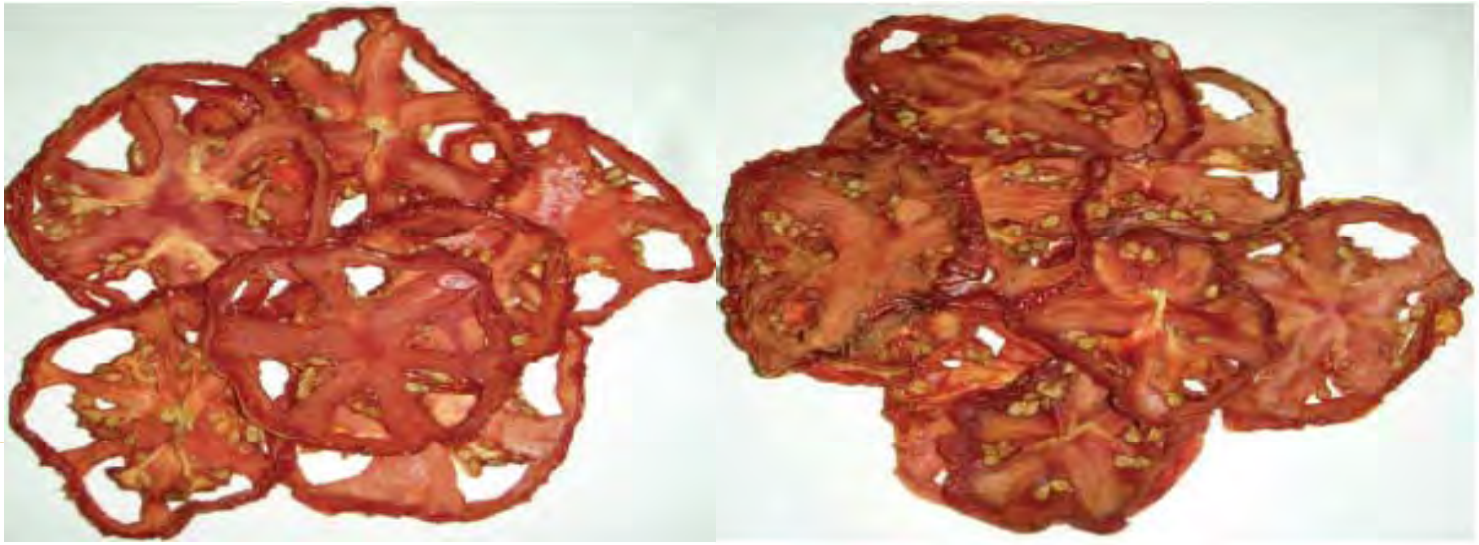
Microwave Assisted Hot Air Ventilation Drying of Tomato Slices



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Introduction

- **Conventional heating or drying involves:**
  - **High temperature**
  - **Long drying times**
  - **Serious damage to flavour, colour and nutrients**
  - **Heating occurs by convection followed by conduction**
- **Microwave treatment**
  - **Reduce drying time**
  - **Reduce quality degradation:**
    - **Nutritional value**
    - **Acceptability**
    - **Safety**

- **Disadvantages of conventional drying**
  - Thermal damage ~ proportional to the temperature and time
  - Higher temperature and longer drying time causes serious damage to the quality attributes
    - Flavour, Colour, Nutrients
    - Reduction in bulk density
    - Reduction rehydration capacity of the dried product
    - Volatile compounds are vaporised
- Search for an alternative efficient drying method
- Increasing interest in microwaves for food drying

- **Principle of microwave heating and drying**
  - Electromagnetic field energy into thermal energy
  - Microwave heating is volumetric heating
  - Volumetric heating means that materials can absorb microwave energy directly and internally and convert it into heat
  - In microwave heating, heat is generated throughout the material, leading to faster heating rates
  - Conventional heating where heat is usually transferred from the surface to the interior
  - Microwave drying is caused by water vapour pressure differences

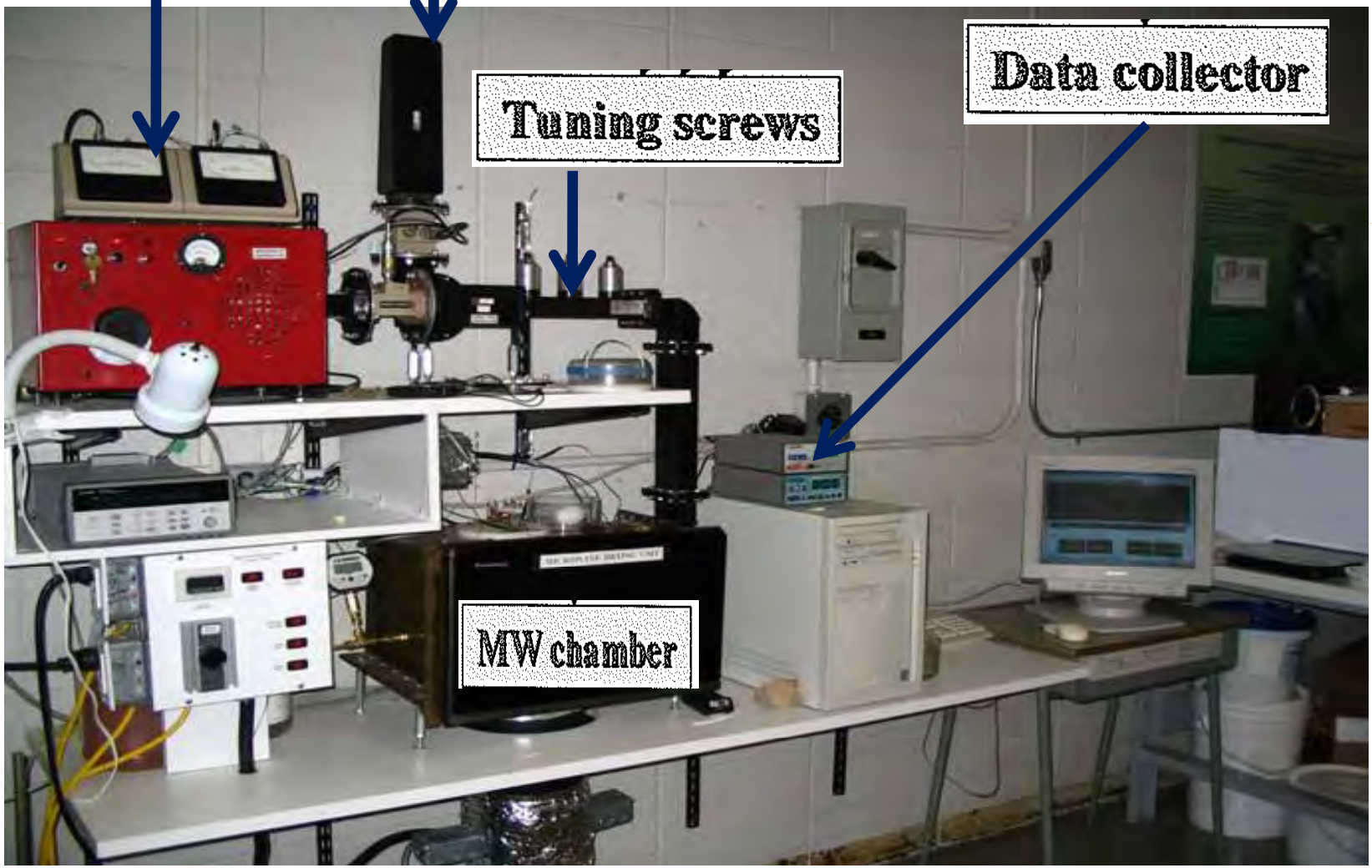
- **Advantages of microwave drying**
  - High thermal efficiency
  - Shorter drying time
  - Improved product quality
  - No problem of case hardening
  - Fast start-up and shut-down
  - Inhibition of high surface temperatures
  - Continuation of product respiration
  - Lowered product temperatures when combined with vacuum drying
  - Reduction in the loss of water-soluble components
  - Energy savings

