



Escola Superior de Biotecnologia
Universidade Católica Portuguesa

Structural Changes During Air Drying of Foods: A Review

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IberDESH 2002 – 25 to 27 September, Valencia-Spain



Introduction

- ◆ Drying is probably the oldest method of preserving foods.



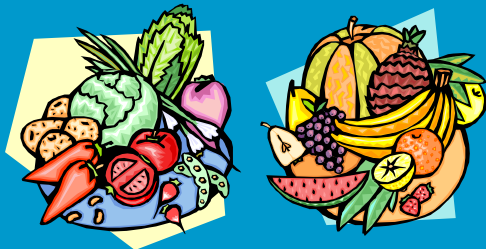
Introduction

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Introduction

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- ◆ Nowadays, drying is also a method for increasing added value of foods.
- ◆ Particular attention has been given to drying fruits and vegetables.





Introduction

Diversified products

Breakfast cereals

Dairy products

Bakery

confectionery



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Introduction

Loss of water and volatiles



Major **structural changes**



Textural changes



Different sensory characteristics



Introduction

Fresh
characteristics



Consumer's interest





Introduction

- ◆ Air drying is a relatively well-studied process.

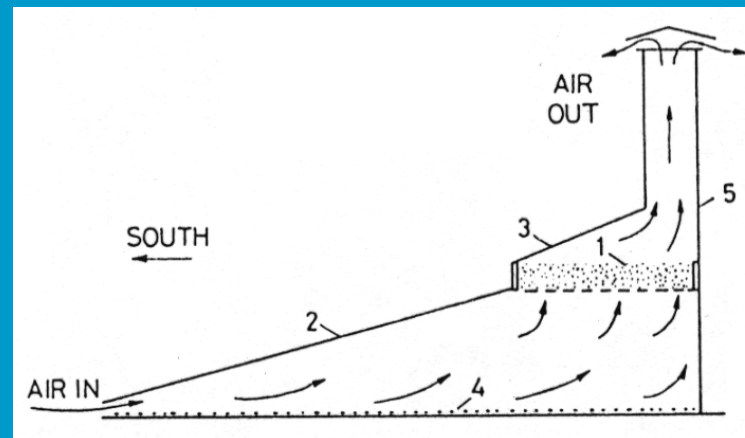


Pilot plant tray drier (Armfield UOP8).



Introduction

- ◆ Solar drying – *a particular example.*



Scheme of a solar dryer.



