มหาวิทยาลัยราชภัฏนครปฐม

9673204
Drying and Storage

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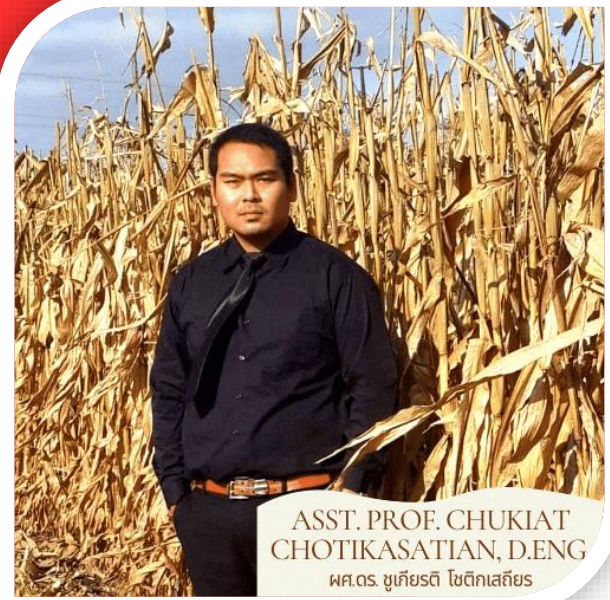
Course Description

Theory of drying, sun drying, principles of air flow, drying of agricultural products by heated air, moisture content determination, relationship of moisture and temperature, equilibrium moisture content, design of dryers storage

Professional Interest Statement:

- Monitoring CO_2/O_2 concentrations to assess biological activity and reduce post-harvest losses
- Establishing verification criteria for unacceptable insect infestation levels
- Supporting fumigation and grain storage management decisions
- Developing agricultural product drying and intelligent drying systems



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Lecture 7 – Drying and Types of Dryers for Fruits, Herbal Plants, and Cereal Grains

Study Questions – Lecture 7

1. *How do drying air conditions (temperature, relative humidity, and airflow) influence the drying rate and product quality of agricultural materials?*
2. *What are the effects of drying temperature on: Moisture migration Colour retention Chemical composition Nutritional value*
3. *Which drying technique is most appropriate for large-scale grain processing, and why?*

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Lecture 7 – Drying and Types of Dryers for Fruits, Herbal Plants, and Cereal Grains

Outline – Lecture 7

1. *Importance of Drying for Fruits, Herbs, and Cereal Grains*
2. *Quality Changes During Drying*
3. *Convective (Hot Air) Drying Technique*
4. *Radiation Drying Techniques*
5. *Drying Systems for Grain Processing*

What are the Air Conditions in a Solar Drying Greenhouse?

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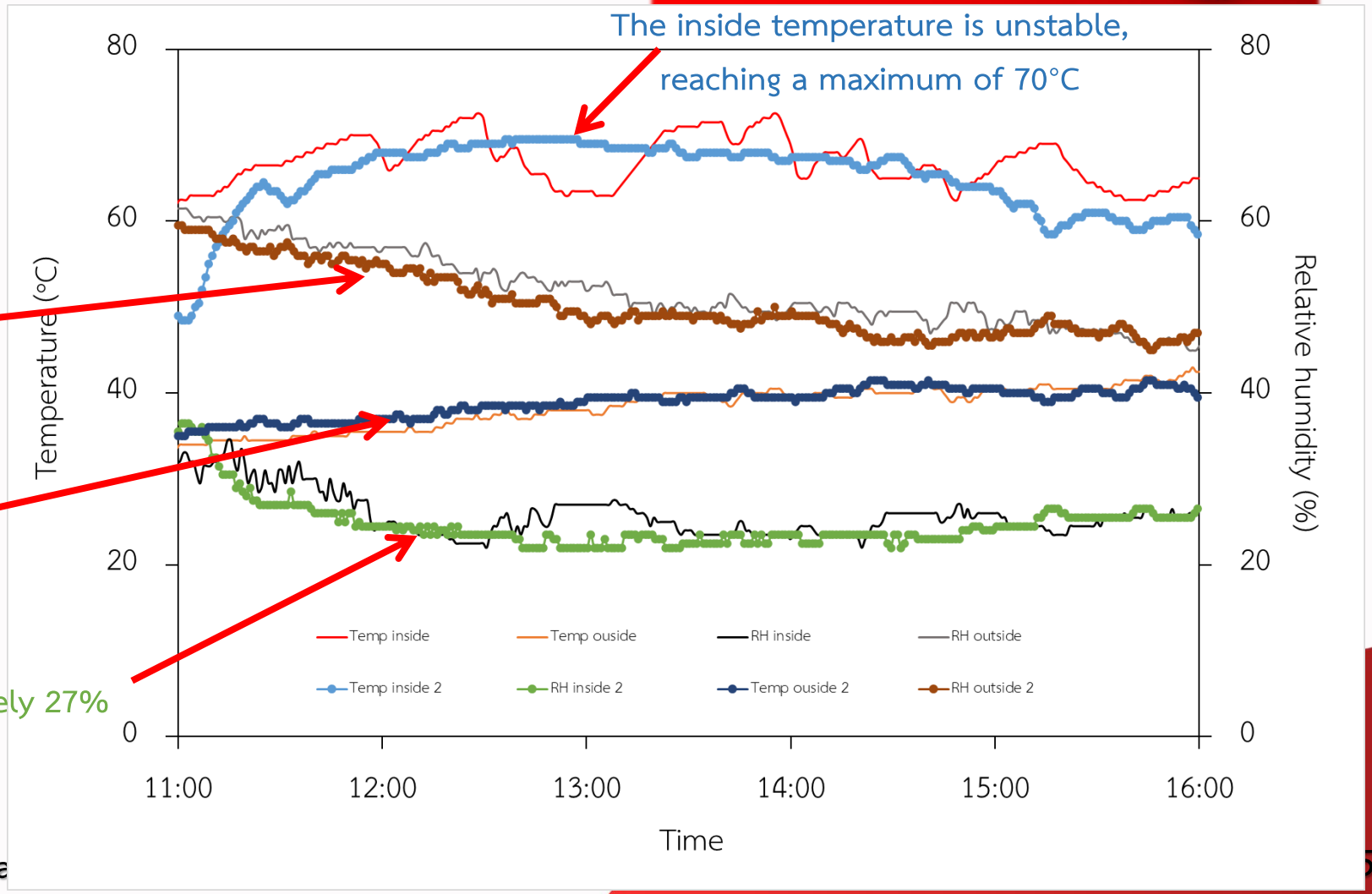
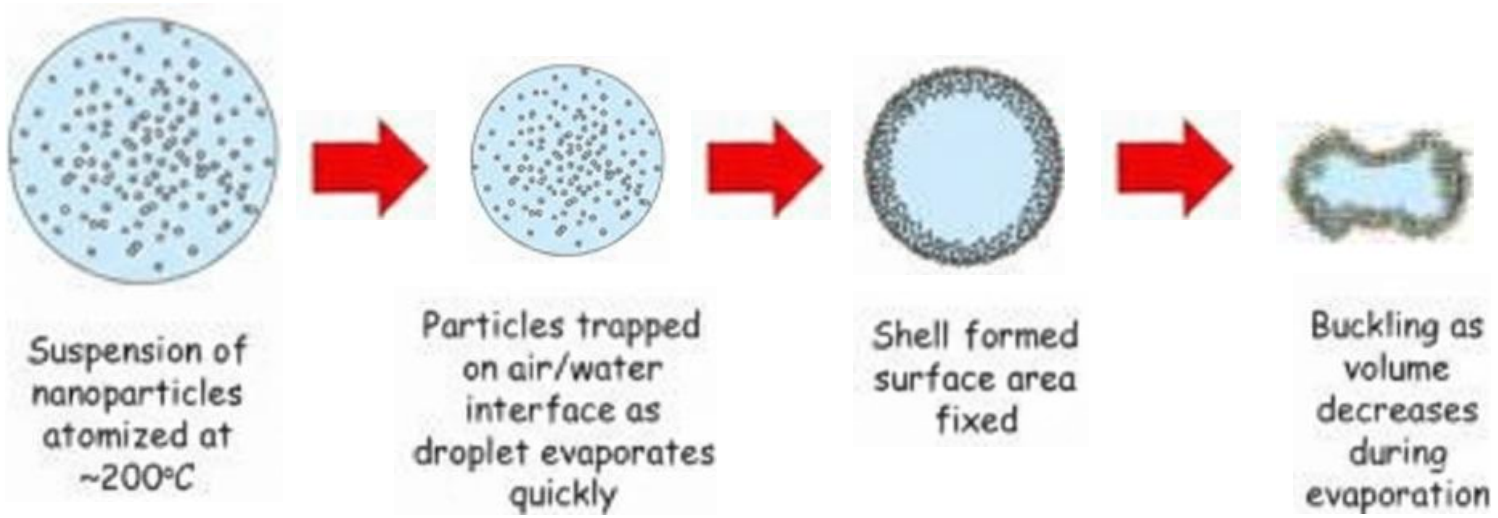
The outdoor RH ranges between 45–59%

The ambient temperature varies from 34-42 ° C

The inside RH are approximately 27%



How does temperature affect the drying of Agricultural Product?



- When the material surface is exposed to high temperature, surface moisture evaporates rapidly
- This leads to surface hardening, which hinders the diffusion of internal moisture from the core to the surface
- Prolonged heat exposure at the surface can result in darkening or browning of the material
- This phenomenon consequently affects the drying rate of the material

Reference: Singh & Dixit, 2014, P.3

Effects of Drying on the Colour of Dried Fruits and Herbs

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Temp.

Colour retention

Fig. 9. Dried black ginger at various drying air temperature.

Pulsed vacuum infrared drying

Hot air drying

Fresh

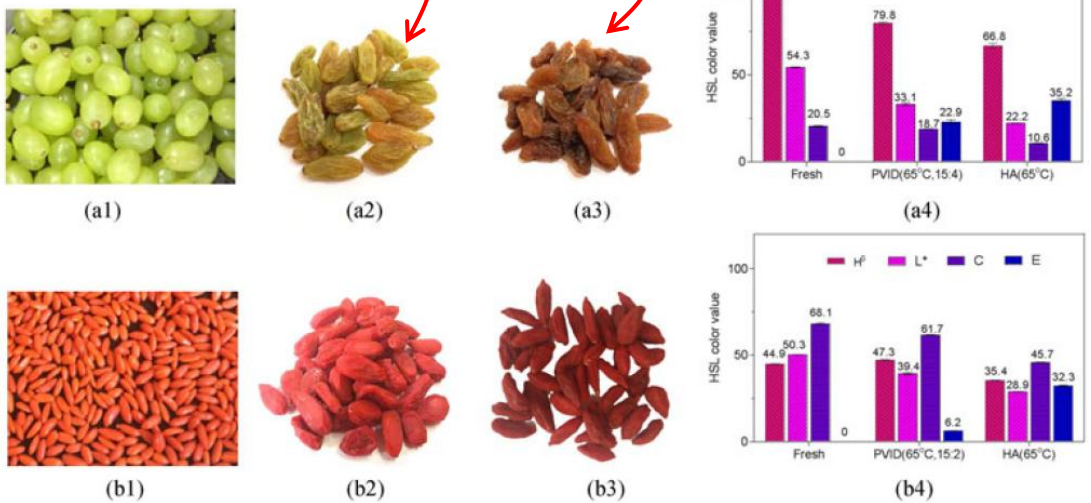


Figure 9. The photos and color values of two berries under HA and PVID technology. (a1) Fresh grapes, (a2) PVID samples, (a3) HA samples, (a4) Color value of grapes, (b1) Fresh goji berries, (b2) PVID samples, (b3) HA samples, (b4) Color value of goji berries.

