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 1 – Importance and Theory of Drying

Study Questions – Lecture 1

1. *Why do agricultural materials dry?*
2. *How are natural drying and artificial drying different in terms of process and control?*
3. *How is the moisture content of agricultural materials determined?*

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Lecture 1 – Importance and Theory of Drying

Outline – Lecture 1

1. *Importance of Drying*
2. *Theory of Drying (Natural Drying & Artificial Drying)*
3. *Moisture Content of Agricultural Materials*
4. *Methods for Determining the Moisture Content in Agricultural Products*

Why is Drying Important for Agricultural Products?

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- ✓ Reduces the moisture content to prevent microbial growth and spoilage
- ✓ Extends shelf life and preserves product quality during storage and transportation
- ✓ Minimizes postharvest losses and stabilizes market supply
- ✓ Reduces weight and volume, lowering packaging and shipping costs
- ✓ Enhances value addition and prepares products for further processing

How Does Drying Contribute to Agricultural Efficiency and Economy?

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- ✓ Increases the availability of high-quality raw materials for food and feed industries
- ✓ Enables farmers to store and market products at the best price
- ✓ Improves utilization of agricultural by-products such as rice husk, corn cobs, and bagasse as drying fuels
- ✓ Reduces dependence on imported energy by promoting local renewable sources

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What Factors Influence the Drying Process?

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- ✓ Type of drying energy: solar, hot air, biomass, or electrical power
- ✓ Efficiency of heat and mass transfer during drying
- ✓ Control of drying temperature, airflow, and humidity
- ✓ Drying time and operating costs
- ✓ Technological development toward sustainable and energy-efficient drying systems

Theory of Drying

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Drying (or dehydration) is a process in which water is removed from a material until the moisture content is reduced to a level that either prevents or slows down the growth of microorganisms and chemical reactions.

References: Vega-Mercado et al., 2001, p. 271

Drying is generally classified into two main types:

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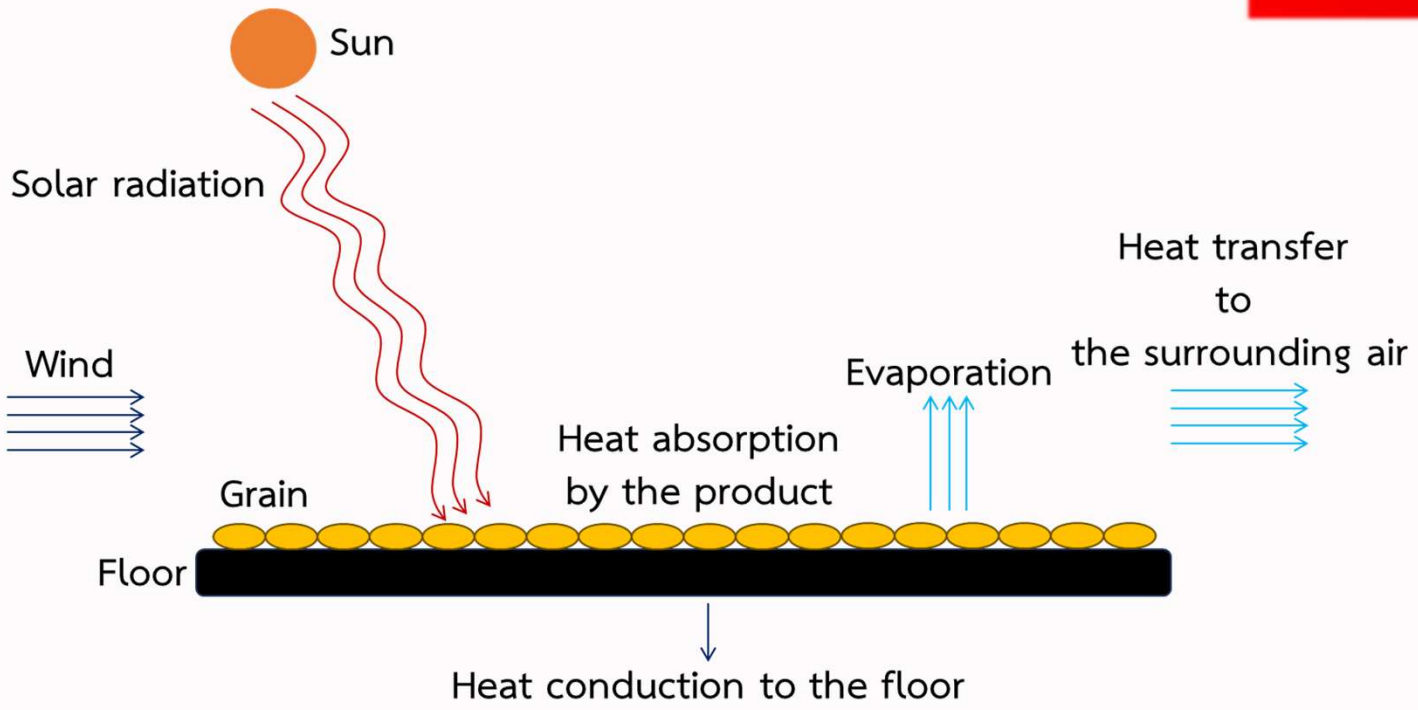
*1. **Natural drying***, which relies on sunlight and ambient air

