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Innovative Applications of Infrared Heating for Food Processing

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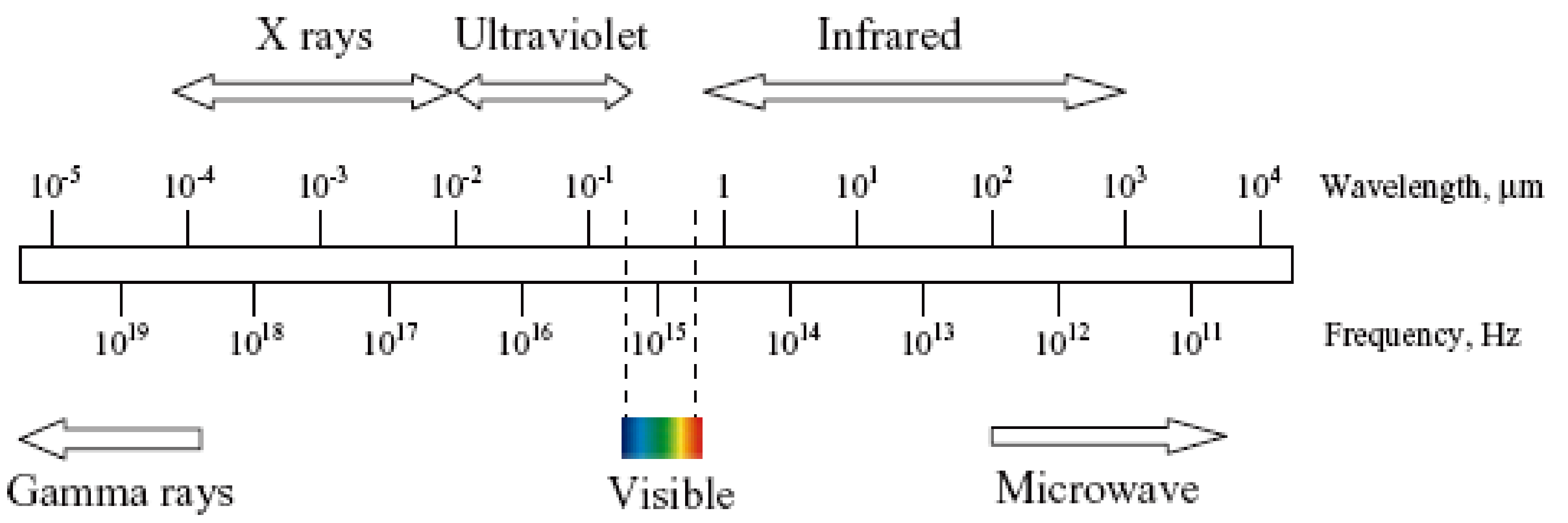
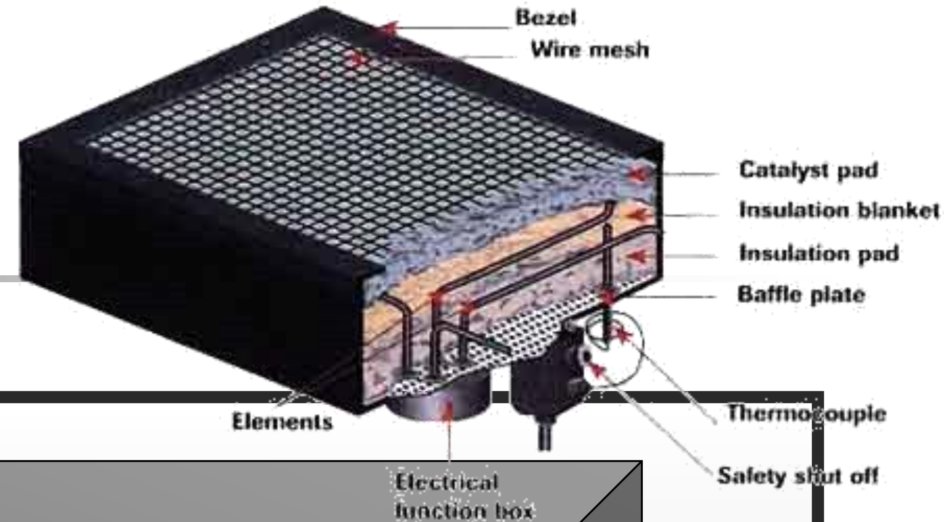
Infrared Radiation

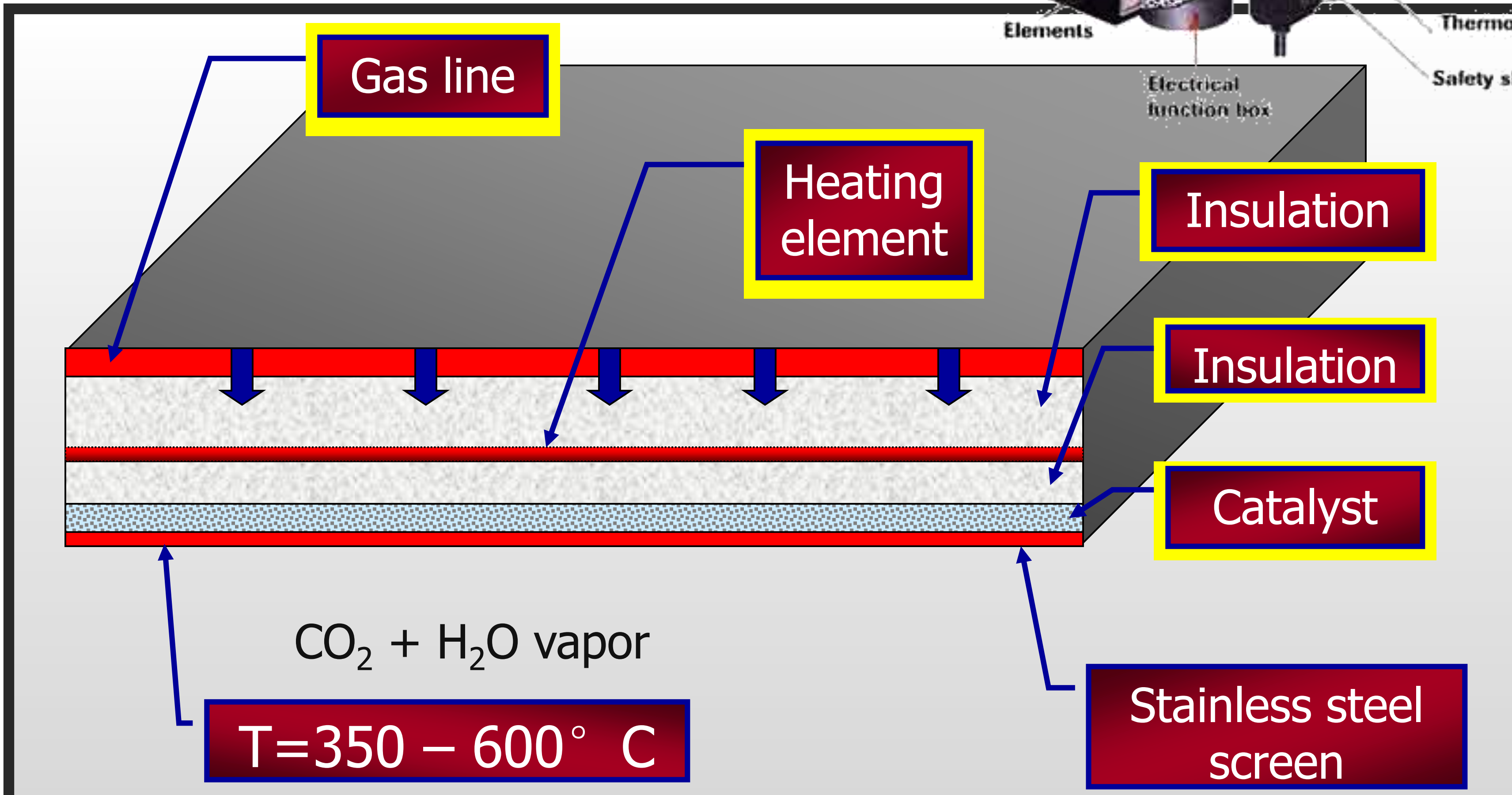


Why Infrared Heating?

