Drying of fruits

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Outline

- General aims and challenges of dehydration
- Scientific approaches
- Orchard related fruit drying
- Quality parameters for dried fruits
- Aims in fruit drying
- Influencing factors on fruit quality
- Improvements in fruit drying
- Powder production

Learning Outcomes

This module should give the user a deeper understanding of the **drying process of fruits** 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:

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

Fruits 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 heat stable or are reduced by enzymatic oxidation

- Changes in structure, texture, colour, flavour, taste
  - Protein denaturation
  - Protein/Lipid oxidation
  - Non-encymatic reactions (e.g. browning)

- 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- ⇨ Out of date technical devices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

Orchard related fruit drying

⇨ **Orchards are extensively used with a high environmental significance**

- Conservation of cultural landscape
- Species conservation
- Cultivation of regional fruits

Negative effect: Smaller yields compared to intensive fruit cultivation

Value adding for products is needed to increase the economical value of orchards

Efficient processing is needed!

Quality parameters for dried fruits

⇨ 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

Quality parameters for dried fruits

- 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

Phases of fruits drying

⇨ Phase I (only when surface moisture exists, shortest phase)

- 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 water until moisture equilibrium is reached

Aims in fruit drying

⇨ The dehydration process for fruits 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**

Aims in fruit drying

The drying process aims to dry the product 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!

Aims in fruit drying

- ➢ Targeted short drying times risk the application of too high drying temperatures
  - Porous surfaces and cell damages of the final product
  - Degradation of valuable compounds

- ➢ Too low temperatures risk unnecessary long drying times
  - quality losses caused by long reaction times for degradation processes
  - High energy consumptions

⇨ **The "Golden medium" needs to be required to achieve minimum quality losses and appropriate energy consumptions**

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, cell damages

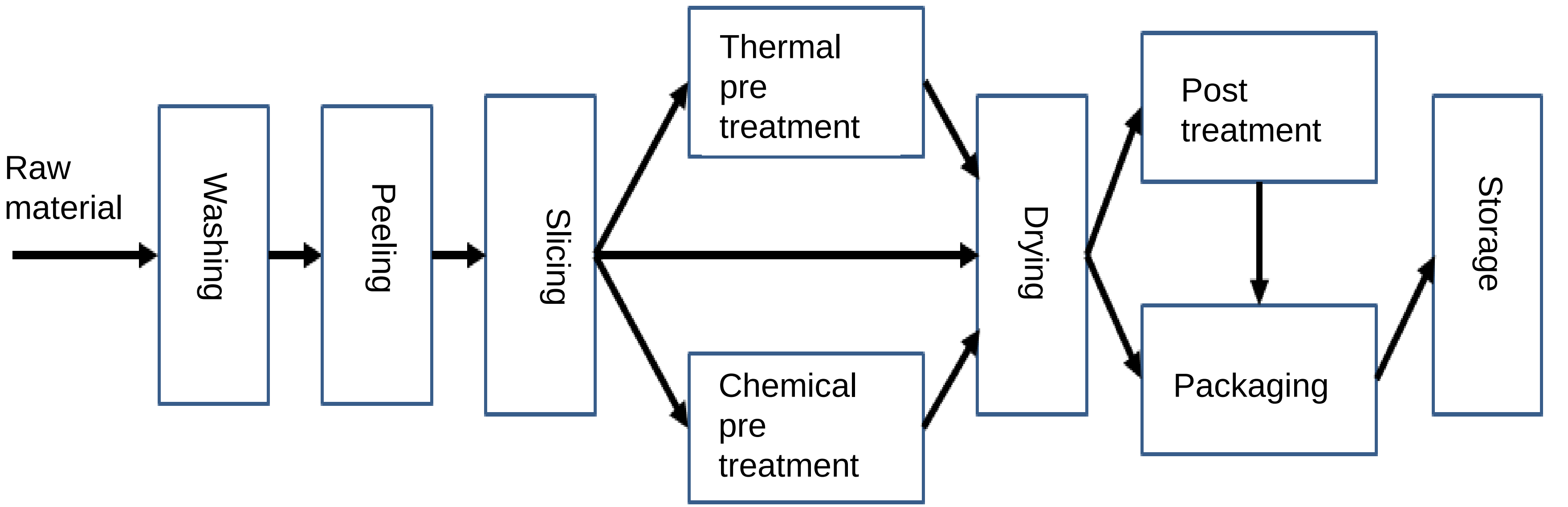
  Relative humidity inside the dryer

  Air flow

  Raw material thickness

Processing steps

- Quality losses during any processing step **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

Pre treatments

Pre treatments of fruits aim to reduce bioactive processes like non-encymatic browning

⇨ Chemical:

- **Ascorbatic acid/citric acid**

⇨ Thermal:

- **Blanching (loss of soluble compounds!!)**

However, all chemical and microbial degradation processes need water

⇨ minimum duration between pre-processing and drying to retain quality, short drying times

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Further quality influencing factors

Air distribution (should be equal throughout the dryer)