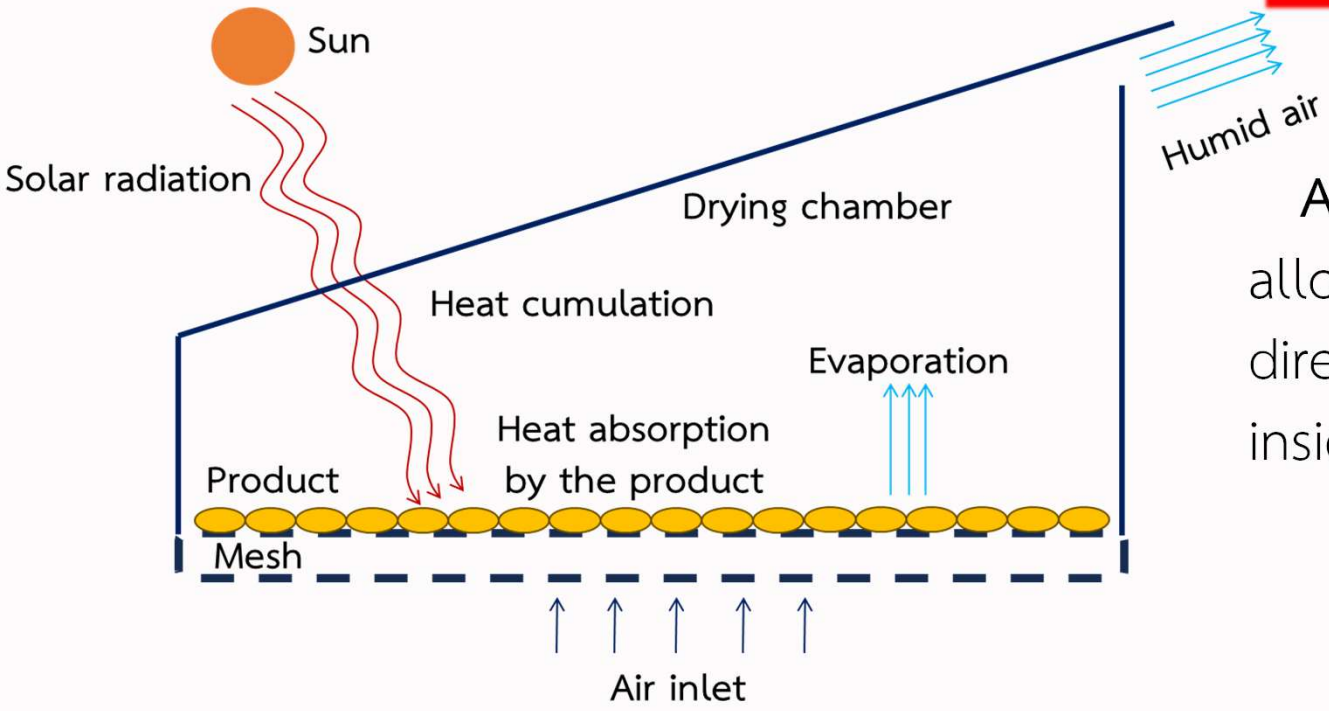
*2. **Artificial drying***, which uses mechanical or controlled systems to supply heat and airflow

Natural Drying



References: Original illustration by Assistant Professor Dr. Chukiat Chotikasatian

Artificial Drying



A direct-type solar dryer allows solar radiation to directly heat the product inside the drying chamber

References: Original illustration by Assistant Professor Dr. Chukiat Chotikasatian