Reference: Muthukumar et al., 2022, P.7; Zhang et al., 2020, p.13

Changes in Chemical Composition During Drying

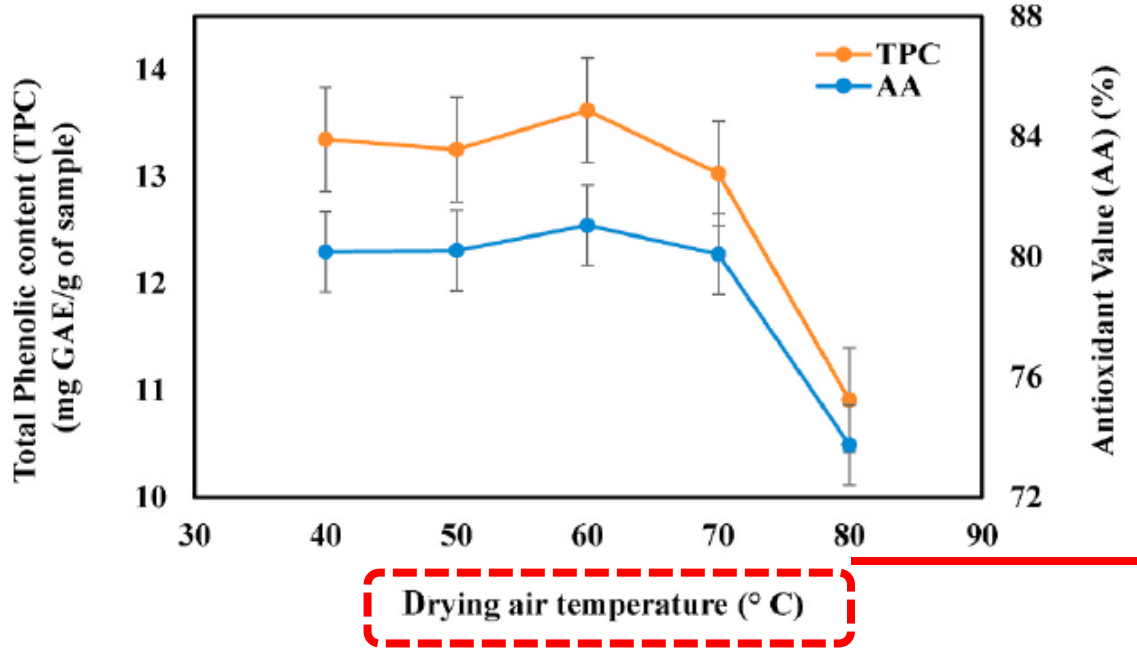


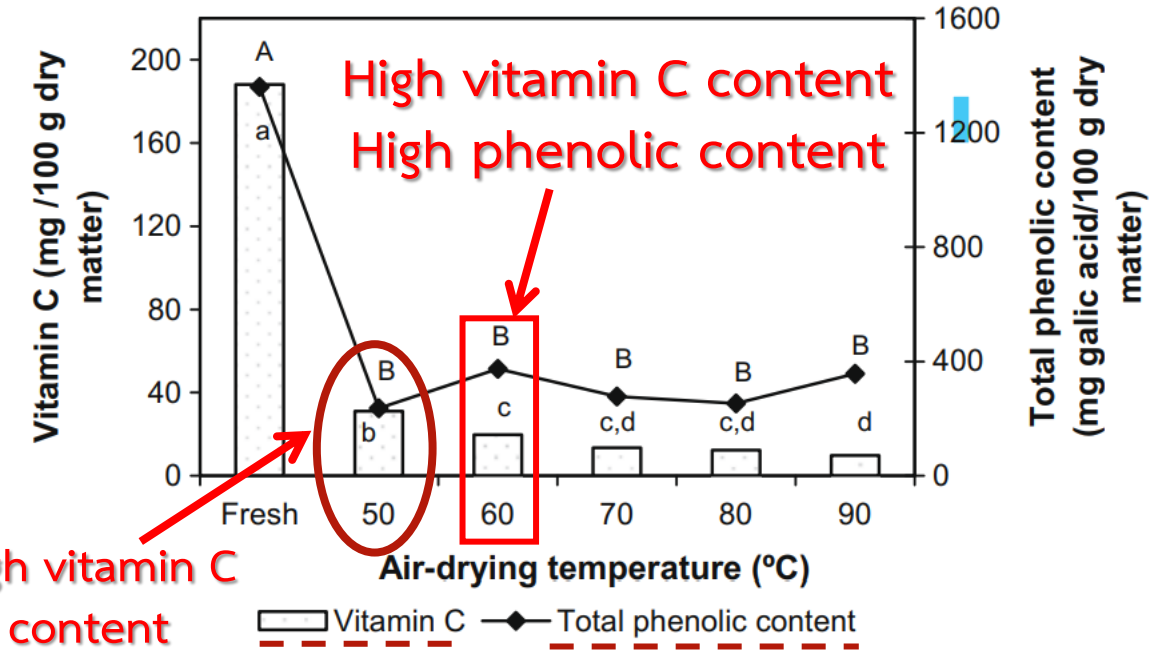
Fig. 8. Total phenolic content (TPC) and antioxidant (AA) values at different drying air temperature (vertical bars indicate standard error).

Phenolic compounds exhibit antibacterial, anti-inflammatory, and anticancer properties, and also function as natural antioxidants

An increase in temperature leads to a reduction in antioxidant properties

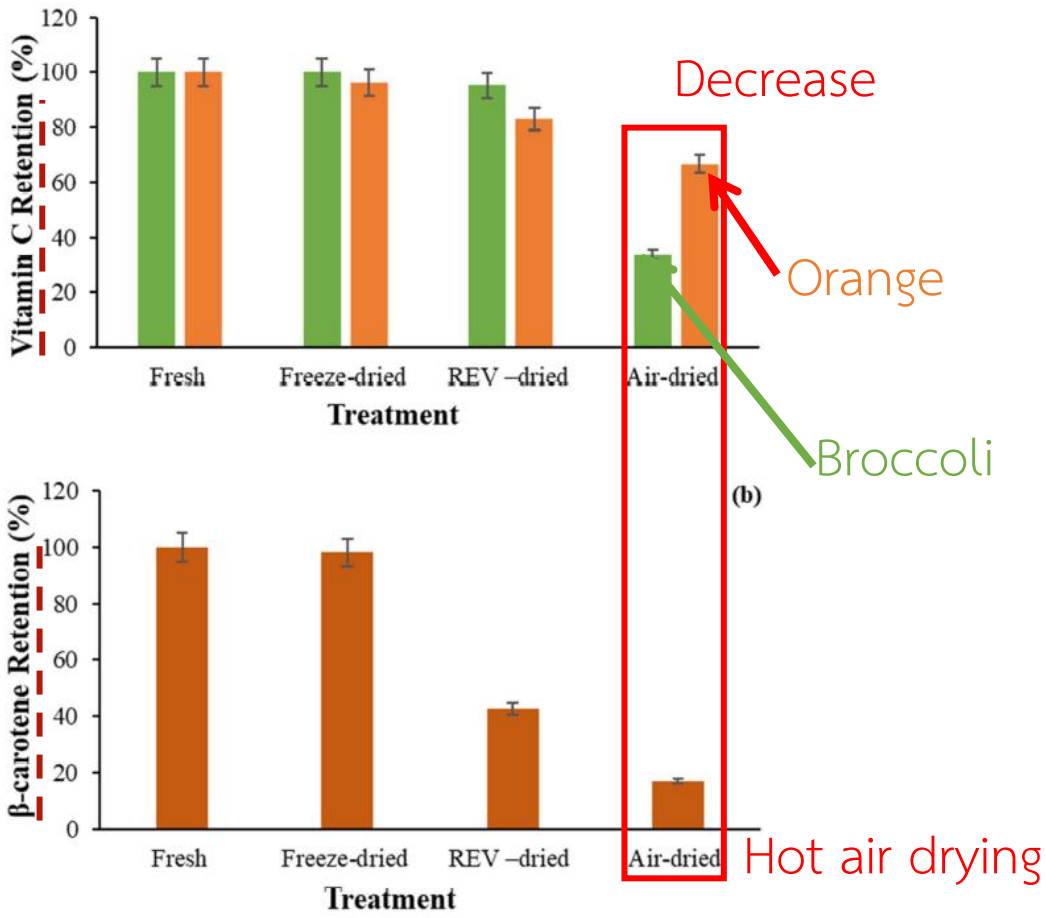
Reference: Muthukumar et al., 2022, P.6

Nutritional Value of Dried Fruits



Effect of air-drying temperature on vitamin C and total phenolic content of fresh and dry-rehydrated pepper samples. Identical letters above the bars indicate no significant difference.

Lower drying temperature (50°C) results in a longer drying duration compared to 60°C



(a) Retention of Vitamin C in broccoli (■) and oranges (■); (b) Retention of β-carotene in carrot; Radiant Energy Vacuum dried (REV-dried).

Reference: Vega-Gálvez et al., 2009, P.650; Mohammadi et al., 2020, P.7

Importance of Drying Fruits, Herbs, and Cereal Grains

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Therefore, the appropriate selection of a drying technique depends on:

- The type of material being dried
- The drying air conditions (temperature, humidity, and airflow)
- The drying method or technology applied

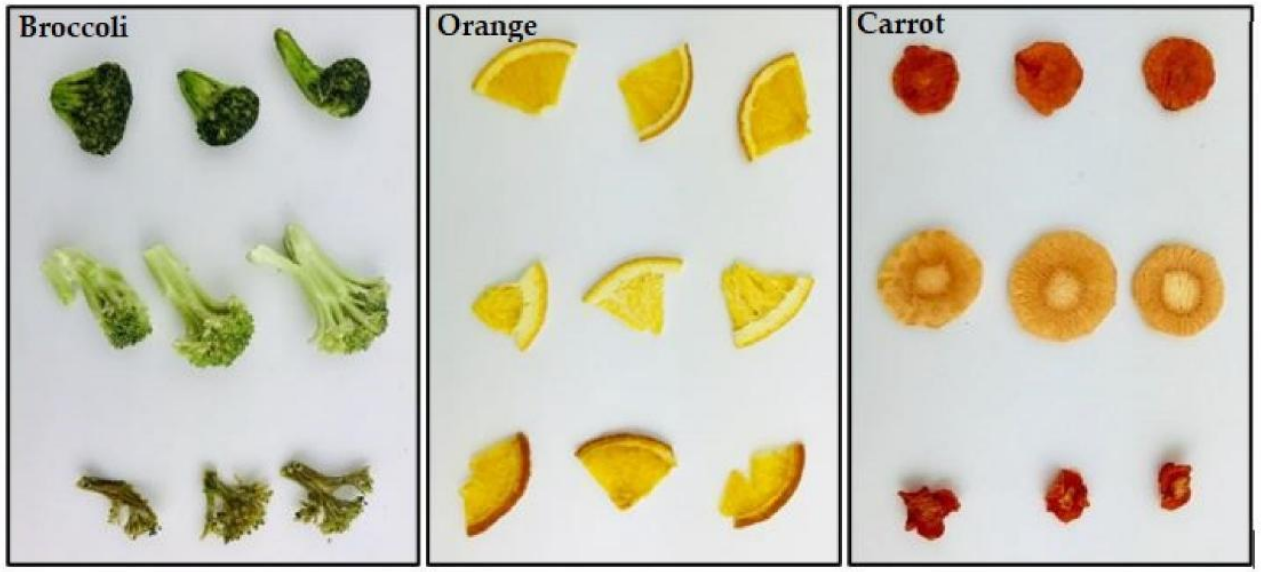

Figure 5. Broccoli, orange, and carrot immediately after drying in the order of the up to down representing REV-dried, freeze-dried, and air-dried.

Reference: Mohammadi et al., 2020, P.13

Hot Air Drying

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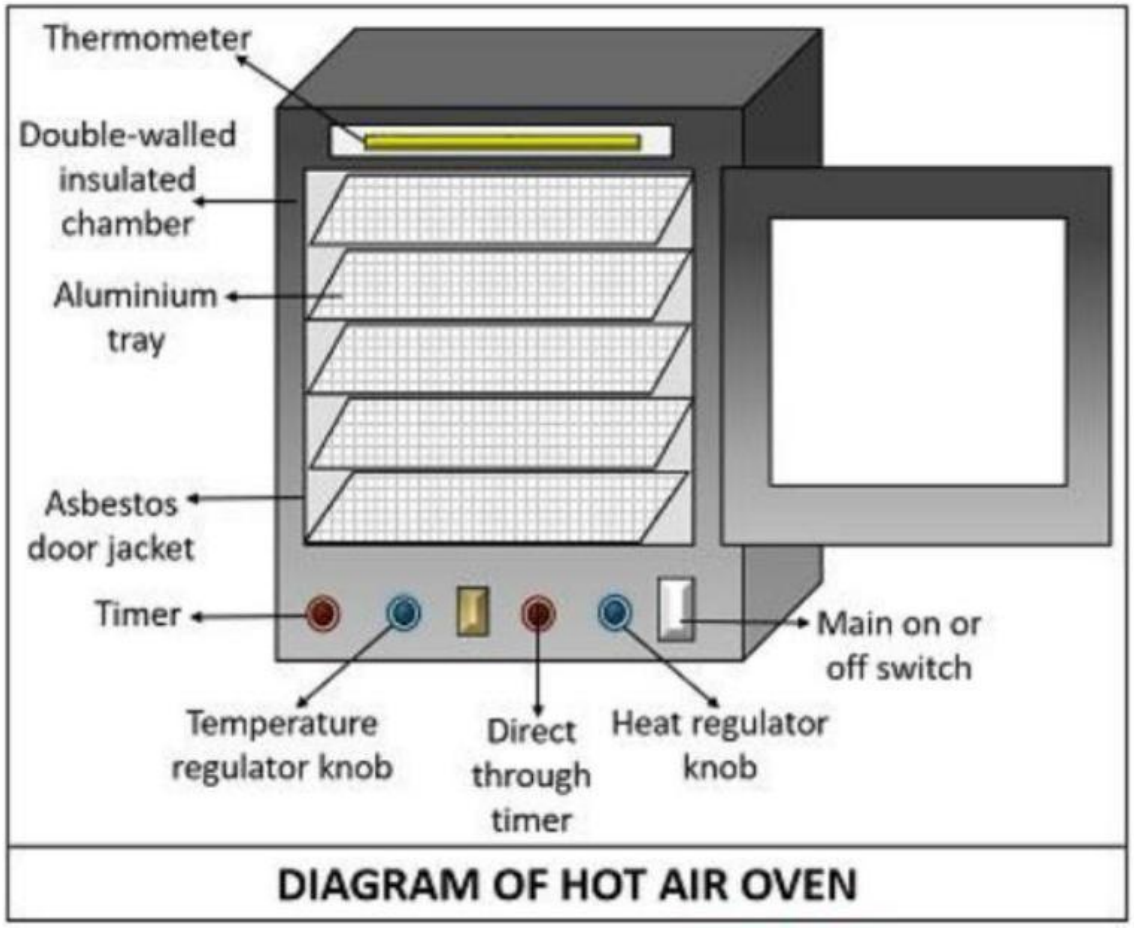
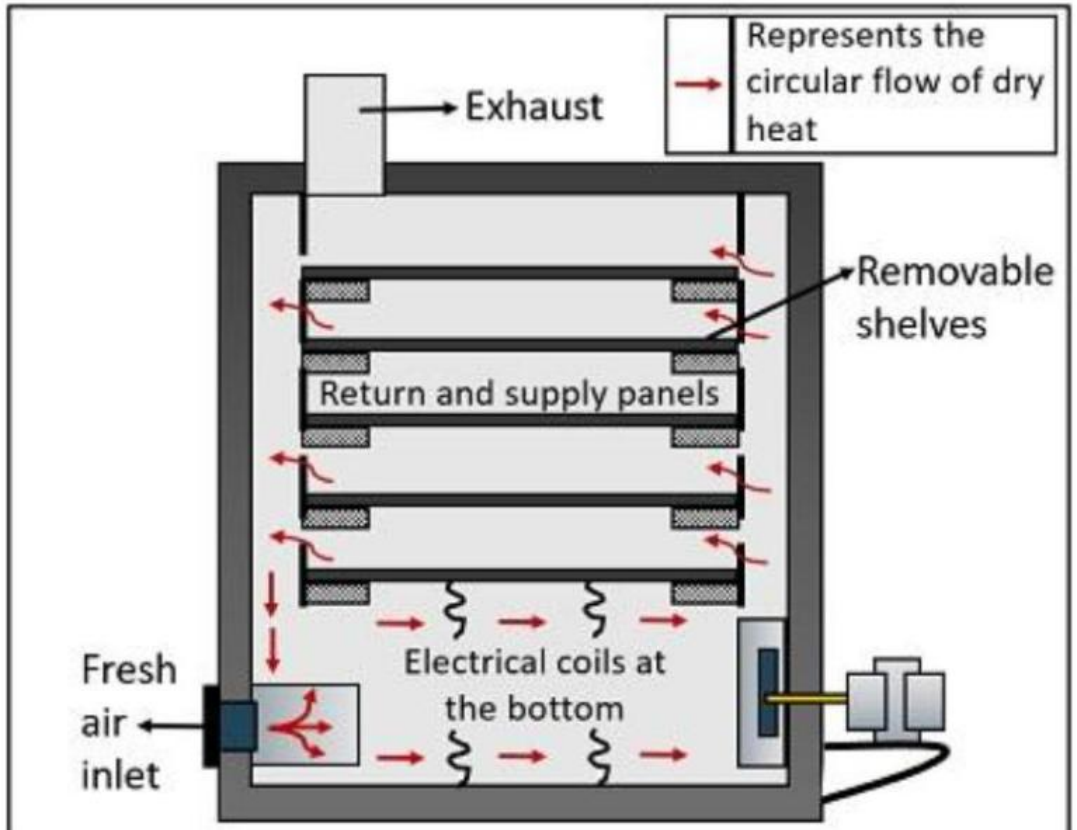


DIAGRAM OF HOT AIR OVEN



WORKING OF HOT AIR OVEN

Reference: Supriya, n.d.

