Drying of herbs and spices

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Outline

- General aims and challenges of dehydration
- Quality parameters for dried herbs
- Aims in herb drying
- Influencing factors on herb quality
- Further influencing factors

Learning Outcomes

This module should give the user a deeper understanding of the **drying process of herbs** and highlights the **influencing factors** on high **product quality** and **efficient processing**

General aims of dehydration

- **Reduction** of moisture content
- **Reduction** of chemical and biological activity
- **Shelf life** extension
- **Prevention** of dry matter losses
- **Easy and cheap** handling of products
- **Maintain** nutritional, biological and technical properties of the product

⇨ Dehydration of food is responsible for **15-25 %** of the industrial energy consumption at **low energy efficiencies** (35-45%) and often unsatisfactory product quality

Excursion moisture content

Wet basis moisture content (MC_{wb}, also known as W) is most common for farmers and producers and is defined as:

$$MC_{wb} = \frac{\text{weight of water}}{\text{weight of dry matter} + \text{weight of water}} \cdot 100$$

Herbs and spices are stable at **10 %** MC_{wb}

Excursion: Moisture content

Dry basis moisture content (MC_{db}, also known as X) is most common for scientists and is defined as

$$MC_{db} = \frac{\text{weight of water}}{\text{weight of dry matter}} \cdot 100$$

It is converted as follows:

$$MC_{wb} = \frac{MC_{db}}{100 + MC_{db}} \cdot 100 \quad \text{or} \quad MC_{db} = \frac{MC_{wb}}{100 - MC_{wb}} \cdot 100$$

Challenges during the drying process

⇨ Vitamin degradation

- Most of the vitamins are not stable heat stable or are reduced by enzymatic oxidation

⇨ Changes in structure, texture, colour, flavour, taste

- Protein denaturation
- Protein/Lipid oxidation
- Loss of essential oils

⇨ Often not fully reconstitutionable

- Complete rehumidification is not possible; less water than being lost during drying can be absorbed

Challenges in industrial drying

Initial Situation (Mujumdar, 2007)

- ⇨ Out of date technical devices
- ⇨ Unnecessarily long drying times
- ⇨ Increased energy demand
- ⇨ Dependency on oil and gas prices
- ⇨ Need of customisation
- ⇨ Product temperature usually is unknown

Goals

- ⇨ Targeted control of process
- ⇨ Technically easily implementable solutions (upgrade of devices)
- ⇨ Increased capacity or smaller devices
- ⇨ Flexibility in production
- ⇨ Reduction of energy costs and demands

Scientific approaches

Process Analysis and Optimisation

⇨ Thermodynamics
⇨ Product quality
⇨ Unit operation or part of whole process

Process Control (air temperature, velocity and rel. humidity)

⇨ Single stage
⇨ Multi stage, time controlled (Chua et al., 2000)
⇨ Multi stage, based on optical analysis (Martynenko, 2008)

- Measured values have to be used to feedback to the system, e.g. adaption of process parameters

  ⇨ At every point of the drying process, the relation between **air temperature**, **velocity** and **relative** humidity should be balanced

Quality parameters for dried herbs

⇨ What does quality mean?

- **It defines the degree of convergence between expectation to/ requirement of a product and its actual characteristics**
  - Product quality
  - Process quality
  - Consumers (retailers) oriented quality

The quality of herbs is defined by

- Colour (appearance)
- Amount of essential oils/aroma (smell, taste, nutritional value)
- Nutritional value (vitamins etc.)
- Secondary plant components (nutritional value)
- Structure (appearance)

  It is not avoidable to influence the parameters negatively during the dehydration process due to oxidation and evaporation, but changes can be reduced to a minimum

  ⇨ drying **cannot** improve the quality of the raw material!