Materials and Methods

Raw Material and Drying process

- Ripe red and firm tomato (*Marglobe*)
- 5 mm thickness tomato slices
- Average weighing 60 ± 2 g
- Storage at 13°C until drying experiment
- Before drying trial, the tomatoes were kept at room temperature
- Initial moisture content was 94.01%
- The drying process was finished when the sample reached the moisture content of 10%

Microwave drying system



Drying Models

Model Name	Model	References
Lewis	$MR = \exp(-kt)$	Lewis (1921), Akpinar et al., (2006)
Page	$MR = \exp(-kt^n)$	Page (1949), Diamente and Munro (1993)
Henderson-Pabis	$MR = A \exp(-kt)$	Henderson - Pabis (1961), Doymaz (2004)

Result and discussions

Drying Kinetics

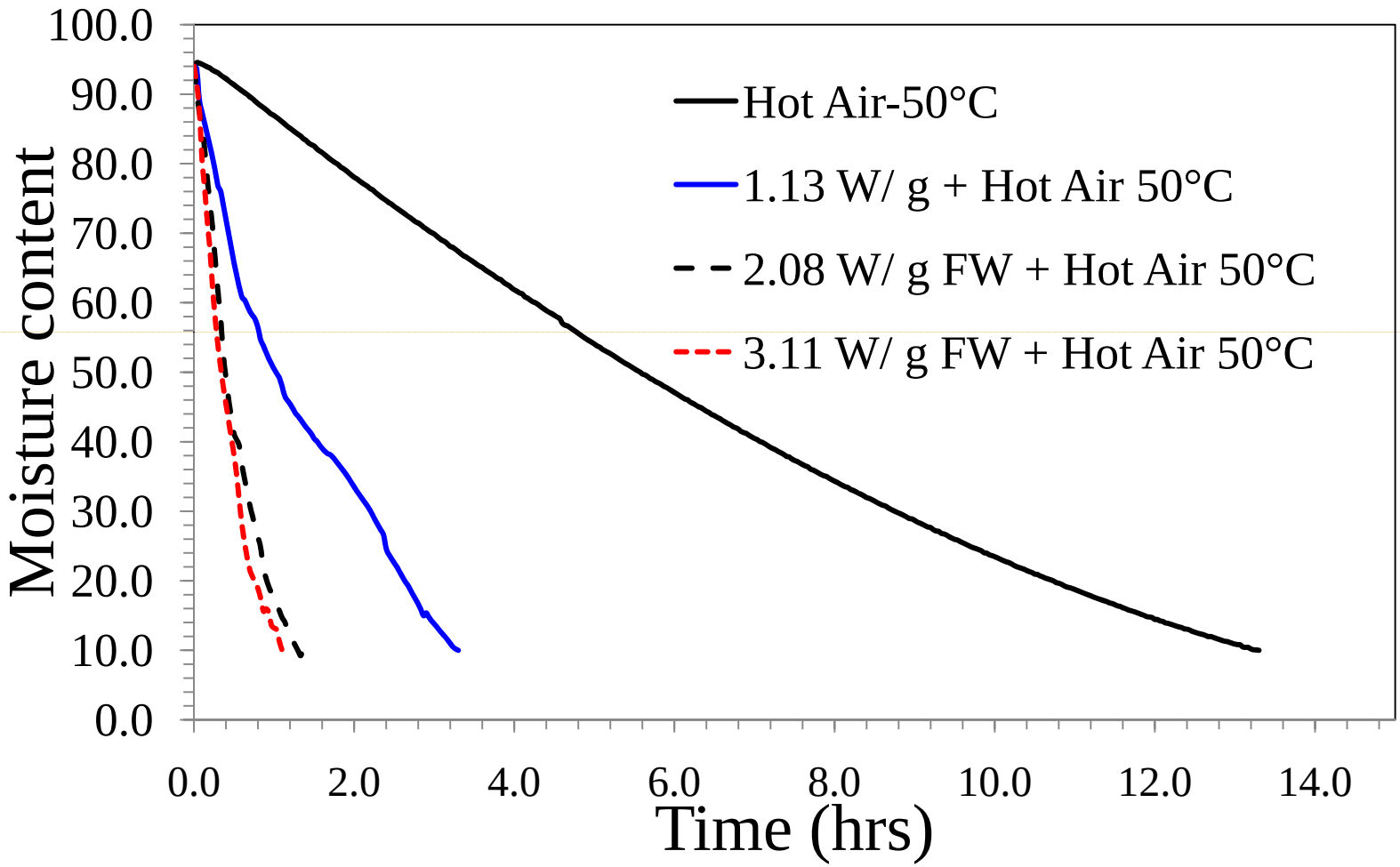


Fig. Moisture content of tomato slices changes with microwave power density and time