Example of Hot Air Drying Technique for Tomato Drying

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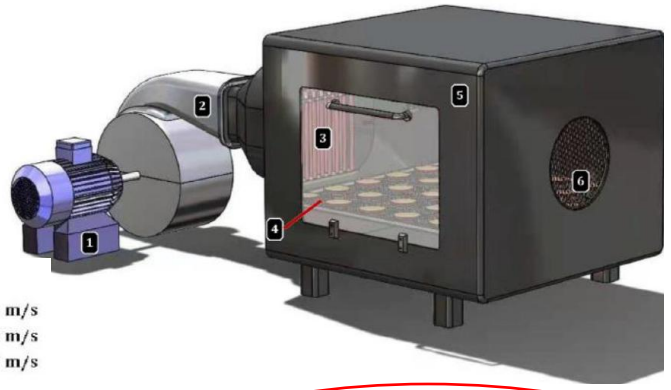
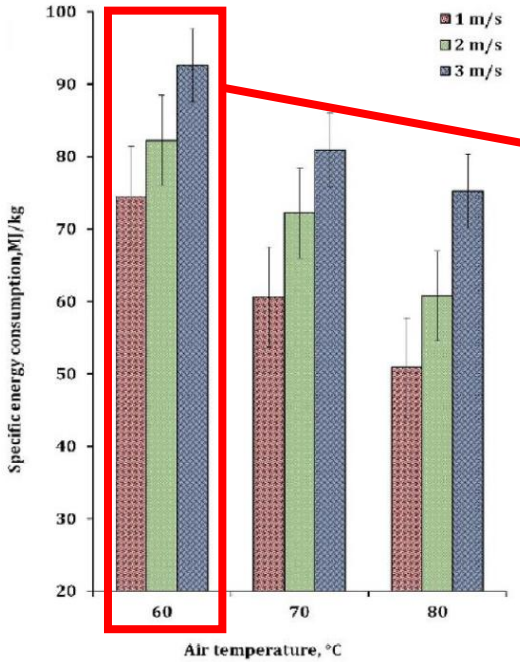
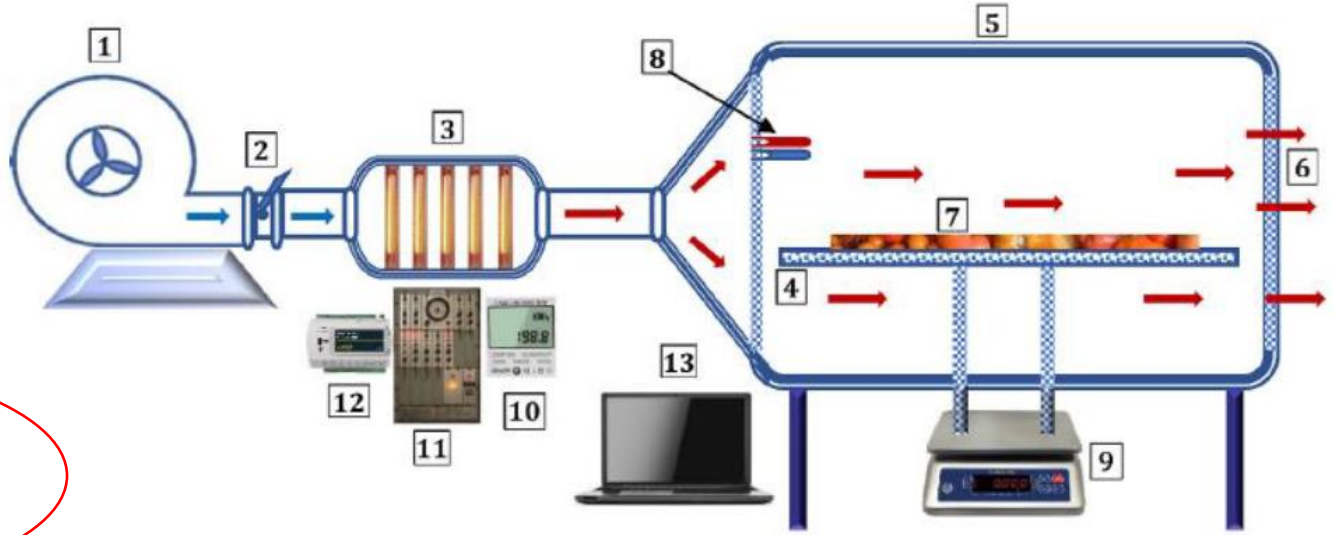




Why is the specific energy consumption highest at 60°C?



1- Fan
2- Velocity control valve
3- Electrical heater
4- Tray
5- Drying chamber
6- Air outlet
7- Tomatoes waste
8- Thermocouples
9- Digital balance
10- Electric counter
11- Control unite
12- Data logger
13- Computer

 Reference: El-Mesery & El-khawaga, 2022, P.3

Example: Hot Air Drying of Lemongrass

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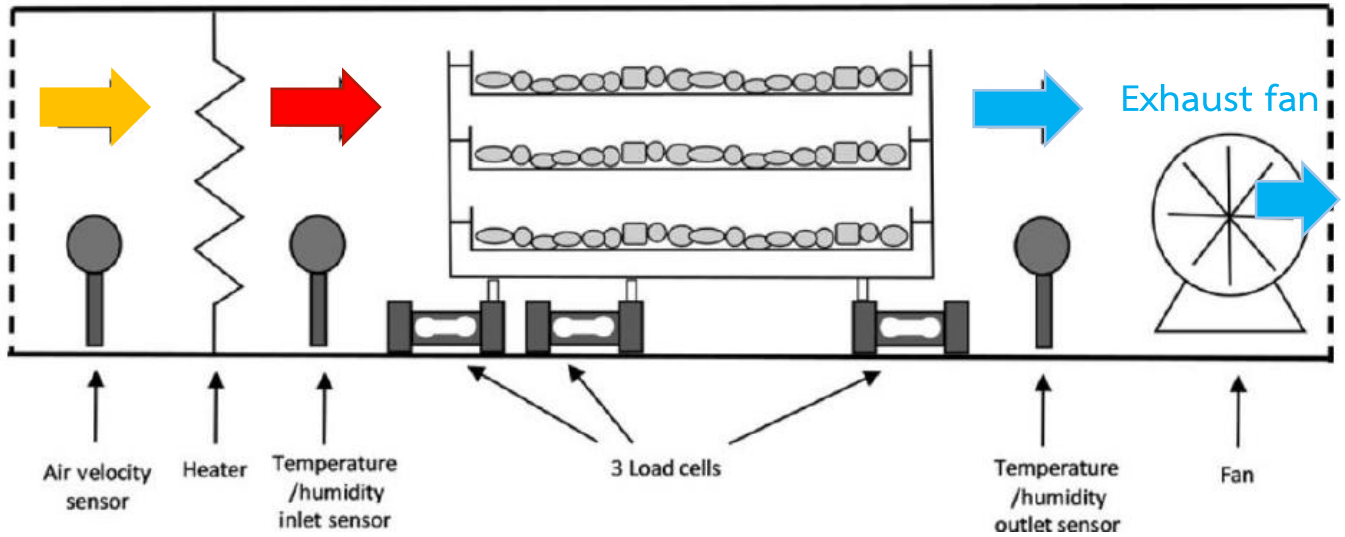
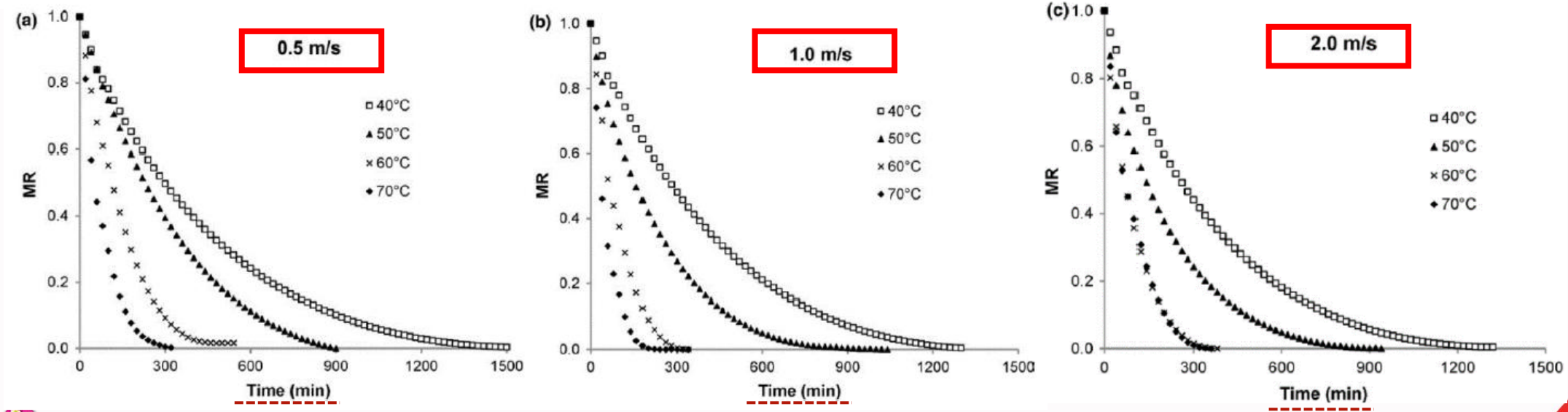
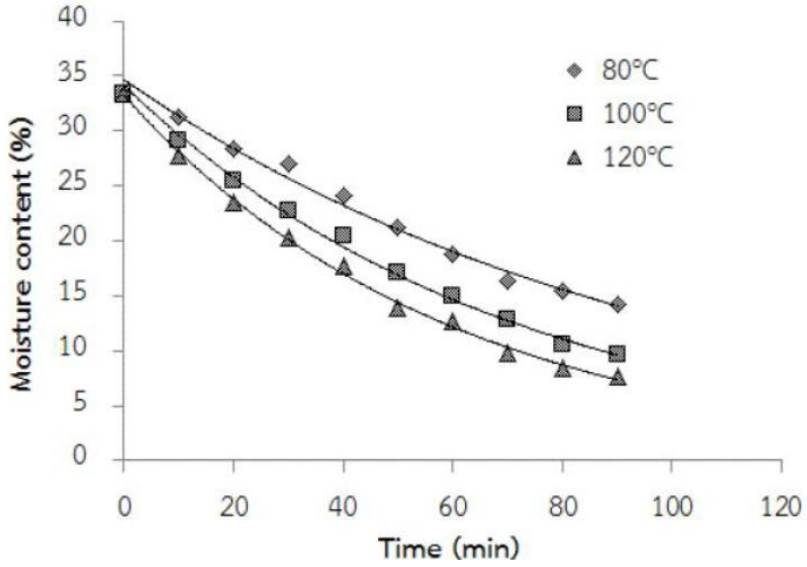


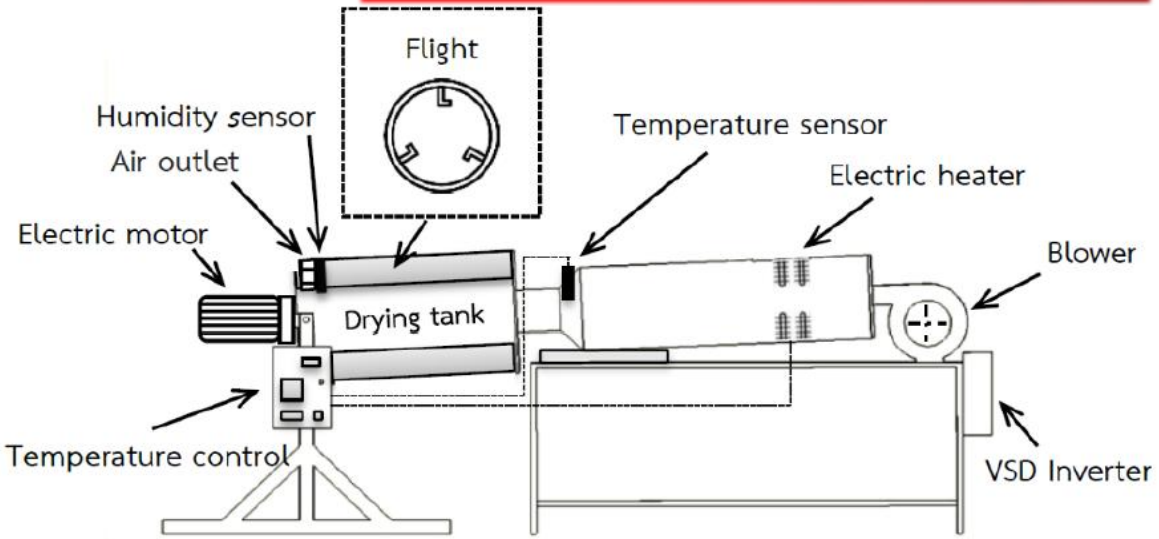
The drying rate depends on air temperature, relative humidity, and air velocity