Artificial Drying

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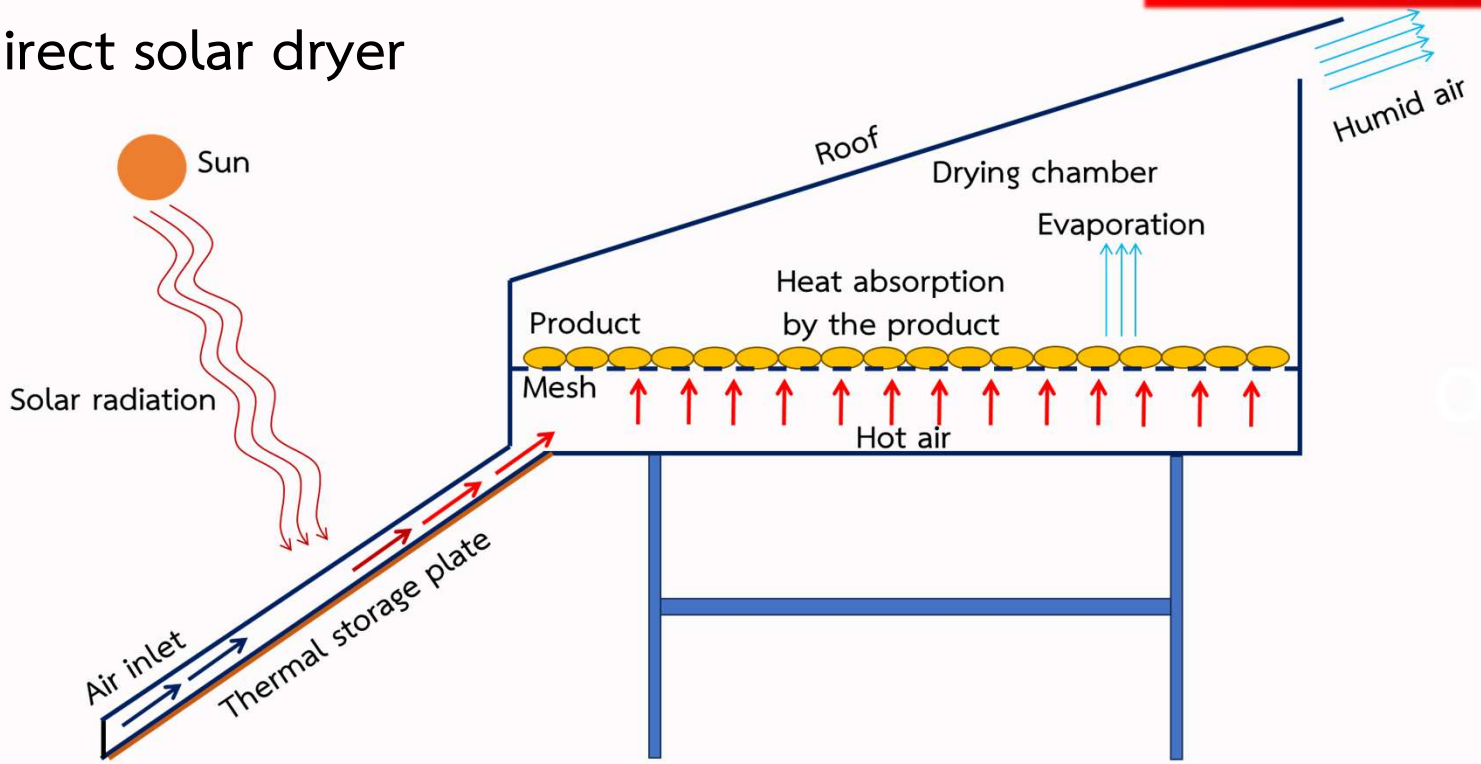
Indirect solar dryer



References: Original illustration by
Assistant Professor Dr. Chukiat Chotikasatian