- Infrared *radiant* heat transfer is often more efficient than convective heat transfer
- *Large amount* of controlled heat for heating food materials
- Improved final product quality

Catalytic IR Emitter





Infrared Radiation Research

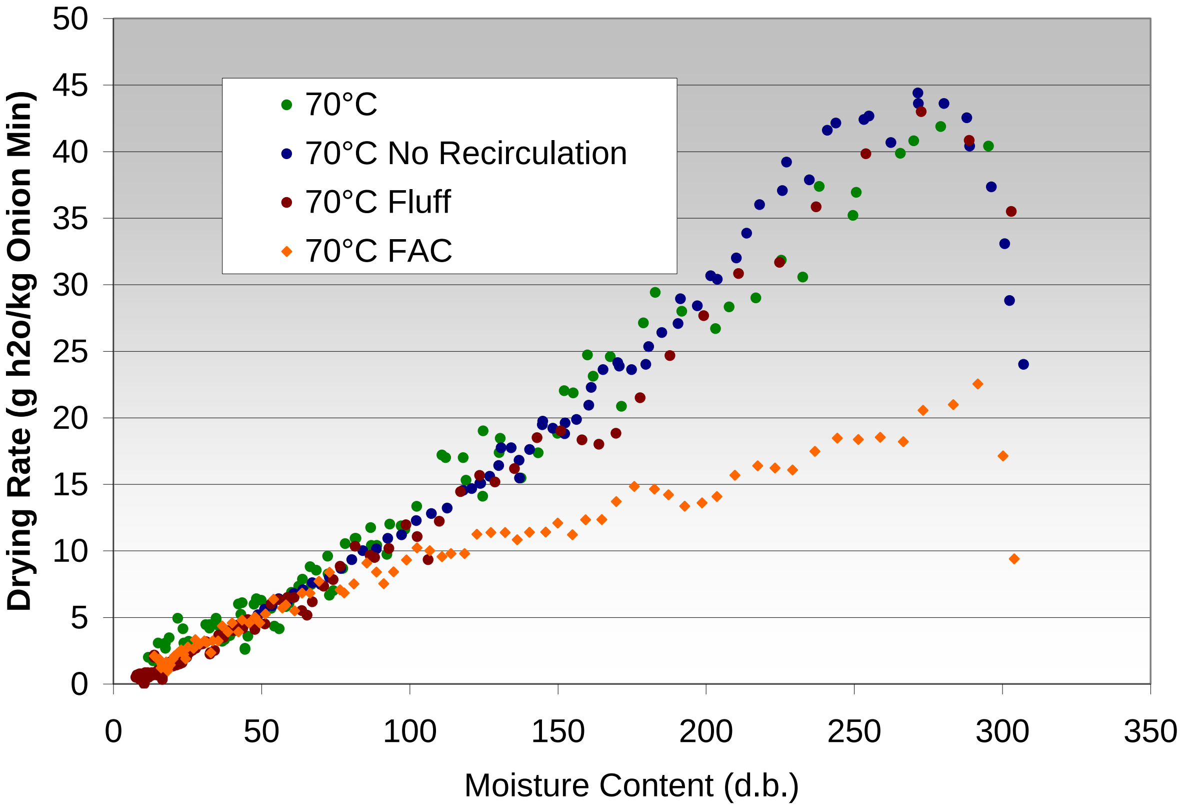
- Dehydration
- Blanching
- Peeling
- Disinfestation
- Disinfection

IR for Dehydration

- Conventional drying
  - Low quality
  - Low drying rate
- IR drying
  - Improved quality and drying rate
  - Sequential IR and Freeze Drying (SIRFD) (patent pending)

Infrared Radiation Drying - Onion

DRYING RATES – 70° C



Gabel. M., Z. Pan, K. S. P. Amaratunga, L. Harris, and J. F. Thompson. 2006. Catalytic infrared dehydration of onions. Journal of Food Science. 71(9):351-358.

Infrared Radiation Drying - Onion

Color Comparison

Infrared Radiation Drying - Onion

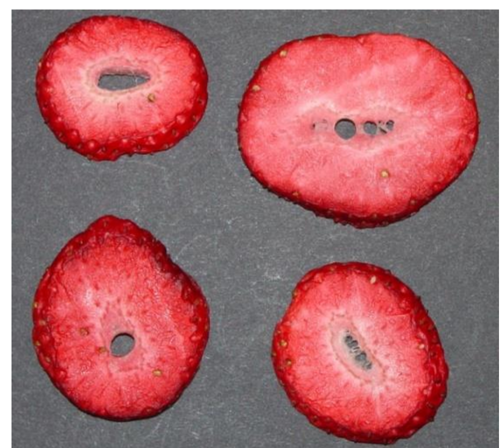
	Trial 1			Trial 2			Average		
Aerobic Plate Counts	Fresh	5.24		Fresh	5.54		Fresh	5.39±0.22	
		CIR	FAC		CIR	FAC		CIR	FAC
	60°C	4.21	4.08	60°C	3.23	3.41	60°C	3.72±0.70	3.75±0.47
	70°C	3.98	4.05	70°C	3.71	3.36	70°C	3.85±0.19	3.71±0.49
	80°C	3.97	4.03	80°C	3.37	3.39	80°C	3.67±0.42	3.71±0.45
Coliform Counts	Fresh	5.27		Fresh	5.51		Fresh	5.39±0.17	
		CIR	FAC		CIR	FAC		CIR	FAC
	60°C	3.04	3.95	60°C	2.40	2.40	60°C	2.72±0.45	3.18±1.10
	70°C	2.18	3.93	70°C	2.40	2.18	70°C	2.29±0.16	3.05±1.24
	80°C	1.70	3.00	80°C	1.00	1.00	80°C	1.35±0.49	2.00±1.41
Yeast and Mold Counts	Fresh	4.56		Fresh	4.84		Fresh	4.70±0.20	
		CIR	FAC		CIR	FAC		CIR	FAC
	60°C	4.16	4.72	60°C	4.12	4.81	60°C	4.14±0.03	4.77±0.07
	70°C	3.83	4.69	70°C	4.00	4.31	70°C	3.92±0.12	4.50±0.27
	80°C	3.44	4.10	80°C	3.44	4.00	80°C	3.44±0.00	4.05±0.07

SIRFD for Strawberry

IR drying

Freeze drying

Regular FD Strawberry

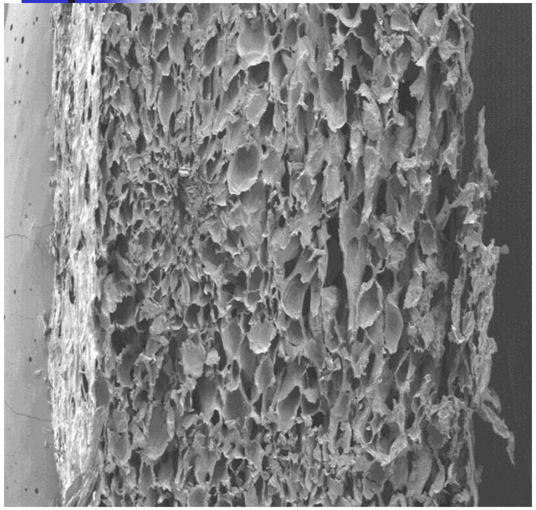


SIRFD Strawberry

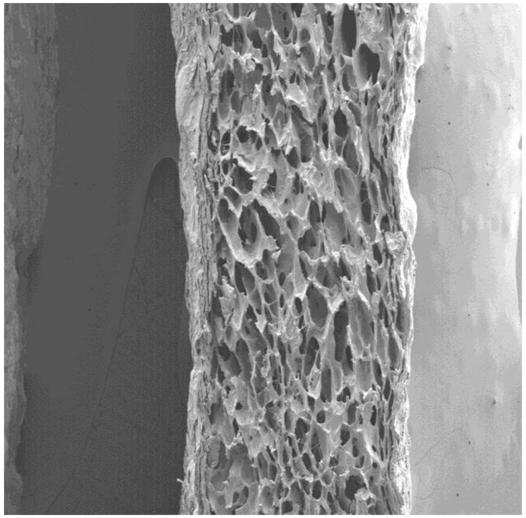
Shih, C., Z. Pan, T. H. McHugh, D. Wood, and E. Hirschberg. 2008. Sequential infrared radiation and freeze-drying method for producing crispy strawberries. Transactions of the ASABE. 51(1): 205-216.