Outline

- **Micro and Macrostrural Changes**

- **Physical Changes**

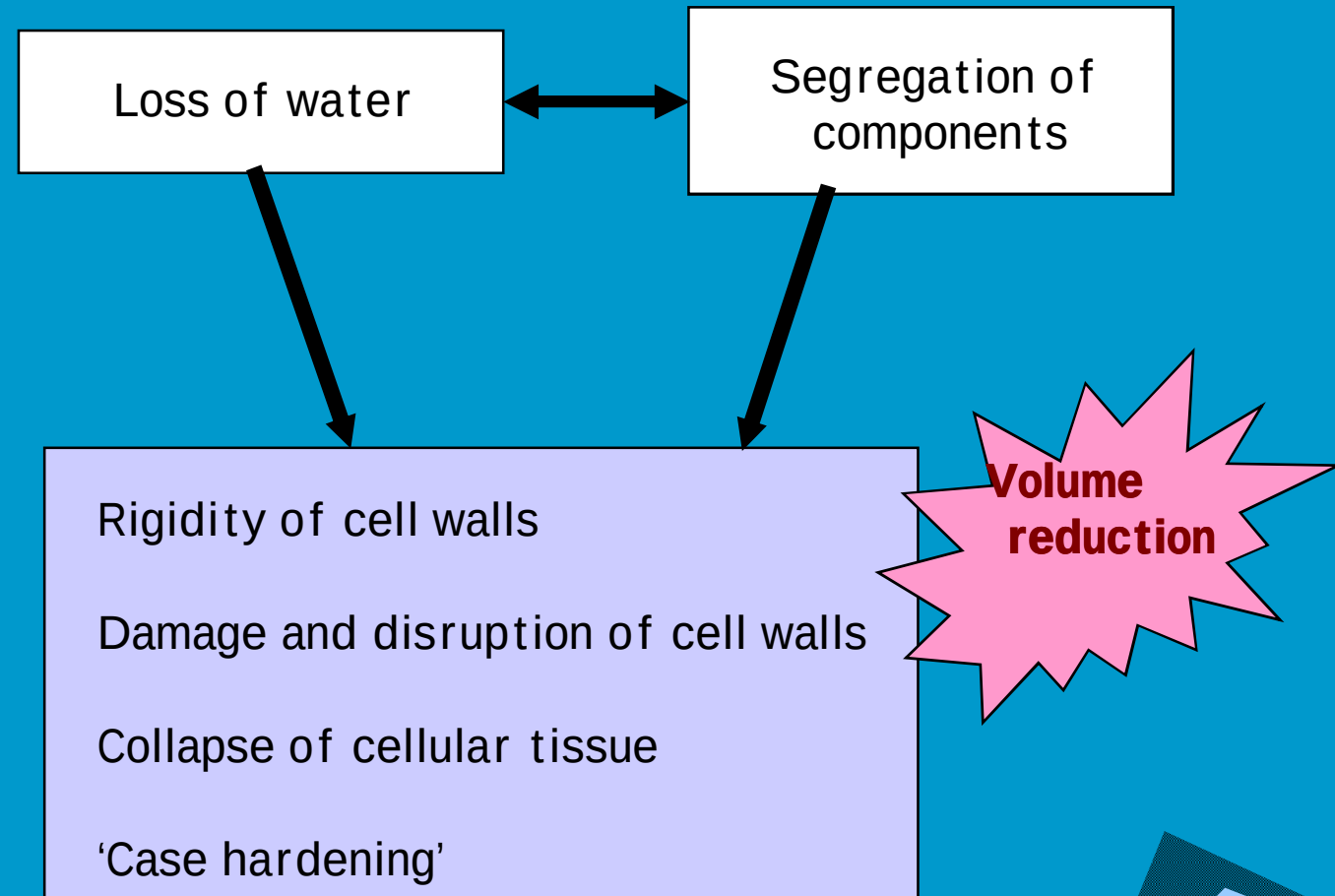
Porosity
Density

- **Texture**

- **Case Study**



Micro and Macrostructural Changes





Micro and Macrostructural Changes

Microstructure studies may improve the:

- understanding of drying mechanisms and
- knowledge of food properties

Qualitative and **Quantitative** information



Micro and Macrostructural Changes

Food Microstructure

Understanding

Perceived characteristics

Produce attractive products



Micro and Macrostructural Changes

- ◆ Use of microscopy, complemented with image analysis.



Micro and Macrostructural Changes

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- ◆ Loss of water originates a reduction in the size of the cellular tissue

Shrinkage phenomena



Micro and Macrostructural Changes

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Shrinkage phenomena

Depends on: drying method
drying conditions

Affects: heat and mass transfer characteristics

**Drying
models**



Physical Changes

◆ Porosity.

$$\varepsilon = \frac{V_a}{V_s + V_w + V_a}$$

◆ Particle Density.

$$\rho_p = \frac{m_s + m_w}{V_s + V_w}$$

◆ Bulk Density.

$$\rho_b = \frac{m_s + m_w}{V_s + V_w + V_a}$$



Physical Changes

♦ Porosity.

Drying $\longrightarrow$ Porosity 

models

$$\varepsilon = f(\text{water content})$$



Physical Changes

◆ Porosity.

Drying $\longrightarrow$ Porosity 

models

$$\varepsilon = f(\text{water content})$$

- Pore size and pore size distribution
- Total porosity and open pore porosity



Physical Changes

◆ Density.

Drying



Density



Water
content





Physical Changes

◆ Density.

Drying



Density



Water
content



- a decrease sometimes is observed, because an increasing number of pores become closed