Artificial Drying

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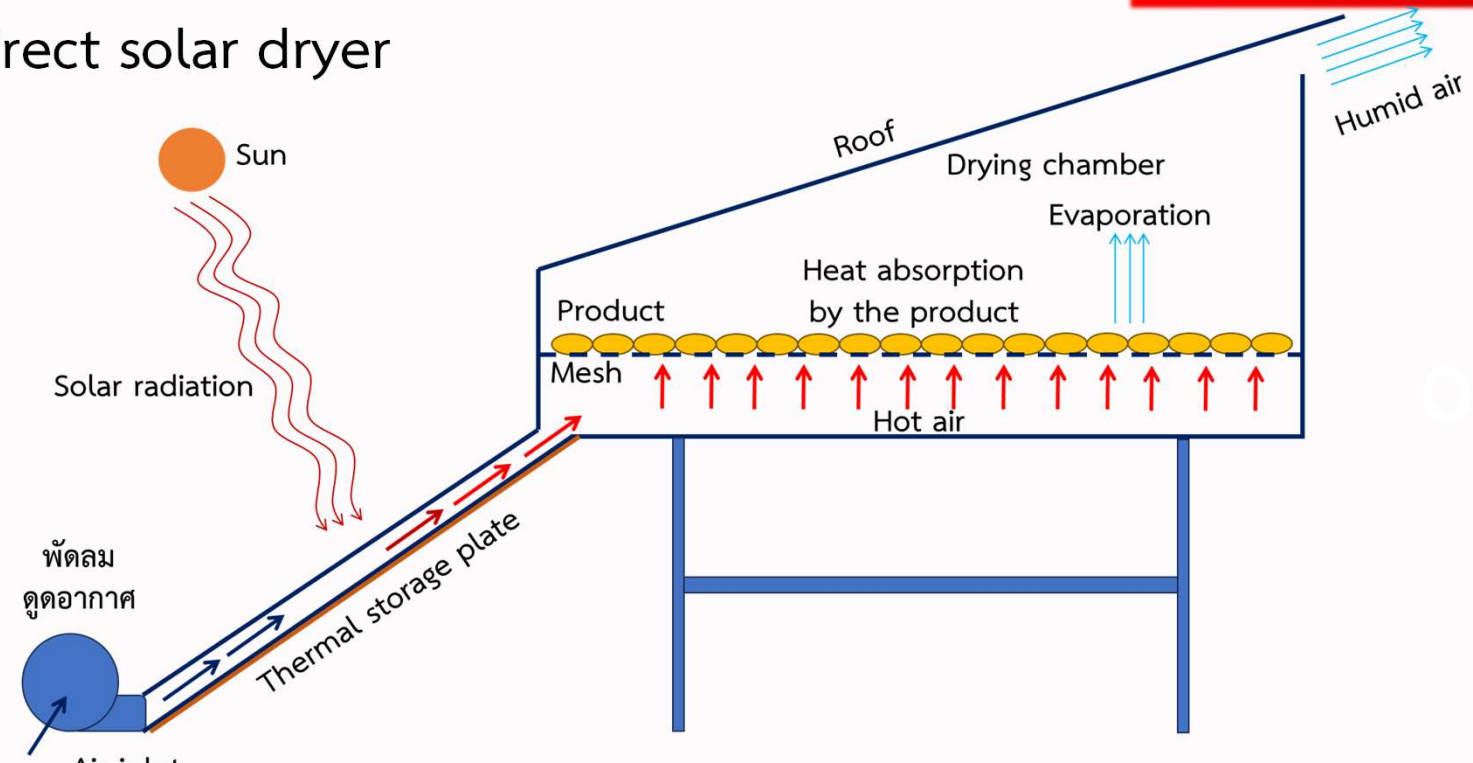
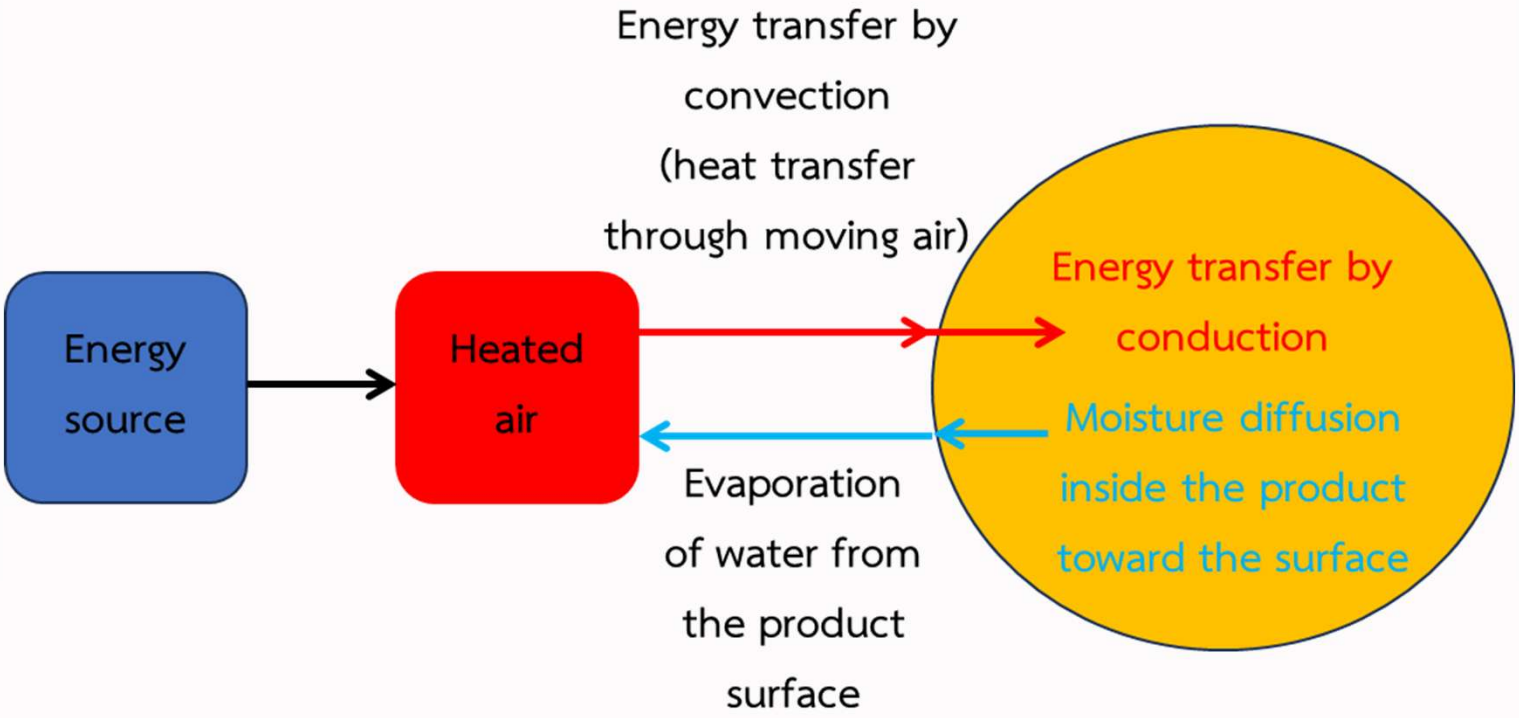
Indirect solar dryer



