Drying of fruits

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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$_{wb}$
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- Out of date technical devices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
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:
  • Ascorbic 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
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**
  - Removal 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
Comparison of air temperature \((T_A)\) and product temperature \((T_P)\) controlled drying

Source: Krischer & Kast, 1978
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.
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


Sturm, B. 2018. Automatic control of apple drying with respect to product temperature and air velocity in
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?