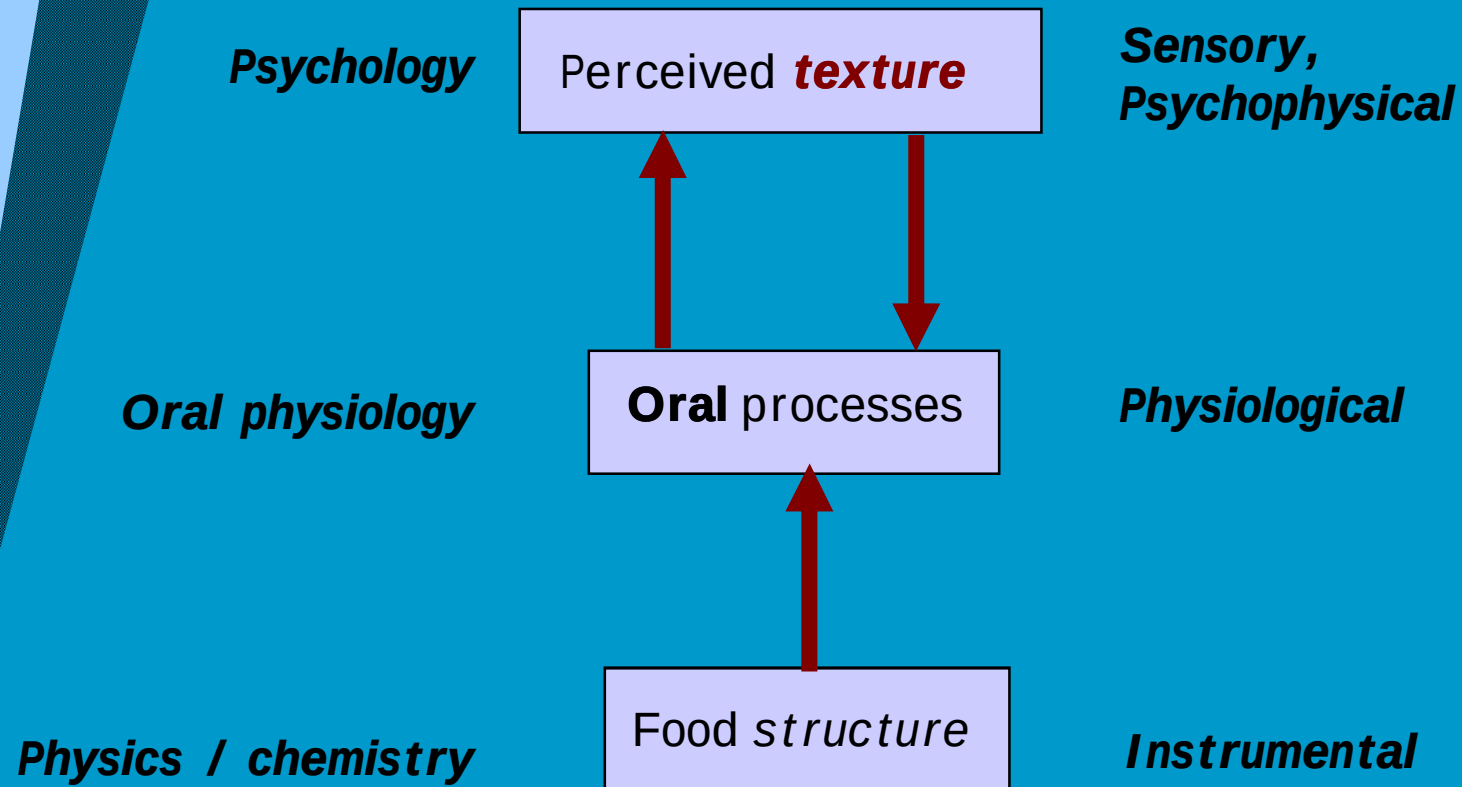


Texture

- ◆ A difficult property to define.



Texture



Wilkinson *et.al.*, 2000

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Case Study

Quantification of Microstructural Changes During Air drying of Grape Tissue

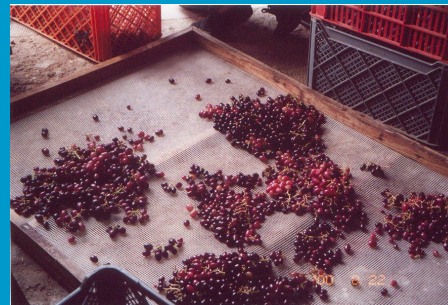
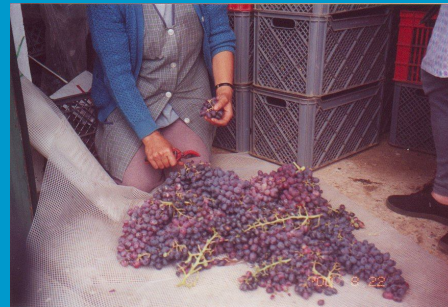


Ramos *et.al.*, 2002

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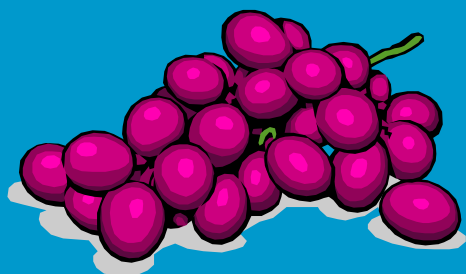
Case Study



Preparative Techniques of Moruca Red seedless grapes.