- Microbial infestation (mould, yeasts, bacterial pathogens)

  ⇨ **cannot** be decreased by drying, but growing can be inhibited

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Phases of herb drying

- Phase I (only for rain-wet raw material)
  - Evaporation on the surface
  - Constant drying rate
- Phase II
  - Evaporation from interior of products and diffusion through already dried layers
  - Increasing temperature inside the product
  - Declining drying rate
- Phase III
  - Further evaporation of physicochemical bound water until moisture equilibrium is reached

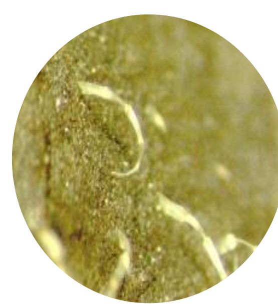
Aims in herb drying

⇨ The dehydration process for herbs should be as short as possible

- **Long drying times decrease product quality** due to chemical and physical changes
- Achievable through **product oriented drying processes** and **control** of drying parameters
- **Avoidance of over drying**
  - and therefore loss of valuable compounds, colour etc.
  - Drying process should be stopped when the final moisture content is reached, **not** after a certain time!
- **High energy saving potential ⇨ reduction of processing costs**

optimum drying

vs.



non-optimum drying

Images: Cuervo-Andrade, 2011

Aims in herb drying

The drying process aims to dry the product surface as quick as possible

to avoid:

- **Microbial growth** (which needs moist and temperature +/- 37°C)
- **Degradation processes** of color and valuable components due to oxidation

The air velocity needs to be sufficient (at least 0.12 m/s) to achieve a sufficient relative air mass flow

- **Too high ->** unsaturated air, inefficient
- **Too low ->** saturated air, moisture remains on the product surface, inefficient, longer drying times
- **Risk of moisture accumulation** due to inequal drying

Especially in low temperature drying the air velocity is the most important drying parameter!

Influencing factors on quality

- Pre drying

  Initial moisture content

  - Conditions during harvesting

  Time between harvest and processing

  - Degradation during storage through self-heating, enzymes, etc.

  Microbial infestation

- During drying

  Air temperature

  - Significant impact on product temperature

    Losses of valuable components

  Relative humidity inside the dryer

  Air flow (risk of recirculation ⇨ pathogen accumulation)

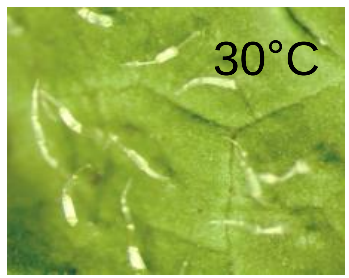
  Bulk (weight/height)

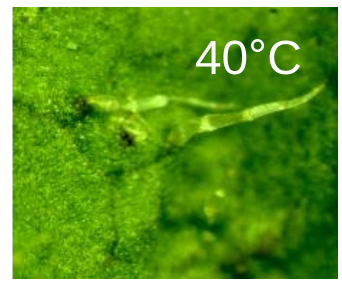
Influencing factors on quality

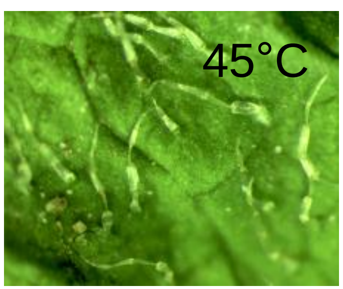
- Quality losses during drying **cannot** be compensated in further processing steps!
  - The **whole processing chain** needs to be excellent!
- The drying process (duration, process parameters) depends on the raw material
  - Each drying process is individual and should be controlled dependent on the raw material quality and loading capacity

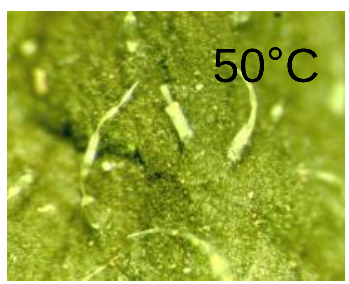
- Targeted short drying times risk the application of too high drying temperatures
  - Porous surfaces and cell damages of the final product, degradation processes

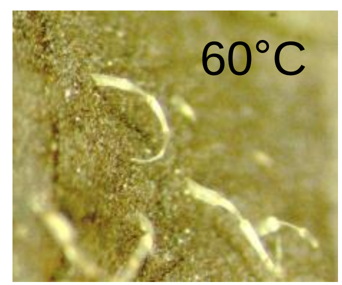
Quality losses!!