SIRFD Strawberries

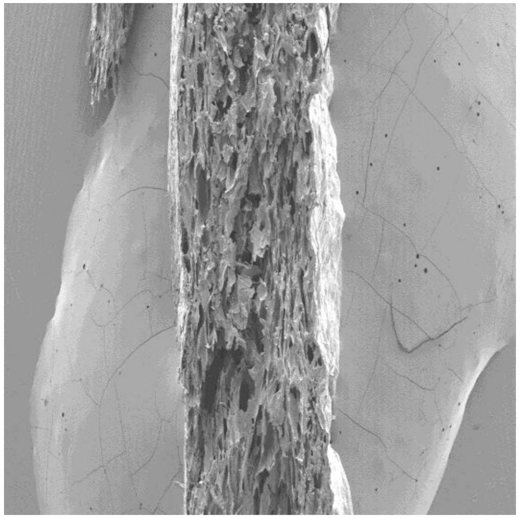
Cross sections



- Regular FD Strawberry



- SIRFD Strawberry



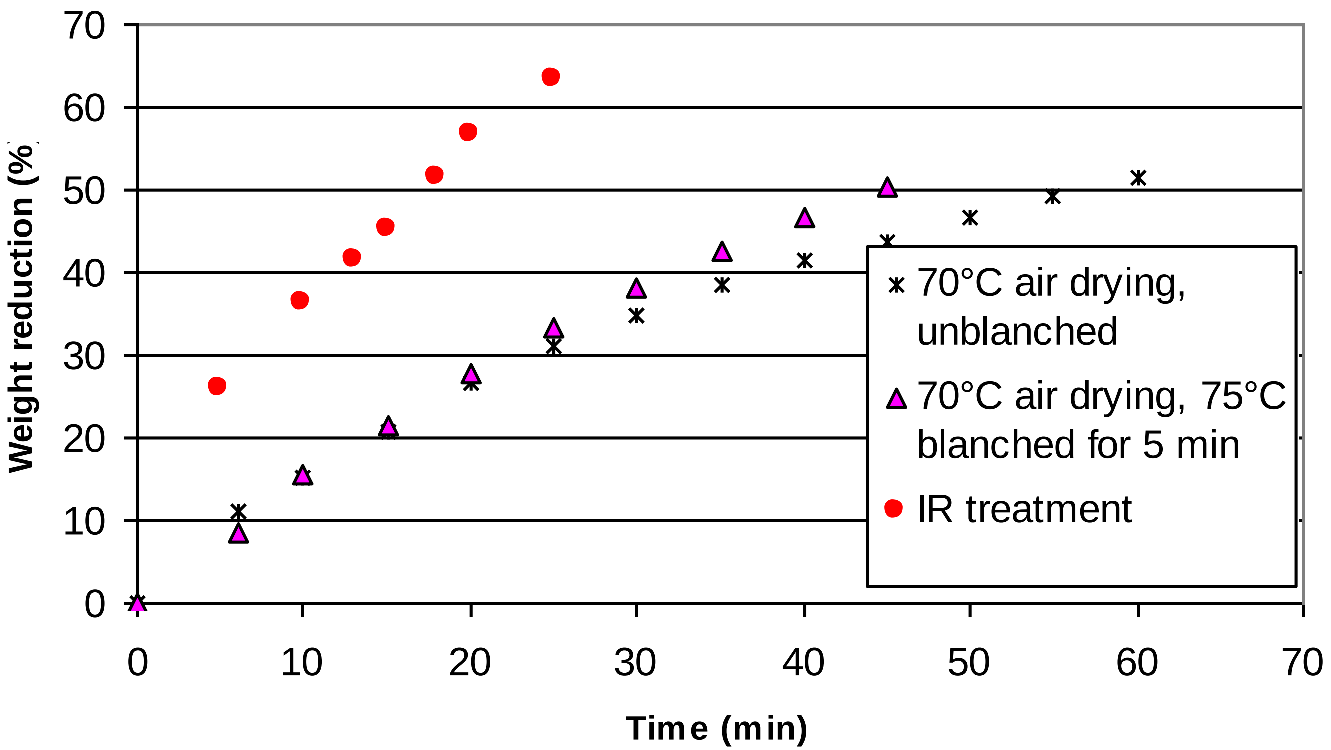
- SHAFD Strawberry

Blanching and Dehydration

- Hot water and steam blanching
  - Wastewater, nutrient loss
- IR blanching
  - No water is needed
  - Fast
- Simultaneous IR dry-blanching and dehydration (SIRDBD) (patent pending)
  - More energy efficient
  - Simplified equipment and process

Infrared Dry Blanching (IDB)

Simultaneous Blanching and Dehydration of Pears



SIRDBD for Fruit Bars

Whole fruit frozen bars (apple and strawberry bars)

90.11 89.01 87.64 85.87 83.52 80.22 75.28

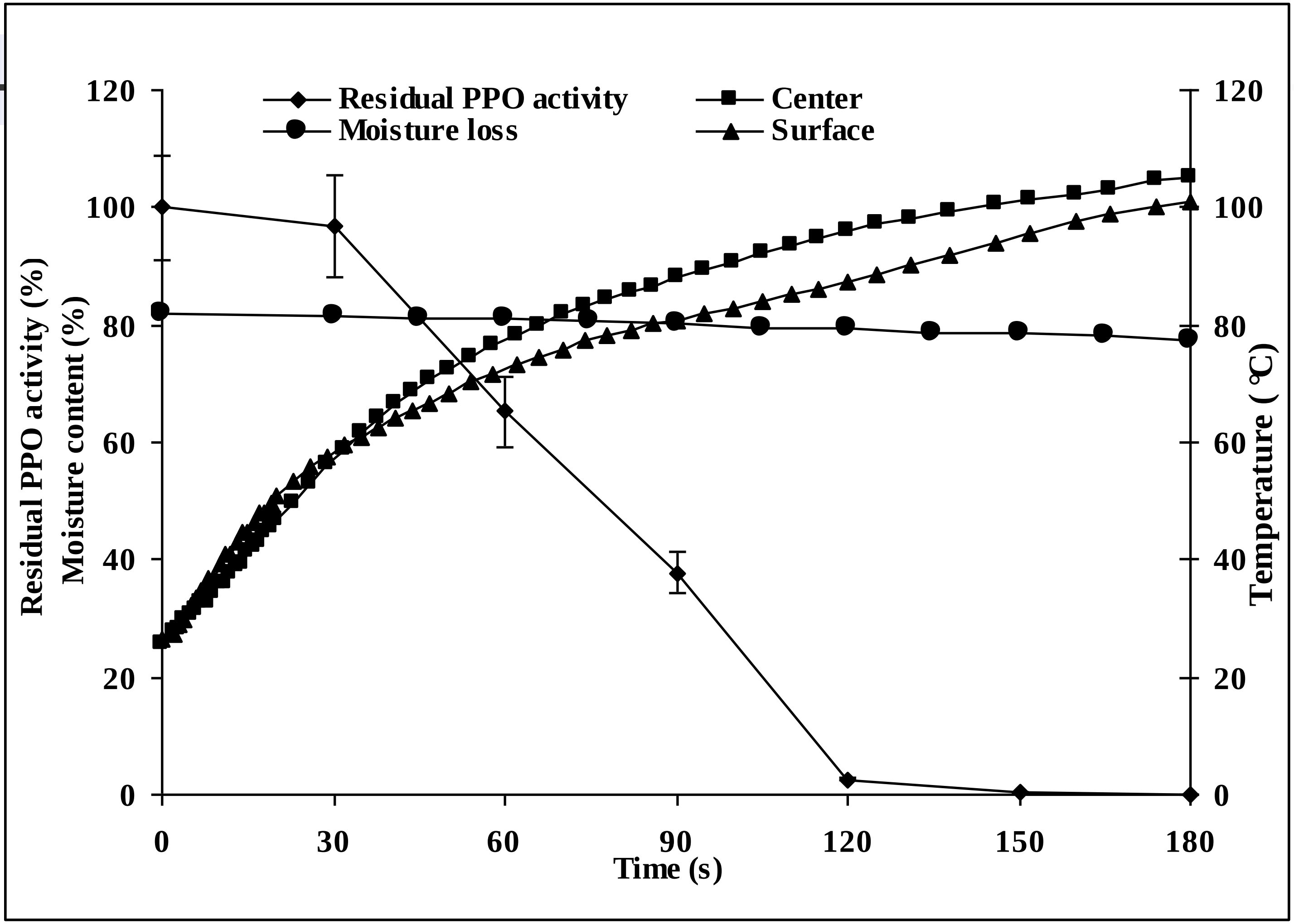
Moisture content (%, w.b.)

92.70 91.42 89.59 86.75 81.78 70.84

Moisture content (%, w.b.)