Case Study



Solar Drier.



Case Study

OBJECTIVES

- Introduce a microstructural approach in convective drying of fruits.
- Monitor physical microstructural changes during air drying of grape quarters.
- Quantify cellular shrinkage.



Ramos *et.al.*, 2002



Case Study

MATERIALS AND METHODS

Samples:

- ❖ Ruby grapes (*Vitis vinifera*) quarters of 2.4 cm diameter
- ❖ water content in a vacuum oven at 70°C = 80.63% $\pm$ 0.14 (w/w)
- ❖ cellular walls stained with methylene-blue 0.034%, during 15 s



Ramos *et.al.*, 2002



Case Study

MATERIALS AND METHODS

Drying Experiments:

- ❖ Control of temperature, relative air humidity:

20, 30, 40, 50, 60°C

- ❖ for approximately 2 hours

- ❖ air velocity = 1.6 ± 0.11 m/s

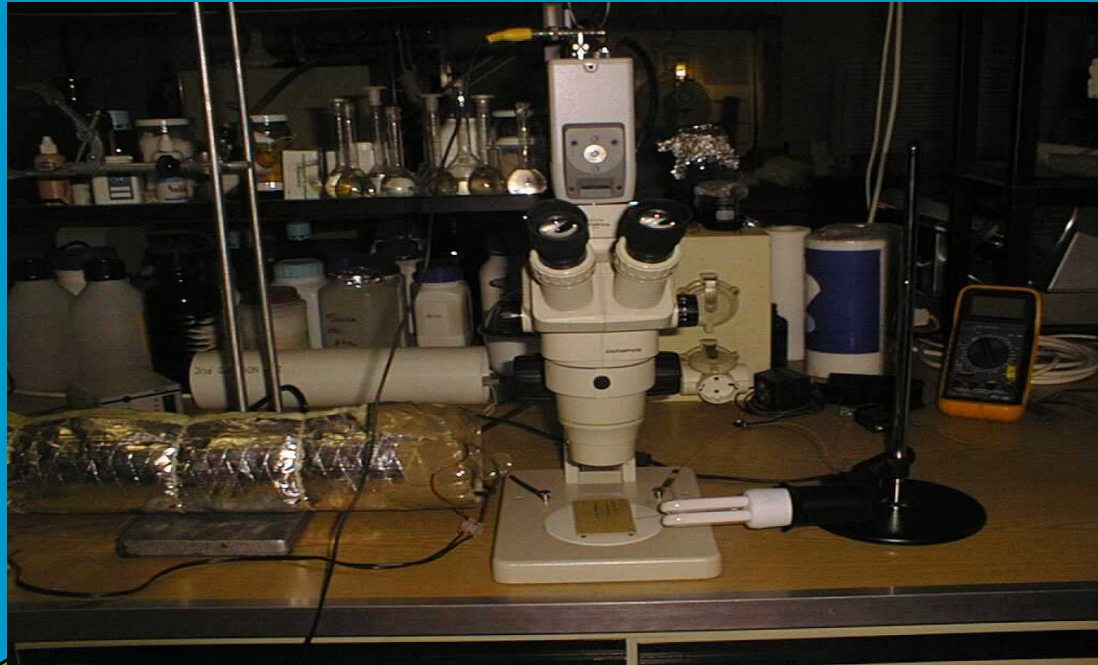


Ramos et.al., 2002



Case Study

MATERIALS AND METHODS



Stereo-microscope with video camera and air-drying tube.