Images: Cuervo-Andrade, 2011

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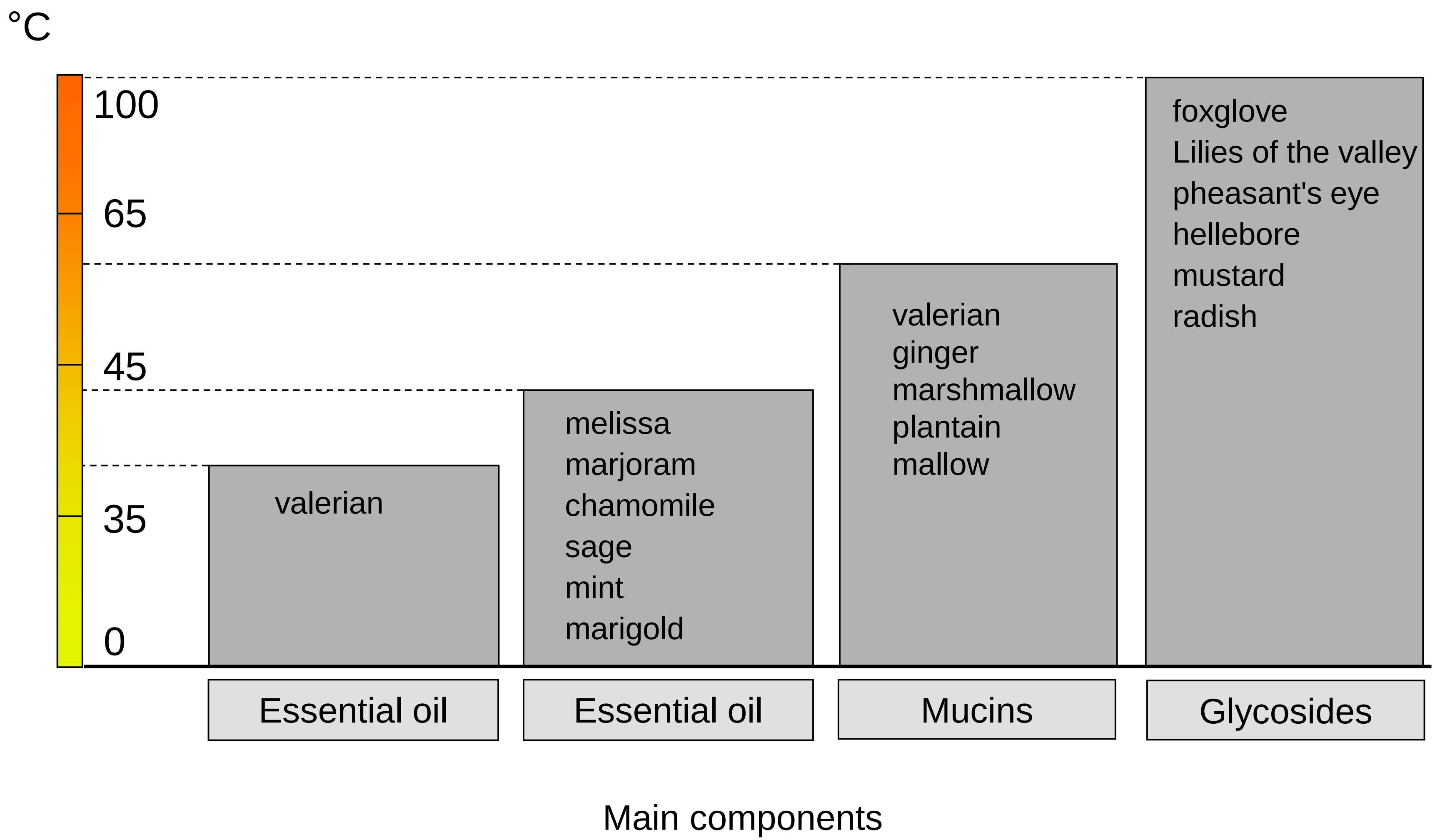
Critical temperatures



Cuervo-Andrade, n.d.

