IFTPS
The Institute For Thermal Processing Specialists

2nd European Conference

Harmonization of Standards in Thermal Processing

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Porto, Portugal

Heating Foods

Integrating Quality and Safety in Thermal Processes

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CBQF – Centro de Biotecnologia e Química Fina
School of Biotechnology
Catholic University of Portugal

Thermal Processes

... Originally designed to inactivate

spoiling and pathogenic microorganisms

safety

bacteria
yeasts
molds

and **enzymes**

quality

prevent the degradation of the original **organoleptic** and **nutritive** food characteristics

however ...

thermal processes affect negatively quality factors

process design

safety

Pathogenic bacteria
Chemical contaminants
...

quality

Texture
Microstructure
Colour
Vitamin C
...

Heating Foods: *Integrating quality and safety in thermal processes*

Mathematical models

$$y = f(x, q) + e$$

process time

kinetic parameters

Heating Foods: *Integrating quality and safety in thermal processes*

Mathematical models

$$y = f(x, q) + e$$

process time

kinetic parameters

The extension and rate of production /degradation

of any safety and quality characteristic can be **quantified**

… as well as the effect of **process conditions** on the kinetic parameters

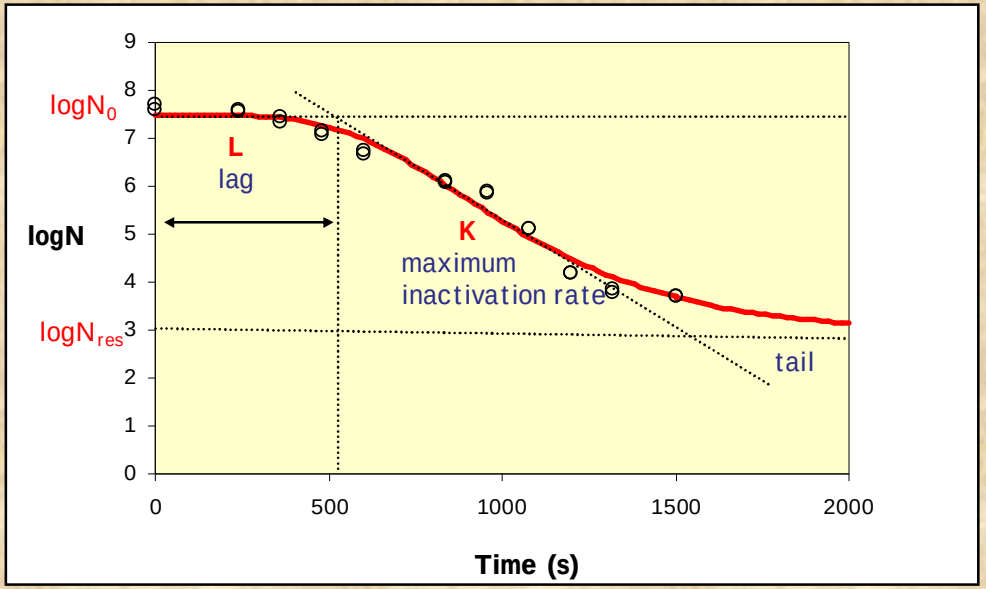
and consequently on final responses

Heating Foods: *Integrating quality and safety in thermal processes*

One example of modeling …

Safety

microbial thermal inactivation in which the kinetic parameters of the model assumed are directly related to specific features …



N – microbial counts
N_0 – initial microbial counts

Gompertz-inspired model

$$\log N = \log N_0 - \log\left(\frac{N_0}{N_{res}}\right)\exp\left(-\exp\left(\frac{k\,e}{\log\left(\frac{N_0}{N_{res}}\right)}(L - t) + 1\right)\right)$$

kinetic parameters

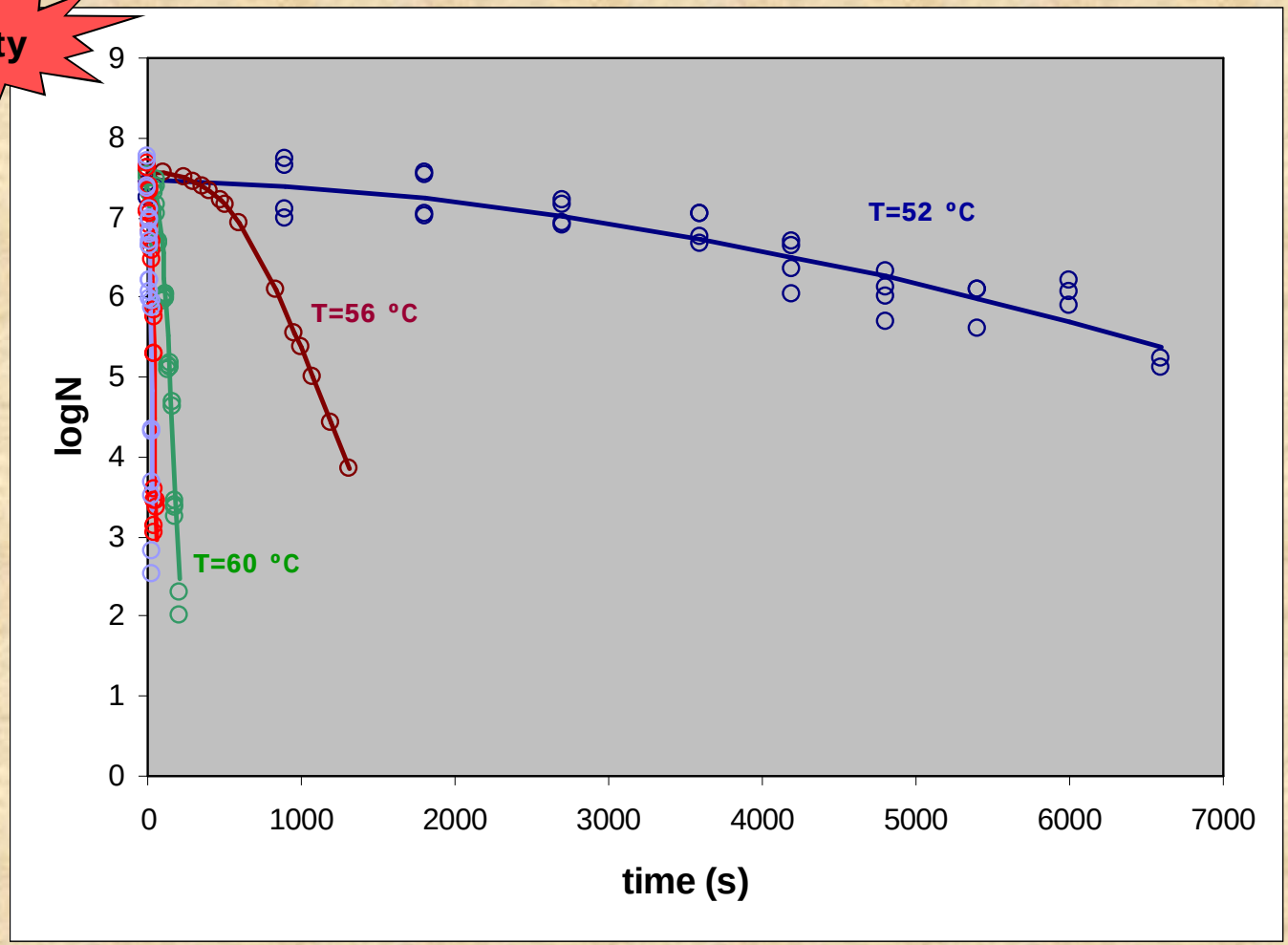
Heating Foods: *Integrating quality and safety in thermal processes*