 Reference: Mujaffar & John, 2018, P.1,086-1,089

Hot Air Drying of Paddy





A hot air temperature of 120°C tends to produce the lowest paddy moisture content, approximately 7%, within about 90 minutes

At the lowest hot air temperature of 80°C, the final moisture content of paddy is approximately 15%

Higher drying temperature enhances mass transfer, resulting in faster moisture removal from paddy grains

Reference: Rattanawong et. al, 2022, P.130, 135

Summary of Hot Air (Convective) Drying Technique

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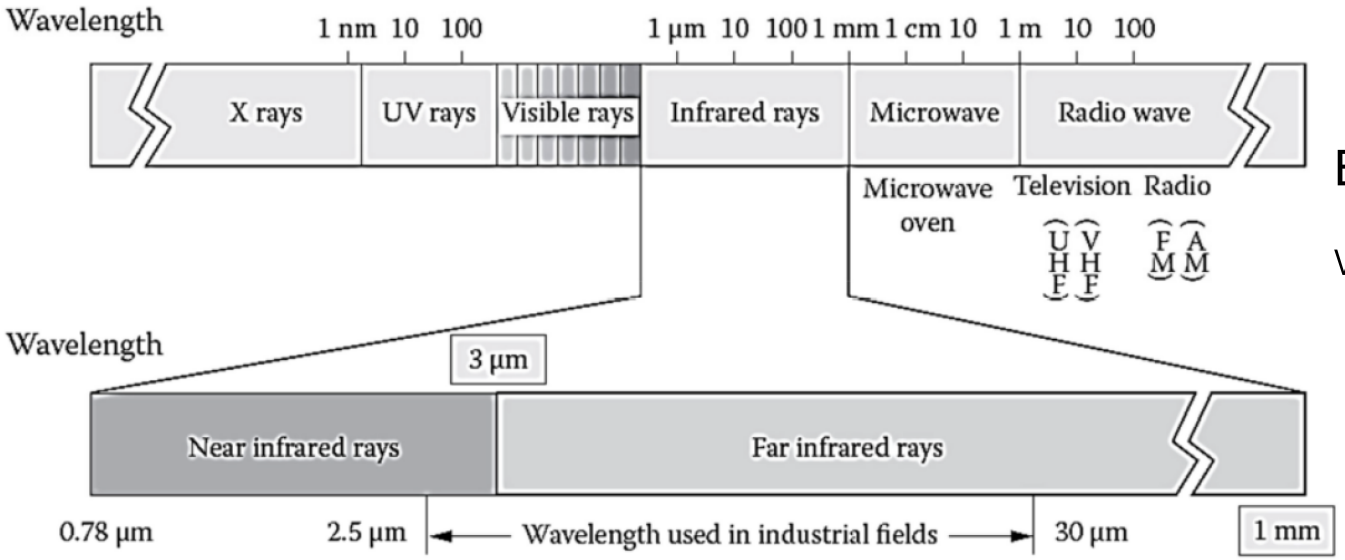
- Heat is transferred from the air to the product surface and diffuses inward, promoting internal moisture migration and surface evaporation

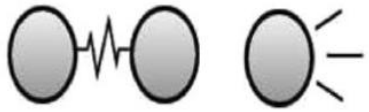
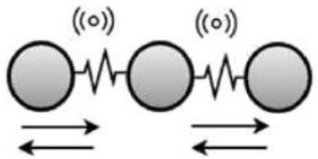
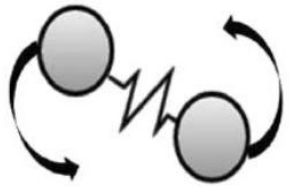
- The drying rate is governed by drying air temperature, relative humidity, and airflow velocity

Radiation drying



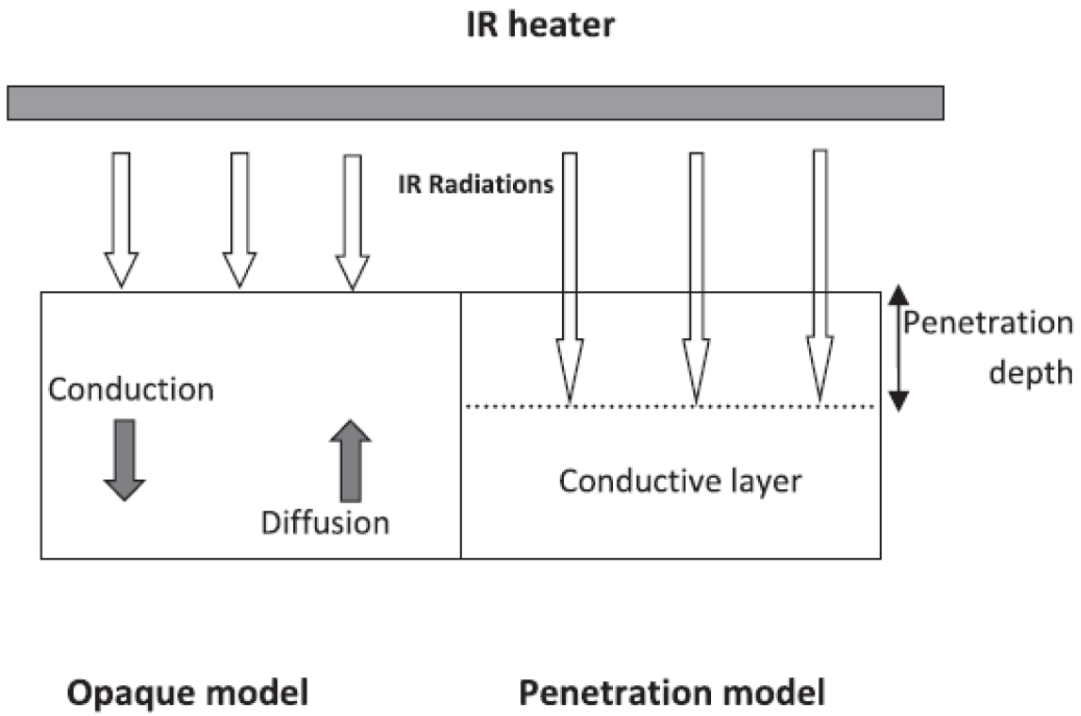
Electromagnetic radiation transfers energy without a medium

- UV radiation may cause molecular dissociation
- Infrared radiation induces molecular vibration
- Microwave radiation generates heat through molecular rotation

Ultraviolet and visible rays	Infrared radiation	Microwaves
		
Molecule dissociates	Molecule vibrates	Molecule rotates

Reference: Aboud et al., 2019, P.3, Sakare et al., 2020, P.383

Penetration Depth of Electromagnetic Radiation



Food material	Spectral peak (μm)	Penetration depth (mm)
Grain wheat	1.0	2
Carrots	1.0	1.5
Tomato paste	1.0	1
Potatoes raw	1.0	6
Potatoes dry	0.88	15–18
Apple raw	1.16	4.1
	1.65	5.9
	2.36	7.4

Reference: Pawar & Pratape, 2015, P.6-7

What are the Advantages of Combining Infrared Radiation with Hot Air Drying?

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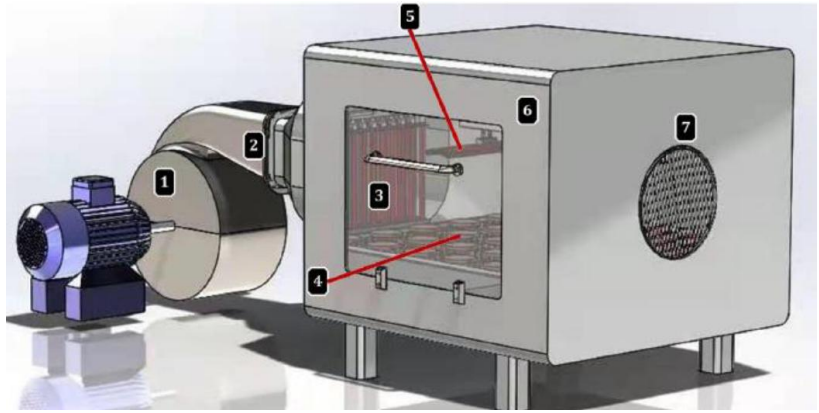

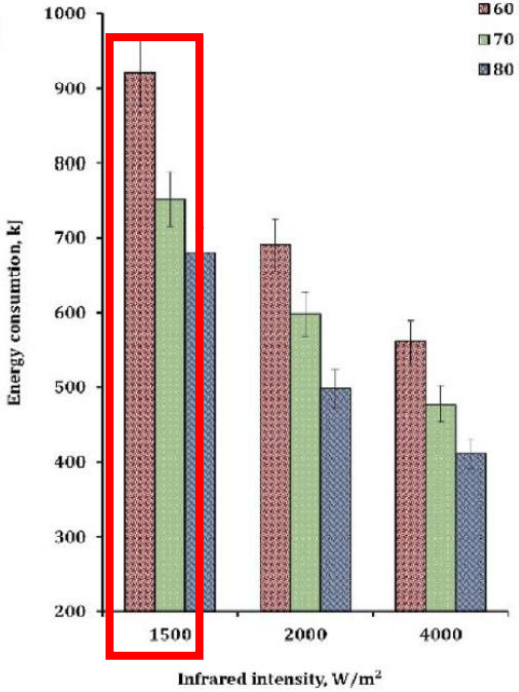

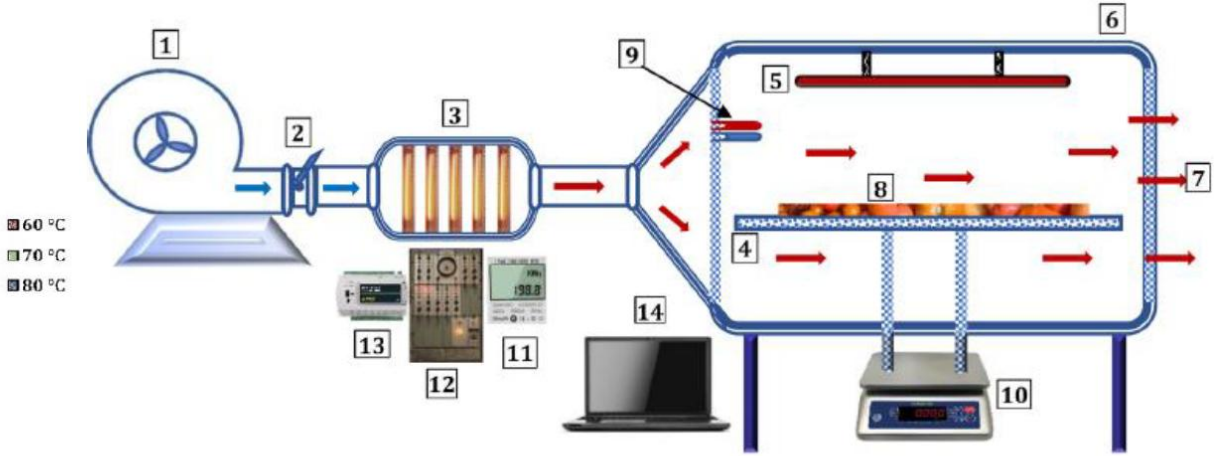

1- Fan
2- Velocity control valve
3- Electrical heater
4- Tray
5- Infrared heater
6- Drying Chamber
7- Air outlet
8- Tomatoes waste
9- Thermocouples
10- Digital balance
11- Electric counter
12- Control unite
13- Data logger
14- Computer

Reference: El-Mesery & El-khawaga, 2022, P.4

Example: Combined Infrared and Hot Air Drying of Pandan Leaves

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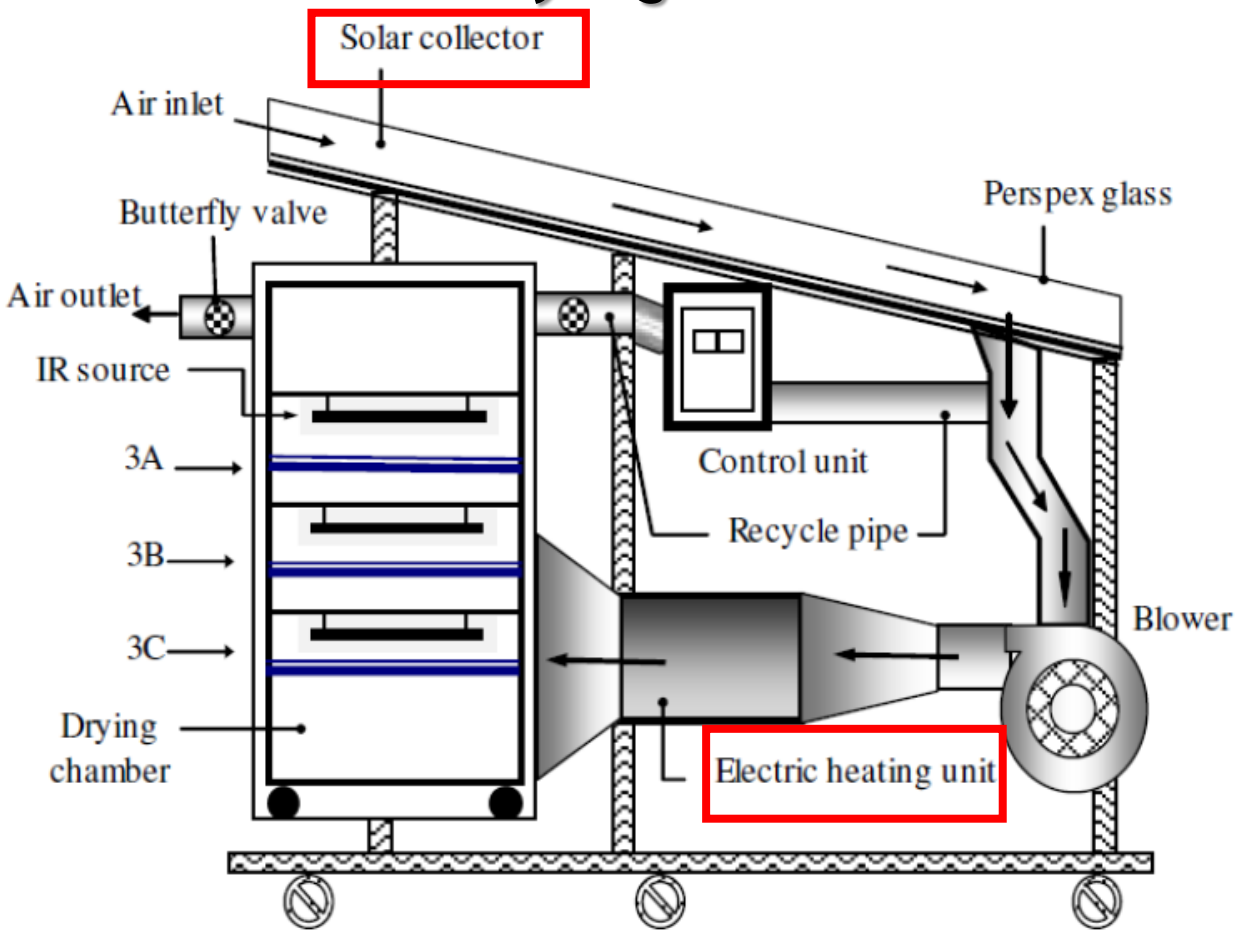