(Patent Pending)

Infrared Blanching of French Fries



- 18.5% weight reduction due to moisture loss

Fresh Frying

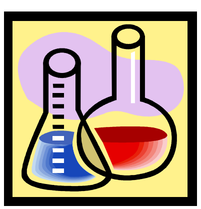
Untreated potato strips

Infrared blanched potato strips

Frying at 146, 160 and 174° C

1, 3, 5 and 7 min

(295, 320 and 345° F)



Analyses

(Oil, color, moisture)

Samples Fried at 160° C

C – 160° C, 1 min

C – 160° C, 3 min

C – 160° C, 5 min

C – 160° C, 7 min

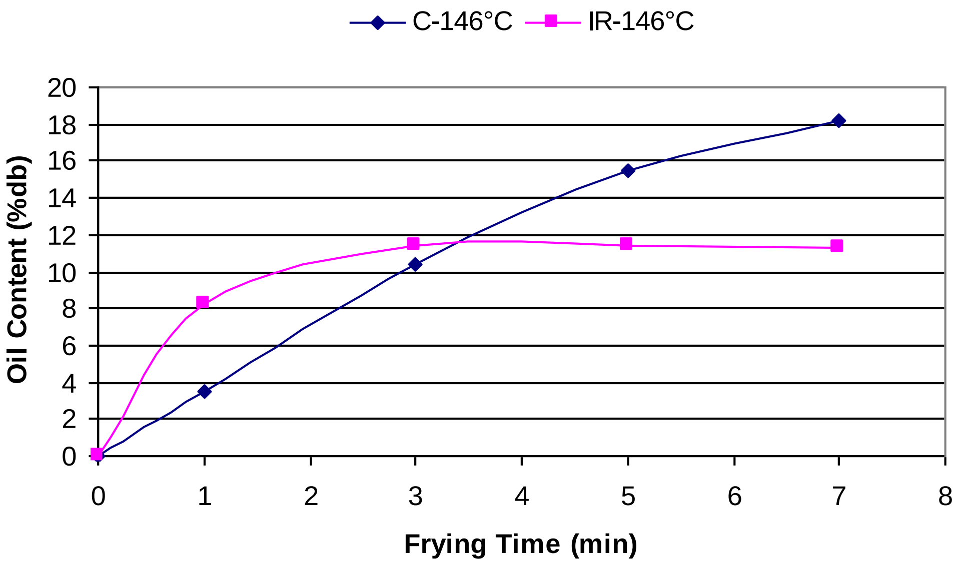
IR – 160° C, 1 min

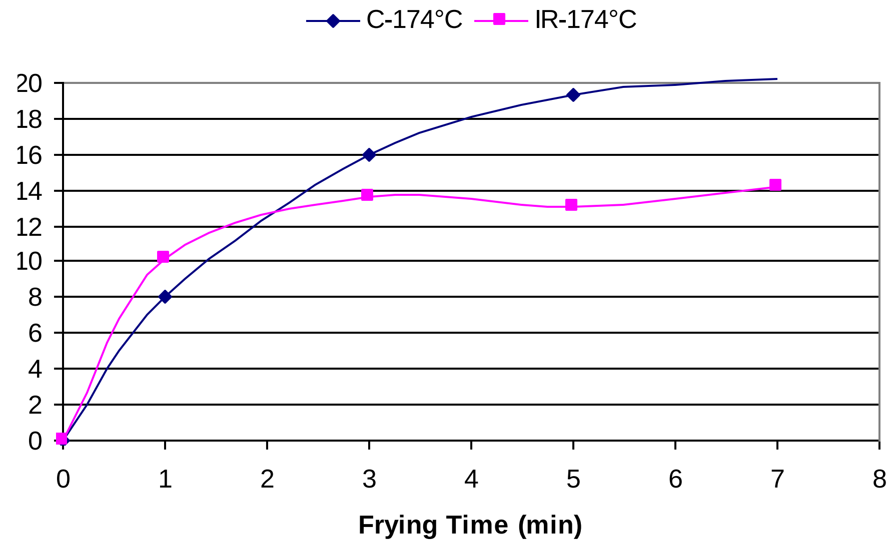
IR – 160° C, 3 min

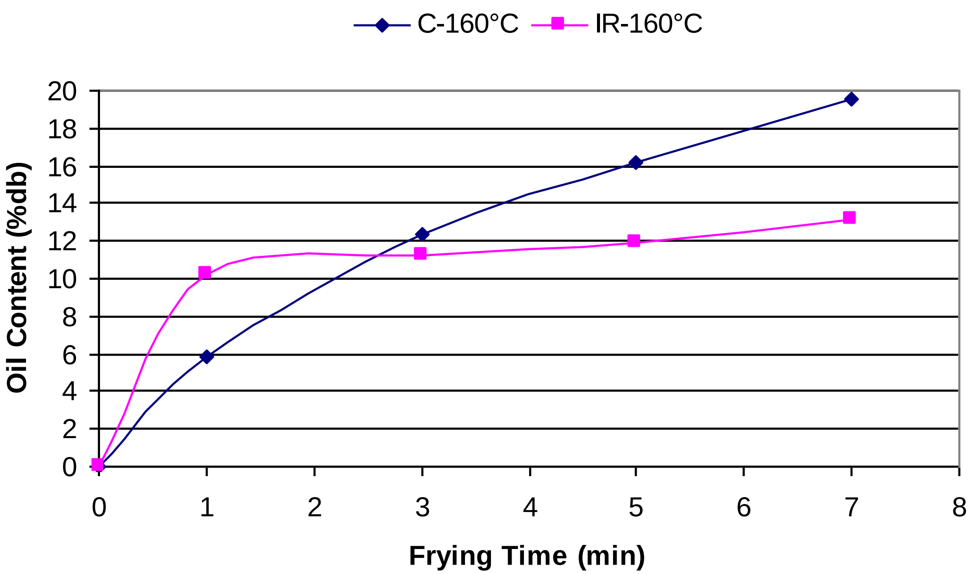
IR – 160° C, 5 min

IR – 160° C, 7 min

Oil Content







At the end of 7 min frying:

- 37.5% reduction at 146° C
- 32.0% reduction at 160° C
- 30.0% reduction at

Sensory Analysis

Average frying times at different frying temperatures

Frying Temperature	Control (min)	IR (min)	Oil Content (IR)	Oil Content (Control)
146° C	7 min 27 s	5 min 30 s	13.93	22.77
160° C	5 min 33 s	4 min 30 s	15.30	21.74
174° C	4 min	3 min 48 s	14.23	20.79

- 77 panelists attended.
- Differences in texture, color, appearance and overall were asked.

Sensory Analysis

P-value of sensory attributes and percentage preferring infrared blanched samples

Sensory Attribute / Frying Temperature (° C)	Taste	Texture	Color	Appearance
146	P=0.168	P=0.0003	P=0.118	P=0.017
	N/A	59.1%	N/A	N/A
160	P=0.113	P=0.0003	P=0.113	P=0.0003
	N/A	46.4%	N/A	39.3%
174	P=0.149	P=0.0020	P=0.0001	P=0.0001
	N/A	59.3%	55.6%	51.9%

Par-Frying

Blanching in water

↓

Dipping in brine solution

↓

Surface moisture removal

↓

Dipping in brine solution

↓

Infrared blanching

↓

Par frying at 174° C for 1 min

↓

Analyses

(Oil, color, moisture)

Fresh Frying

Untreated potato strips — Infrared blanched potato strips

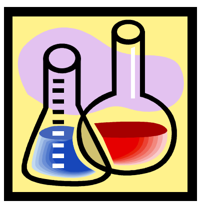
↓ ↓

Frying at 146, 160 and 174° C

1, 3, 5 and 7 min

(295, 320 and 345° F)

↓



Analyses

(Oil, color, moisture)