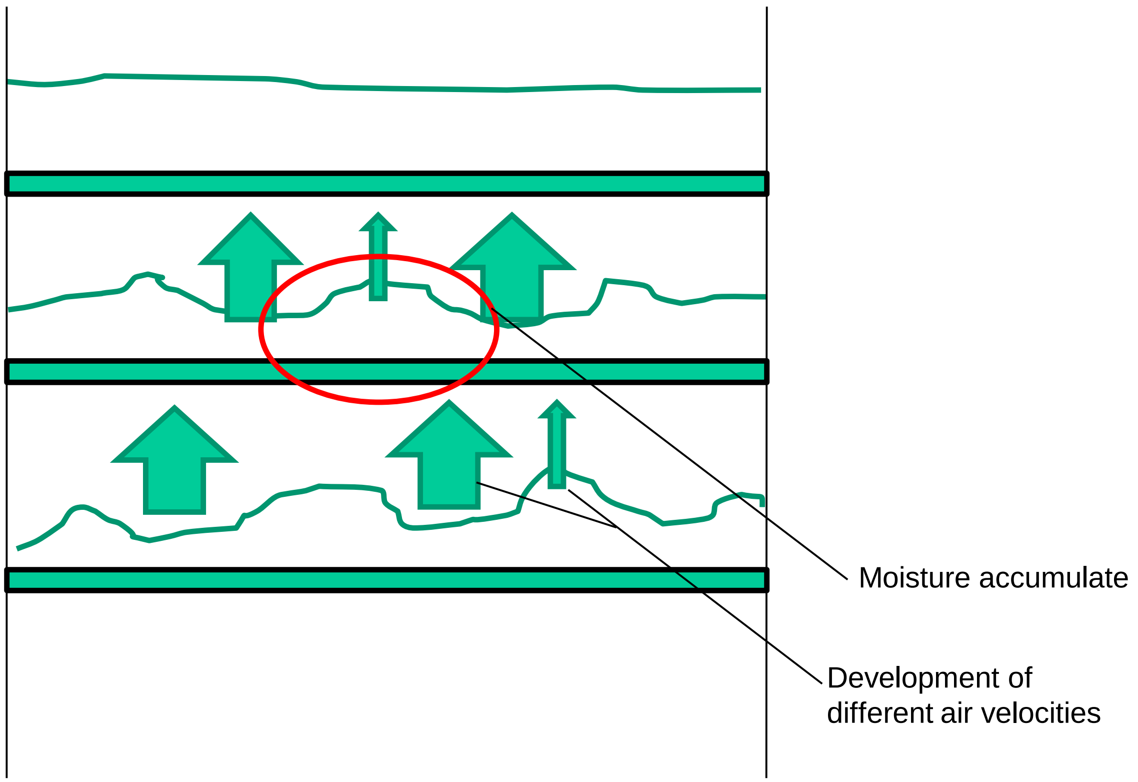
Further influencing parameters

- Bulk: **bulk weight** is a more appropriate indicator than bulk height, as the bulk height neglects
  - The initial moisture content of the raw product
  - The particle size (volume)

  Changes in air distribution throughout the bulk!

- Air distribution
  - Unequal air distribution results in unequal drying of the bulk
  - Can be improved by small changes of the dryer construction
  - Can be improved by implementation of appropriate fans

Keyword: Moisture accumulates



Air always goes the path of least resistance, which leads to moisture accumulation ⇨ non-uniform air distribution

