2019

ETCC

WEBINAR SERIES

EMERGING TECHNOLOGIES COORDINATING COUNCIL

Energy Efficient Infrared Drying of Healthy Snacks and Walnuts

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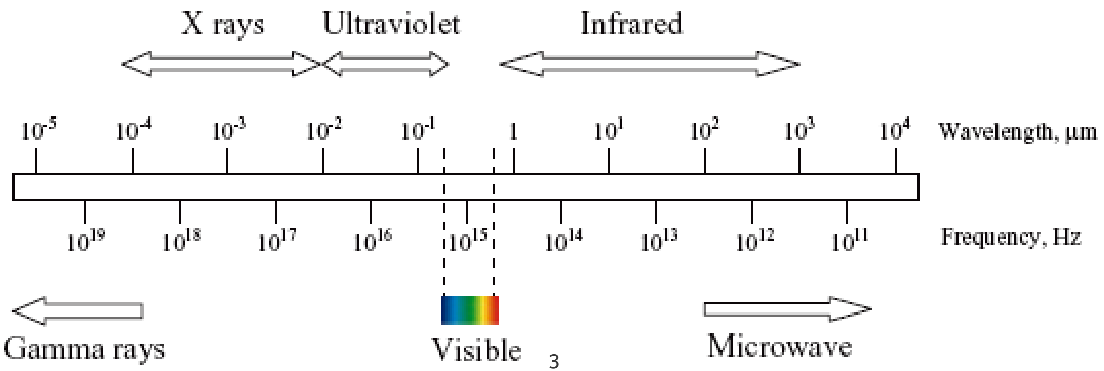
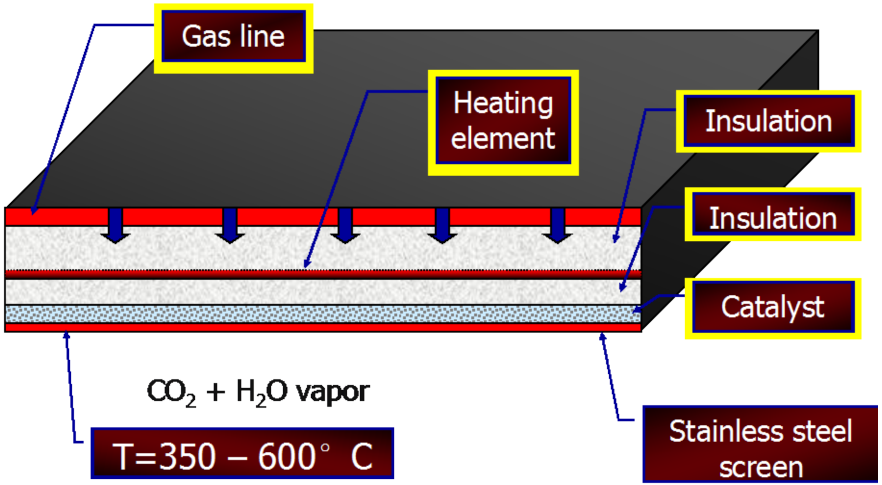
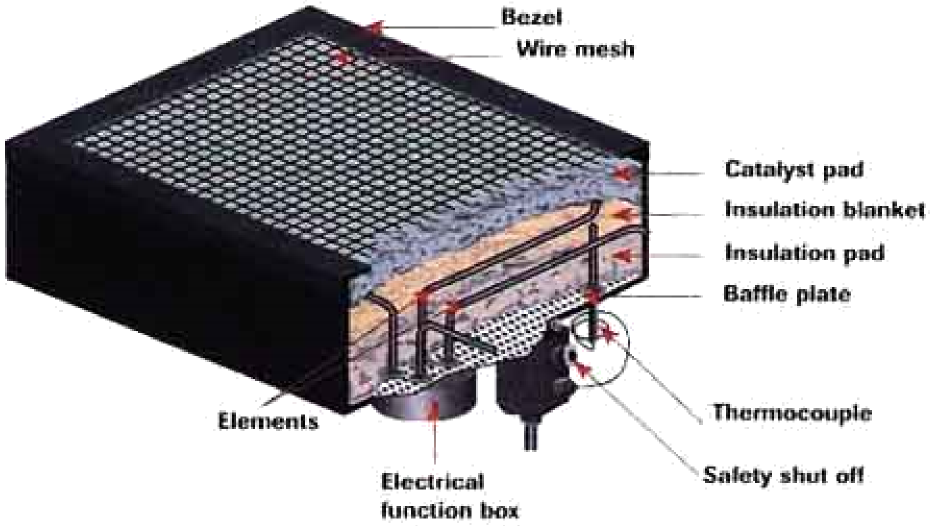
Infrared Heating