References: Original illustration by
Assistant Professor Dr. Chukiat Chotikasatian

Heat and Mass Transfer Mechanisms in Drying



References: adapted from Wadsworth et al. (1990, p.199)

Moisture Content (*MC*)

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Classified into two types:

1. The moisture content on **a wet basis ($MC_{w.b.}$)**

The ratio of the mass of water contained in the material to the total mass of the material

2. The moisture content on **a dry basis ($MC_{d.b.}$)**

The ratio of the mass of water in the material to the dry mass of the material

References: ASABE, 1999, p.512

Equations Related to the Moisture Content in Agricultural Products

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$$MC_{w.b.} = \frac{G_w - G_d}{G_w} \times 100\%$$

$$MC_{d.b.} = \frac{G_w - G_d}{G_d} \times 100\%$$

$$MC_{w.b.} = \frac{MC_{d.b.} \times 100\%}{100 + MC_{d.b.}}$$

$$MC_{d.b.} = \frac{MC_{w.b.} \times 100\%}{100 - MC_{w.b.}}$$

$$G_w = \frac{G_d \times 100\%}{100 - MC_{w.b.}}$$

$$G_d = \frac{G_w \times 100\%}{100 + MC_{d.b.}}$$

when

G_w represents the total mass of the material (g)

G_d denotes its dry mass (g)

Note: the dry mass remains constant throughout the drying process.

References: ASABE, 1999, p.512

Example 1

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A farmer harvested paddy rice from the field with a **moisture content of 28%$_{w.b.}$** and **a total weight of 2,300 kg**. Before selling it to the rice mill, the farmer must dry the paddy to reduce its moisture content to 12.5%$_{w.b.}$. Determine the final weight of the paddy received by the rice mill after drying.

Concept: To find the dry mass of paddy (G_d),

Let $MC_{w.b.} = 28\%_{w.b.}$ and $G_W = 2{,}300\ kg$

$$MC_{w.b.} = \frac{G_w - G_d}{G_w} \times 100\%$$

$$28\% = \frac{2{,}300 - G_d}{2{,}300} \times 100\%$$

$$G_d = 2{,}300 - \frac{28\% \times 2{,}300}{100\%} = 1{,}656\ kg$$

Example 1 (Cont.)