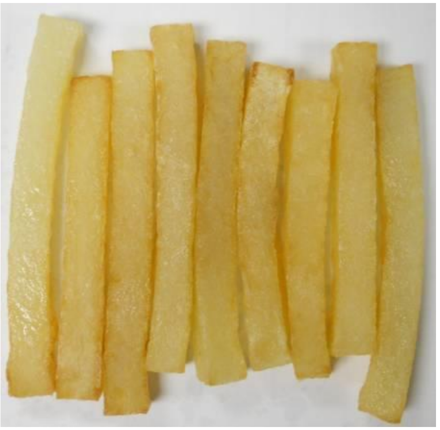
Samples Fried at 174° C

C – 174° C, 1 min

C – 174° C, 2 min

C – 174° C, 3 min

C – 174° C, 4 min



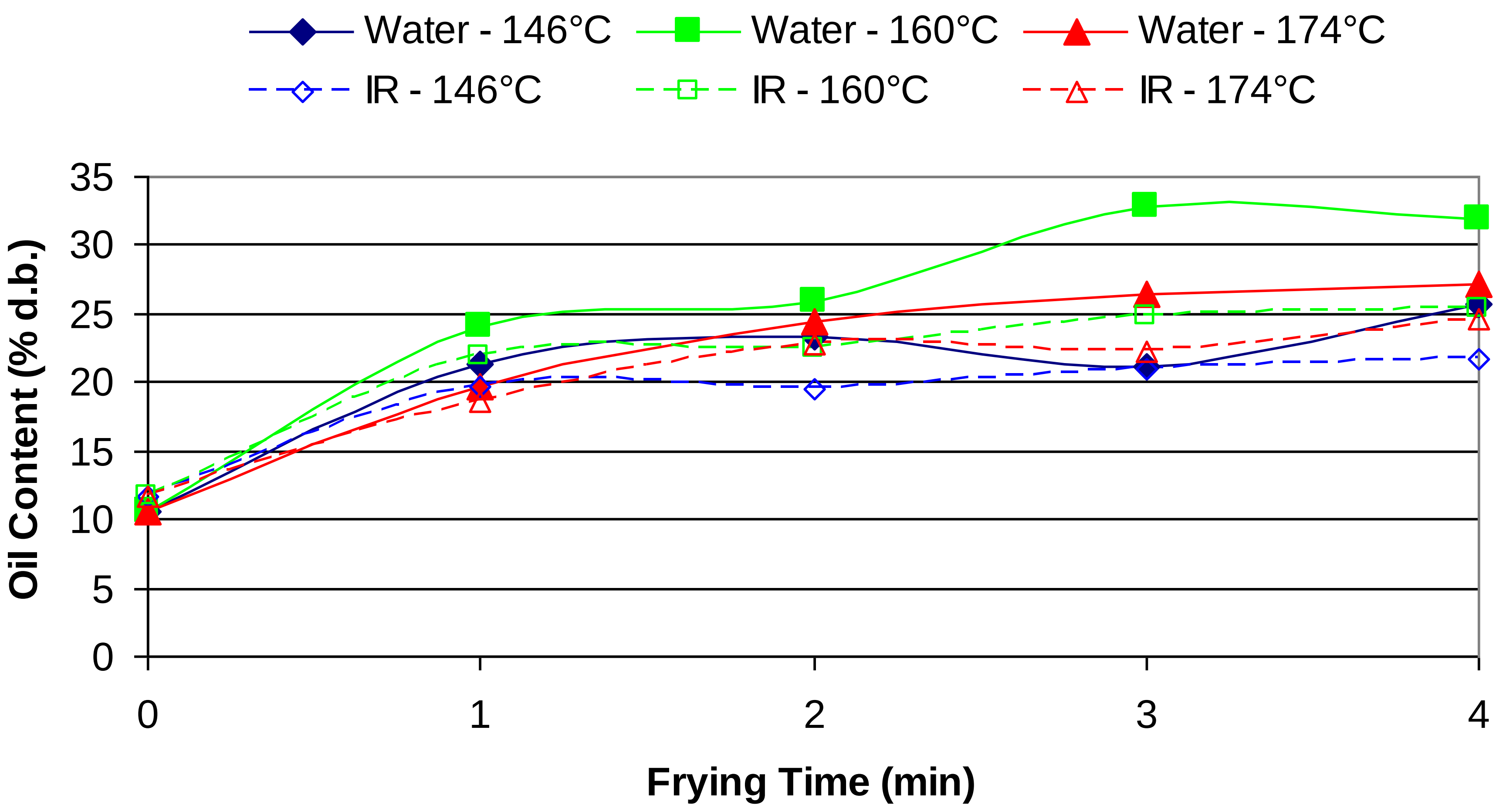
IR – 174° C, 1 min

IR – 174° C, 2 min

IR – 174° C, 3 min

IR – 174° C, 4 min

Oil Content

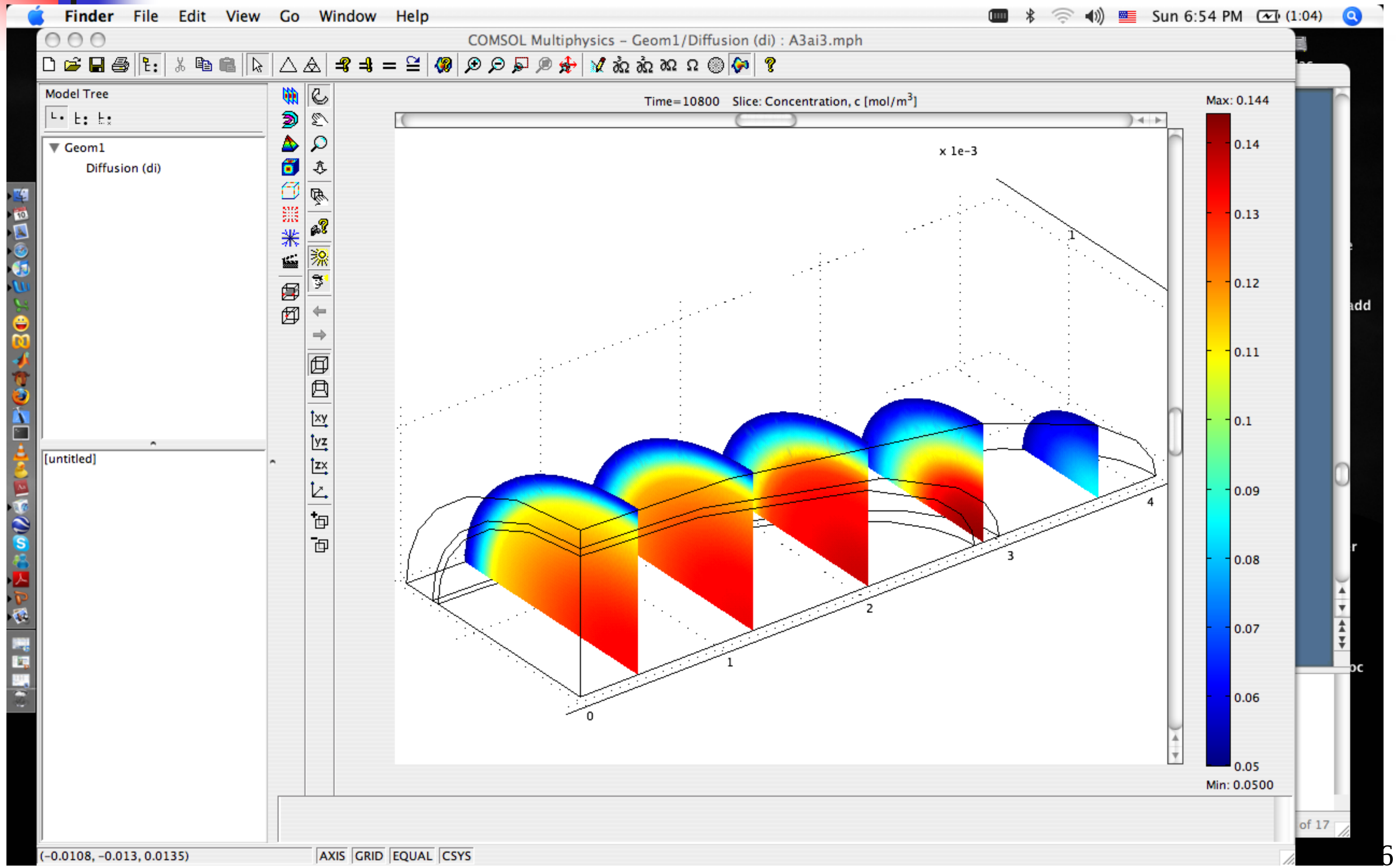


Water - 146°C
Water - 160°C
Water - 174°C
IR - 146°C
IR - 160°C
IR - 174°C
Oil Content (% d.b.)
35
30
25
20
15
10
5
0
0
1
2
3
4
Frying Time (min)

Rice Drying and Disinfestations

- Current heated air drying
  - 15-20 min to remove about 2% MC
- IR drying
  - 1 min heating to 60° C
  - Remove more than 4% MC during heating and cooling
  - Improved head rice yield
  - Kill insects