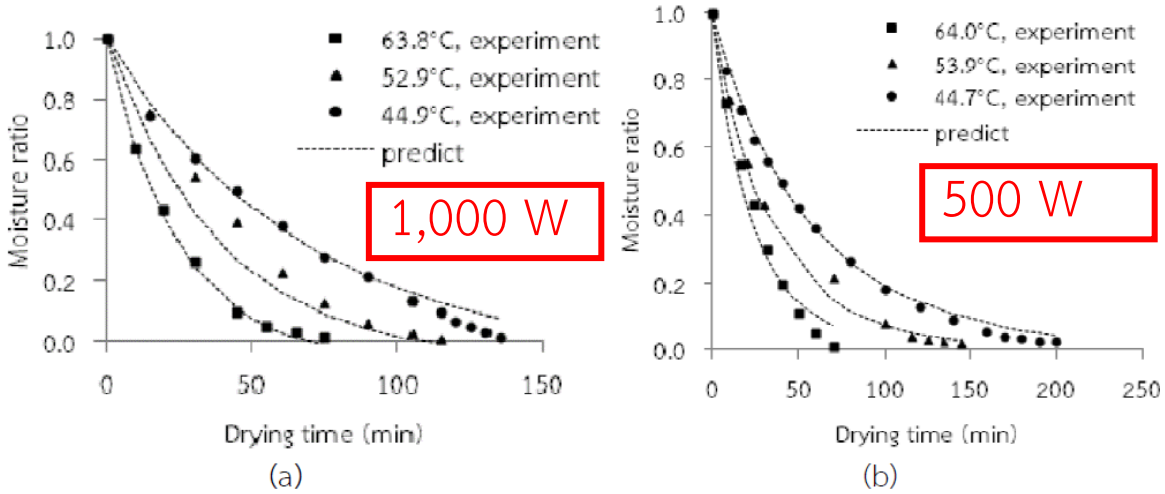

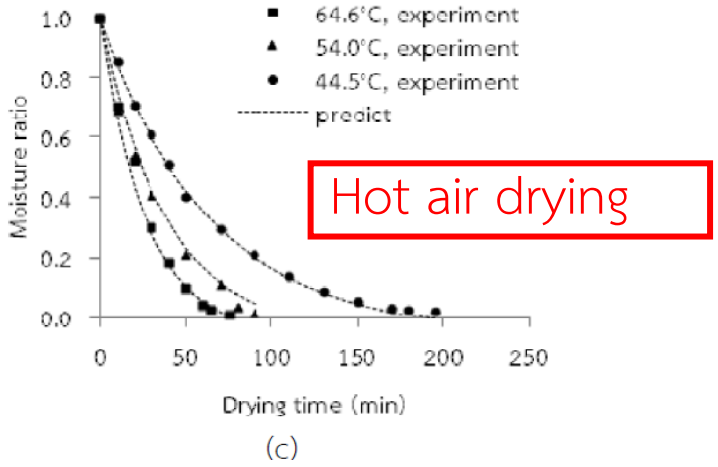

Reference: Nadee et. al, 2012, P.89, 91

Rotary dryer using infrared ray combined exhausted hot air

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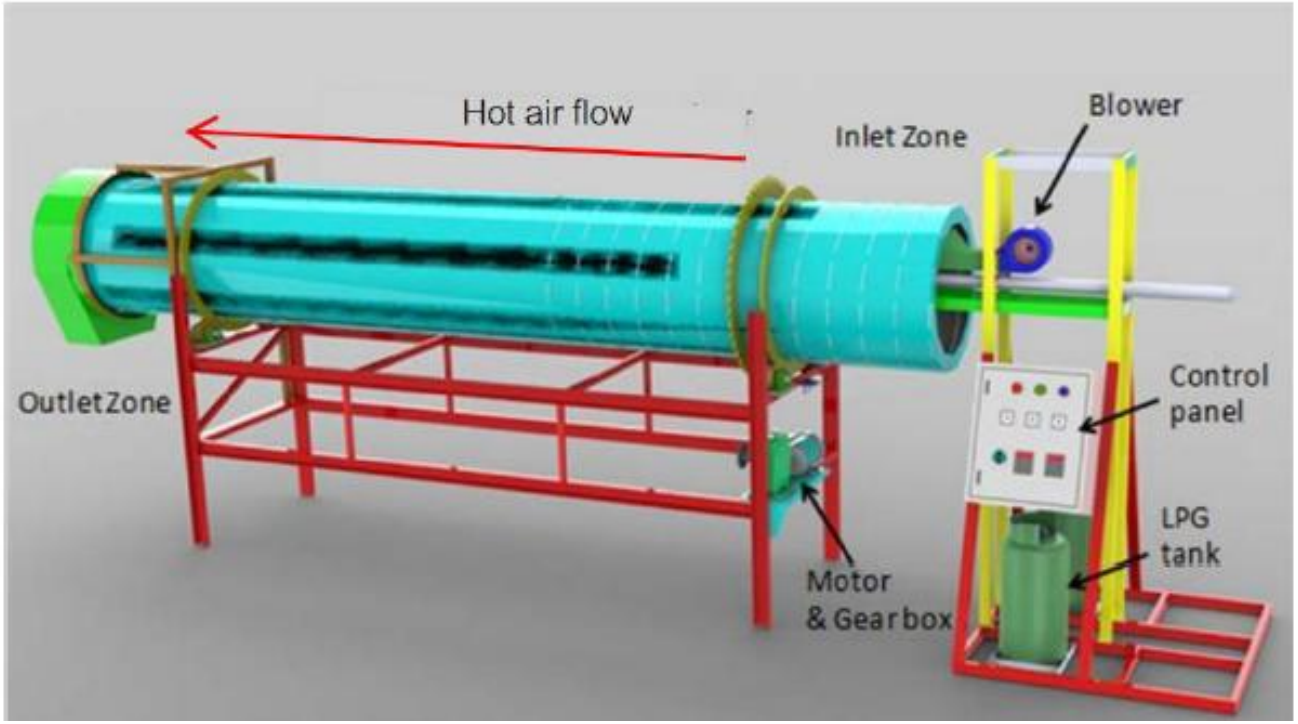

The feed rate of rice is maintained at 200 kg·h^{-1}, and the material undergoes two drying cycles within the dryer

	Drying 1 round		Drying 2 round	
	Moisture content before drying (% wb.)	Moisture content after drying (% wb.)	Moisture content before drying (% wb.)	Moisture content after drying (% wb.)
average	32.11	28.19	26.82	23.69
max	32.20	28.39	26.94	23.72
min	32.02	28.01	26.68	23.64
SD	0.09	0.19	0.13	0.04

Reference: Wijanjak et. al, 2017, P.52-53

Example: Microwave Drying of Tomatoes

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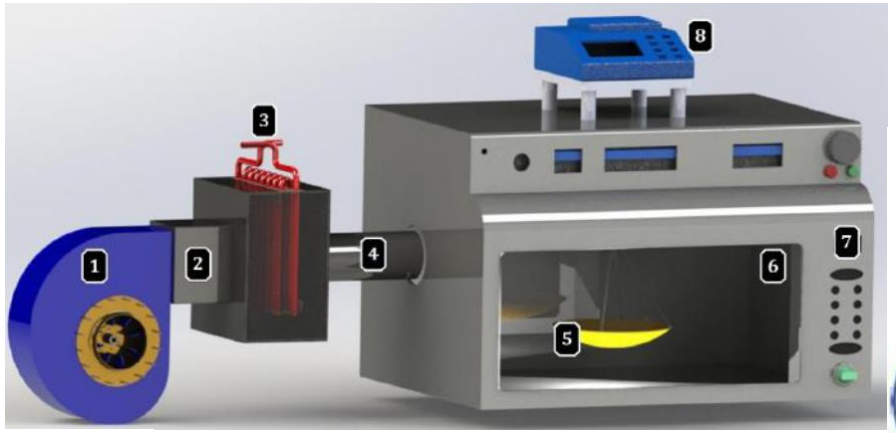

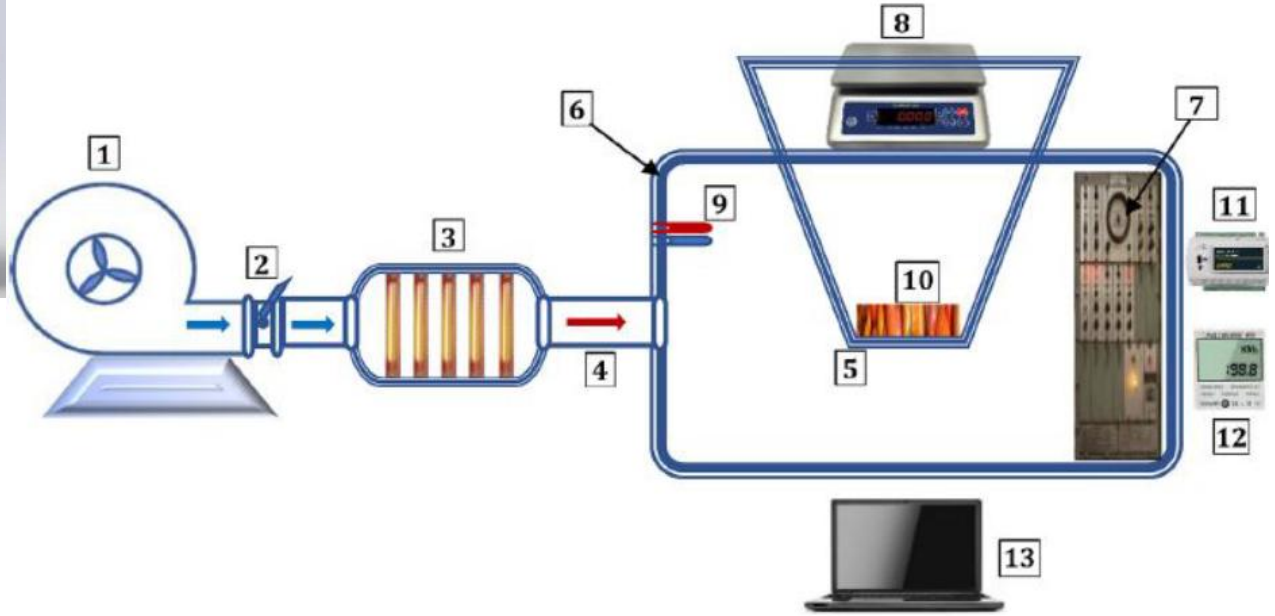

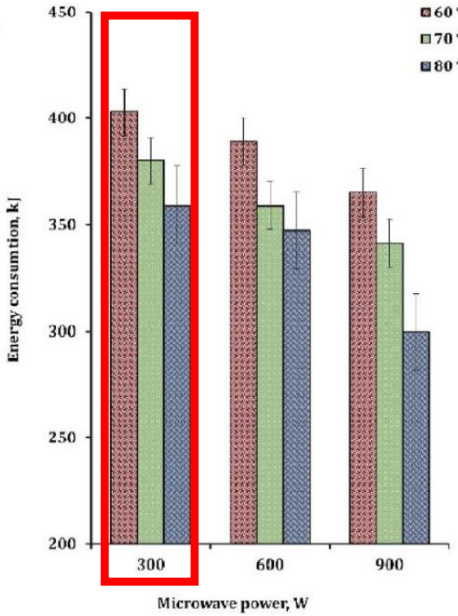

1- Fan
2- Velocity control valve
3- Electrical heater
4- Air inlet
5- Tray
6- Microwave oven
7- Digital control MW Power
8- Digital balance
9- Thermocouples
10- Tomatoes waste
11- Data logger
12- Electric counter
14- Computer