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MATERIALS AND METHODS

Microstructure and Image Analysis:

- ❖ magnification of 25X
- ❖ 20 cells selected
- ❖ softwares Paint Shop Pro 4.12 and UTHSCA Image Tool 2.0



Ramos *et.al.*, 2002



Case Study

MATERIALS AND METHODS

Microstructure and Image Analysis:

❖ Parameters:

→ Dimensional: **area, perimeter,**

major and minor axis length

$$\text{Ferret diameter} - FD = \sqrt{\frac{\text{area}}{\pi}}$$



Ramos et.al., 2002



Case Study

MATERIALS AND METHODS

Microstructure and Image Analysis:

→ Shape: **elongation**

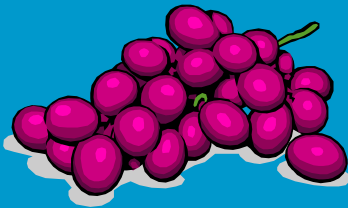
$$\text{elongation} = \frac{\text{major axis length}}{\text{min or axis length}}$$

roundness

$$\text{roundness} = \frac{4\pi \text{ area}}{\text{perimeter}^2}$$

compactness

$$\text{compactness} = \frac{FD}{\text{major axis length}}$$

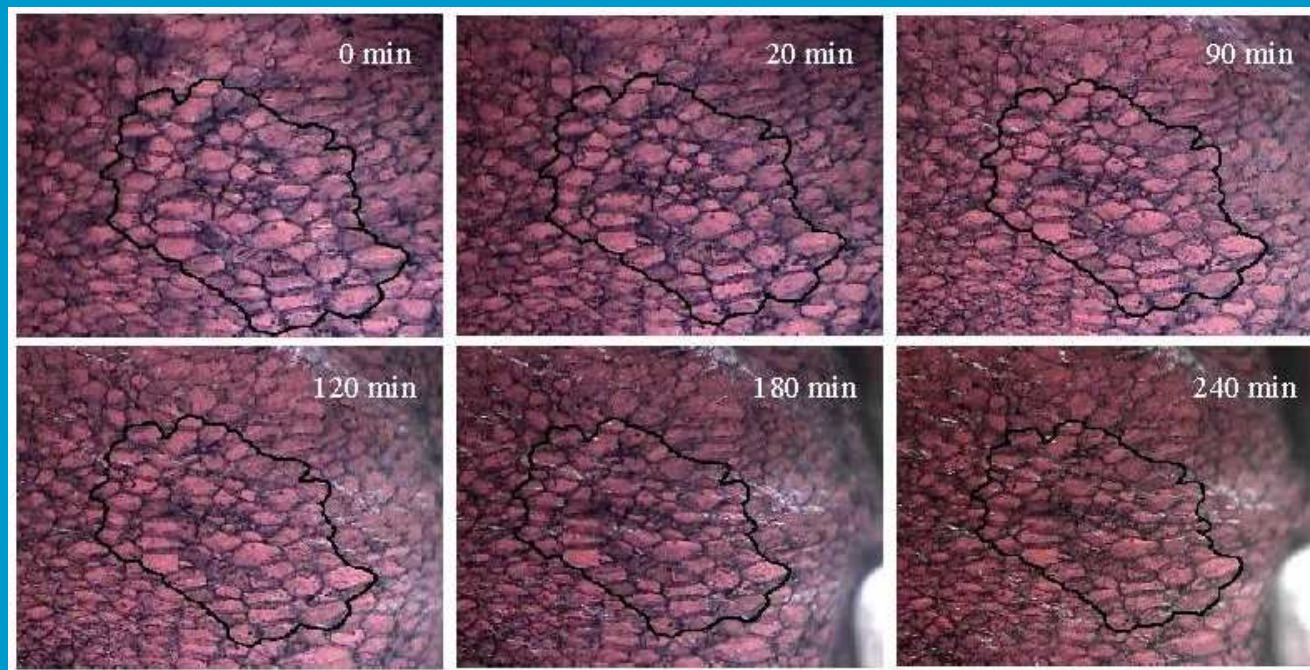


Ramos *et.al.*, 2002



Case Study

RESULTS AND DISCUSSION



Images of grape cells shrinkage at 40°C as a function of time.

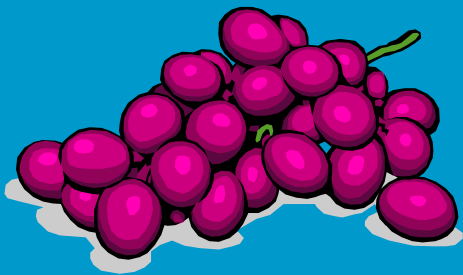
Ramos et.al., 2002

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Case Study

- Disruption of cellular walls/
- Cellular collapse /
- Surface progressively more brilliant with the gradual increase of liquid water.