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



Catalytic Infrared Emitter





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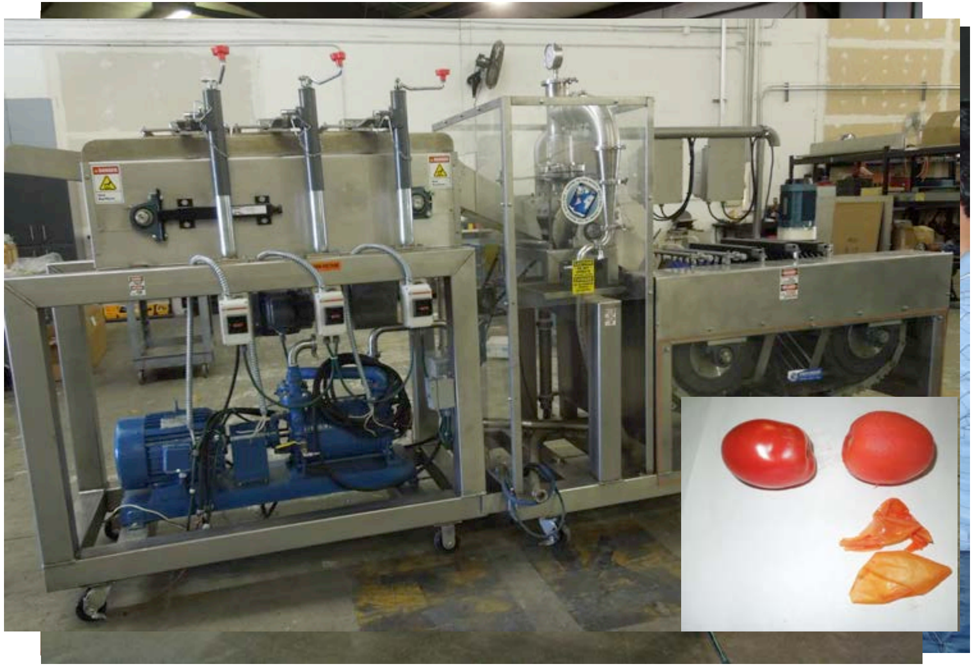
Infrared Heating for Food and Ag Processing



Research and applications

- Dehydration
- Blanching
- Peeling
- Disinfestation
- Disinfection
- Stabilization

Commercial Demonstration of Innovative Energy Efficient Infrared Processing of Healthy Fruit and Vegetable Snacks

Need for Healthy Snacks

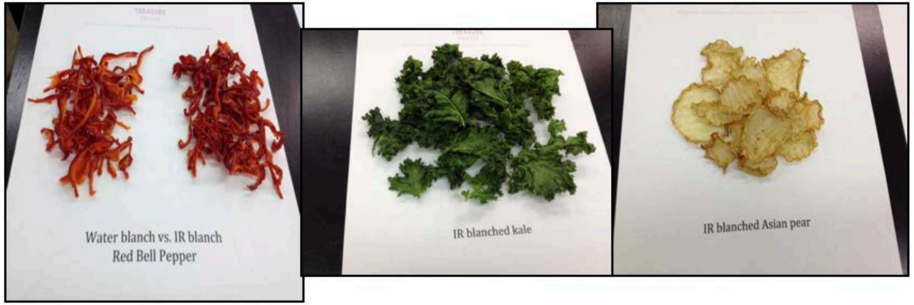
Blanching → Drying → Vacuum frying

Steam blanched and vacuum fried vs IR treated and vacuum fried chips

Sequential IR Blanching/Drying and Hot Air Drying

New processing method for healthy snacks

- IR for simulations blanching and drying
- Followed by hot air drying



Commercial Production System

Objective

- Demonstrate new sequential IR and hot air drying technology
  - Energy saving
  - New healthy snacks