Reference: El-Mesery & El-khawaga, 2022, P.5

Example: Microwave Dryer

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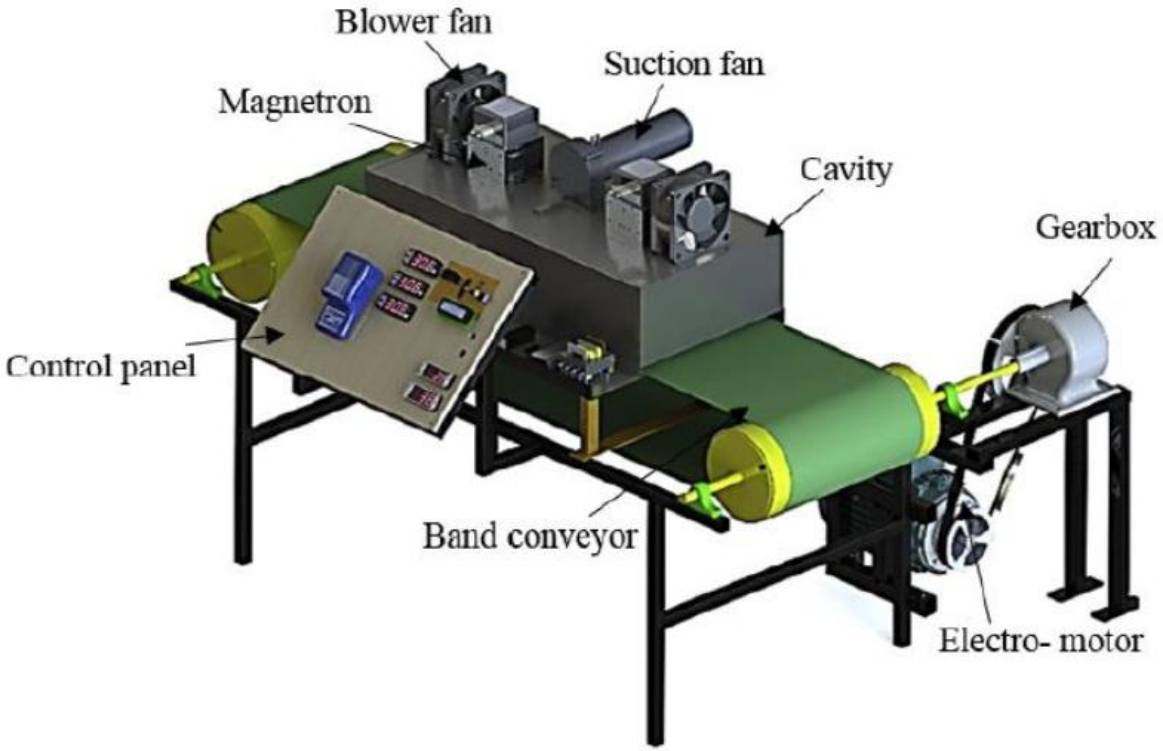
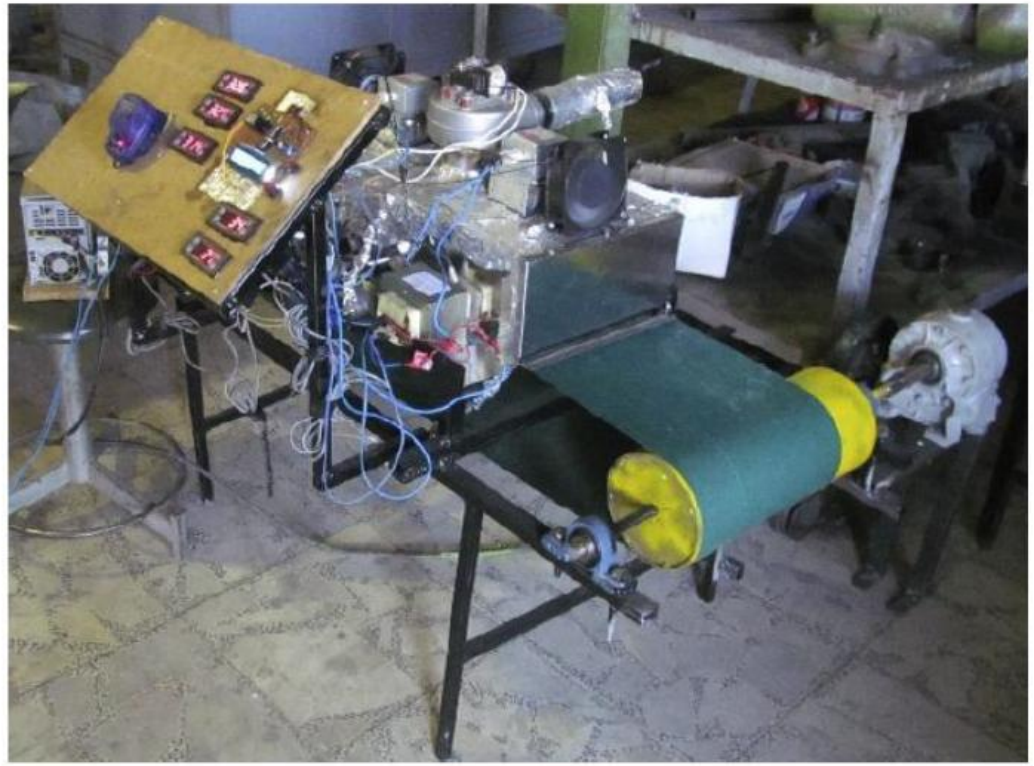


(a)



(b)

Speed 0.24 m·min^{-1}

Reference: Jafari et al., 2018, p. 648

Temperature and Moisture Ratio Versus Drying Time at Different Powers and Layers

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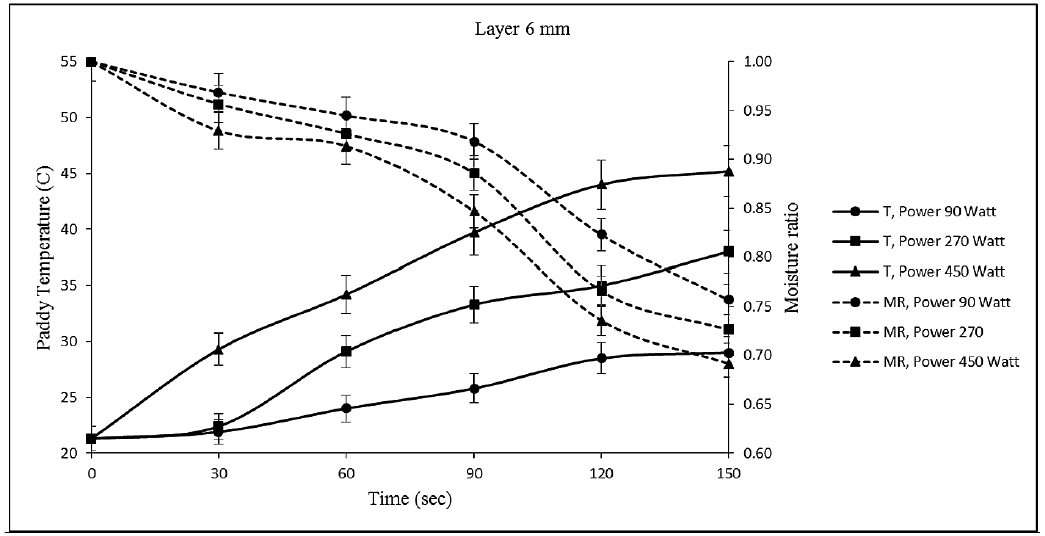

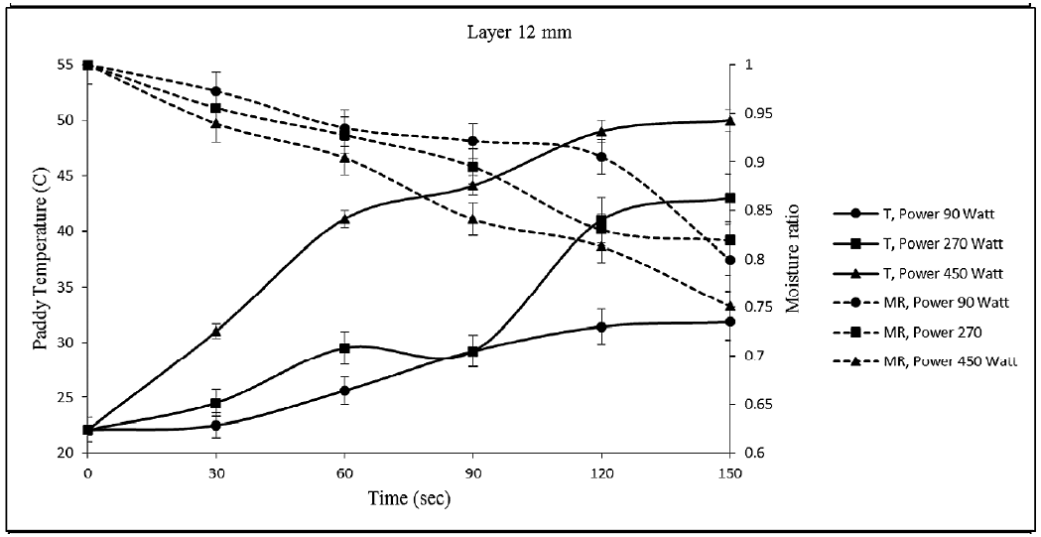

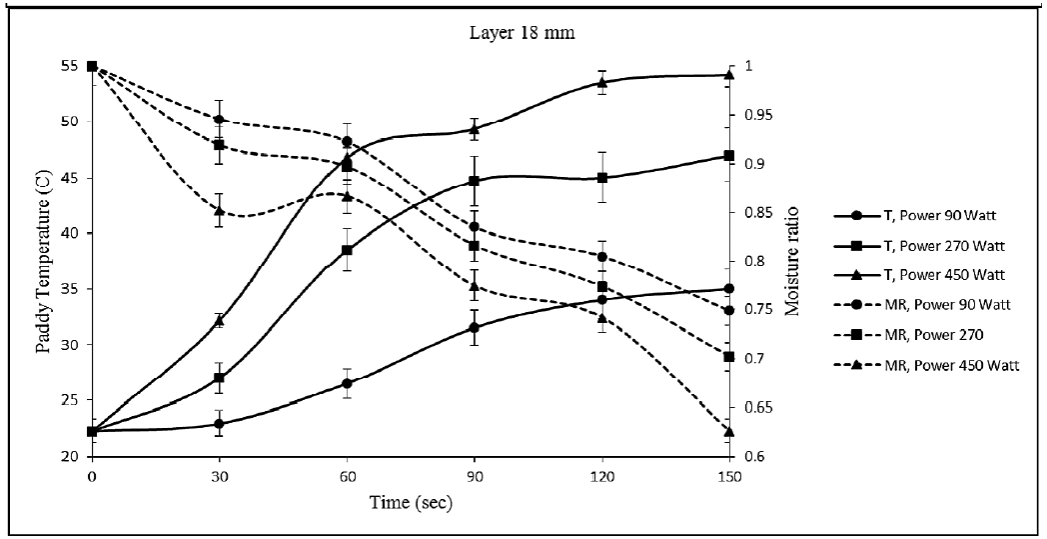

Reference: Jafari et al., 2018, p.651

9673204 Drying and Storage

Assistant Professor Dr. Chukiat Chotikasatian

Comparison of Radiation Drying Techniques

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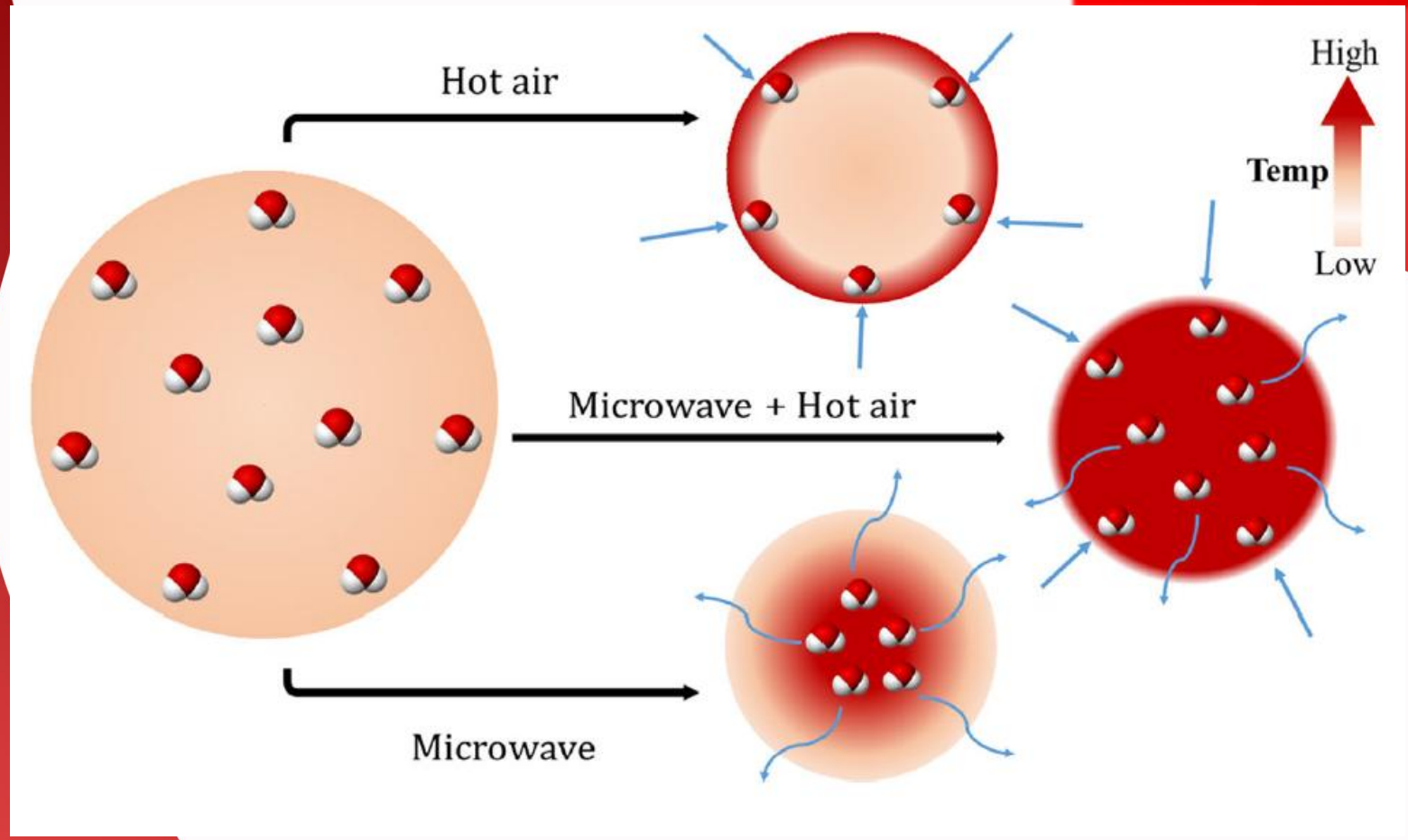