Ramos *et.al.*, 2002



Case Study

- Dimensional parameters showed an exponential decrease with drying time

$$\frac{p}{p_o} = \exp(-k_T t)$$

- Temperature accelerates the rate of change

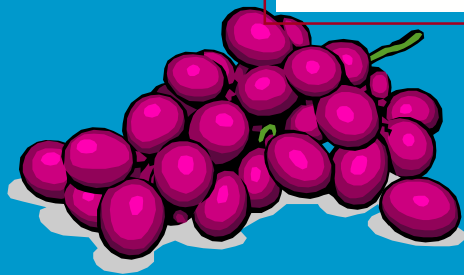
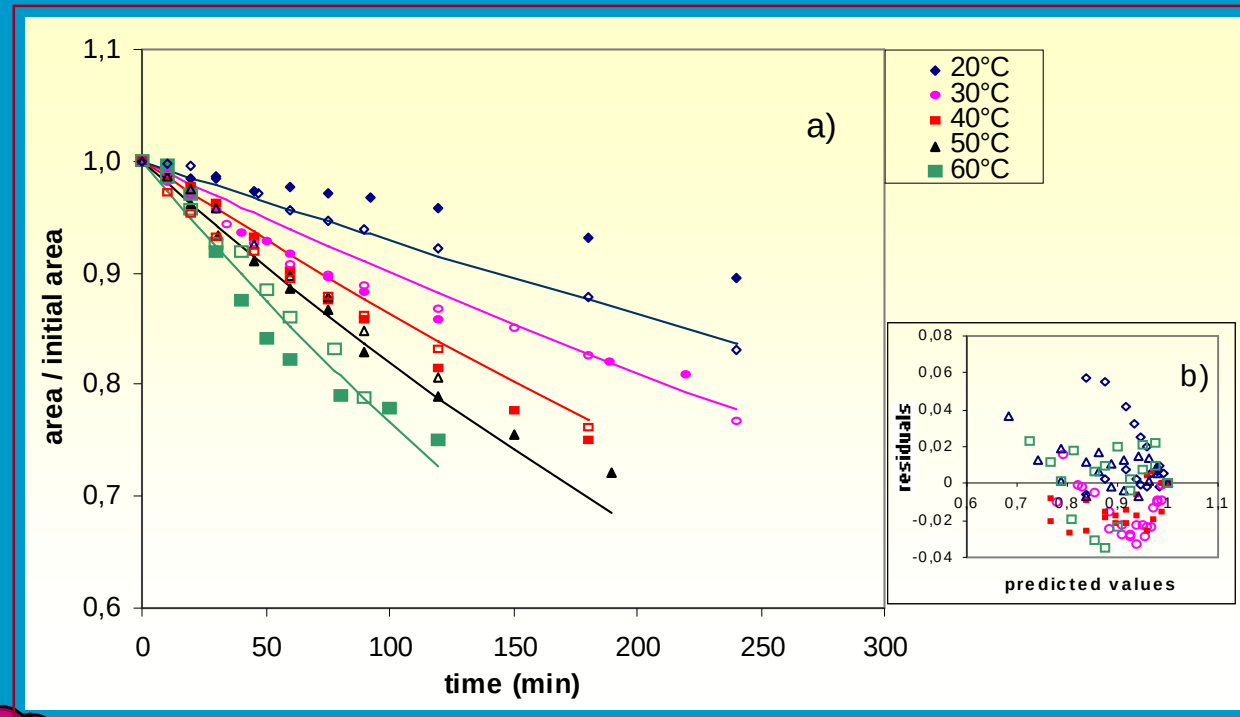


$$k = k_{\text{ref}} \exp \left[-\frac{E_a}{R} \left(\frac{1}{T} - \frac{1}{T_{\text{ref}}} \right) \right]$$