Data of *L.monocytogenes* Scott A at 52,56,60,64,68°C

(24 hours incubation at 5°C in half cream)

Casadei et al. (1998)

Safety



Heating Foods: *Integrating quality and safety in thermal processes*

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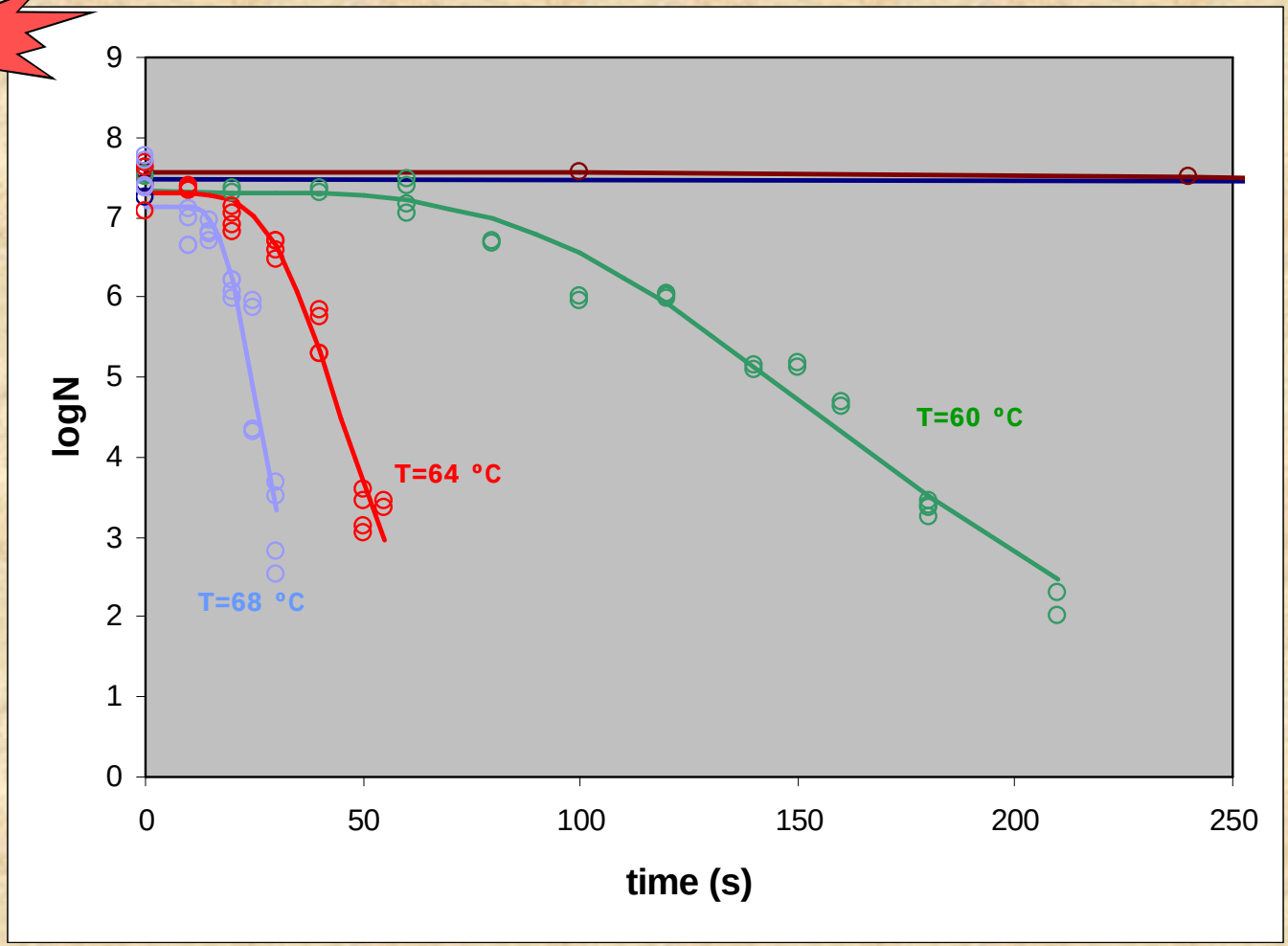
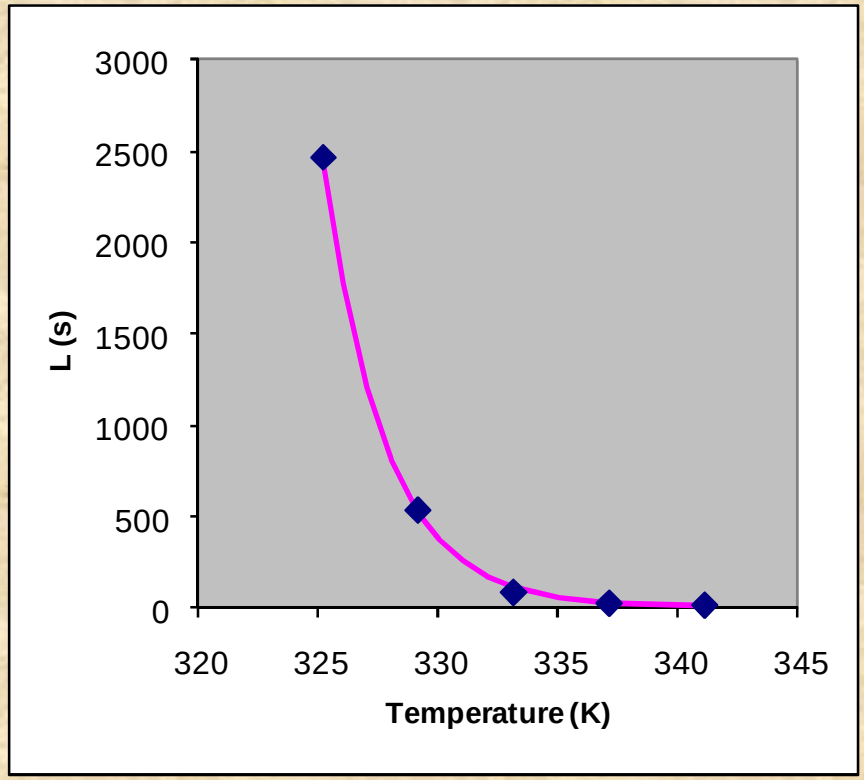
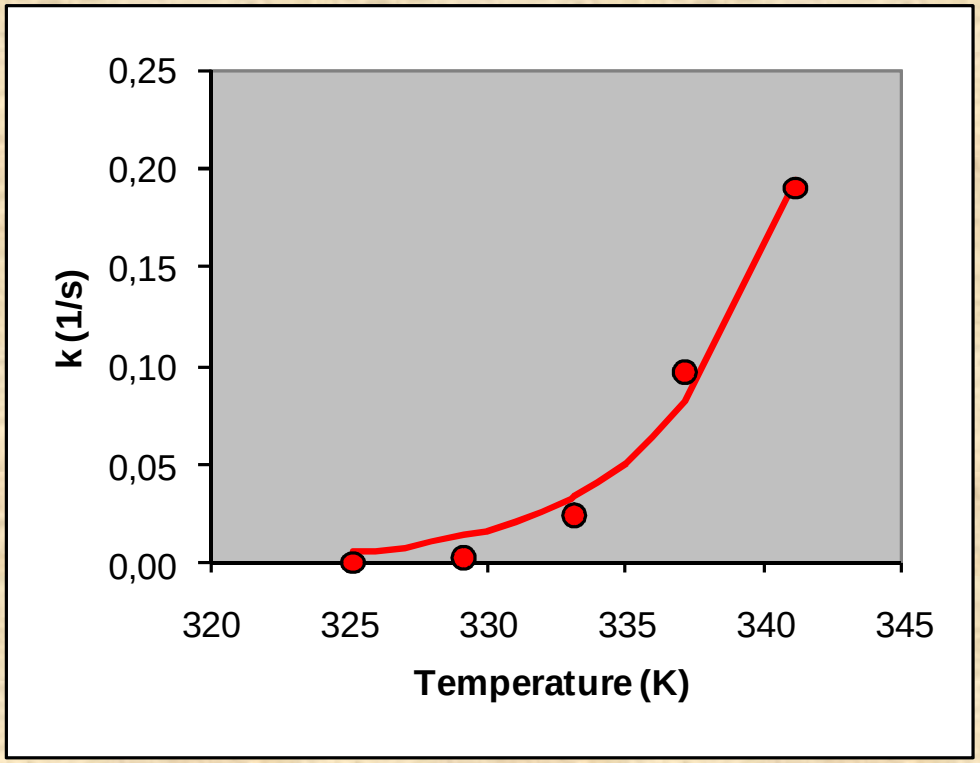