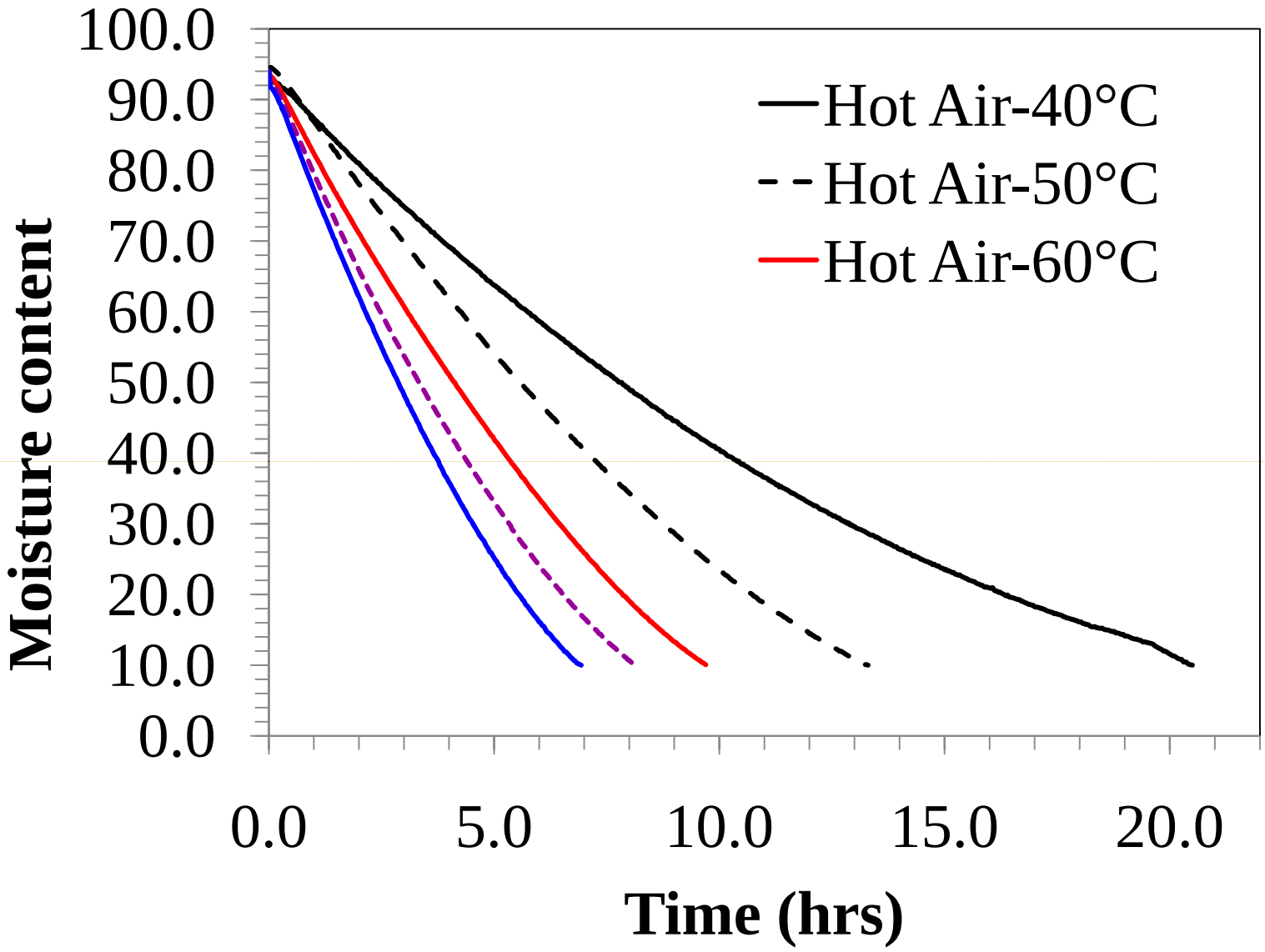


Fig. Moisture content of tomato slices changes with drying air temperature and time

Dimensionless Moisture content

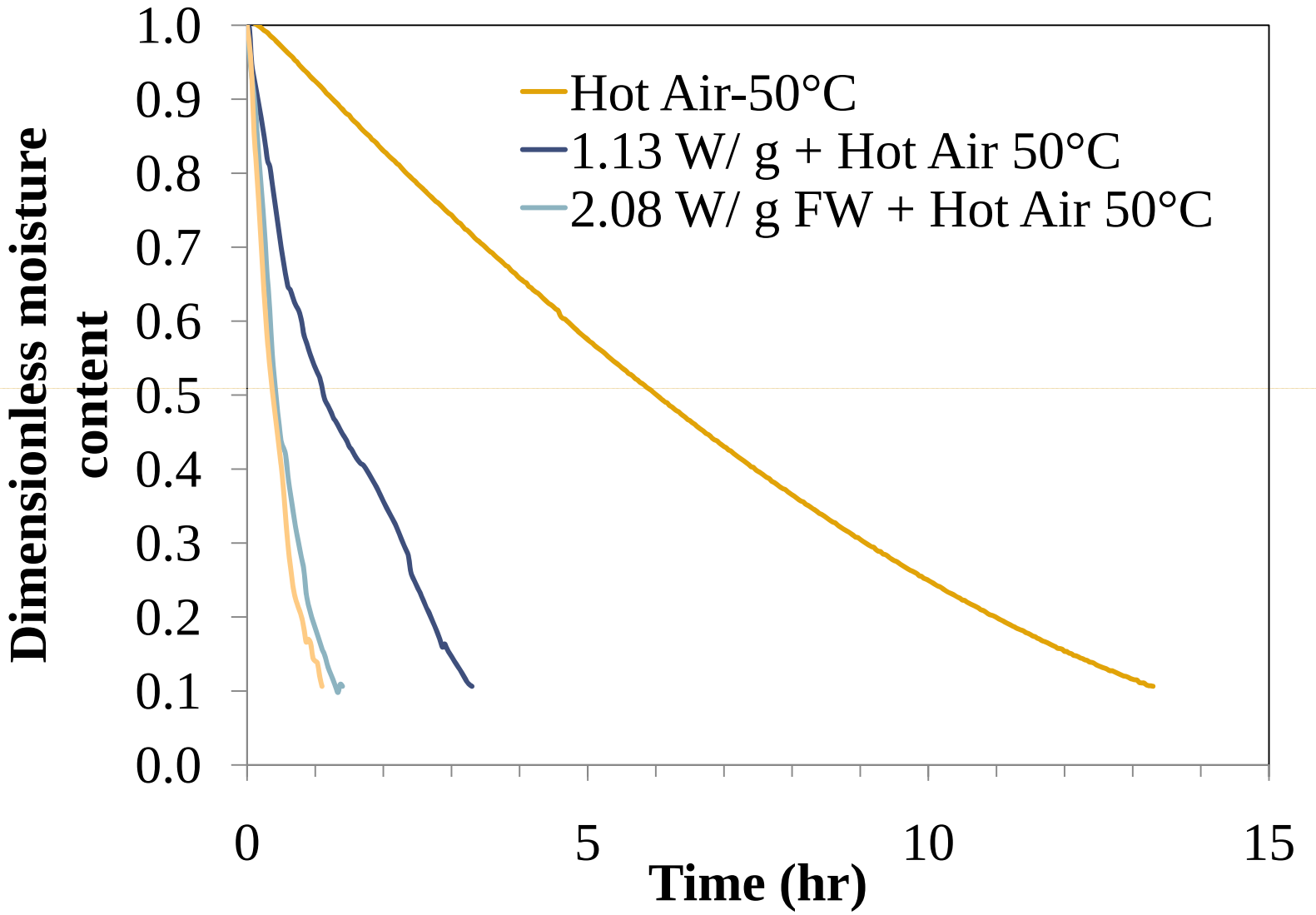


Fig. Dimensionless moisture content of tomato slices changes with microwave power density and time