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A farmer harvested paddy rice from the field with a moisture content of 28%$_{w.b.}$ and a total weight of 2,300 kg. Before selling it to the rice mill, the farmer must dry the paddy to reduce its **moisture content to 12.5%$_{w.b.}$. Determine the final weight of the paddy received by the rice mill after drying.**

Thus, the dry mass of paddy (G_d) is 1,656 kg.

To find G_w that $MC_{w.b.}$ = 12.5%$_{w.b.}$ and solve.

$$G_w = \frac{G_d \times 100\%}{100 - MC_{w.b.}}$$

$$G_w = \frac{1{,}656 \times 100\%}{(100 - 12.5)\%} = 1{,}892.57 \ kg$$

The weight of paddy at 12.5%$_{w.b.}$ is 1,892.57 kg.

Example 2

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A student needs to conduct a research requiring a total amount of 5,200 kg of corn with **a moisture content of 11.5%$_{d.b.}$**. However, when measuring the corn moisture content in the farmer's field, it was found to be 24%$_{w.b.}$. Determine how many kilograms of corn the student must purchase from the farmer to obtain the equivalent amount required for the research.

<u>Concept:</u> For the $MC_{d.b.}$ = 11.5%$_{d.b.}$, the moisture content in terms of $MC_{w.b.}$ can be calculated using the following equation:

$$MC_{w.b.} = \frac{MC_{d.b.} \times 100\%}{100 + MC_{d.b.}}$$

$$MC_{w.b.} = \frac{11.5\% \times 100\%}{(100 + 11.5)\%} = 10.31\%_{w.b.}$$

Example 2 (Cont.)

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A student needs to conduct a research requiring **a total amount of 5,200 kg of corn** with a moisture content of 11.5%$_{d.b.}$. However, when measuring the corn moisture content in the farmer's field, it was found to be 24%$_{w.b.}$. Determine how many kilograms of corn the student must purchase from the farmer to obtain the equivalent amount required for the research.

Concept: From G_w = 5,200 kg, the weight of water contained in the corn can be calculated as $(G_{water}) = G_w - G_d$, and with $MC_{w.b.}$ **= 10.31%$_{w.b.}$**, the values are substituted into the below equation.

$$MC_{w.b.} = \frac{G_w - G_d}{G_w} \times 100\%$$

$$10.31\% = \frac{G_{water}}{5,200} \times 100\%$$

$$G_{water} = \frac{10.31\% \times 5,200}{100\%} = 536.12 \ kg$$

Example 2 (Cont.)

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Therefore, the weight of water contained in the corn is calculated as: $(G_{water}) = G_w - G_d$

$$G_d = 5{,}200 - 536.12 = 4{,}663.88 \text{ kg}$$

The dry weight of corn required for the research is **4,663.88 kilograms**

The problem states that "However, when measuring the corn moisture content in the farmer's field, it was found to be $24\%_{w.b.}$".

Let's convert the moisture content into $\%_{d.b.}$ using the following equation:

$$MC_{d.b.} = \frac{MC_{w.b.} \times 100\%}{100 - MC_{w.b.}} \qquad MC_{d.b.} = \frac{24\% \times 100\%}{(100 - 24)\%} = 31.58\%_{d.b.}$$

Example 2 (Cont.)

At the moisture content of 31.58%$_{d.b.}$ and the **dry weight of corn of 4,663.88 kg**, the weight of water contained in the corn can be calculated using the equation shown below.

$$MC_{d.b.} = \frac{G_w - G_d}{G_d} \times 100\%$$

$$31.58\% = \frac{G_w - G_d}{4,663.88} \times 100\%$$

$$G_w - G_d = \frac{31.58\% \times 4,663.88}{100\%} = 1,472.85 \ kg$$

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Total corn required for the research:

$$(G_{water}) = G_w - G_d$$

$$1,472.85 = G_w - 4,663.8$$

$$G_w = 4,663.88 + 1,472.85 = \underline{\mathbf{6,136.73\ kg}}$$

The MC measurements can be performed using two general approaches:

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Direct measurement methods

American Society of Agricultural and Biological Engineering **(ASABE)** Standard

Association of Official Analytical Chemists **(AOAC)** Standard

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Indirect measurement methods

Resistance method

Relative humidity method

American Society of Agricultural and Biological Engineering (ASABE) Standard

Grain	Oven temperature (±1°C)	Heating Time		Sample Size (g)	The Number of Sample
		h	min		
Beans	103	72	0	15	1
Carrot	100	1	40	10	2
Corn	103	72	0	15 or 100*	1, 3
Oats	130	22	0	10	2
Onion	130	0	50	10	2
Rye	130	16	0	10	2
Sunflower	130	3	0	10	3
Wheat	130	19	0	10	2