The **kinetic parameters** were correlated with **temperature** by an Arrhenius expression





$L = 116.3 \exp(344.1/R*(1/T - 1/333.15))$

$k = 0.0216 \exp(-203.3/R*(1/T - 1/333.15))$

Heating Foods: *Integrating quality and safety in thermal processes*

One example of modeling …

Safety

Gompertz-inspired model

$$\log N = \log N_0 - \log\left(\frac{N_0}{N_{res}}\right)\exp\left(-\exp\left(\frac{k\,e}{\log\left(\frac{N_0}{N_{res}}\right)}(L - t) + 1\right)\right)$$

$$k = 0.0216\exp(-203.3/R*(1/T - 1/333.15))$$

$$L = 116.3\exp(344.1/R*(1/T - 1/333.15))$$

The microbial load is just a function of the process temperature, which is a valuable tool to design efficient and controlled processes from a safety point of view.

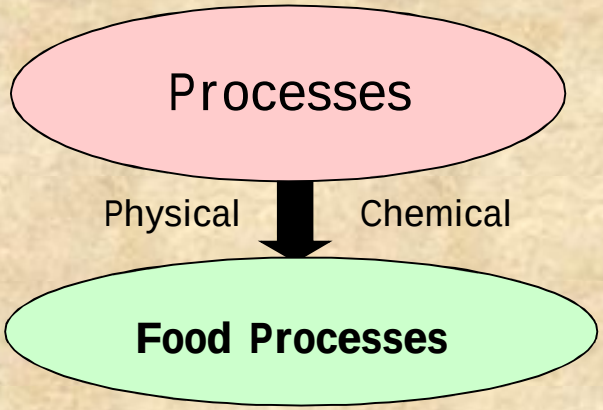
Heating Foods: *Integrating quality and safety in thermal processes*

The role of mathematical modeling on understanding process induced changes in foods

Transport Phenomena
- heat
- mass
- *momentum*

Reaction kinetics

Properties



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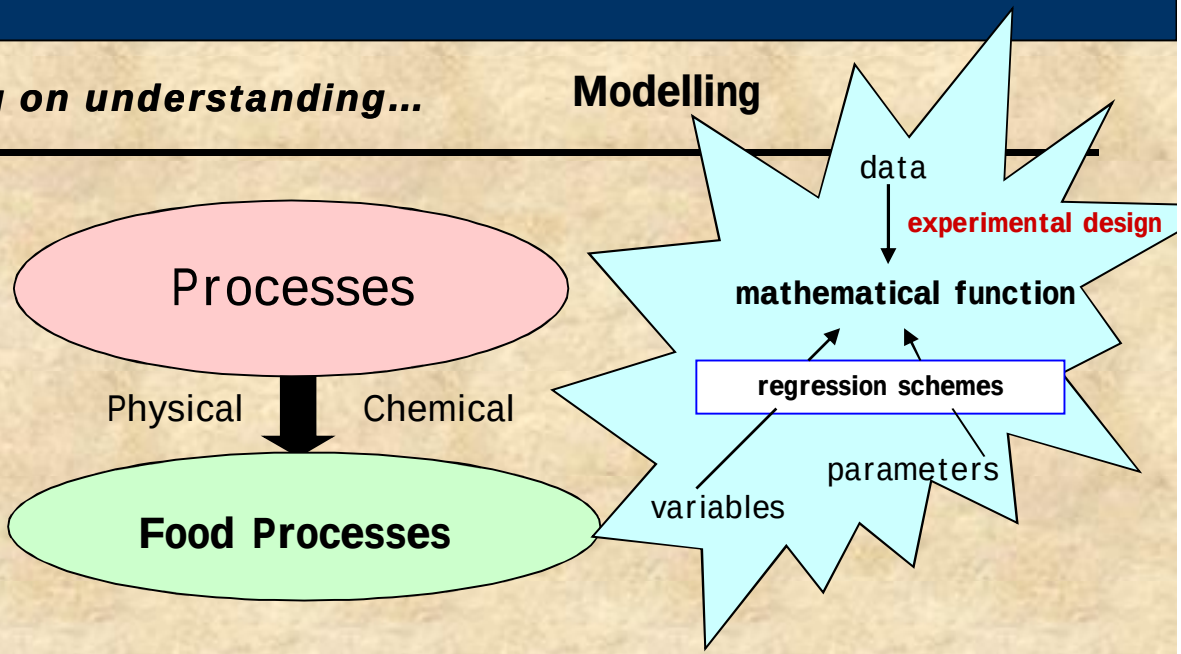

