp (-kt)+bt	(Midilli et al, 2002)
Henderson and Pabis Modificado	MR = a exp[-(kt)+b exp (-gt)+ c exp (-ht)	(Karathanos, 1999)

- El coefficient of determination (R^2)
- reduced chi-square
- (χ^2) y el root mean square error analysis (RMSE)

Initial and final humidity and water activity obtained by different drying methods (average).

Dryer type	Moisture content (%)		Water activity (aw)	
	Initial	Final	Initial	Final
Natural Convection	92.30	10.93	0.956	0.178
Forced convection	91.25	9.01	0.975	0.198
Open sun	91.43	9.73	0.945	0.163

FRESH CACTUS COLOR

L	a*	b*
31.42	-13.96	22.76
+.04	+.15	+.20
-.04	-.15	-.20

Goodness of MR adjustment Direct dryer with forced convection

Model	R^2	x^2	RMSE
Midilli	0.99	0.0016832	0.985752
Modifed Page	0.99	0.0021132	1.236752
Two Term Exponencial	0.989	0.0023832	1.236752
Henderson and Pabis	0.989	0.0028732	1.440752
Modified Henderson and Pabis	0.988	0.0016512	3.668752
Newton	0.988	0.0044632	1.634752

OPEN SUN FITTING

	a	0.9856
Logarítmico	c	-0.018
	k	0.1845
	r^2	**0.9997**
	RMSE	0.022
Page Modificado	k	0.2982
	n	1.2022
	r^2	**0,9976**
	RMSE	0.0125
	X^2	1.8242
Page	k	0.2339
	n	1.2006
	r^2	**0,9976**
	RMSE	0.0125
	X^2	1.8242

Fitting results of direct dryer with natural convection

Dos términos	a	0.2674
	b	0.7314
	c	1.098
	d	0.0846
	r^2	**0.9895**
	RMSE	0.0231
	X^2	0.069
Modified Page	k	0.1183
	n	0.4532
	r^2	**0.9922**
	RMSE	0.0199
	X^2	0.0406
	k	0.2477
	n	0.6854
Page	r^2	**0.9839**
	RMSE	0.0286
	X^2	0.1022

COLORIMETRY

L	a*	b*
38.54	-11.26	31.69

Direct dryer forced convection

L	a*	b*
41.42	-10.58	33.52

Direct dryer natural convection

L	a*	b*
48.42	-9.96	42.76

Direct dryer open sun

CONCLUSIONS

The kinetics of drying by natural convection proved to reach a faster equilibrium at 420 minutes and 480 were needed using forced convection, while at 550 with open sun. However, colorimetric analyzes indicate that the negative effect of temperature is reduced by forced convection

The adjusted equation showed that the Midilly model was the best model for the thin layer of 4 mm thick with empirical constants presented here, for this technology, followed for Modified Page and Two term exponential, which have a very good fit for the solar dryer without forced convection and drying in open sun.
It is proven that solar drying technologies are suitable for nopal drying and lead to energy savings to improve environmental impact.


MUITO
OBRIGADA