- ⇨ Unequal air distribution results in unequal drying of the bulk
- ⇨ Can be improved by small changes of the dryer construction to get an uniform distribution
- ⇨ Can be improved by implementation of appropriate fans

Raw material

- ⇨ peeled/unpeeled
- ⇨ initial moisture content
- ⇨ thickness

Improvements in fruit drying

⇨ **Product specific drying**

- Product species, shape
- Knowledge of valuable components

⇨ **Control of air velocity**

- Removement of moisture
- Equal air distribution

⇨ **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**

Powder production

Big demand for fruit powders worldwide

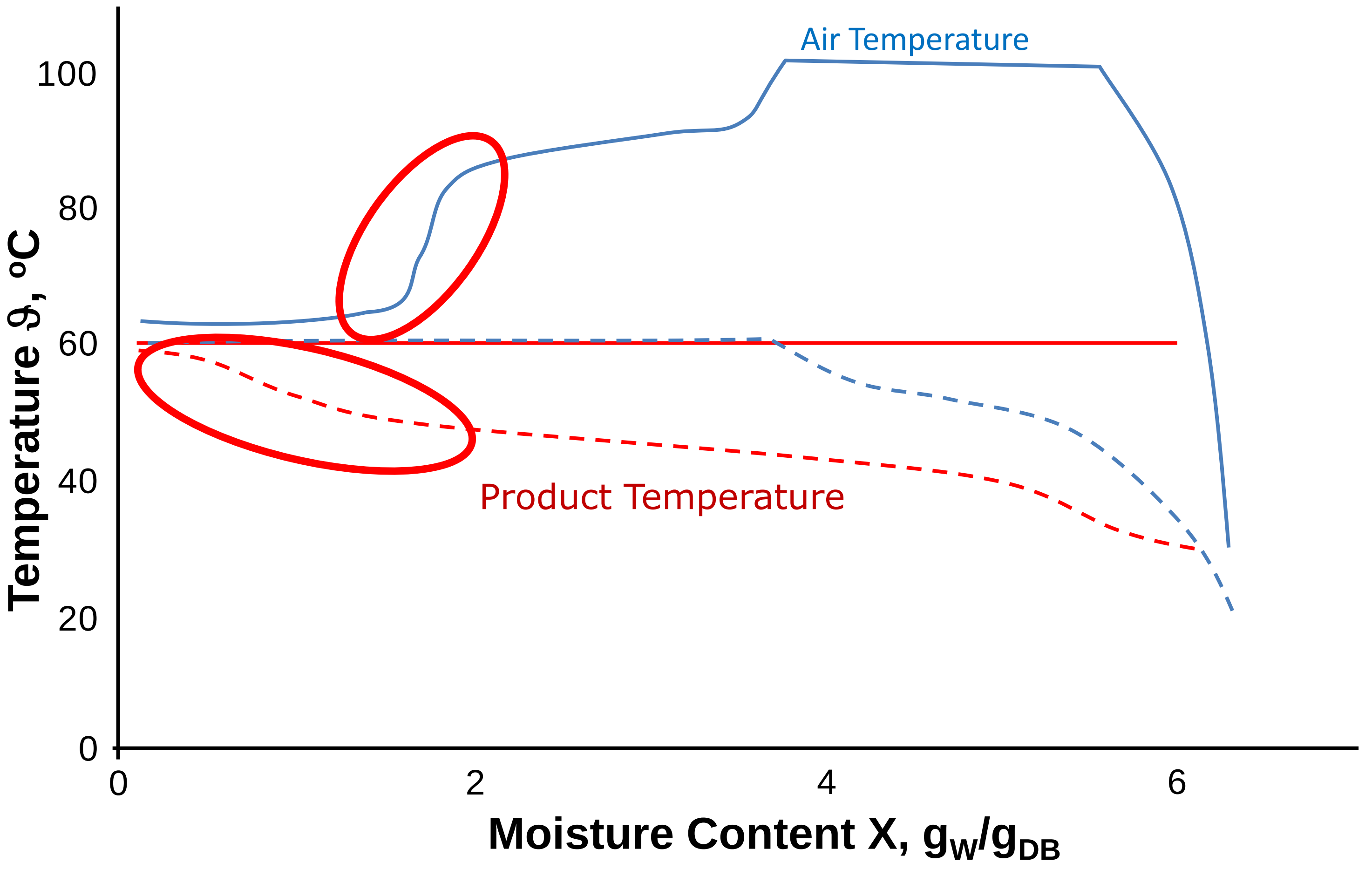
- ⇨ Natural colourants
- ⇨ Food supplements
- ⇨ Pharmaceutica

Possibility to gain > 80 €/kg fruit powder (quality dependent)

Requirements:

- ⇨ < 5 % moisture content
- ⇨ Gentle milling to avoid heat stress ⇨ quality losses!
- ⇨ Product specific packaging and storage to avoid remoistening