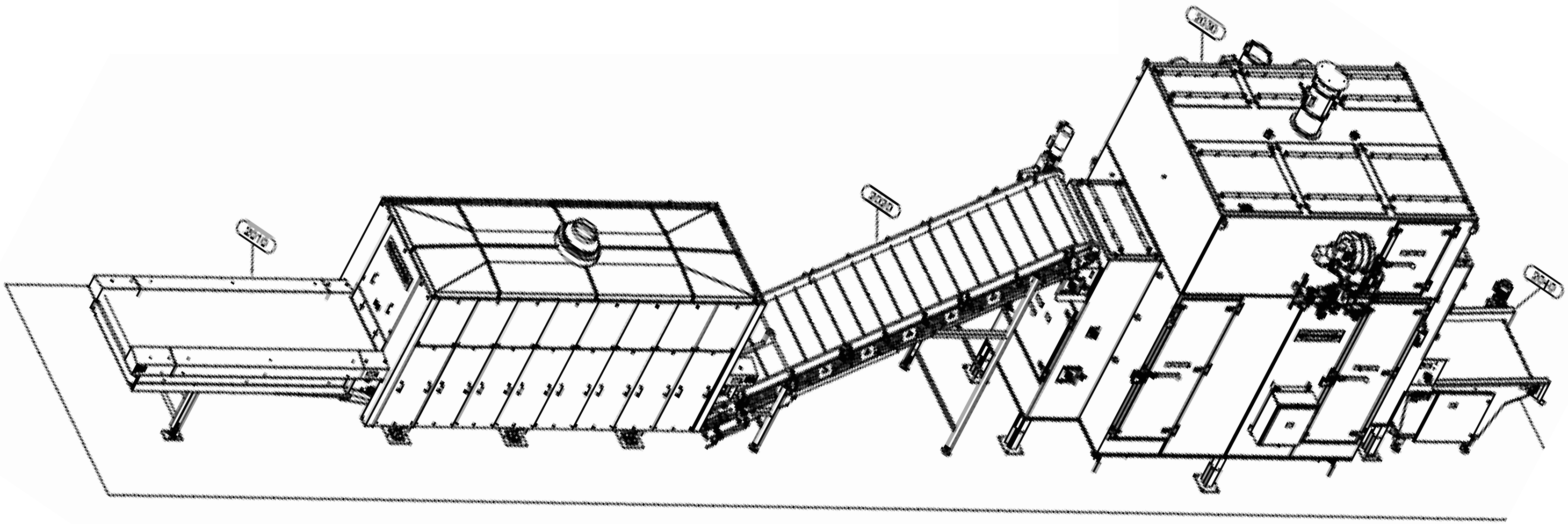
Partners

- UC Davis
- USDA-ARS
- Treasure8

USDA ARS Agricultural Research Service
Healthy Processed Foods Research Unit

TREASURE8
Deploying nutrition to humanity

Commercial Production System Design



Innovative and Energy Efficient Infrared Processing of Healthy Fruit and Vegetable Snacks

