Comparison of Sun Drying - Solar Dryer and Cabinet Tray Dryer

Prof. Dr.-Ing. Dr. h.c. Werner Mühlbauer
Silpakorn University, March 5, 2018

Frame Conditions

Before introducing a solar dryer it should be carefully analyzed if there is a market for the dried product.

- Which are the basic requirements in terms of **quantity** and quality?
- How much is the prize per kg of dried material
- Do the farmers get a higher price for a better quality?
- How much are the total cost for drying per kg of dry material?
- Are there any alternatives? Fresh marketing, use of tray dryer?

It is easy to produce a product but it is much more difficult to sell the product for a good price

Evaluation Criteria

- Investment for dryer and equipment
- Drying capacity
- Quality of the dried product
- **Energy requirement and energy cost**
- Labour requirement and labour cost
- Drying cost per unit
- **Availability of a market for the dried product**

1. Investment

Evaluation Criteria:

Specific investment based on the drying capacity in kg dry material per day or per year

Sun Drying

Mats – foils – trays with substructure – (concrete floor)

Lowest investment of all competing drying system

Solar Dryer

Concrete platform – greenhouse dryer with fans – trays with substructure – (supplementary heater with air distribution system)

Tray Dryer

Cabinet dryer with trays – additional trolly with trays - fan – gas or electric heater
Investment for the building which is required for installation of the dryer

2. Drying Capacity

How many kg of wet material can you dry per day or per year?
How many kg of dry material can you produce?

Drying time

How long does it take to dry the product to a **moisture content** which is **safe** for storage

Sun Drying

(Drying area in m^2 x loading density kg/m^2) : drying time in days = drying capacity per day

Drying capacity depends on unpredictable weather conditions
Drying air temperature depends on ambient temperature and solar radiation
Drying process is interrupted during night and **rainy weather**

Solar Dryer

(Drying area in m^2 x areal density kg/m^2) : drying time in days

Drying rate is higher compared to sun drying due to higher drying air temperature
Drying air temperature depends on fluctuating solar radiation
Drying process is reduced during night and adverse weather
With supplementary heater continuous dryingg is possible even during rainy season

Tray Dryer

(Loading capacity wet material – water removed) in kg x batches per day = capacity **per day** in kg dry material

Dryer can be operated continuously independent of the weather conditions
Drying air temperature is constant
Number of batches per day depend on availability of labour
In general during night time the dryer will not be unloaded or loaded

Drying capacity depends on the loading capacity per batch and the number of batches dried per day

3. Water Removal

How many kg of water were removed during the drying process

Water to be removed m_W:

$m_W = m_0 - m_1$

Mass of wet material m_0 and
Mass of dried material m_1

have to be determined by weighing the product with balance

In general initial moisture content only can be determined in the Lab. During transportation to the lab the product can spoil and this influences the moisture content

If you know the final moisture content, the mass of wet and the mass of dry material you can calculate the initial moisture content as follows:

$$m_w = m_0 \frac{MC_{wb0} - MC_{wb1}}{100 - MC_{wb1}}$$

Initial moisture content MC_0
Final moisture content MC_1

MC_0 = ……………..

Final moisture content can be determined by taken a sample, put it in vapour proof plastic bag and determine the moisture content in the Lab

4. Energy Requirement

Evaluation Criteria

- **Energy Consumption**

Electricity:

Total electricity consumption for fan and (heater) E in kWh per batch

Thermal Energy Consumption

LPG consumption per batch in kg LPG

Calorific value H of LPG: 42 500 kJ/kg gas = 11.8 kWh / kg gas

Conversion rate 1 kWh = 3600 kJ

Specific Energy Consumption

For comparison of different drying systems specific values are used

Specific thermal energy to remove 1 kg of water expressed in kJ/kg or kWh/kg

$q = Q : m_W$

Specific electrical energy to remove 1 kg of water expressed in kWh/kg

$e = E : m_W$

Evaluation Criteria for the energy consumption

Thermal energy

4000 kJ/kg or 1.1 kWh/kg	very good
6000 kJ/kg or 1.6 kWh/kg	acceptable
8000 kJ/kg or 2.1 kWh/kg	very high

Figures can be used to evaluate the thermal efficiency of a tray dryer

Tray dryer:

Precoppe: 6720 kJ/kg = 1.86 kWh/kg for a tray dryer, capacity 140 kg, litchi

Electric energy consumption

Electric energy consumption for operating the fans in a solar dryer is negligibly.

Tray Dryer:

Precoppe: 0.1 kWh/kg

Solar Dryer

During dry season supplementary heater is not required -> specific thermal energy consumption is zero

If supplementary heater is used during rainy season the specific thermal energy consumption has to be calculated as follows:

Total mass of water removed **per year** m_W
Mass of LPG used during rainy season m_G
Thermal energy consumption: $Q = m_G$ in kg x H in kJ/kg = ….. kJ

Specific thermal energy consumption q

$q = (m_G \times H) : m_W$

5. Energy Cost

Evaluation Criteria

Specific Energy Cost

Price per kJ or kWh is different for the energy sources

Thermal Energy from LPG

Calorific value H for LPG = 42 500 kJ/kg
Prize per kg LPG = 25 Baht/kg

Specific energy cost for LPG -> efficiency 100 %

42 500 kJ/kg : 25 Baht = 1700 kJ/kg per Baht = 1700 kJ/kg/Baht : 3600 KJ/kWh / Baht = 0.5 kWh per Baht

Thermal Energy from Electricity

1 kWh = 4 Baht

Thermal energy cost produced from electricity is 8 times more compared to use of gas

- ➔ **Tray dryers should be operated with LPG instead of electricity**

Energy Savings from Solar Drying (per year)

Sun Drying

neither fossil fuels nor electricity are required -> energy saving are zero

Solar Dryer

Solar Drying without supplementary heater

If the dryer is operated without a supplementary heater the LPG/Electricity savings can be calculated as follows

Drying capacity of the solar dryer per year ….. tons

How many tray dryers do you need for drying the same amount taking into consideration that tray dryer cannot be operated continuously?

Energy cost savings: How many kg of LPG/kWh electricity) do you need to dry … tons in the tray dryers

The farmer is not interested in saving energy he is only interested to reduce his energy bill

Solar Drying with supplementary heater

The dryer is operated during rainy season with supplementary heater

Energy cost savings:

Energy cost for operating the tray dryer (LPG; electricity) – Energy cost for operating the supplementary heater of the solar dryer (LPG)