Excursion: Temperatures as Functions of Moisture Content



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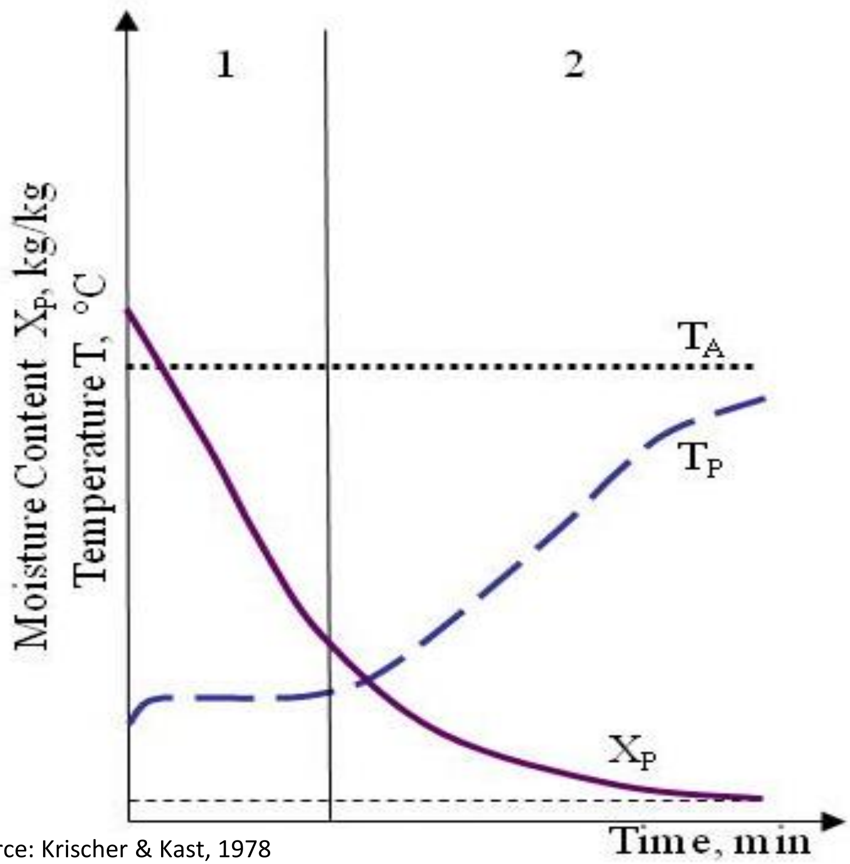
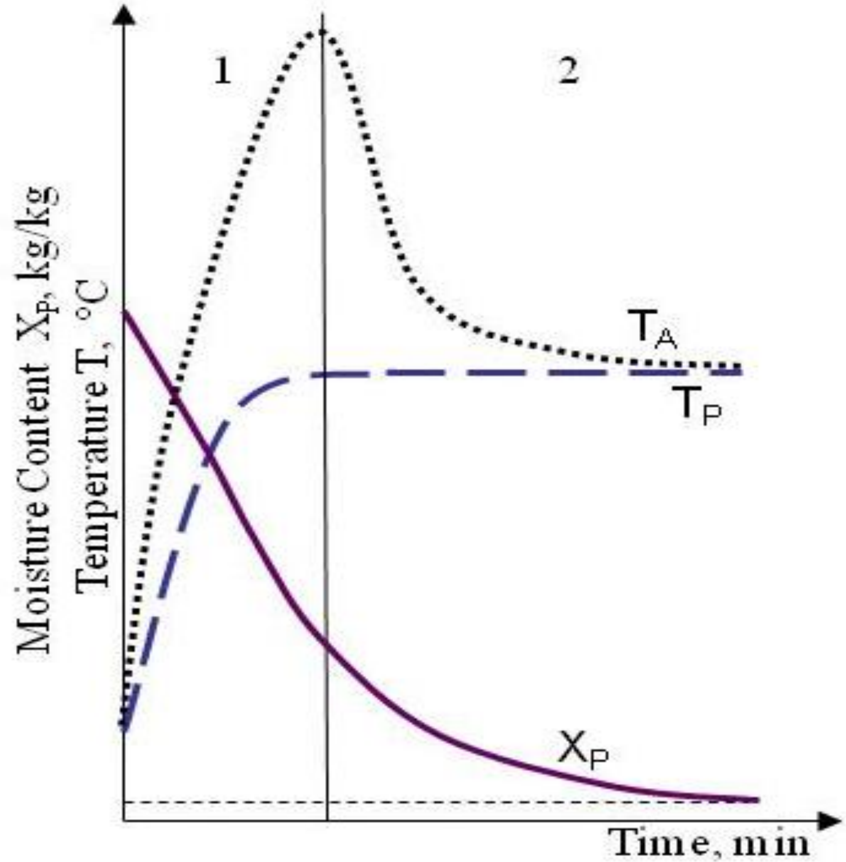
Comparison of air temperature (T_A) and product temperature (T_P) controlled drying

Air Temperature



Product Temperature



Source: Krischer & Kast, 1978

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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

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

therefore

- **The drying time of fruits 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 fruit drying?
2. What causes quality losses in dried herbs

   pre drying?

   during drying?
3. Name a risk that can occur during blanching (pre treatment)
4. What is the final moisture content for producing fruit powders?