 Reference: Karimi et al., 2021, P.136

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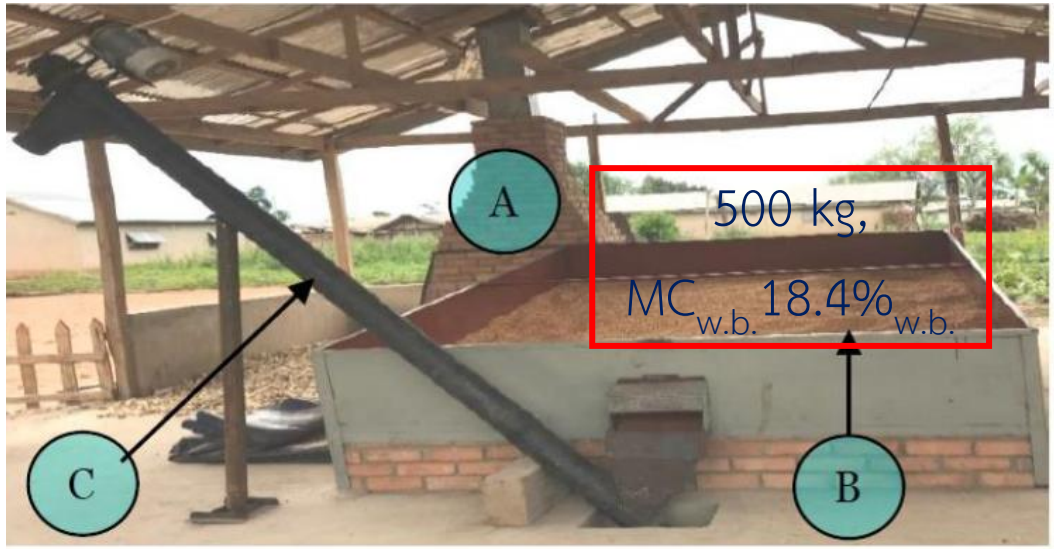
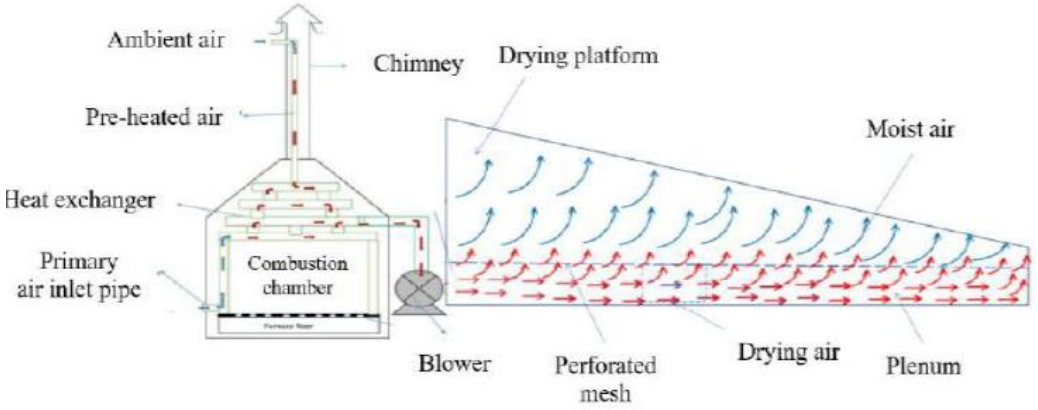
Which Drying Technique Is Most Suitable for Large-Scale Grain Processing?

In-Bin Dryer



(a)



(b)

Reference: Akowuah et al., 2021, P.38

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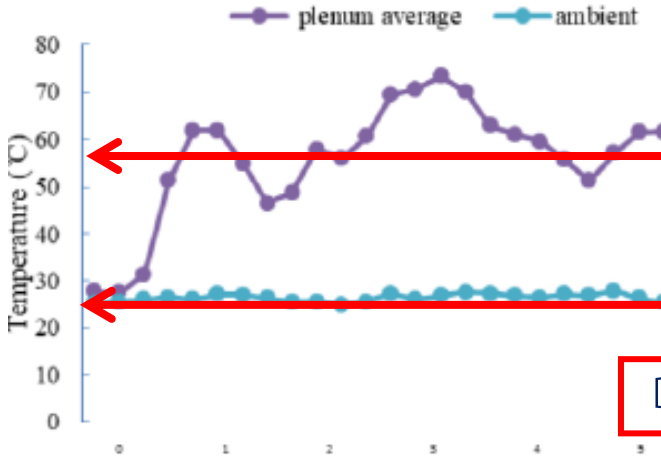
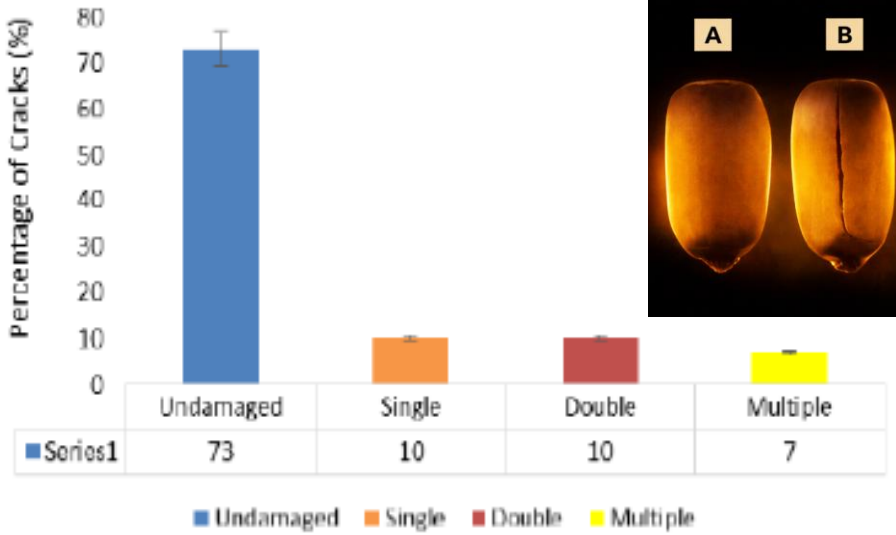


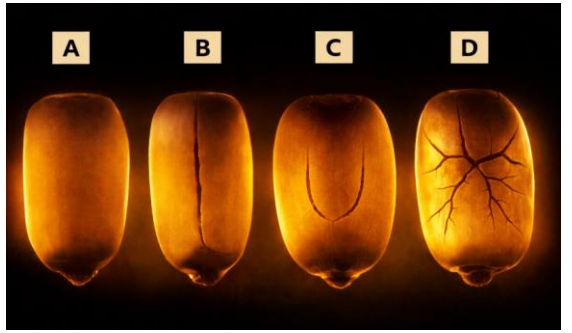
Average kernel surface temperature: 33.0°C

55.8°C

26.1°C

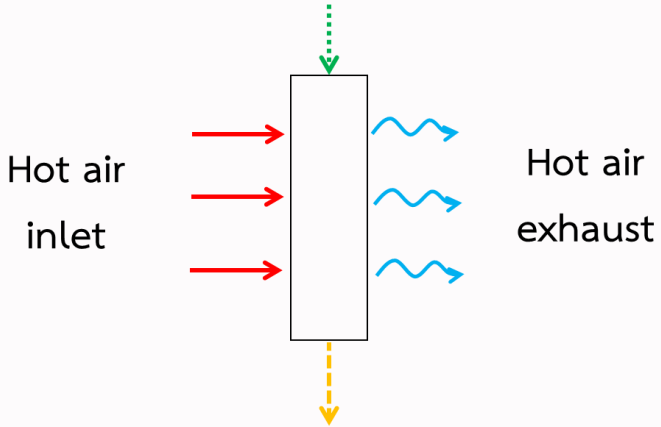
Drying time: 5 h, MC w.b. 13.4% w.b.



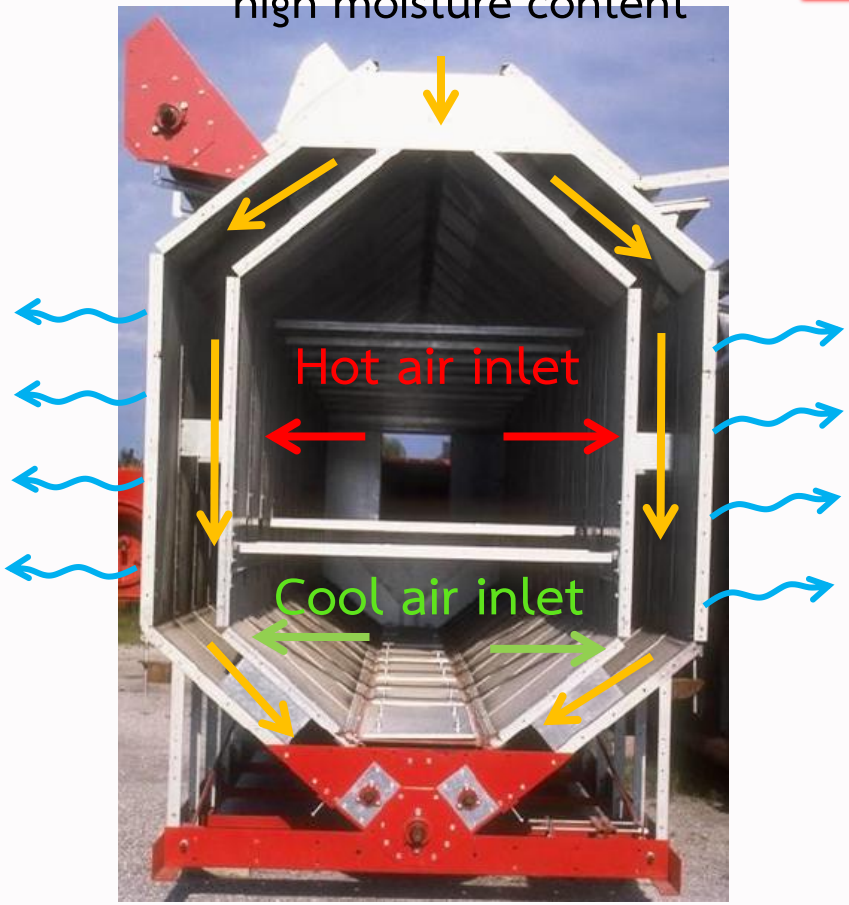


Crossflow Grain Dryer

Flow direction of grains with high moisture content

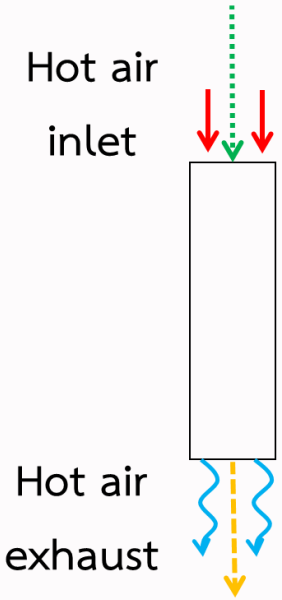


Flow direction of grains with high moisture content

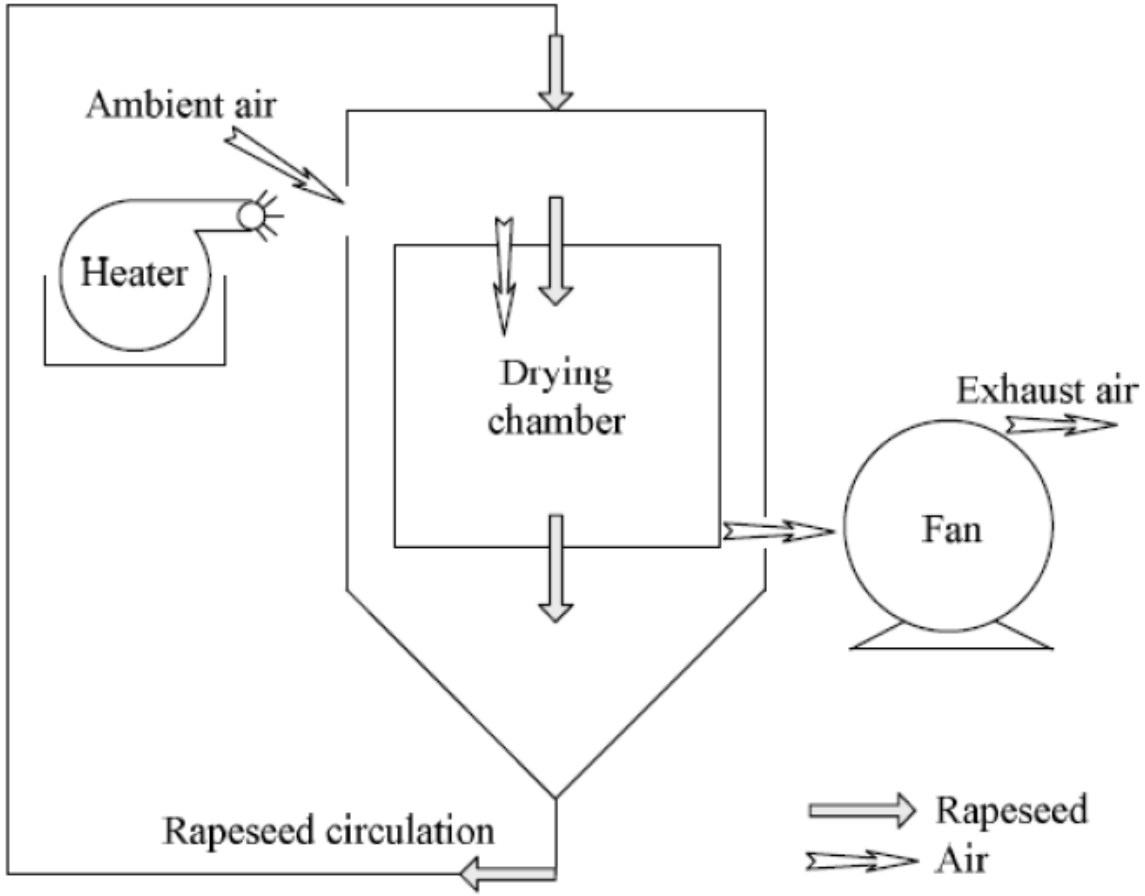


Concurrent-Flow Grain Dryer

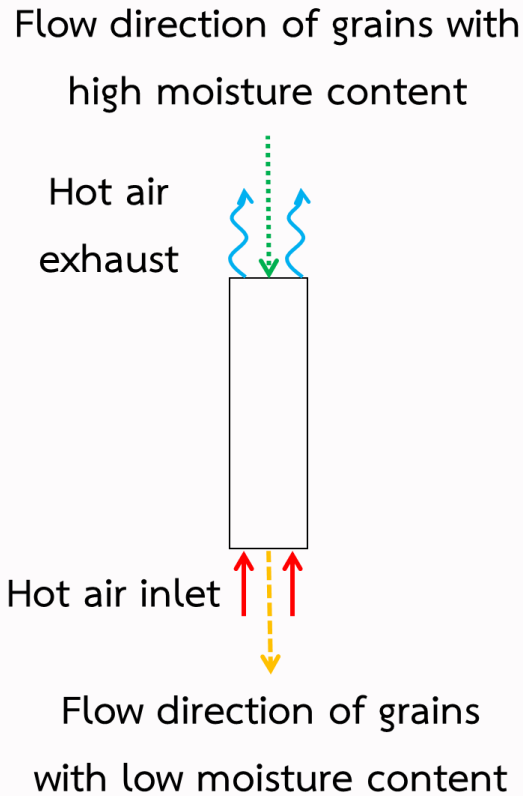
Flow direction of grains with high moisture content