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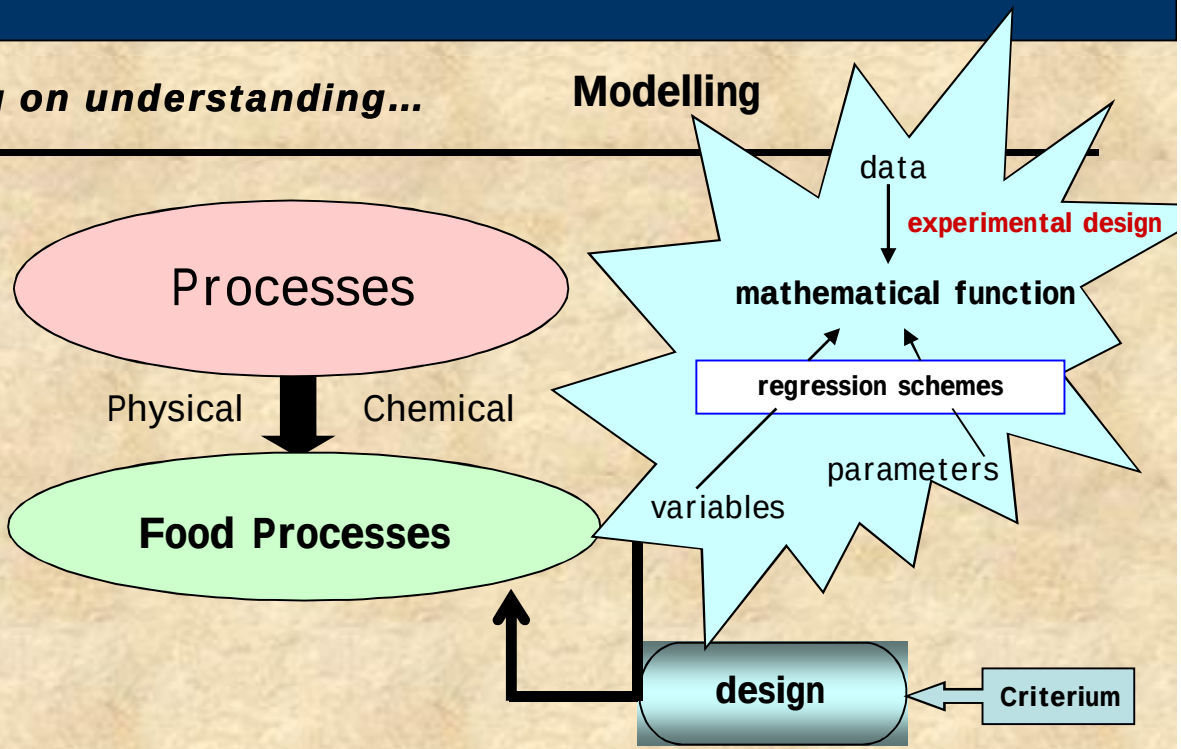

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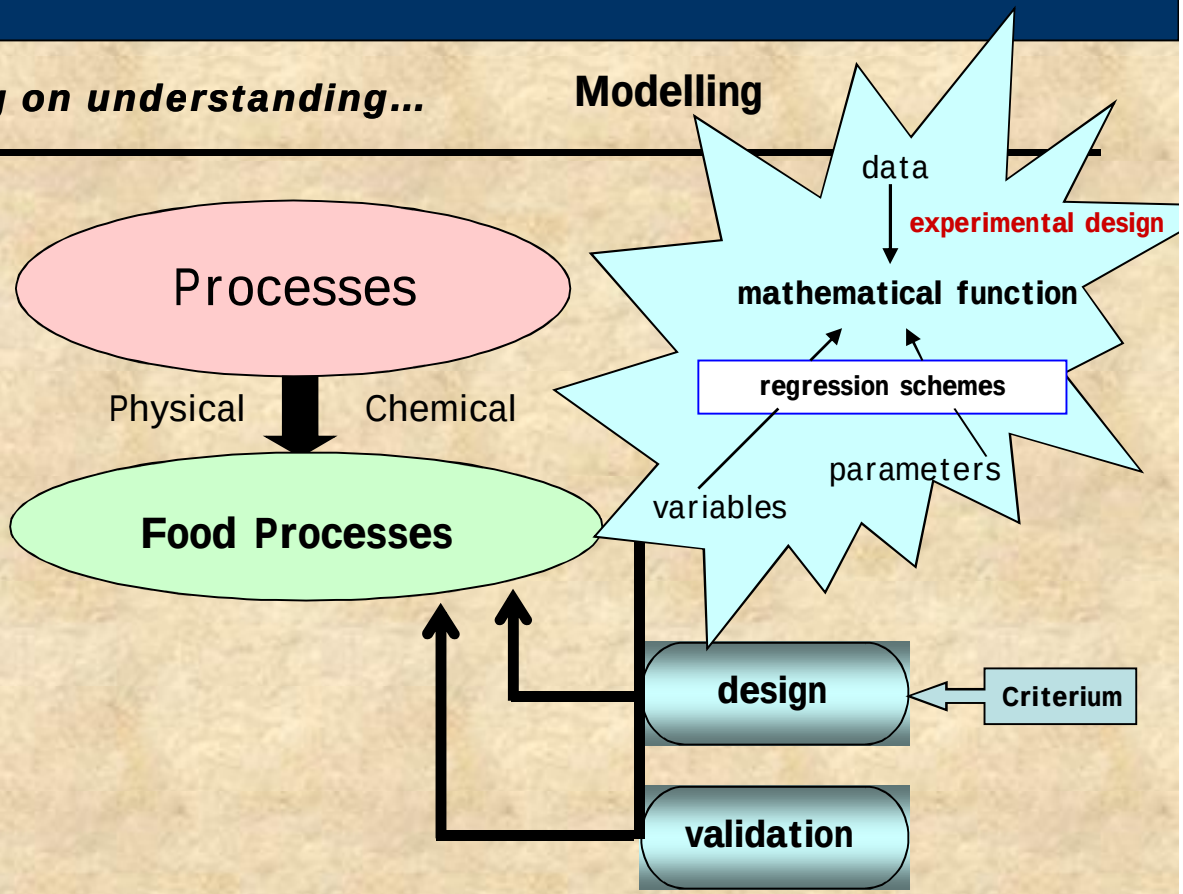