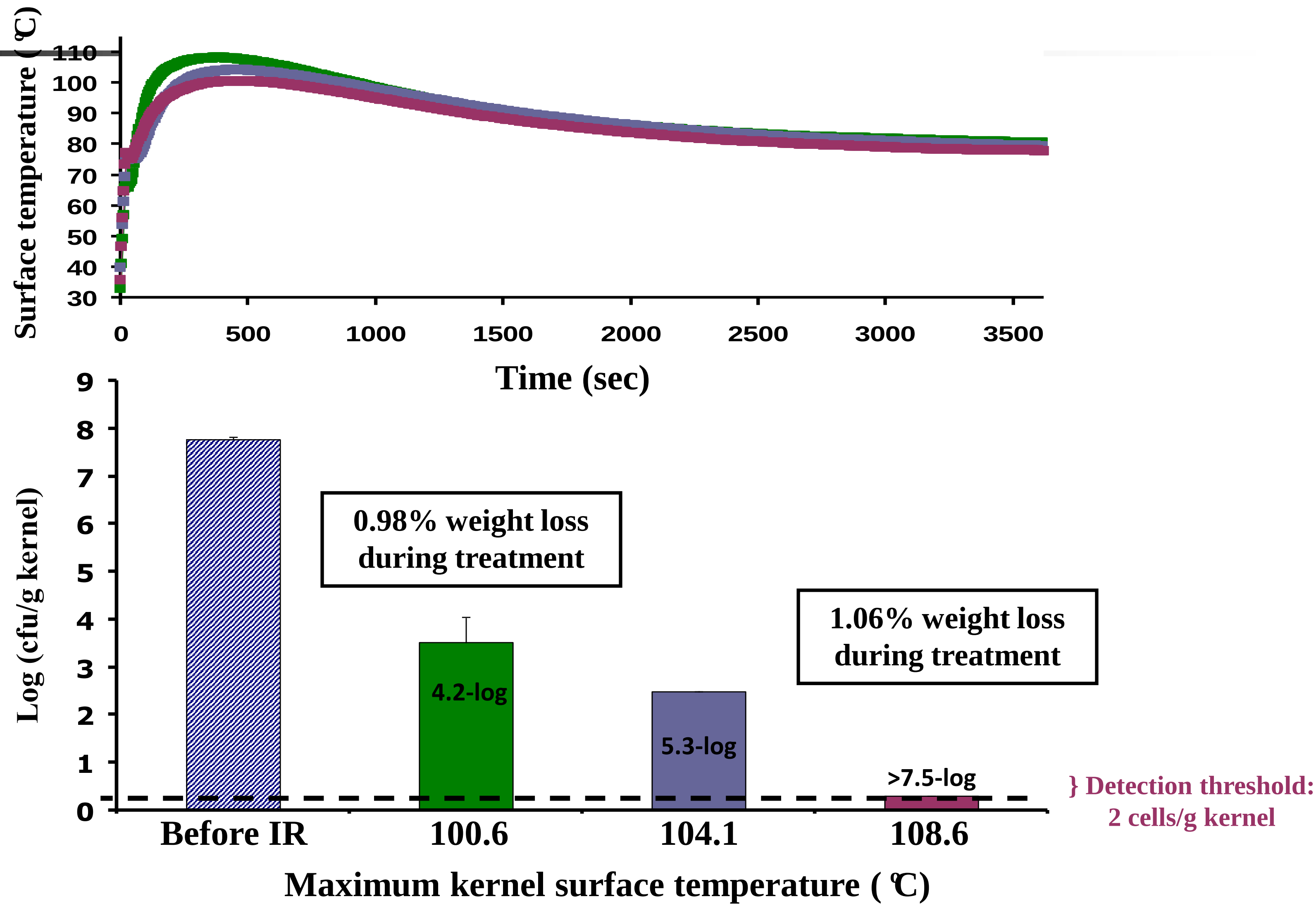
Comsol FEM Modeling



Almond Pasteurization and Roasting

- Raw almond pasteurization
  - Maintain quality characteristics
- Roast almonds and pasteurization
  - Reduce processing time
  - Meet pasteurization requirement

Effect of maximum kernel surface temperature on decontamination



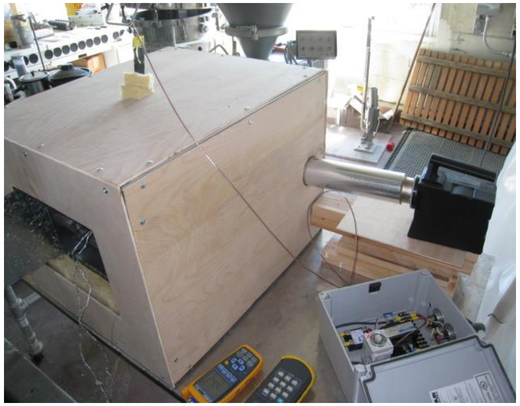
Quality of IR-treated Raw Almonds

IR + 30-min holding (104 ℃ max.)

CONTROL

Almond Roasting

- **Roasting methods**
  - Infrared roasting (**IR**)
  - Sequential IR and hot air roasting (**SIRHA**)
  - Hot air roasting (**HA**)
- **Temperatures**
  - 130℃
  - 140℃
  - 150℃



California Almonds
Almond Board of California

Roasting Time Reduction

Roasting degree (ΔE)	Method	HA			SIRHA			IR		
	Temp. (℃)	130	140	150	130	140	150	130	140	150
Light (5.7)	Time (min)	22	14	9	12	5	2	6	3.5	2
	Reduction (%)	-	-	-	45	64	78	73	75	78
Medium (11.5)	Time (min)	34	18	13	21	11	5	11	6	4
	Reduction (%)	-	-	-	38	39	62	68	67	69
Dark (21.4)	Time (min)	72	30	19	52	24	12	20	14	7
	Reduction (%)	-	-	-	28	20	37	72	53	63

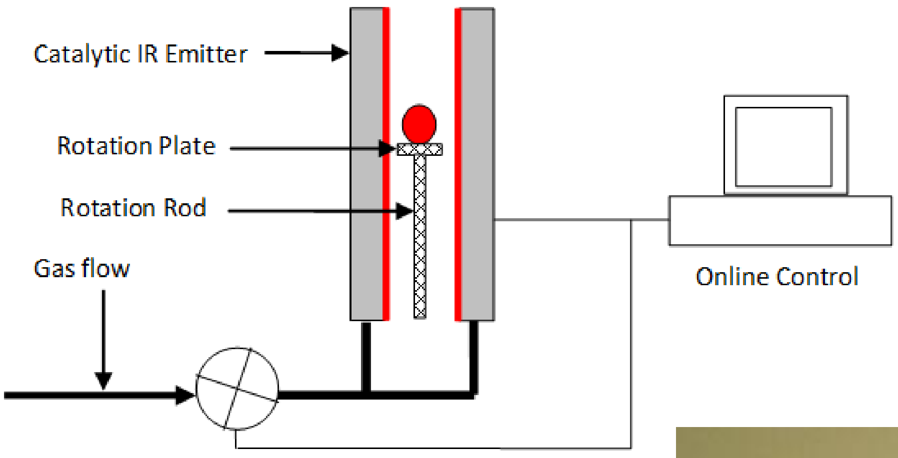
Reduction of Bacteria

Methods	SIRHA			HA			IR		
Temp. (℃)	150	140	130	150	140	130	150	140	130
Dark	8.55	7.41	7.45	8.48	8.21	7.87	4.53	4.35	3.56
Medium	6.96	5.82	4.10	5.39	4.62	3.58	4.12	3.21	2.94
Light	3.33	3.17	3.59	1.58	1.89	1.96	2.82	2.91	2.19

IR Dry-Peeling

- California needs alternative peeling methods
  - Reduce and avoid water and lye
  - Bring environmental benefit
  - Improve product quality
  - Improve energy efficiency

IR Experimental Setup



Effect of time and rotation on peeling with IR for cv. Sun6366

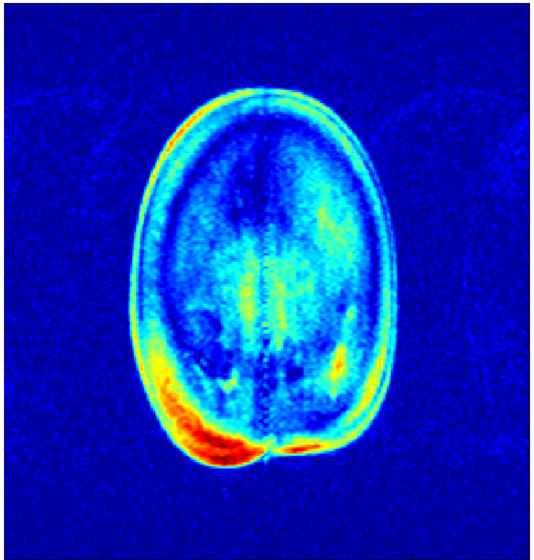
Responses	Time (sec)	Rotation with 120mm gap		Mean
		Yes	No	
Ease of peeling				
	30	1.8±1.0	1.4±0.5	**1.6a**
	45	2.9±0.7	3.0±0.7	**3.0b**
	60	4.1±0.9	4.0±0.9	**4.1c**
	75	4.8±0.4	4.3±0.5	**4.6d**
Peeling loss (%)				
	30	7.35±3.01	[illegible]	**7.64a**
	45	5.18±1.08	[illegible]	**6.11b**
	60	7.27±1.30	[illegible]	**7.74b**
	75	9.81±2.23	[illegible]	**9.41b**
Peeled Firmness (kg)				
	30	1.8±0.4	[illegible]	**1.8 a**
	45	1.8±0.5	[illegible]	**1.8 a**
	60	1.5±0.5	[illegible]	**1.5 a,b**
	75	1.8±0.4	[illegible]	**1.6 b**

Lye Peeling
11.46
11.68

Lye Peeling
1.5
1.3

IR Dry-Peeling

- IR Dry-peeling
  - No water
  - No chemicals
  - Improved quality



BHAGWATI PRAKASH / UC DAVIS

Zhongli Pan, an adjunct professor in the Department of Biological and Agricultural Engineering at UC Davis, treats tomatoes with infrared heat to remove peels prior to processing.