Dimensionless moisture content

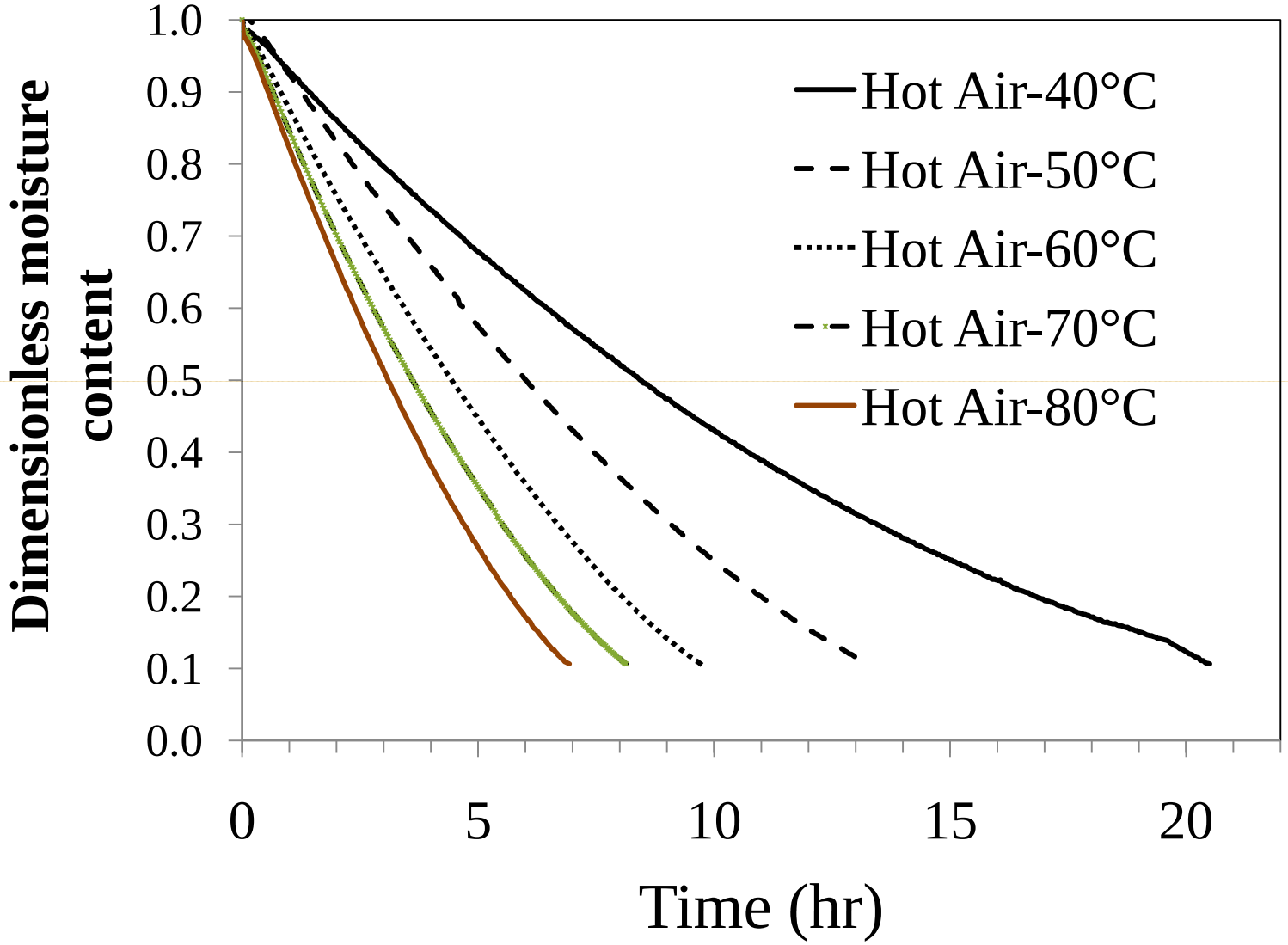
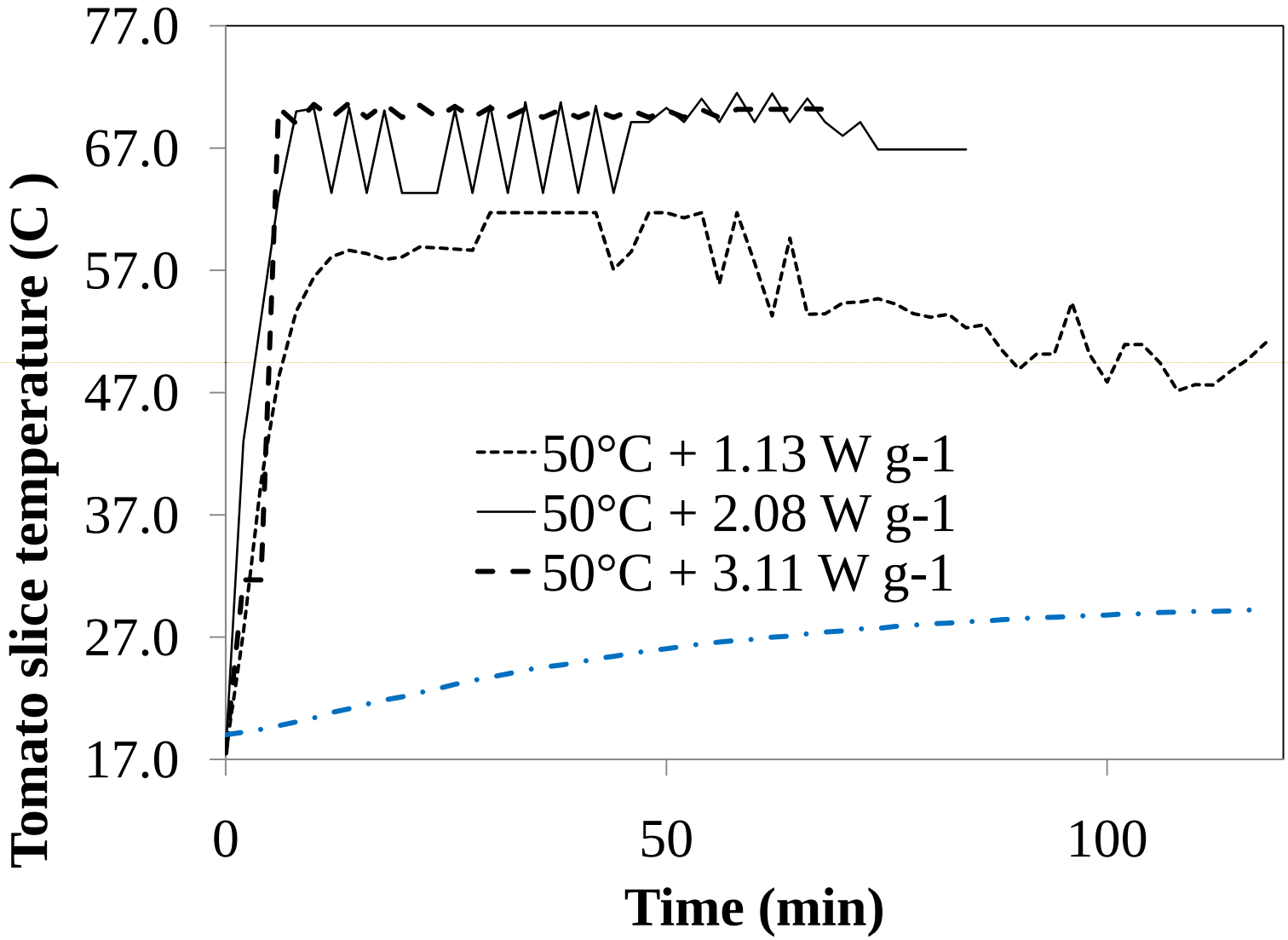
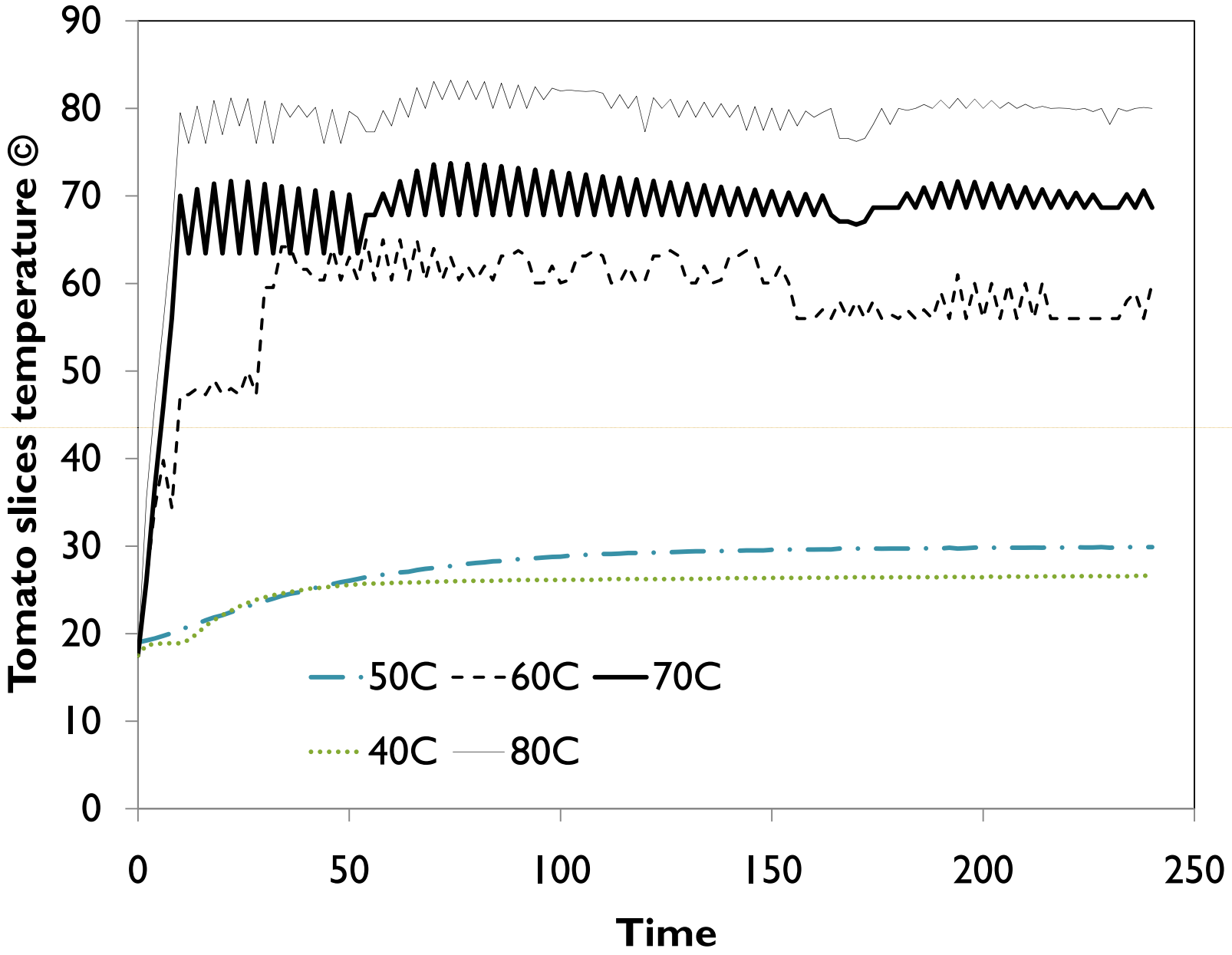