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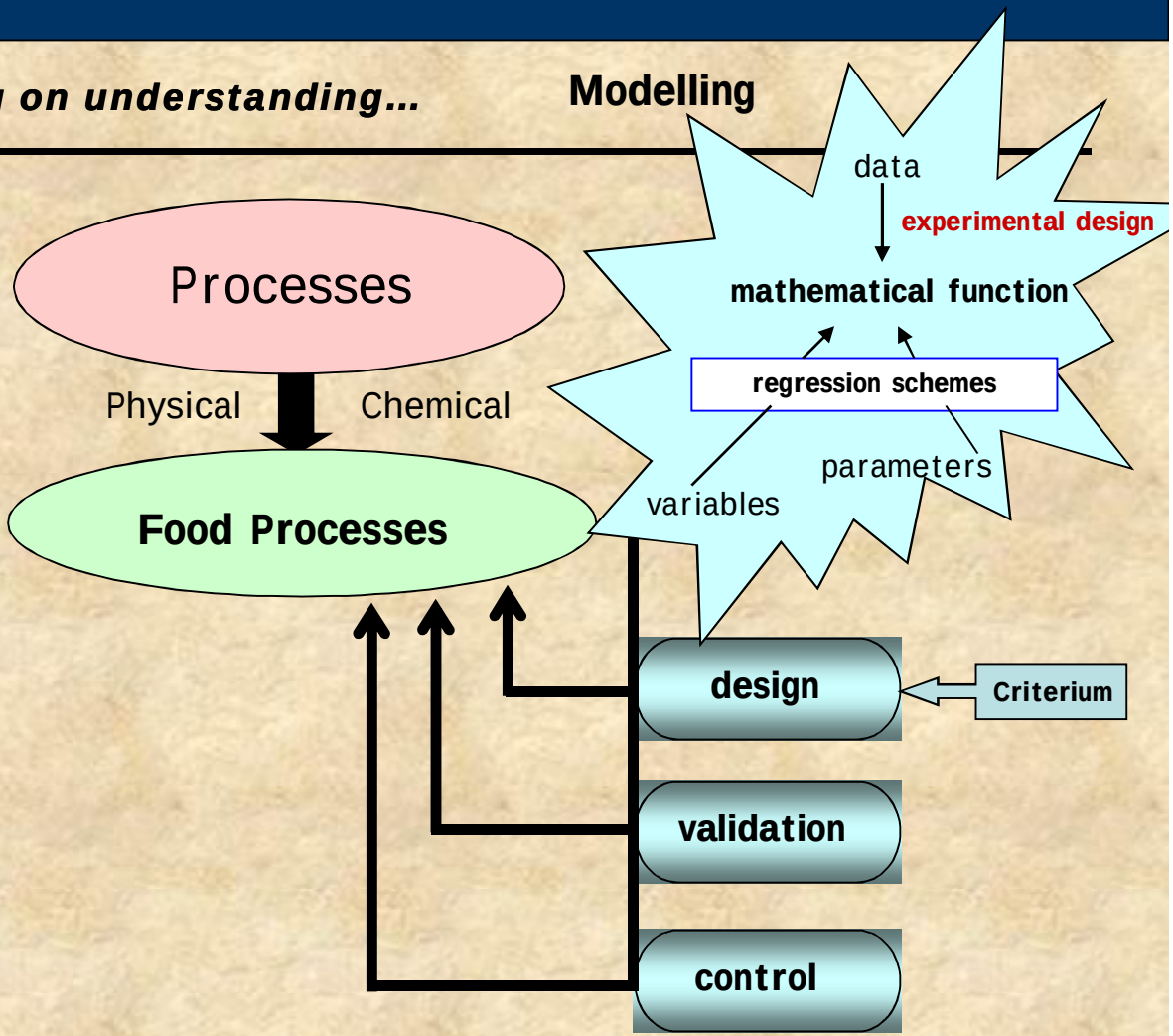

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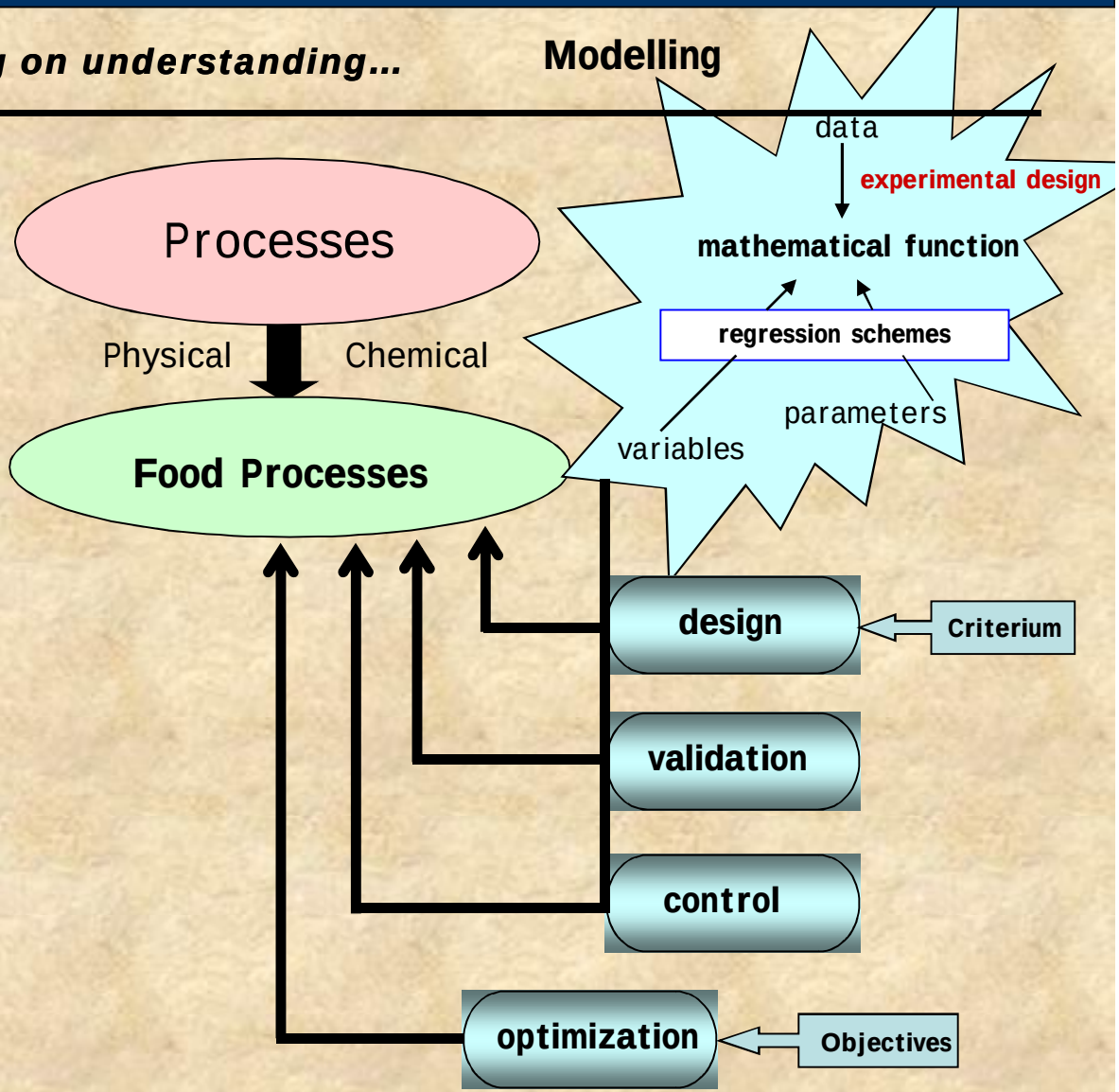