Reducing water use in tomato processing

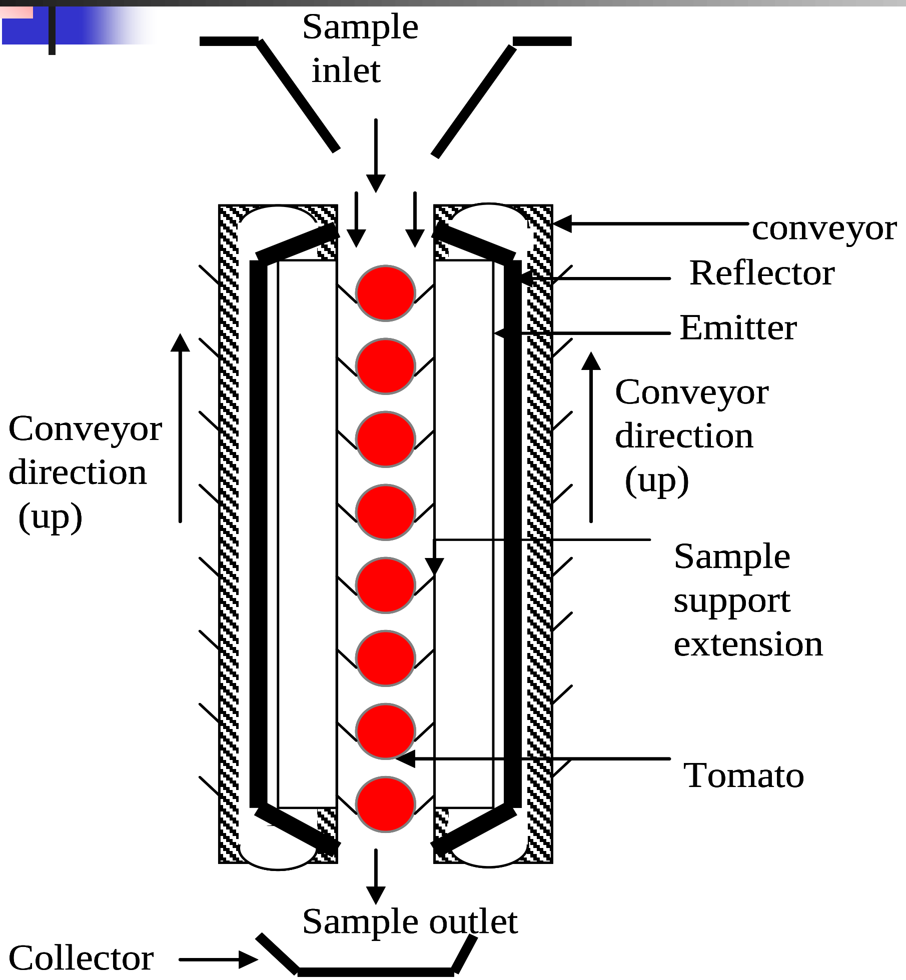
"The tomato processing industry has long been interested in finding a better way of peeling tomatoes," says Zhongli Pan, a USDA-ARS research engineer at the Western Regional Research Center in Albany, Calif., and an adjunct professor in the Department of Biological and Agricultural Engineering at UC Davis. He and his colleagues found that peeling tomatoes with infrared heat eliminates lye use, greatly reduces water use, and results in better quality tomatoes.

Infrared heat is similar to heat from the sun. It allows for efficient heat transfer from the source to the product. "The real advantage is that infrared heat doesn't penetrate the product very deeply, so the tomato skins can be heated and removed easily while maintaining firmer, higher-quality peeled tomatoes," Pan explains.

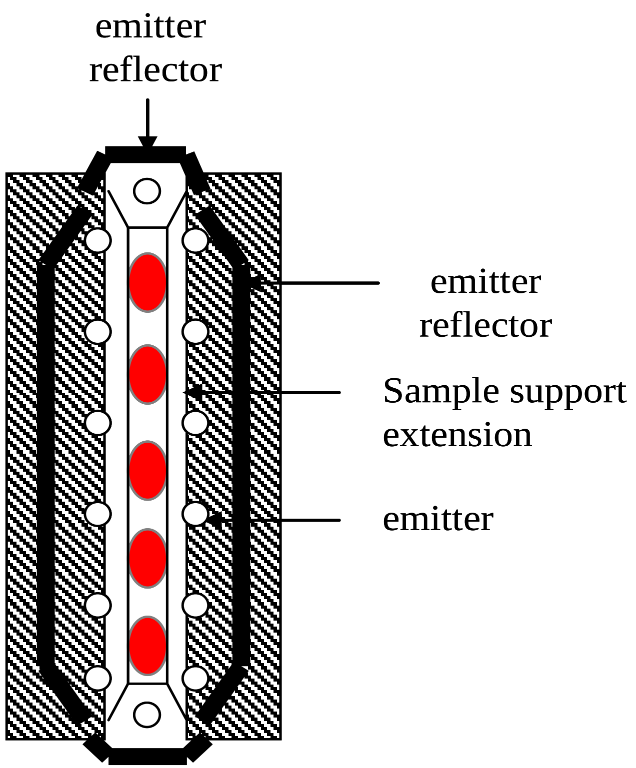
Another advantage is that the removed peel is purer and more concentrated, allowing it to be used in other ways, such as added back into tomato paste or as a new food additive. Infrared heat has promising potential not only for dry-peeling tomatoes, peaches, and other produce, but also for blanching many fruits and vegetables before freezing, such as apples and "baby" carrots.

With financial support from the California League of Food Processors, the California Energy Commission, and six tomato

IR Dry-Peeling - Next Step



(a) Side View



(b) Top View

Industrial IR Equipment for Demonstration

- Runs with the state-of–the-art catalytic emitters powered with natural gas.
- Weighs 4500 lbs.
- H × L × W → 77” × 240” × 77”

The Gas Company

Southern California Gas Company

Dry-blanching & Dehydration Tests

Tested Commodities

Bell pepper

Carrot

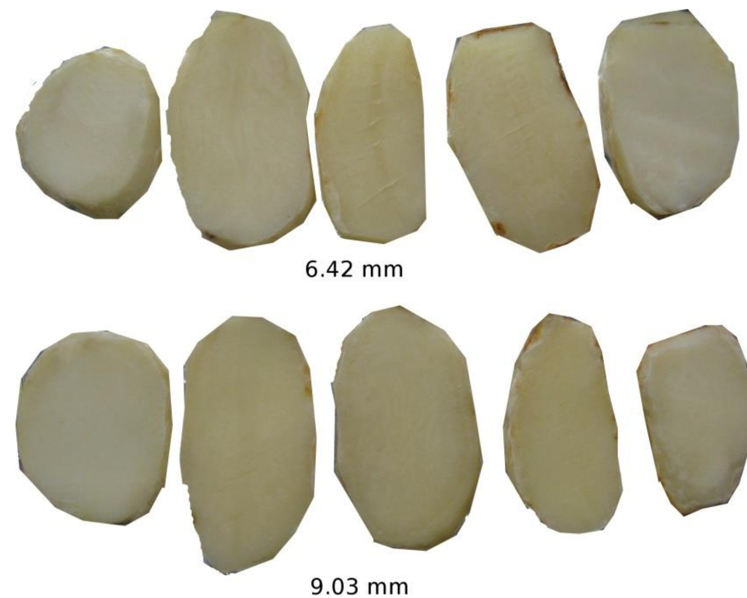
Onion

Potato

Parameters Evaluated

- Weight loss
- Temperature Profile
- Color
- Enzyme Inactivation
    - Polyphenol Oxidase
    - Peroxidase