Fig. Dimensionless moisture content of tomato slices changes with drying temperature and time

Tomato slice temperature




Tomato slices temperature ©
90
80
70
60
50
40
30
20
10
0
0
50
100
150
200
250
Time
50C
60C
70C
40C
80C

Drying rate

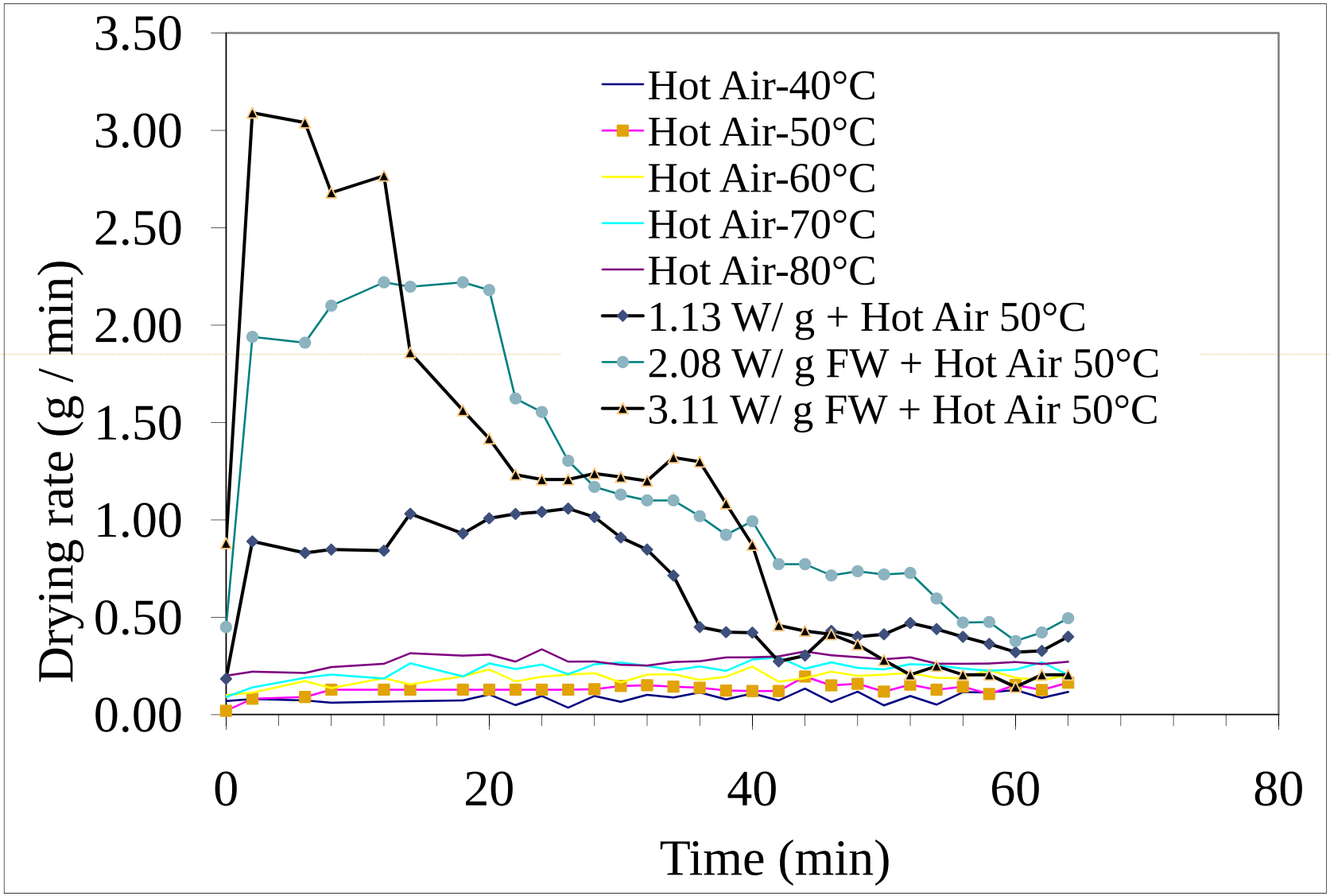


Fig. Drying rate of tomato slices changes with drying time

Constant rate of drying period

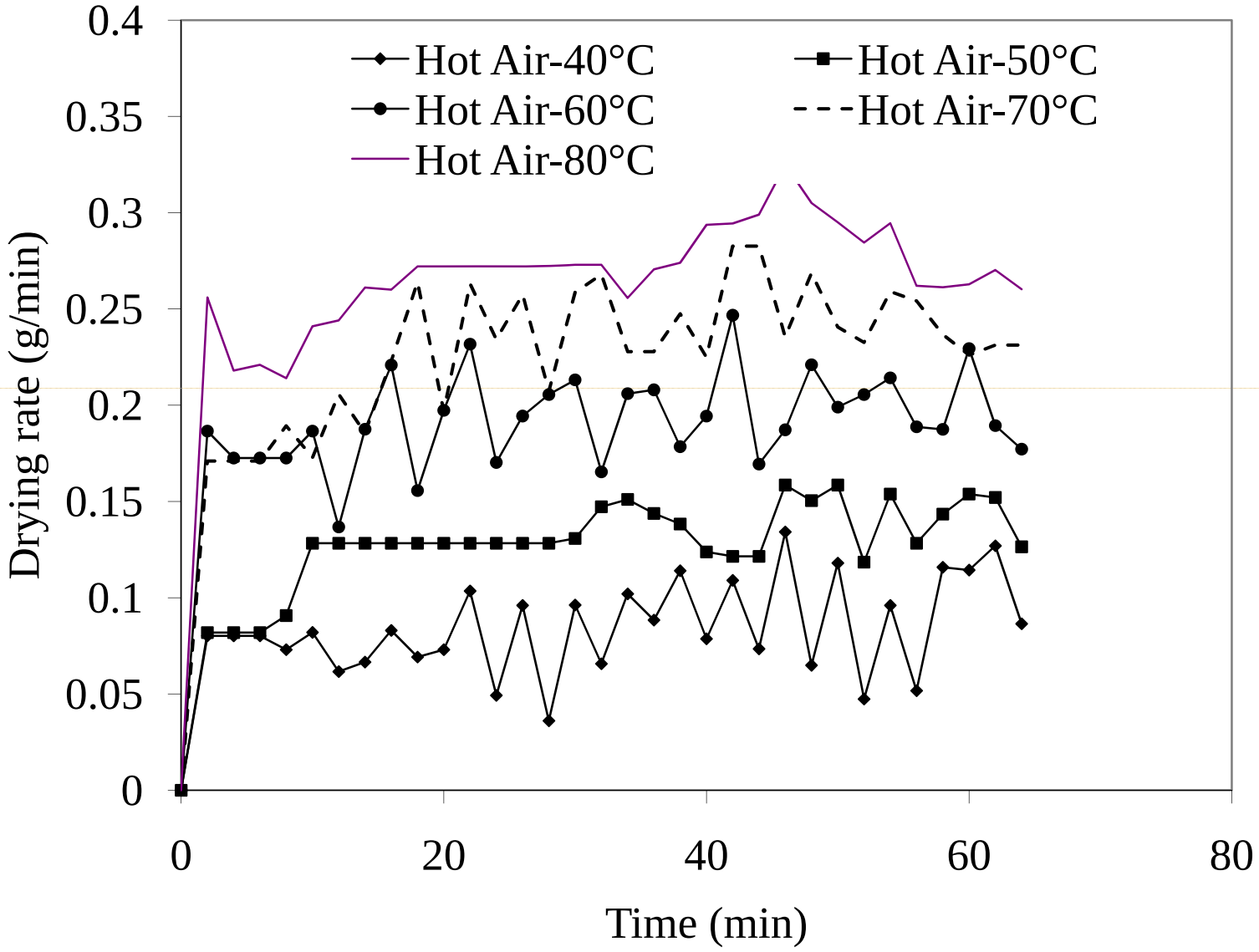


Fig. Drying rate of tomato slices changes with drying time

Hot Air Ventilation Drying

Temperature	Time (h)	% reduction in DT
40°C	20.5	0
50°C	13.3	35
60°C	9.70	53
70°C	8.13	60
80°C	6.93	66

Microwave assisted hot air ventilation drying

Treatment	Time (h)	% reduction in DT
50°C + 0 W/ g	20.5	0
50°C + 1.13 W/ g	3.3	84
50°C + 2.08 W/ g	1.4	93
50°C + 3.11 W/ g	1.1	95

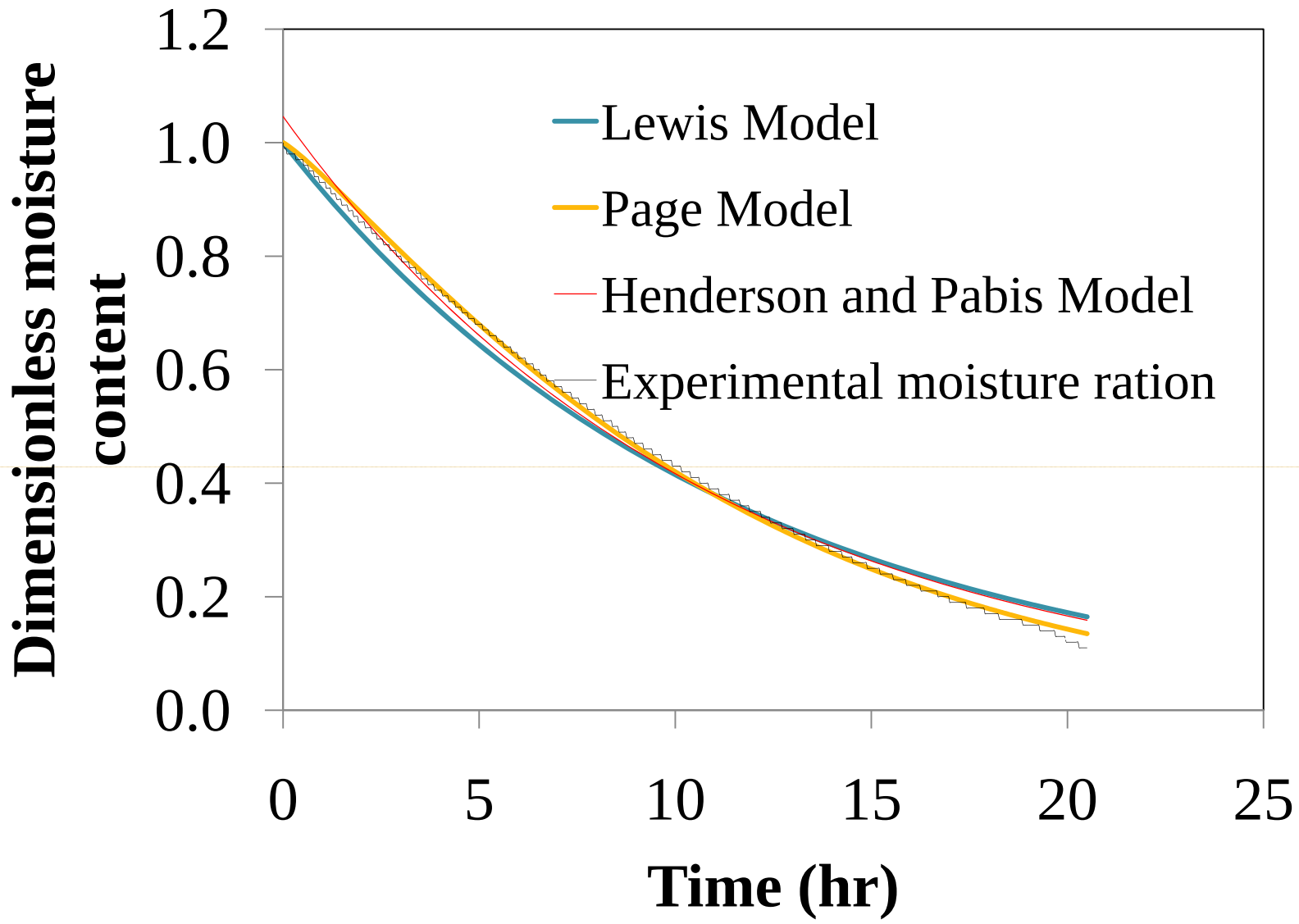


Fig. Experimental and calculated dimensionless moisture content of tomato slices (T = 40C)

Drying models parameters:

Model	Drying treatment	k, min^{-1}	R^2
Lewis	1.13 W g^{-1} + 50°C	1.592	0.991
	2.08 W g^{-1} + 50°C	1.914	0.993
	3.11 W g^{-1} + 50°C	0.584	0.984
	0 W g^{-1} + 50°C	0.124	0.991
	60°C	0.172	0.994
	70°C	0.210	0.978
	80°C	0.246	0.976
	40°C	0.086	0.989

Drying models parameters:

Model	Drying treatment	k, min^{-1}	n	R^2
Page	1.13 W g^{-1} + 50°C	0.606	0.930	0.986
	2.08 W g^{-1} + 50°C	1.668	1.140	0.997
	3.11 W g^{-1} + 50°C	2.066	1.122	0.998
	50°C	0.067	1.321	0.998
	60°C	0.106	1.289	0.997
	70°C	0.144	1.256	0.997
	80°C	0.171	1.275	0.997
	40°C	0.059	1.167	0.999

Drying models parameters:

Model	Drying treatment	α	(k), min^{-1}	R^2
Henderson & Pabis	1.13 W g^{-1} + 50°C	0.967	0.560	0.986
	2.08 W g^{-1} + 50°C	1.057	1.692	0.996
	3.11 W g^{-1} + 50°C	1.048	2.019	0.997
	40°C	1.092	2.092	0.993
	50°C	1.089	0.140	0.985
	60°C	0.072	0.187	0.983
	70°C	1.066	0.227	0.986
	80°C	1.066	0.266	0.984

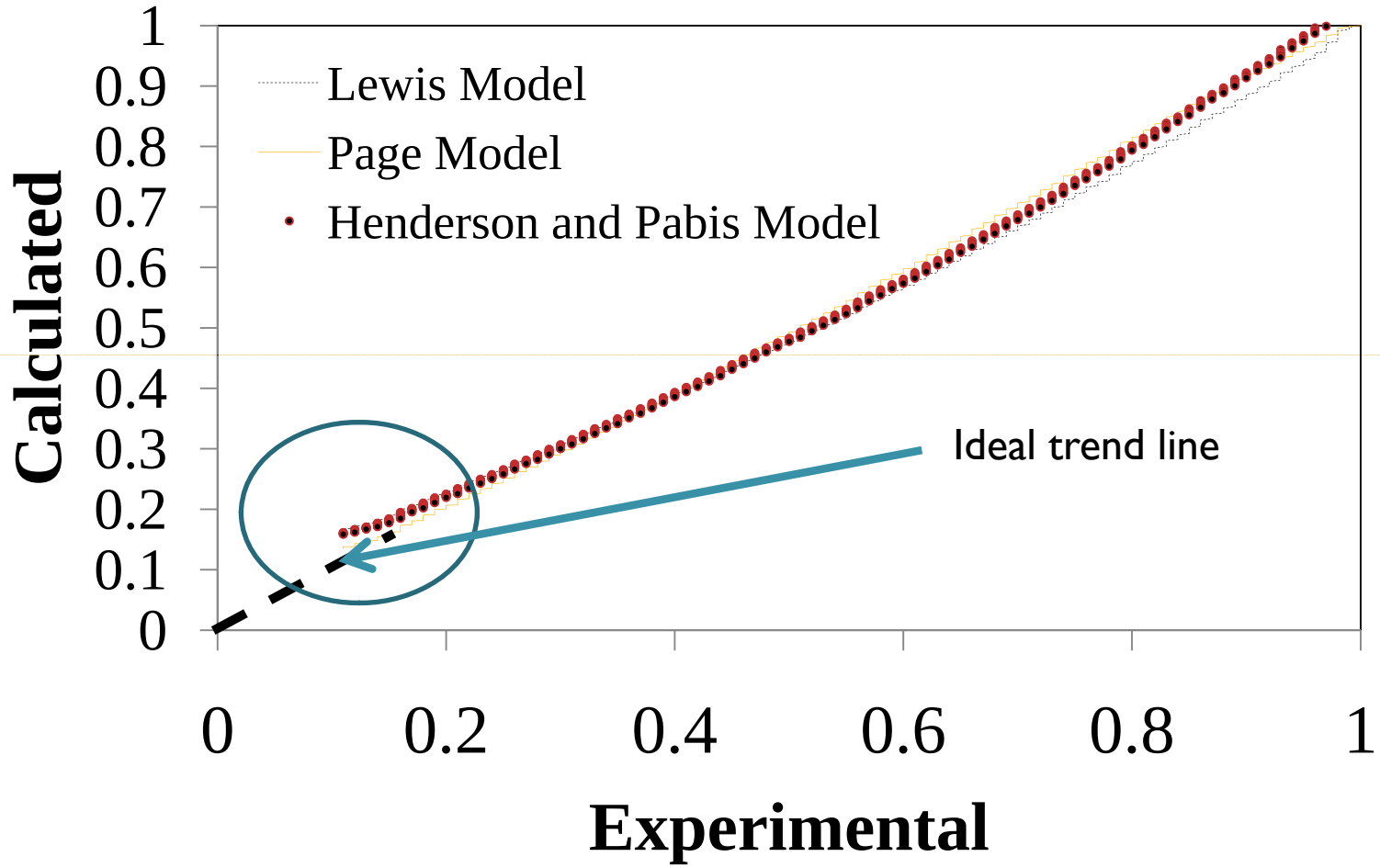
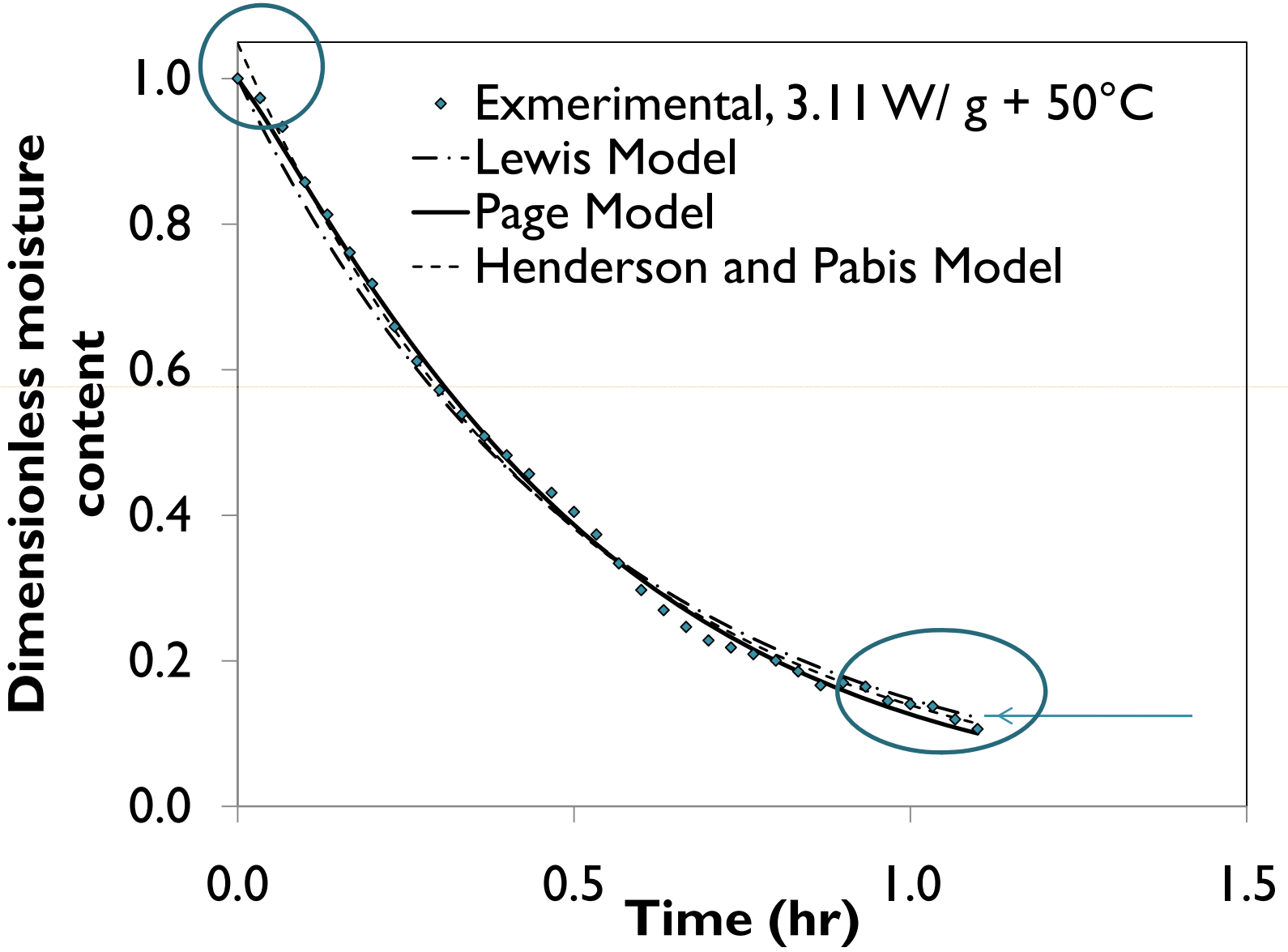
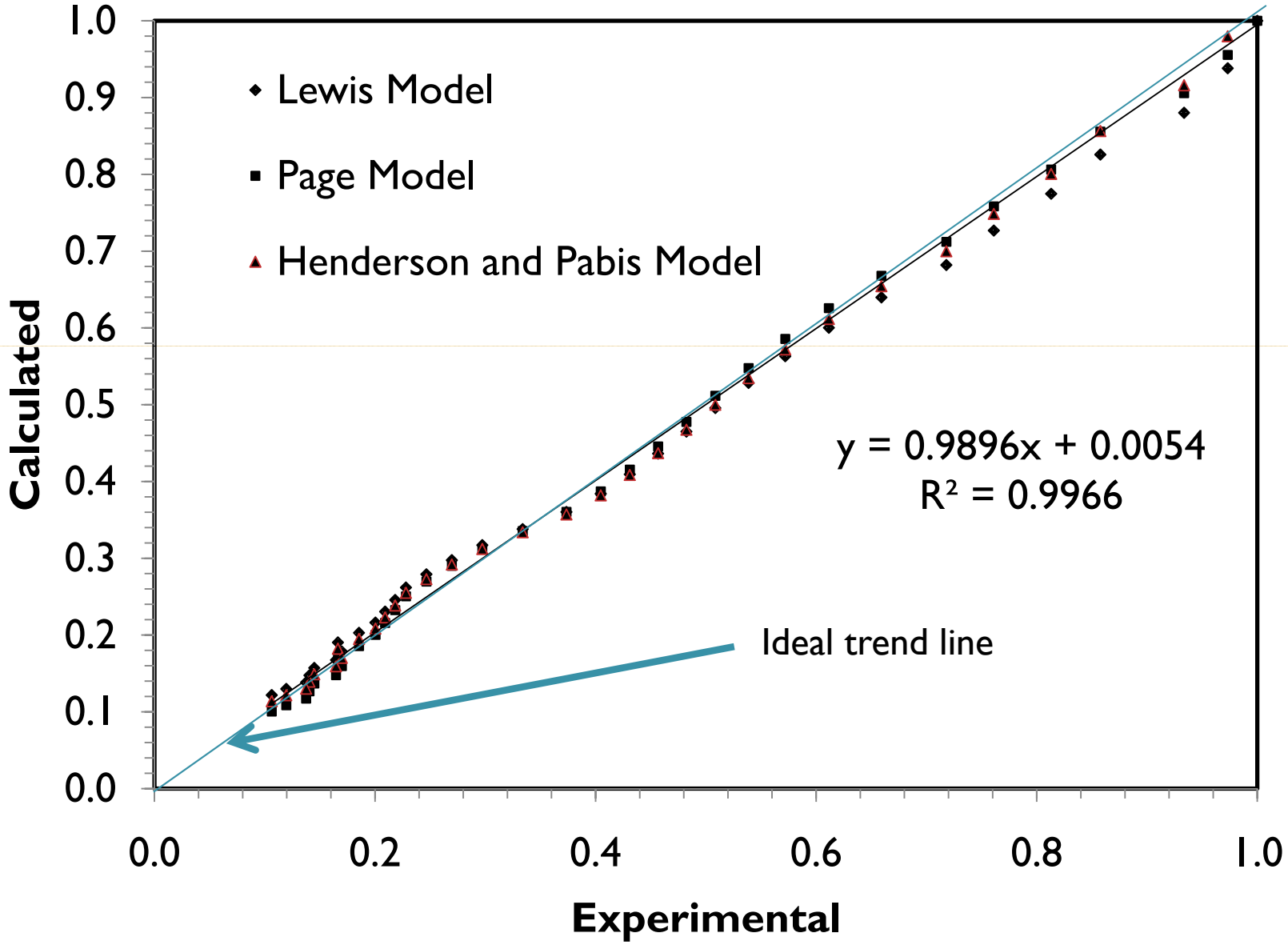