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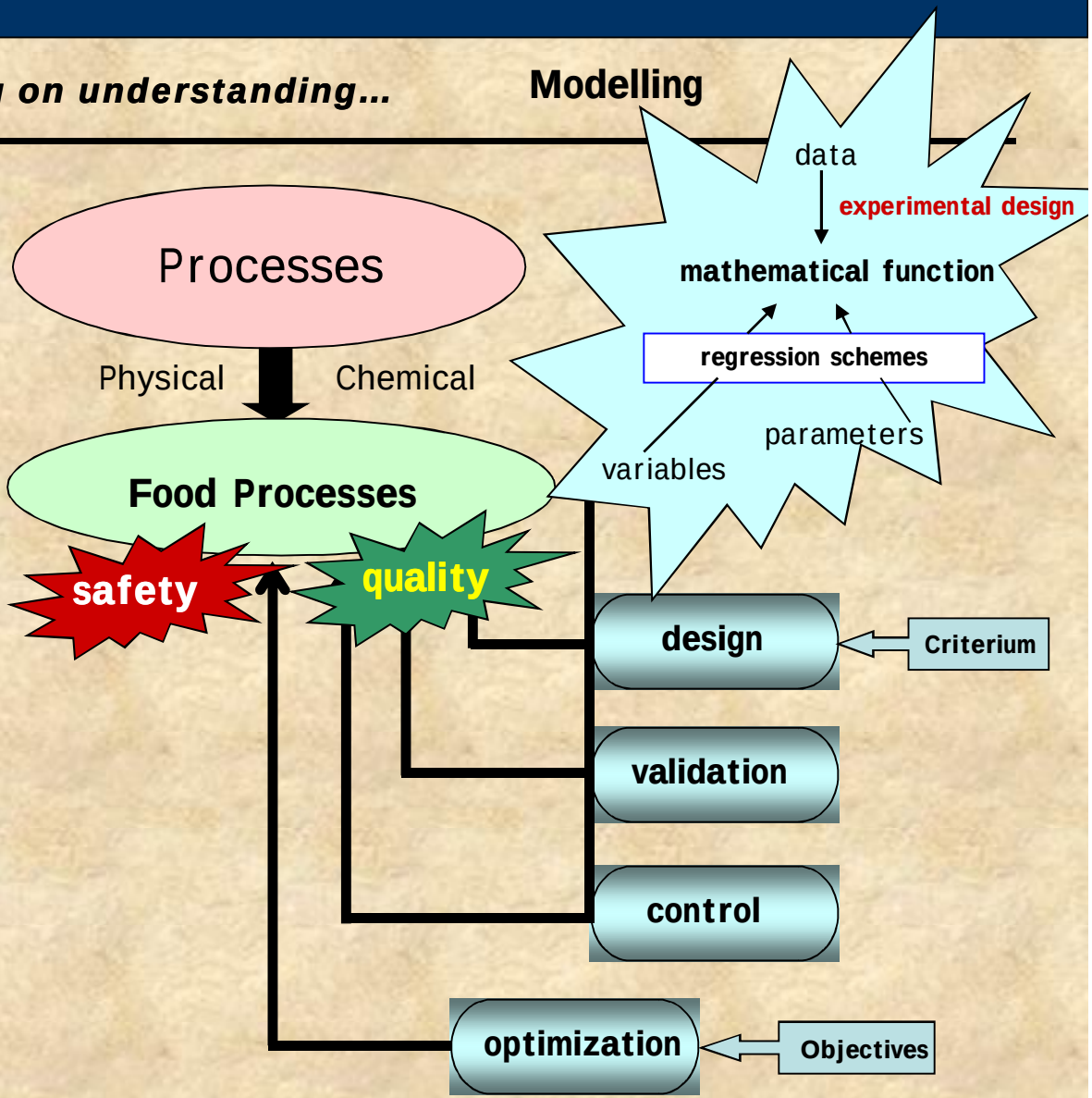


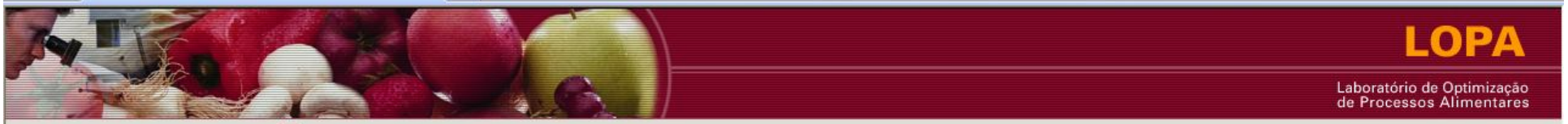
Heating Foods: *Integrating quality and safety in thermal processes*

Today's Presentation

1. Heat Processing – effect on food quality and safety

2. Combining Heat and other Non-Thermal Technologies to preserve foods

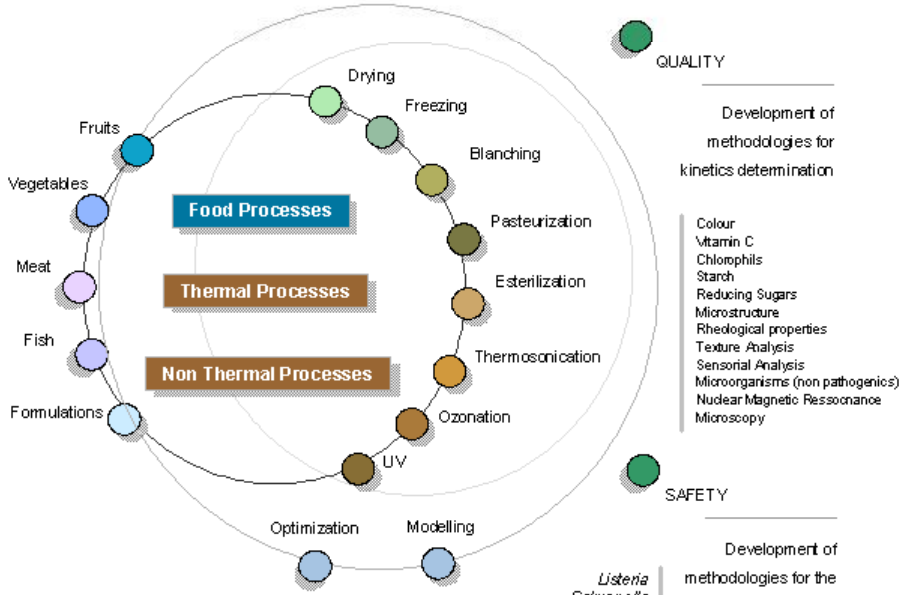
3. New Approaches on Understanding Heat Degradation in Foods



LOPA

Laboratory for the Optimization of Food Processes

LOPA - Laboratory for the Optimization of Food Proc esses - is a laboratory aiming the research in the food quality and food safety fields, with a strong work on process modelling and optimization.