Ramos *et.al.*, 2002



Case Study

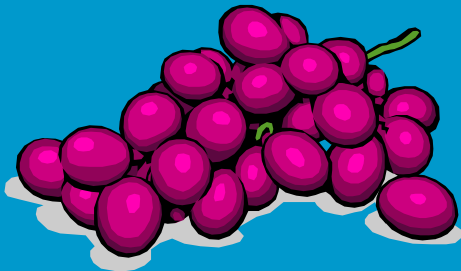
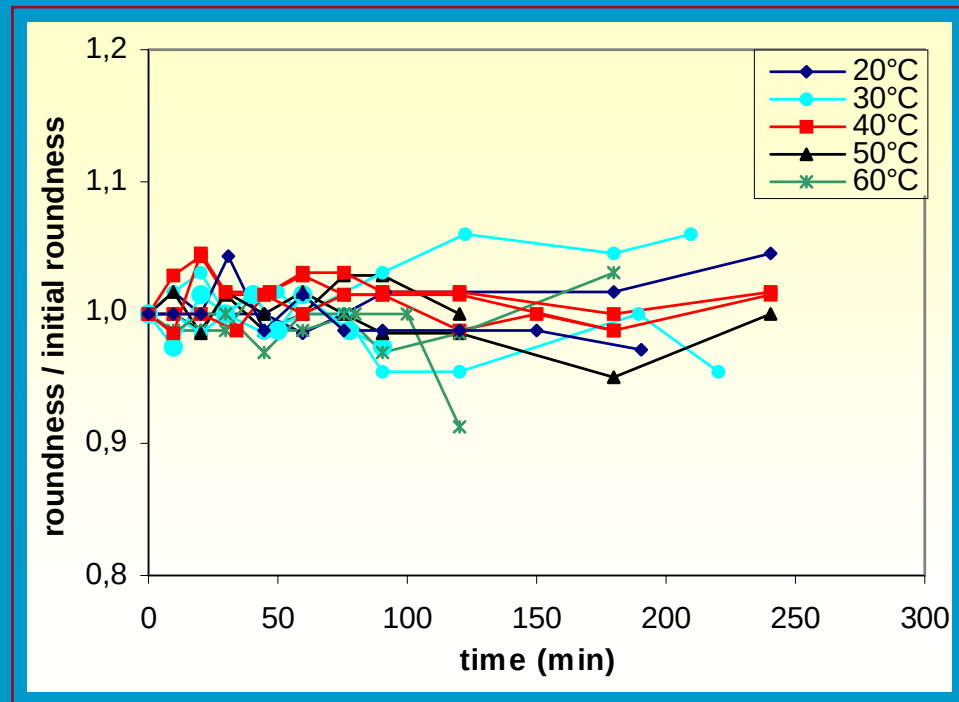


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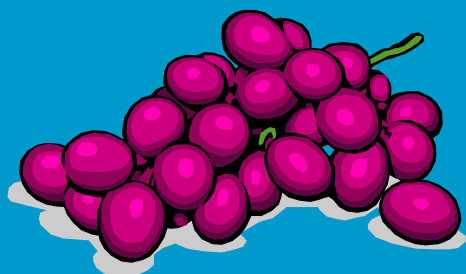
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Cellular parameters	$k_{40^{\circ}\text{C}} \times 10^{-3} (\text{min}^{-1})$	$E_a (\text{kJ/mol})$
Area	1.46 ± 0.05	3.1 ± 0.3
Perimeter	0.89 ± 0.05	3.1 ± 0.4
Major axis	0.88 ± 0.05	2.9 ± 0.3
Minor axis	0.95 ± 0.05	3.6 ± 0.7
FD	0.91 ± 0.04	3.3 ± 0.3



Ramos *et.al.*, 2002



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CONCLUSIONS



Stereo-microscopy is a useful non-invasive tool in studying drying.

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Case Study

CONCLUSIONS



Stereo-microscopy is a useful non-invasive tool in studying drying.



Cells dimensions suffered modifications during drying, but their shape remained unchanged.

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CONCLUSIONS

-  Stereo-microscopy is a useful non-invasive tool in studying drying.
-  Cells dimensions suffered modifications during drying, but their shape remained unchanged.
-  Area, perimeter, major and minor axis length and Feret diameter presented an exponential decrease with drying time and a first-order model was well fitted. Within the studied range, temperature increased the rate of cellular shrinkage and this effect followed an Arrhenius type behavior.

Ramos *et.al.*, 2002



Case Study

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-  There was no consistent trend of cellular elongation, roundness or compactness with time or temperature.