Keyword: Moisture accumulates

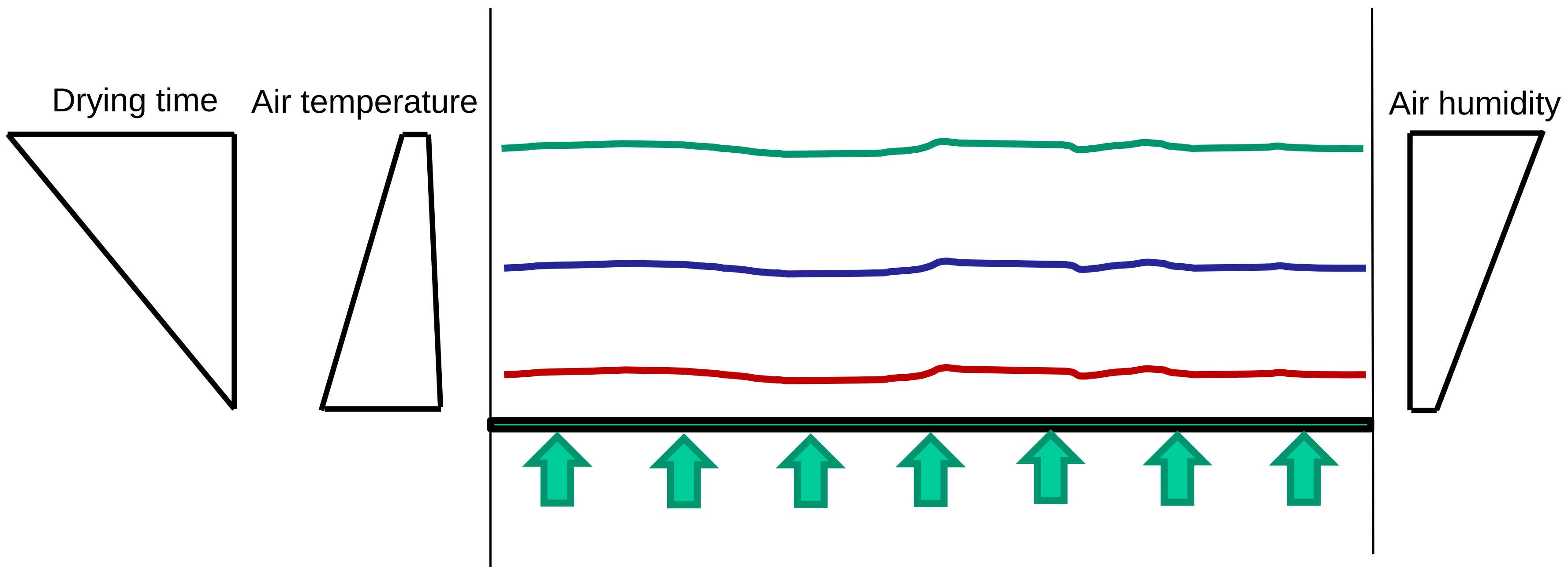
Non-uniform air distribution is produced by

- Too high bulks
  - ⇨ **Solution: The lower the bulk, the lower the compaction (related to volume reduction), the less air ducts⇨ the better the air flow**

- increasing air velocities as the air resistance decreases during drying
  - ⇨ **The air velocity needs to be adapted during the process**

A continuous through flow of the drying air has to be enabled during the whole drying process!

Effect on bulk height on air velocity and distribution



The heigher the bulk, the more the velocity decreases throughout the bulk, the more uneven the distribution!

Valuable parts of the plant

leaves	bark
whole plant	fruits
seeds	stem
blossoms	roots

Risk for drying of whole plants: Overdrying or inadequate drying of different parts (indifferent drying behaviour)

Energy consumption in herb drying

- Energy consumption of ca. 2000 kJ/kg dried herbs is possible!

However:

- Measured consumption on farm:
  - 8500 kJ/kg (Tray dryer)
  - 5000-6000 kJ/kg (belt dryer)
  - Worst measurement **20000 kJ/kg!!**

Improvements in herb drying

- Product specific drying
  - Whole plant/parts
  - Knowledge of valuable components
  - Adapted bulk weights
- Control of air velocity
  - Moisture removal ⇨ rel. air humidity ≤ 70% above the bulk
  - Equal air distribution, availability of enough air
- Product temperature controlled drying

  Phase drying: higher temperatures in the beginning until the surface is dry, further drying at quality saving temperatures
  - Quality parameters have to be defined
  - Critical temperature has to be known