QUALITY

Development of methodologies for kinetics determination

Colour
Vitamin C
Chlorophils
Starch
Reducing Sugars
Microstructure
Rheological properties
Texture Analysis
Sensorial Analysis
Microorganisms (non pathogenics)
Nuclear Magnetic Ressonance
Microscopy

SAFETY

Development of methodologies for the determination of microbial kinetics

Listeria
Salmonella
E. coli
Pseudomonas

Thermal Processes (e.g. blanching, pasteurization e esterilization, drying and freezing) and **Non-Thermal Processes** (e.g. ozonation, thermosonication and UV) are the food processes on which our research effort lays on. The main research framework is based on horticultural products, although food formulations, meat and fish are emergent food products under our skills.

Heating Foods: *Integrating quality and safety in thermal processes*

Today's Presentation

1. **Heat Processing – effect on food quality and safety**

2. **Combining Heat and other Non-Thermal Technologies to preserve foods**

3. **New Approaches on Understanding Heat Degradation in Foods**

1. Heat Processing – effect on food quality and safety

Blanching ..... **Freezing**

In spite of the benefits of blanching such as prolonging storage life by the inactivation of enzymes responsible for quality degradation and reducing the number of bacteria and other contaminants, it also leads to excessive loss of weight, alterations in colour, softening of the tissue and loss of nutrients through their diffusion into the water

… particularly important in VEGETABLES

Heating Foods: *Integrating quality and safety in thermal processes*

1. Heat Processing – effect on food quality and safety

Blanching

carrots

Daucus carota L.

Quality

pumpkin

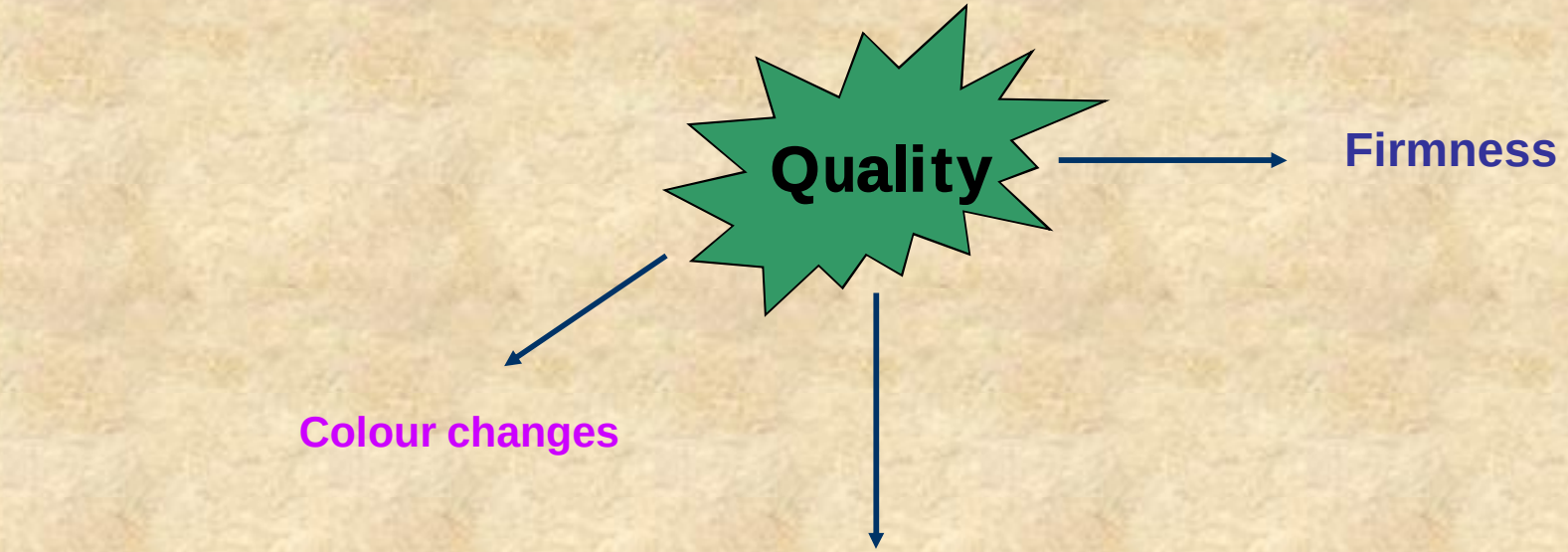
Cucurbita maxima L.

broccoli

Brassica oleracea L.

Heating Foods: *Integrating quality and safety in thermal processes*

1. Heat Processing – effect on food quality and safety



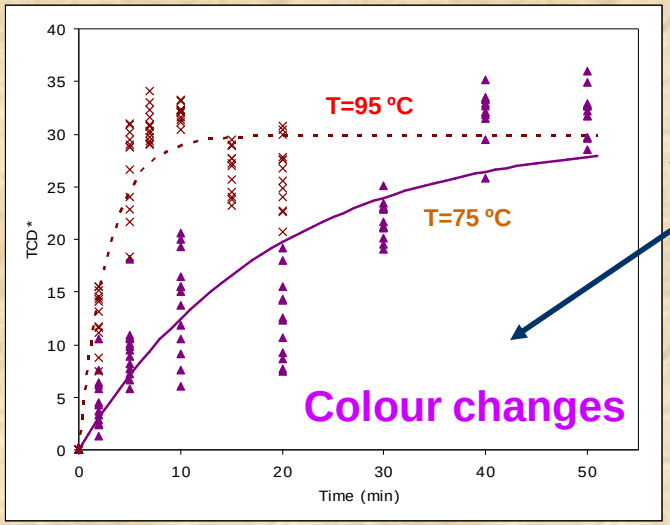
pumpkin

Cucurbita maxima L.

Heating Foods: *Integrating quality and safety in thermal processes*

1. Heat Processing – effect on food quality and safety

Total Colour Difference, Hunter (L,a,b) scale, colourimeter (CR-300, Minolta)



Quality

Firmness

pumpkin

Cucurbita maxima L.