Ramos *et.al.*, 2002



Case Study

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-  Stereo-microscopy is a useful non-invasive tool in studying drying.
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-  There was no consistent trend of cellular elongation, roundness or compactness with time or temperature.
-  The study of drying at microscopic level will certainly contribute to better understand its mechanisms.

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Final Remarks

- ◆ There is still a lack of information concerning structural changes during air drying.



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- ◆ **Correlating microstructure, texture measurements and sensory analysis is an attractive area.**



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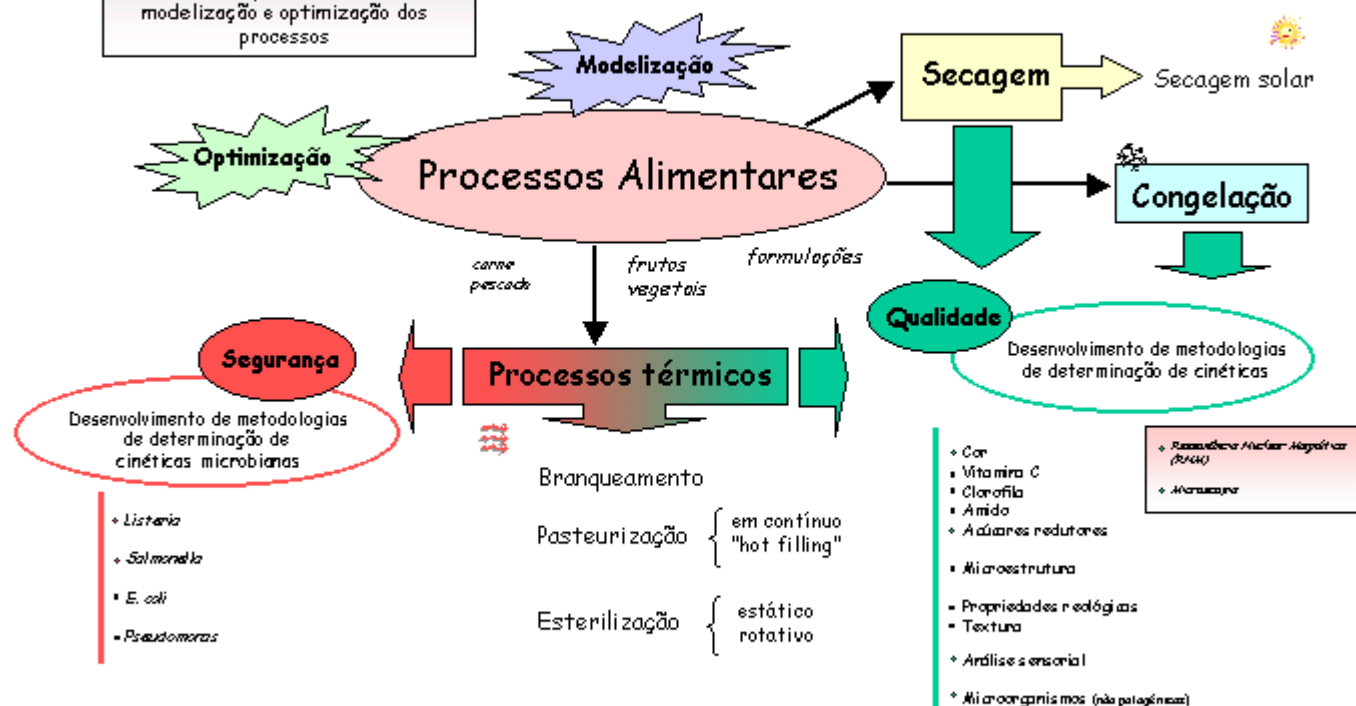
- ◆ There is still a lack of information concerning structural changes during air drying.
- ◆ Relating physical properties, and particularly texture, with microstructure is a relatively new area.
- ◆ Correlating microstructure, texture measurements and sensory analysis is an attractive area.
- ◆ **Videomicroscopy and image analysis is an interesting technique.**



Missão

A investigação desenvolvida visa a **QUALIDADE e SEGURANÇA** de alimentos processados, com um forte desempenho nas áreas de modelização e optimização dos processos

LOPA
Laboratório de Optimização de Processos Alimentares



<http://www2.esb.ucp.pt/twt/lopa/>

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CYTED XI.13 “Relaciones Estructura -
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Thank you



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