Western Regional Research Center， USDA-ARS & UC Davis

Dr. Zhongli Pan

USDA ars Agricultural Research Service

UC DAVIS UNIVERSITY OF CALIFORNIA

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Healthy Snacks

Carrot

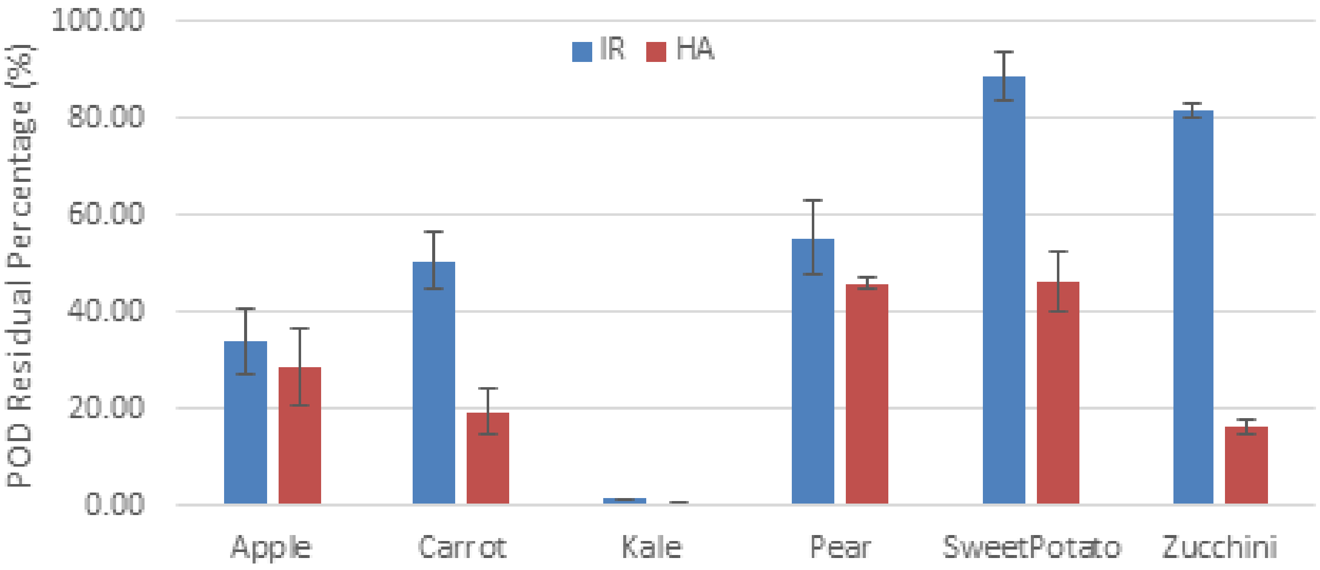
Bell pepper

Kale

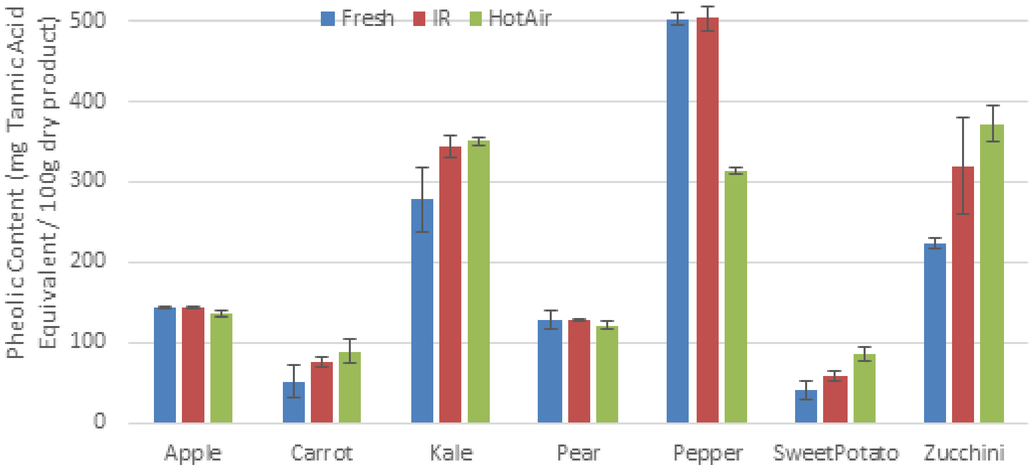
Drying Time

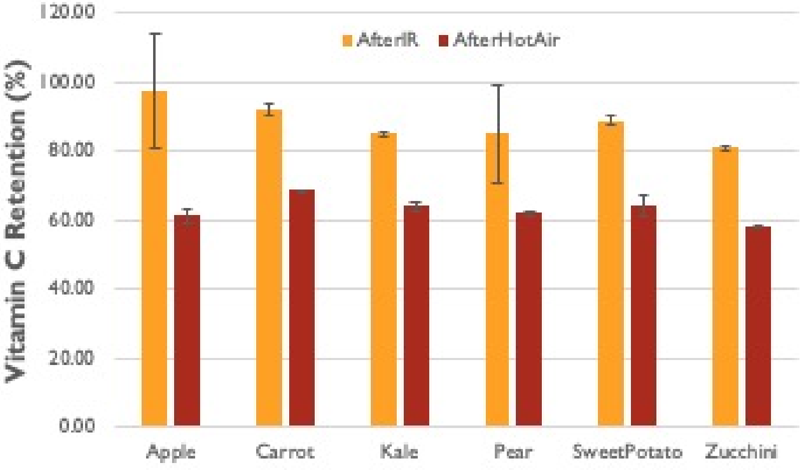
Product	thickness, mm	IR drying time	H A drying time
Kale	original thickness	2 min	50 min
Carrot	1.4 mm	2.25 min	60 min
Pear	1.6 mm	2.25 min	60 min
Squash	2.2 mm	2.25 min	60 min
Bell pepper	3.3 mm	2.25 min	60 min
Apple	2.1 mm	2.5 min	60 min

Residual Peroxidase Enzyme Activities after IR and Hot Air Drying



Phenolic Content and Vitamin C Retention





Energy Consumption

- Fried potato chips energy consumption is 833.33 kW per 100 kg (Wu et al. 2010)
- SIRDBHAD saved about 26.3% (bell pepper) to 72.6% (kale) energy against frying
- Compared to freeze drying, the SIRDBHAD could save 62.5-82.5% of energy (Rudy, 2007)

Product	Capacity, Kg fresh/h	Energy used per 100 kg of fresh product			Specific energy, MJ/kg of water removed
		Natural gas, therms	Electricity, kW	Total energy, kW	
Apple	95.0	12.57	25.89	394.21	16.73
Carrot	79.7	10.66	20.95	333.54	13.63
Kale	78.5	7.25	15.66	228.17	9.64
Pear	113.0	7.54	14.82	235.88	10.07
Pepper	110.1	22.64	50.36	614.00	24.03
Sweet Potato	88.02	9.22	18.11	288.32	13.30
Zucchini	132.0	16.35	35.96	515.23	19.62

Onsite Demonstration

Onsite Demonstration

Conclusions

- SIRDBHAD technology produces crispy and healthy snacks with capacity - 78.5 kg/h to 132.3 kg/h
- The IR dry-blanching inactivated 50-99% of the peroxidase enzyme reducing enzymatic browning
- SIRDBHAD dried chips has same level of overall acceptance compared to freeze dried products
- The energy saving by SIRDBHAD technology to oil frying varied from 26.3% to 72.6%
- Comparing to freeze drying, the SIRDBHAD resulted in huge energy savings of 62.5-82.5%

Demonstration and Commercial Implementation of Energy Efficient Drying for Walnuts