Note: use 100 g is moisture exceeds 25%

References: adapted from ASABE, 2012, p.1

Resistance Method

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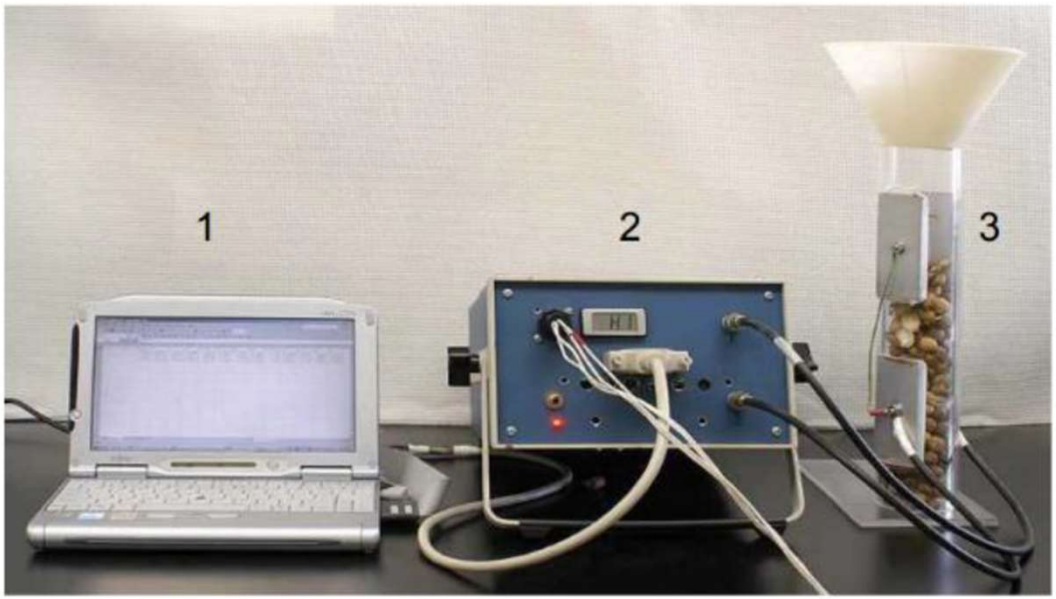

Measuring system: 1. Computer, 2. Impedance meter, 3. Cylindrical tube with sensors

References: Kandala & Butts, 2007, p.5

Relative Humidity Method

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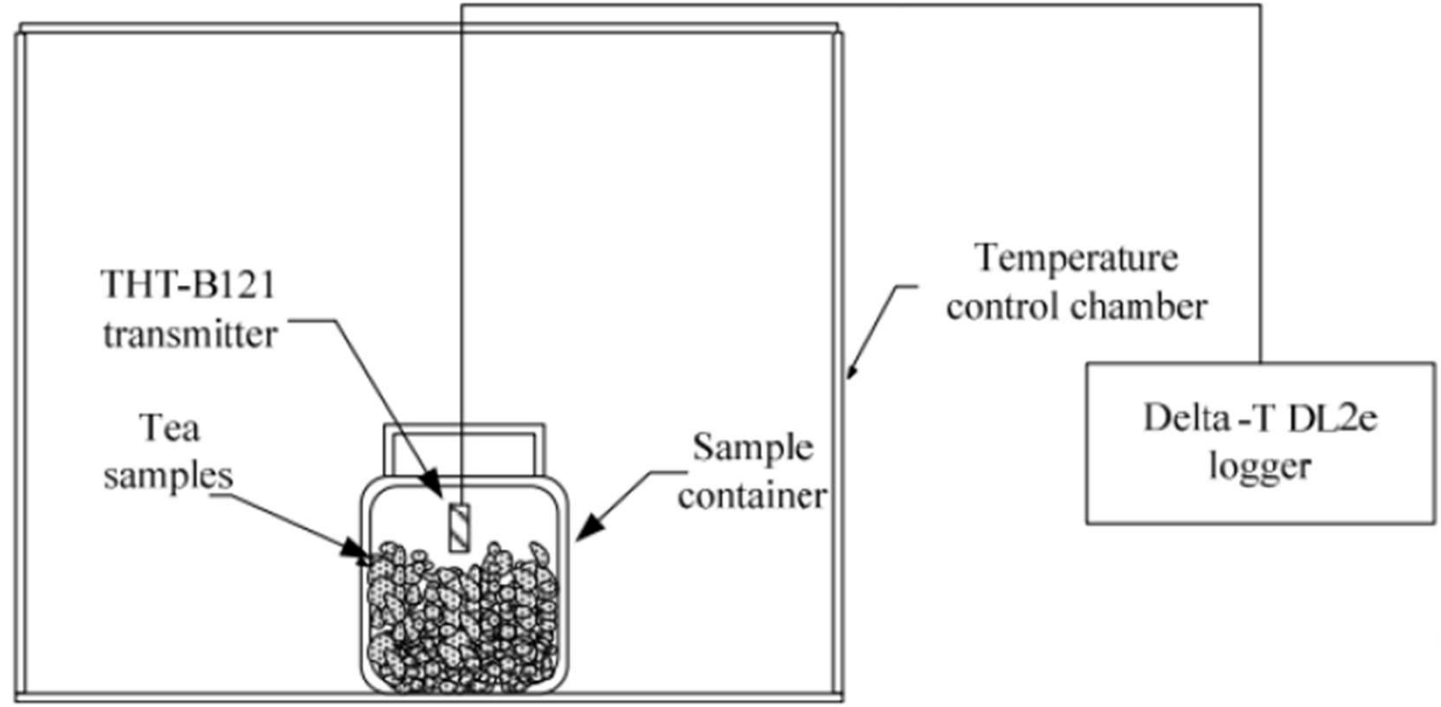