Fig. Comparison of experimental and calculated moisture ratios of tomato slices (T = 40°C)


Exmerimental, 3.11 W/ g + 50°C
Lewis Model
Page Model
Henderson and Pabis Model
Dimensionless moisture content
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
Time (hr)


Lewis Model
Page Model
Henderson and Pabis Model
y = 0.9896x + 0.0054
R² = 0.9966
Ideal trend line
Calculated
Experimental
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.0
0.2
0.4
0.6
0.8
1.0

Colour changes

Drying Treatment	L* (lightness or darkness)	a* (redness)	b* (yellowness)
Fresh	52.78^{a}	14.15^{a}	12.68^{f}
3.11 W g^{-1} + 50°C	43.11^{e}	10.96^{d}	17.80^{c}
2.08 W g^{-1} + 50°C	**45.00^{d}**	13.01^{b}	13.45^{edf}
1.13 W g^{-1} + 50°C	**47.89^{b}**	12.76^{cb}	13.04^{ef}
0 W g^{-1} + 50°C	48.07^{b}	12.85^{b}	13.96^{ed}
60°C	46.02^{cd}	12.06^{c}	14.18^{d}
70°C	45.06^{d}	10.29^{ed}	20.21^{b}
80°C	**39.09^{f}**	9.70^{e}	21.71^{a}
40°C	47.57^{cb}	12.79^{b}	13.95^{ed}

Significance

P	< 0.0001	< 0.0001	< 0.0001
R^2	0.944	0.938	0.975
CV	2.308	3.559	3.983
RMSE	1.063	0.429	0.624

Conclusions

- Tomato experiences all three rates of drying
- Faster drying when MW heating is coupled with hot air ventilation at 50°C
- The drying times were significantly reduced by MW power
- Better colour quality was maintained with MW assisted hot air ventilation drying

THANK YOU