Current Walnut Harvest and Drying Practices

Current Walnut Harvest and Drying Practices

- Long time (up to 24 h) - limiting the throughput capacity
- Energy intensive - 12 therms of gas and 24 kWh electricity per ton of dried nuts
- High variability in moisture - Commingling all nuts and causing over-drying and under-drying
- Over-drying of low moisture nuts leading to 6-8 h of additional drying time
- Over-drying and under-drying leading to poor quality and wastage of energy
- Moisture picked up during washing (4%) absorbed into shells during 2-3 h of waiting in bins resulting in additional 4-6 h of drying

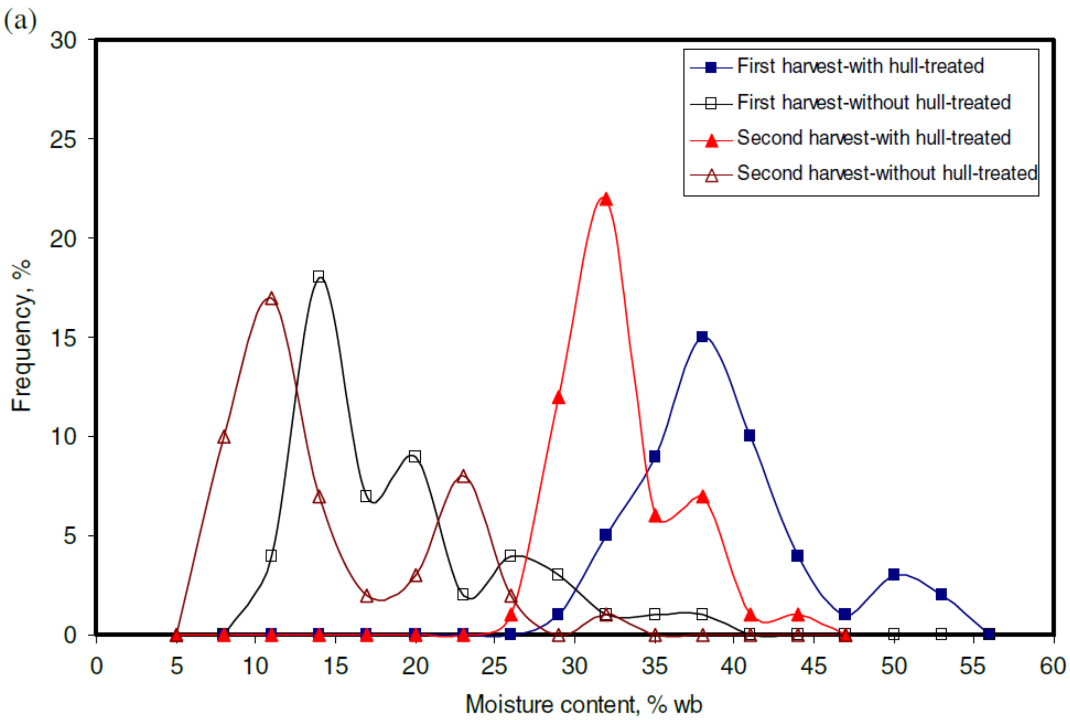
Walnuts at Harvest

Whole Hull Attached

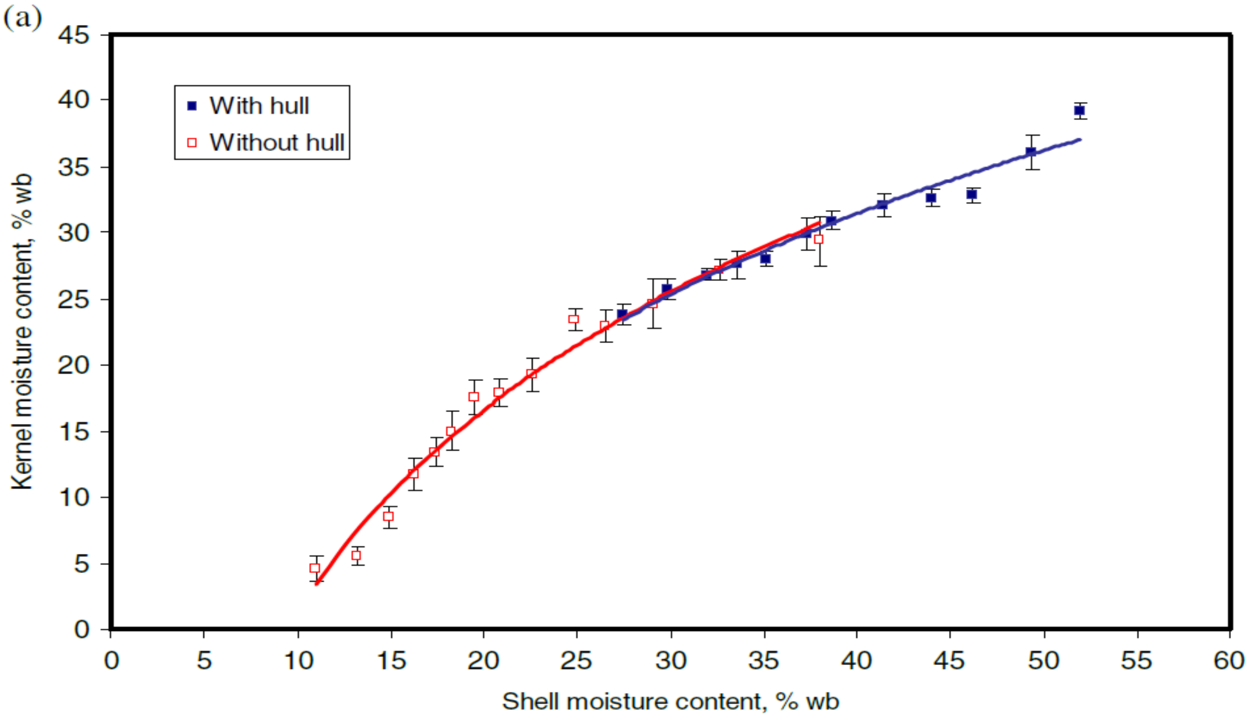
Partial Hull Attached

Without Hull

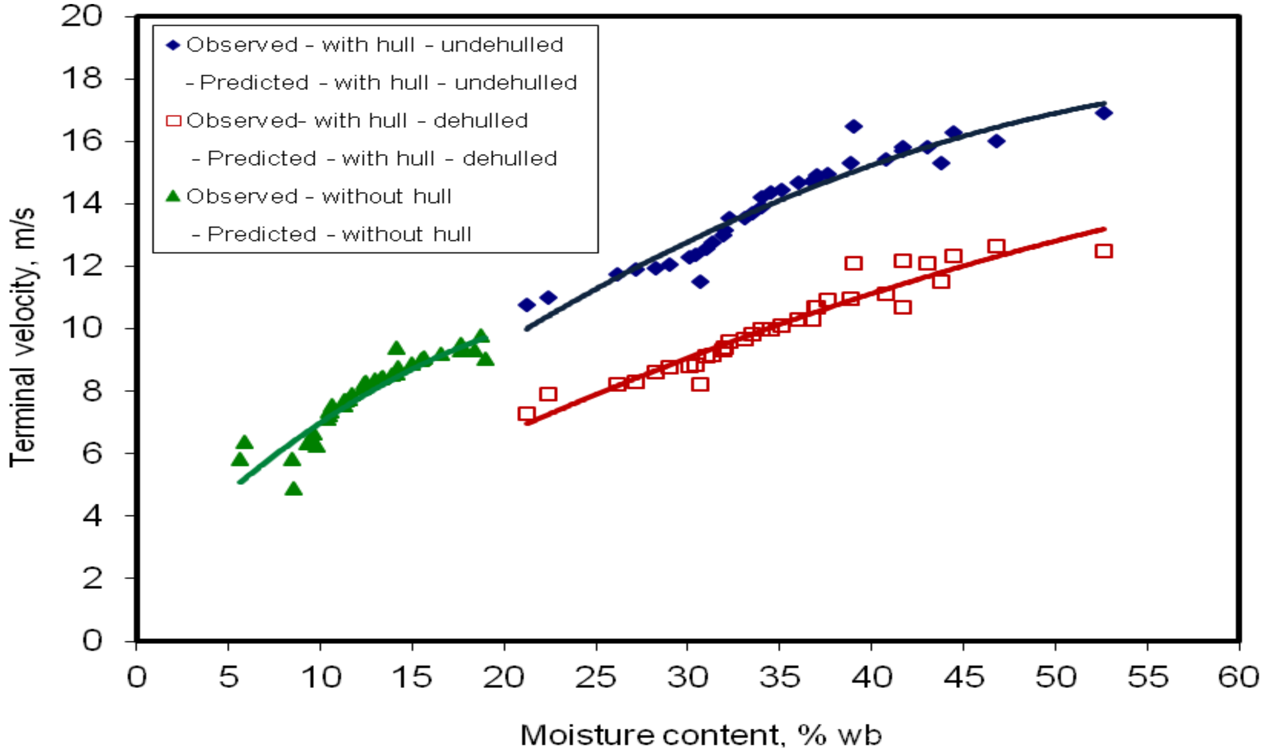
Moisture Variability



Relationship Between Shell and Kernel MCs



Terminal Velocity



Walnut Drying

Commercial Drying System

Objective

- Demonstrate the new drying technology
  - Terminal velocity separation
  - Sequential IR and hot air drying technology
  - Energy saving
  - Improved throughput