References: Chen et al., 2014, p.11,597

Example 3

Based on the data in the ASABE standard's table (**slide 24**), a farmer wants to measure the moisture content of corn in the field according to the ASABE Standard after harvesting, without any preliminary drying. The sample weight obtained after testing according to the standard is 65 g. Determine the moisture content of the corn in the field.

It can be observed that the corn in the field before drying likely had a high moisture content, which is expected to **be greater than 25%**.

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Grain	Oven temperature (±1°C)	Heating Time		Sample Size (g)	The Number of Sample
		h	min		
Corn	103	72	0	15 or 100*	1, 3

Note: use 100 g is moisture exceeds 25%

$$MC_{w.b.} = \frac{G_w - G_d}{G_w} \times 100\%$$

$$MC_{d.b.} = \frac{G_w - G_d}{G_d} \times 100\%$$

Example 3 (Cont.)

$$MC_{w.b.} = \frac{G_w - G_d}{G_w} \times 100\% = \frac{100 - 65}{100} \times 100\% = 35\%_{w.b.}$$

$$MC_{d.b.} = \frac{G_w - G_d}{G_d} \times 100\% = \frac{100 - 65}{65} \times 100\% = 53.85\%_{d.b.}$$

From the calculation results, it can be concluded that

the moisture content of the corn in the field was 35%$_{w.b.}$ or 53.85%$_{d.b.}$

Summary

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1. The total weight of agricultural materials consists of dry matter and water content.

2. This lesson introduced the methods for determining moisture content and explained both wet basis and dry basis calculations.

3. The next lesson will discuss these two moisture content bases in more detail to strengthen students' understanding of moisture calculations and the importance of drying in agricultural products.

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Thank you very much for your kind attention.

Questions?

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Study Questions – Lecture 1

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1. *Why do agricultural materials dry?*

2. *How are natural drying and artificial drying different in terms of process and control?*

3. *How is the moisture content of agricultural materials determined?*

Assignment – Lecture 1

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1. A batch of 150 kg of red chili peppers with an initial moisture content of 75% dry basis ($\%_{d.b.}$) is to be dried in a hot-air dryer until the final moisture content is reduced to $8\%_{d.b.}$. Determine the amount of water removed from the product during the drying process.

2. The moisture content of bananas is initially 55% wet basis ($\%_{w.b.}$). The farmer dries the bananas using sun drying until the final moisture content is reduced to $10\%_{w.b.}$. Determine the amount of water removed during the drying process.

3. A farmer has 200 kg of soybeans with a moisture content of $13\%_{d.b.}$ stored in sacks. These are mixed with another 1,700 kg of soybeans having a moisture content of $13\%_{w.b.}$. The combined soybeans are then dried until the final moisture content is reduced to $11\%_{d.b.}$. Determine the total weight of soybeans after drying.

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References

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Vega-Mercado, H., Marcela Góngora-Nieto, M. & Barbosa-Cánovas, G. V. (2001). "Advances in dehydration of foods." **Journal of Food Engineering**, 49 (4), 271-289.

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