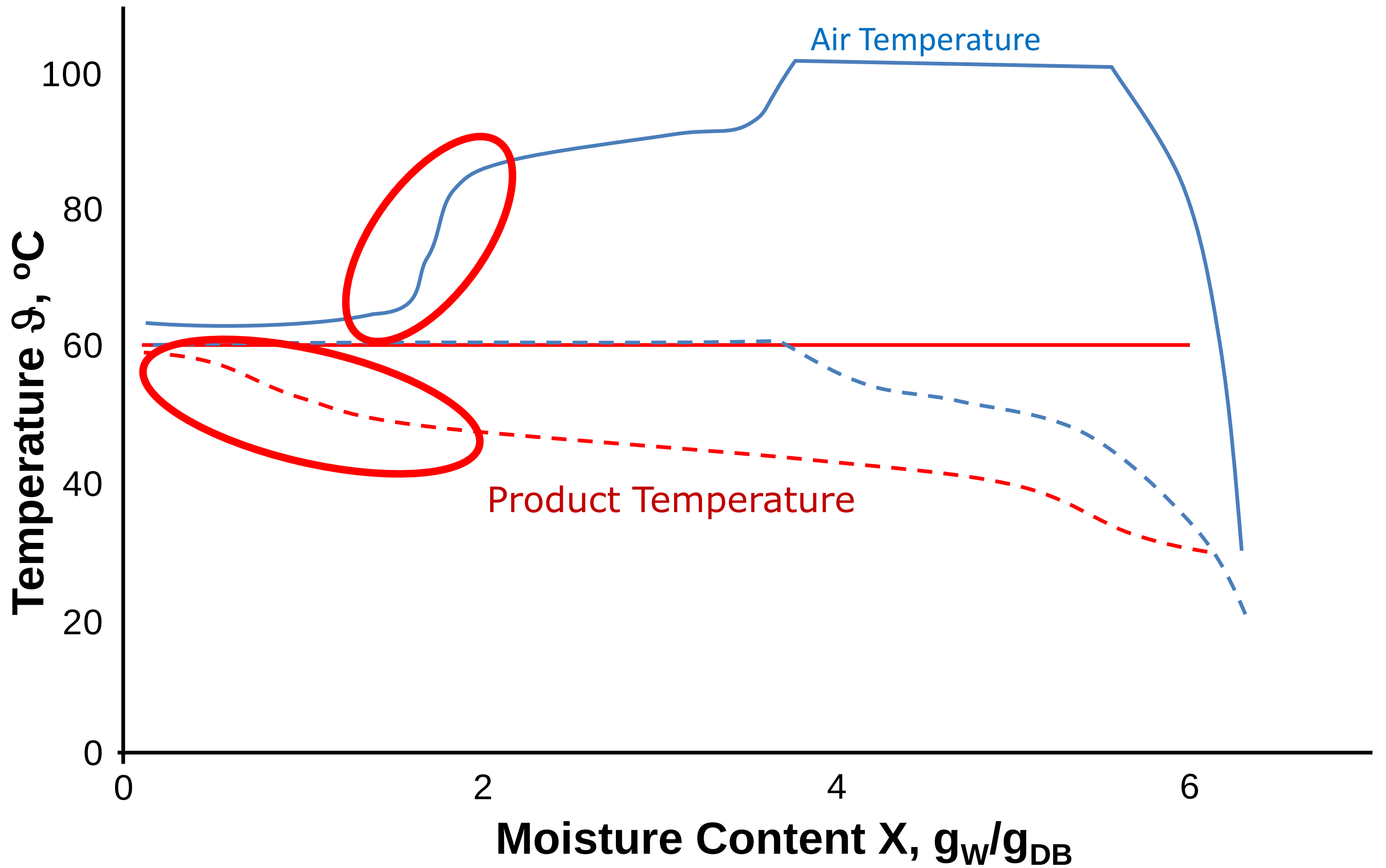
⇨ **decreased drying times, high product quality**

Comparison of air temperature (T_A) and product temperature (T_P) controlled drying

Air Temperature **Product Temperature**

Source: Krischer & Kast, 1978

Temperatures as Functions of Moisture Content



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Cost effective devices for product surface temperature measurement

- **Pyrometer**
- **Infrared (IR) camera**

  - Data can feed back into the system

    Product Temperature controlled drying

Further

- **Drying strategies based on colour**
  - CCD sensor applications (RGB cameras etc.)
- **Drying strategies based on spectral information**
  - photospectrometer, hyper spectral imaging etc.

Conclusions

Herb drying aims to achieve high product qualities and low energy consumptions

therefore

- **The process duration of herb drying should be as short as possible**
- **Processing parameters are related to every individual product**
- **Drying parameters are not fixed and their control is related to the changes of the product during drying**

References

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Self evaluation

1. What is the minimum air velocity required for herb drying?
2. What causes quality losses in dried herbs

   pre drying?

   during drying?
3. How much energy should be consumed o average (kJ/kg dried herbs)?
4. What is the most important drying parameter for low temperature drying?