Partners

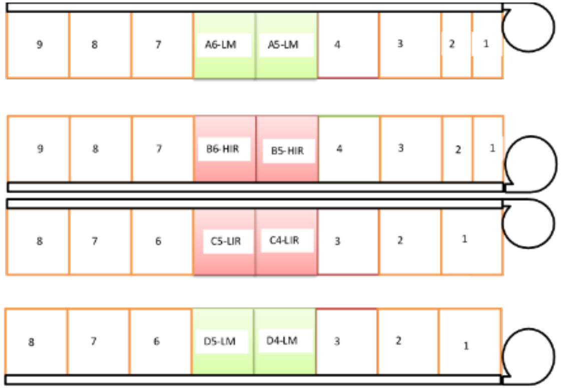
- UC Davis
- USDA-ARS
- Wizard Manufacturing
- Emerald Farms

New Walnut Drying Method

- Terminal velocity separation
  - High moisture and low moisture nuts
- IR drying
- Followed by hot air drying

New IR and Hot Air Walnut Drying

Locations of Test Bins



Measurements

- Ambient temperature
- Hot air temperature below the bins
- Static air pressure below the bins
- Samples for MC at Initial, 12%, 10% and 8%
- Drying time for individual bins

With IR pre-drying Without IR pre-drying

Drying Time Reduction

Walnut type	Bin	Air velocity, (m/s)	Hot air temp, °C	Drying time to 8% MC (min)	Drying time saving by IR drying (%)
Low	A5	0.58	42.4	1554	22.69
	A6	0.58	42.4	1685	
Low IR	C4	0.60	40.1	1232	
	C5	0.60	40.3	1272	
High	D4	0.60	42.4	1400	17.05
	D5	0.60	43.8	1532	
High IR	B5	0.60	41.3	1112	
	B6	0.60	41.4	1320	

Test #1

Test #2

Walnut type	Bin	Air velocity, (m/s)	Hot air temp, °C	Drying time to 8% MC (min)	Drying time saving by IR drying (%)
Low	A5	0.60	42	688	13.55
	A6	0.60	42	700	
Low IR	C4	0.60	39	617	
	C5	0.60	39	583	
High	D4	0.60	41	968	26.50
	D5	0.60	41	1051	
High IR	B5	0.60	40.5	783	
	B6	0.60	40.5	700	

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Energy Saving

Test #1

Walnut type	Bin	Drying time (min)	Hot air temp, C	HA energy, MJ	IR energy, MJ	El. energy, MJ	Total energy, MJ	Average Total Energy (MJ	Energy Saving, %
Low	A5	1554	42.4	18711	0	932	19643.68	20471.64	**19.94**
	A6	1685	42.4	20289	0	1011	21299.61		
Low IR	C4	1232	40.1	13076	2228	758	16061.32	16388.65	
	C5	1272	40.3	13707	2228	782	16715.98		
High	D4	1400	42.4	17402	0	840	18242.35	19967.94	**14.54**
	D5	1532	43.8	20774	0	919	21693.54		
High IR	B5	1112	41.3	12835	2228	686	15748.49	17064.57	
	B6	1320	41.4	15342	2228	810	18380.65		

Test #2

Walnut type	Bin	Drying time (min)	Hot air temp, °C	HA energy, MJ	IR energy, MJ	El. energy, MJ	Total energy, MJ	Average Total energy, MJ	Energy Saving, %
Low	A5	688	42	8997	0	413	9410	9492	9.96
	A6	700	42	9154	0	420	9574		
Low IR	C4	617	39	6619	1566	559	8744	8546	
	C5	583	39	6254	1566	528	8348		
High	D4	968	41	12044	0	581	12625	13166	13.90
	D5	1051	41	13077	0	631	13708		
High IR	B5	783	40.5	9317	1845	710	11872	11336	
	B6	700	40.5	8322	1845	634	10801		

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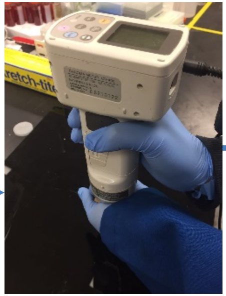
Quality and Shelf Life of Walnuts

Incubator at 35°C and 52±1% RH



Kernel lightness measurement

Oil extraction

Oil separation

Quality evaluation

- PV (Iodine clock reaction)
- AV (Neutralization reaction)
- Kernel lightness (Colorimeter)