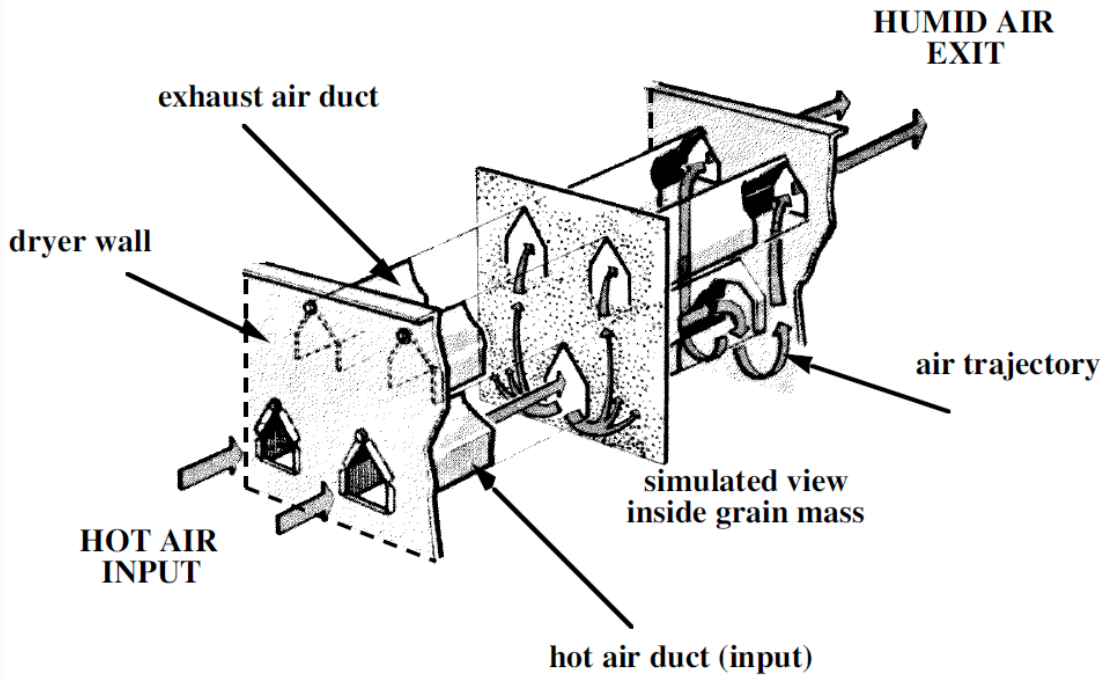


Flow direction of grains with low moisture content



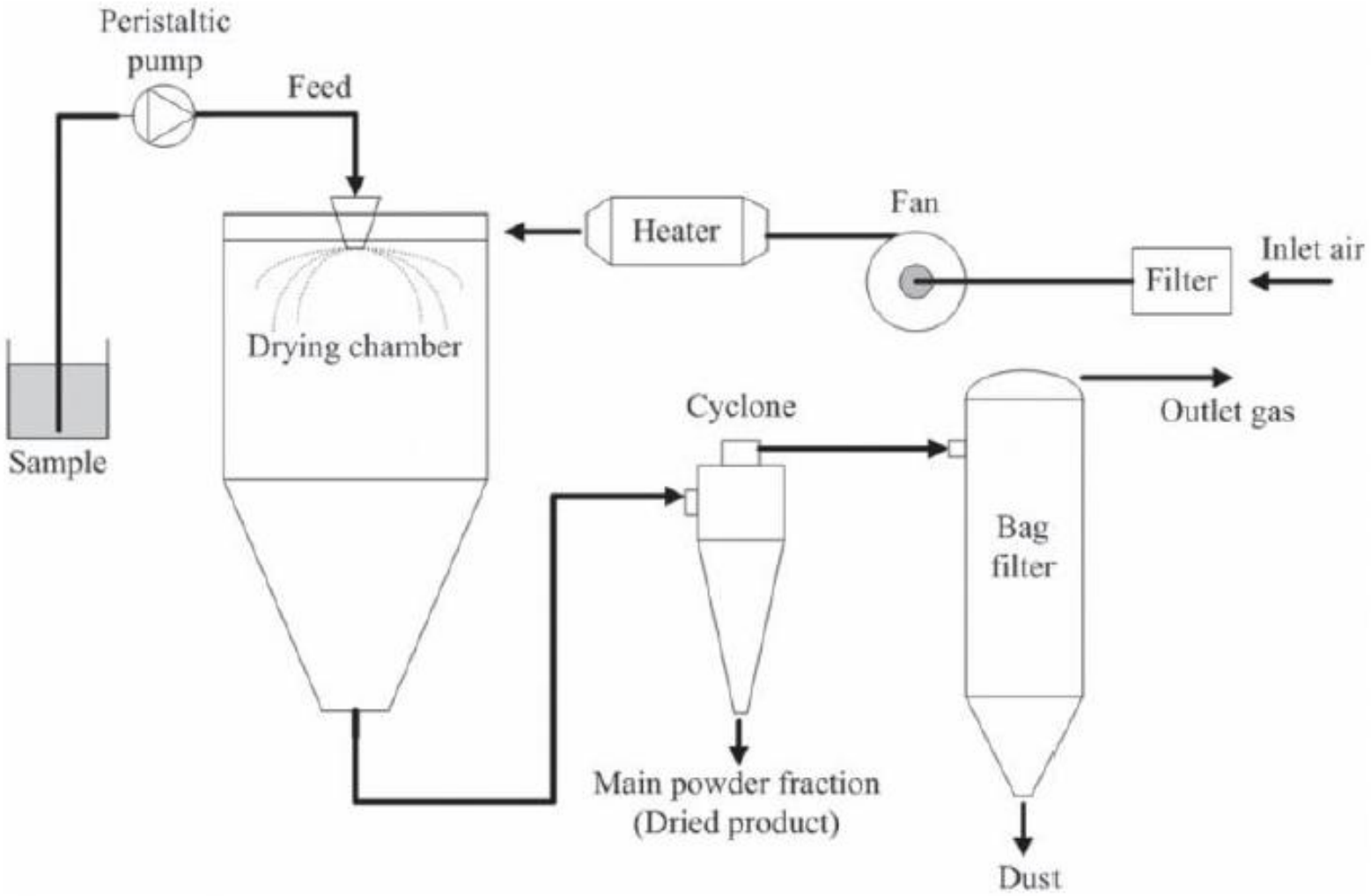
Counterflow Grain Dryer





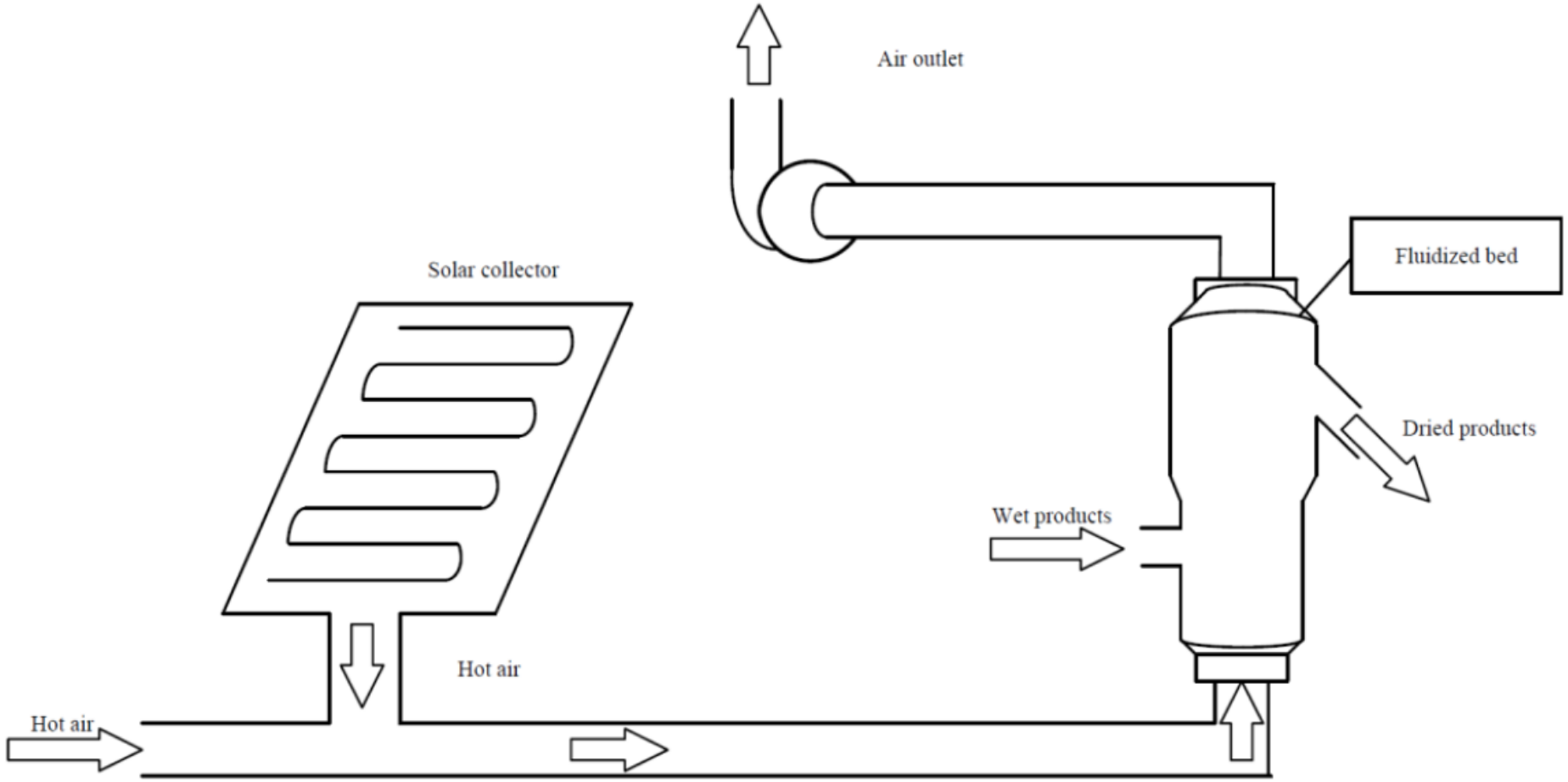
 Reference: Courtois, 1995, P.1,158

Spray Dryer



 Reference: Jittanit et al., 2010, P.500

Fluidized Bed Dryer



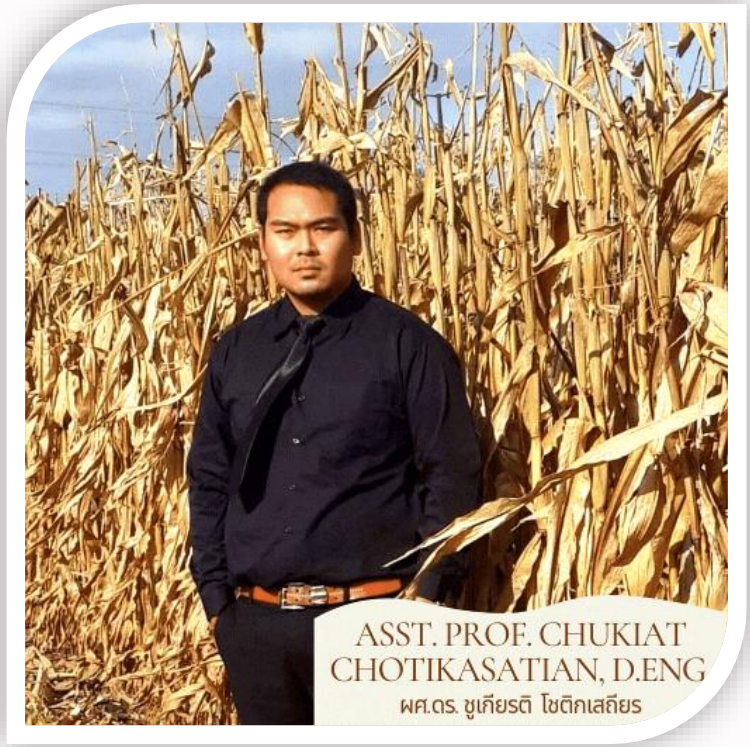
 Reference: Deng et al., 2021, P.73

Summary

1. In addition to the techniques discussed in this chapter, several other drying methods are available, such as vacuum drying and freeze drying.

2. These techniques generally involve relatively high production costs and are therefore more suitable for high-value products.

3. Consequently, the selection of an appropriate drying technique for agricultural products must take into consideration factors such as heat sensitivity or sensitivity to specific types of radiation, material quantity, and physical characteristics of the product.



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Thank you very much for your kind attention.

Questions?

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Study Questions – Lecture 7

1. *How do drying air conditions (temperature, relative humidity, and airflow) influence the drying rate and product quality of agricultural materials?*
2. *What are the effects of drying temperature on: Moisture migration Colour retention Chemical composition Nutritional value*
3. *Which drying technique is most appropriate for large-scale grain processing, and why?*

Assignment – Lecture 7

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1. Describe the differences in drying agricultural products using infrared radiation, microwave radiation, and conventional electric heaters. Compare their heating mechanisms, heat transfer modes, moisture removal characteristics, and practical applications.
2. Explain the mechanisms of energy absorption of electromagnetic waves in materials, in the following order: ultraviolet (UV), visible light, infrared (IR), and microwave radiation. Discuss how wavelength and frequency influence the interaction between radiation and biological materials.
3. Based on a literature review, select one drying system used for each of the following categories: Fruits Medicinal herbs Cereal grains. For each case, describe the dryer type, operating principle, heat source, and key drying performance characteristics reported in the research.

04

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