Potatoes - Sliced



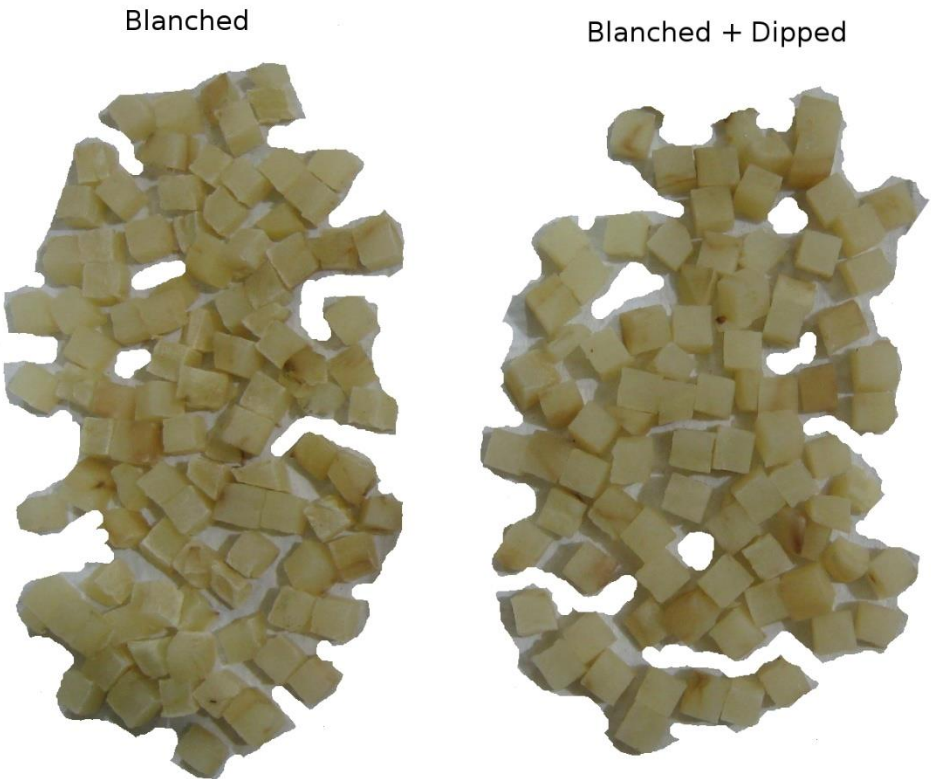
Test 2
Section 2: OFF
Speed: 1.0 m/min

Test 3
Section 2: OFF
Speed: 0.7 m/min

Test 4
Section 2: 50%
Speed: 1.1 m/min

Potatoes - Diced

- After 4 minutes exposure to IR radiation, the MC decreased to 66.31%.
- Dipping into water for 1 minute after blanching increased the MC to 70.2%.
- Dipping after blanching improved the final appearance of diced potatoes



Green Bell Pepper

- Color of IR treated green bell peppers did not change significantly.

Untreated 1.224 m/min 1.428 m/min 1.935 m/min

White Onions

- Color of IR treated white onions did not change significantly.

Untreated

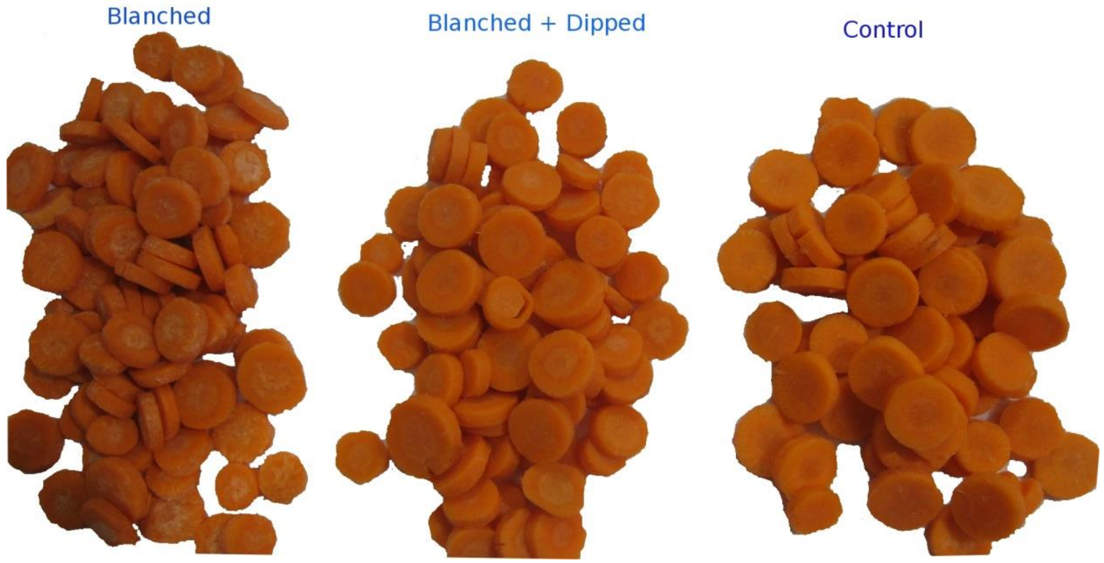
1.224 m/min

1.428 m/min

1.935 m/min

Carrots - Sliced

No significant change in appearance after 4 min IR exposure.



Dipping the samples into water after blanching eliminated the dry-look.

Carrots - Pomace

Wet

0.274 m/min

0.504 m/min

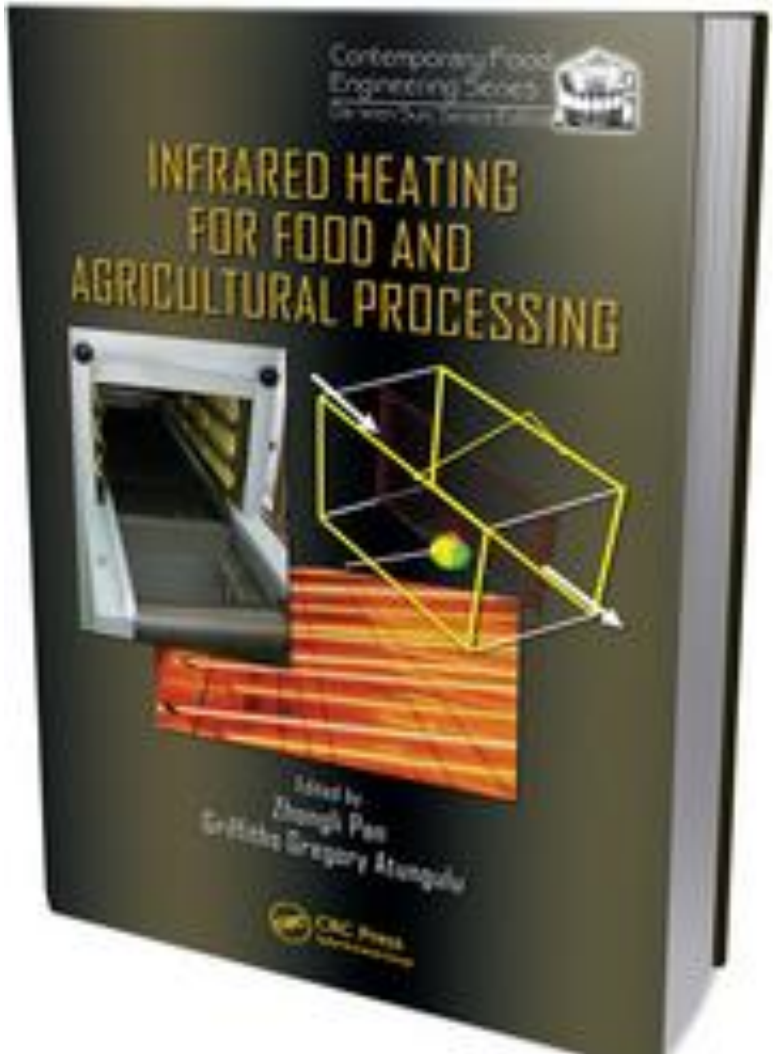
0.220 m/min

- Color of carrot pomace became lighter as the weight loss increased.
- IR drying of carrot pomace was successful.

Conclusions

- Advantages
  - Various applications in food and agricultural product processing
  - Environmentally Friendly
  - Improved processing efficiency
  - Improved energy efficiency
  - Improved product quality

New IR Book



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