Shelf life study

- Accelerated aging experiment

Quality and Shelf Life of Walnuts

Color after drying

Low moisture

Low moisture IR

High moisture

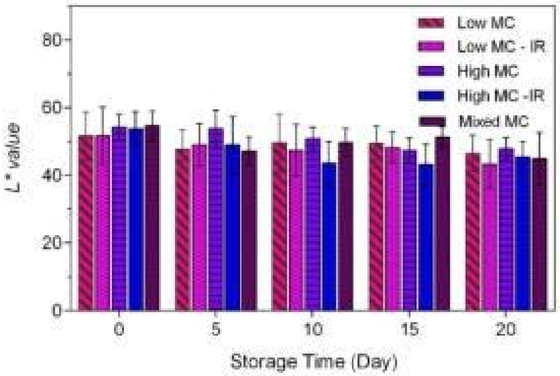
High moisture IR

Mix moisture

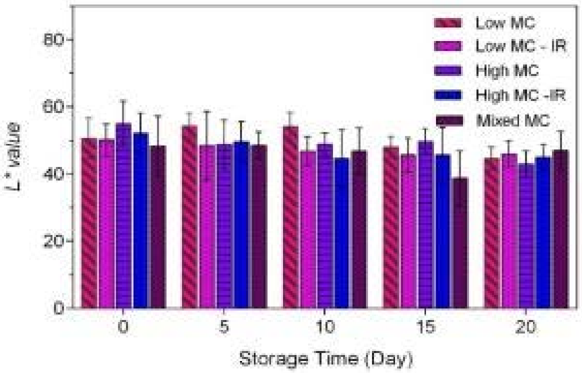
Sept_20 Sept_30

Kernel lightness value during storage

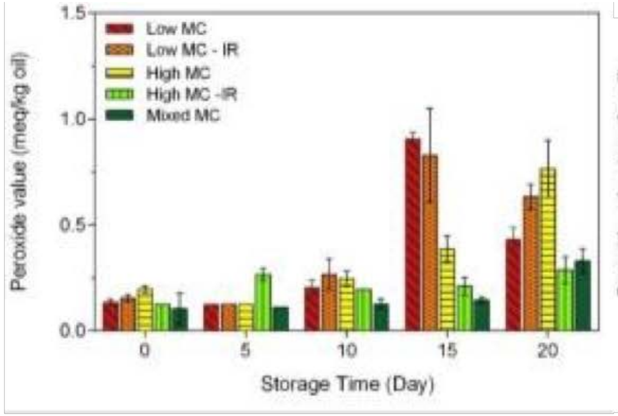
Test 1

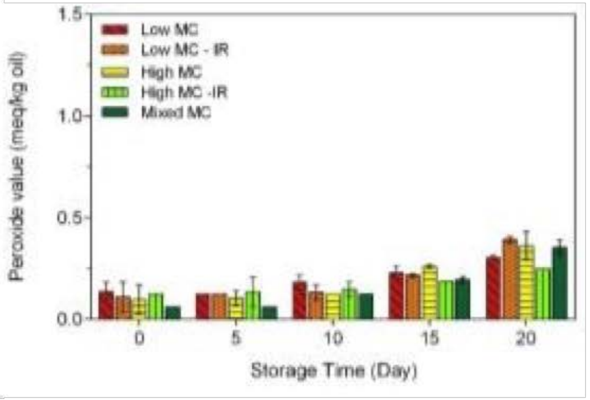


Test 2



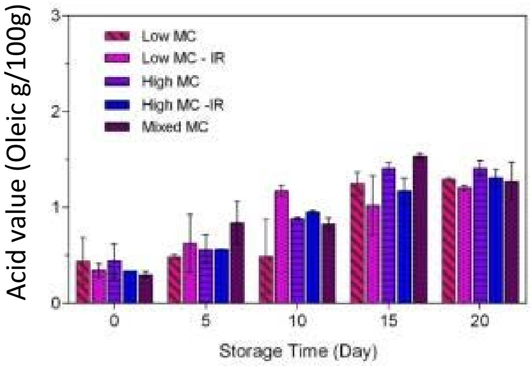
Quality and Shelf Life of Walnuts

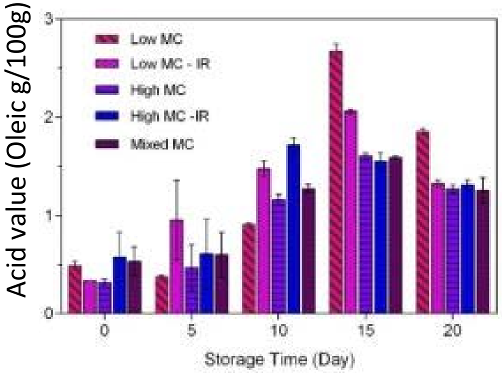




PV value

Acid value





Demonstration

Conclusions

- IR dryer Capacity - 10.67 to 14.22 tons/h
- Drying time reduction - 13.55% to 26.50%
- Energy saving - 9.96% to 19.94%
- Quality and shelf life
  - No significant difference in the color, PV and AV in 2 years of storage

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Acknowledgements

Project team

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Collaborators and Supporters

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- Kevin Mori (CEC)
- Virginia Lew (CEC)
- Rob Neenan (CLFP)
- UC Davis
- USDA-ARS
- Treasure8
- Wizard Manufacturing
- Emerald Farms

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For more information, contact Kevin Mori at kevin.mori@energy.ca.gov

Information on the project can be found at:

Walnuts: http://innovation.energy.ca.gov/SearchResultProject.aspx?p=29784

Healthy Snacks:http://innovation.energy.ca.gov/SearchResultProject.aspx?p=29803&tks=637024379874521535