Peroxidase

Heating Foods: *Integrating quality and safety in thermal processes*

1. Heat Processing – effect on food quality and safety

Fractional conversion model

$$\frac{TCD - TCD_{eq}}{TCD_0 - TCD_{eq}} = e^{-kt}$$

k(T) → Arrhenius

Quality

Firmness

Peroxidase

pumpkin

Cucurbita maxima L.

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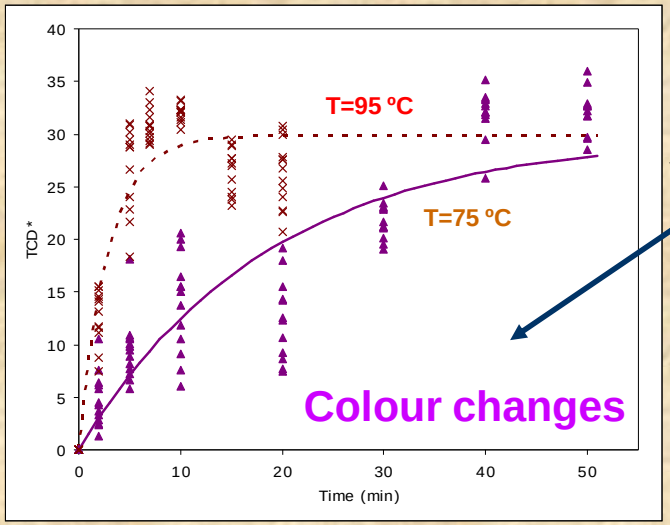
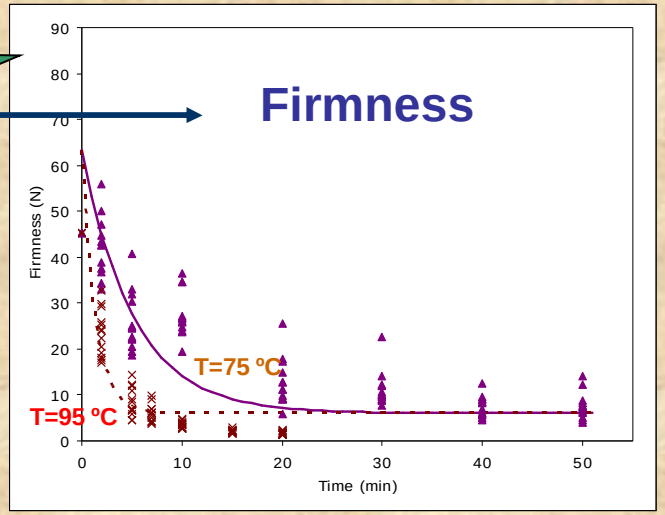
1. Heat Processing – effect on food quality and safety



Quality

Texture Analyser (Stable Micro-System Ltd, Godalming, UK)
single puncture measurement,10 mm depth of penetration, velocity of 1.0 mm s^{-1}



pumpkin

Cucurbita maxima L.

Peroxidase

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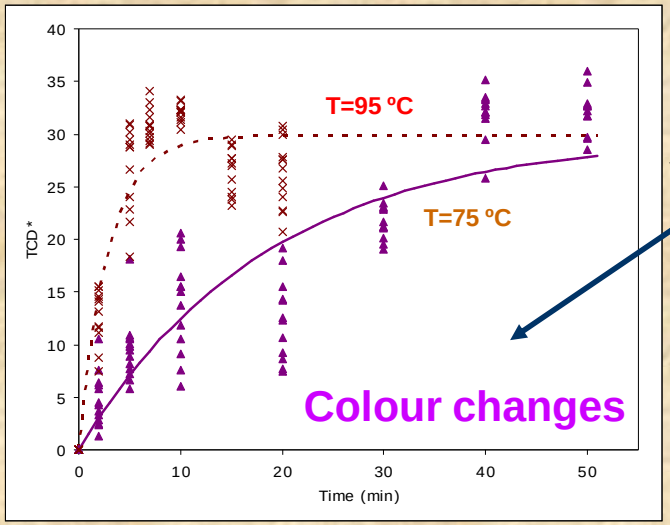


Colour changes

Quality

Firmness

Fractional conversion model

$$\frac{Firmness - Firmness_{eq}}{Firmness_0 - Firmness_{eq}} = e^{-kt}$$

k(T) → Arrhenius

pumpkin

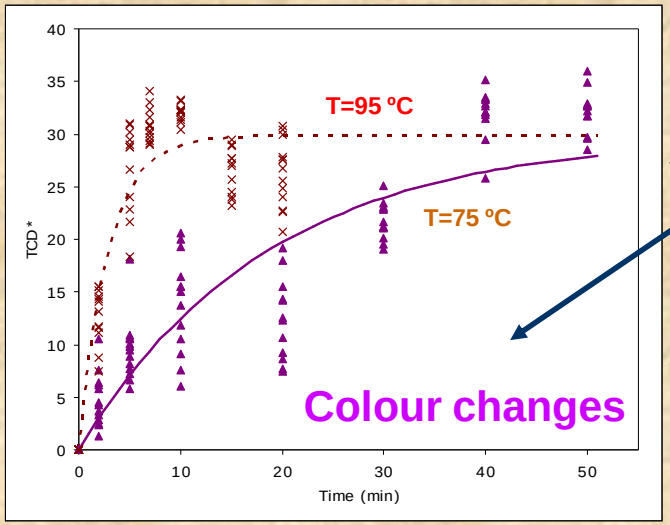
Cucurbita maxima L.

Peroxidase

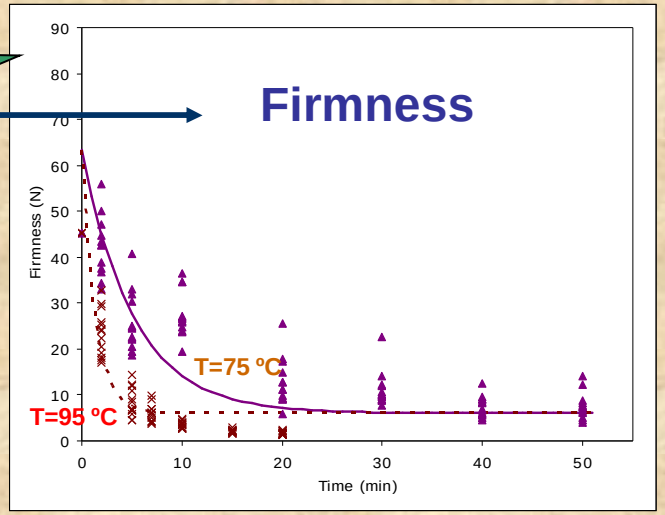
ATI Unicam spectrophotometer (Unicom Limited, Cambridge, United Kingdom).

Heating Foods: *Integrating quality and safety in thermal processes*

1. Heat Processing – effect on food quality and safety

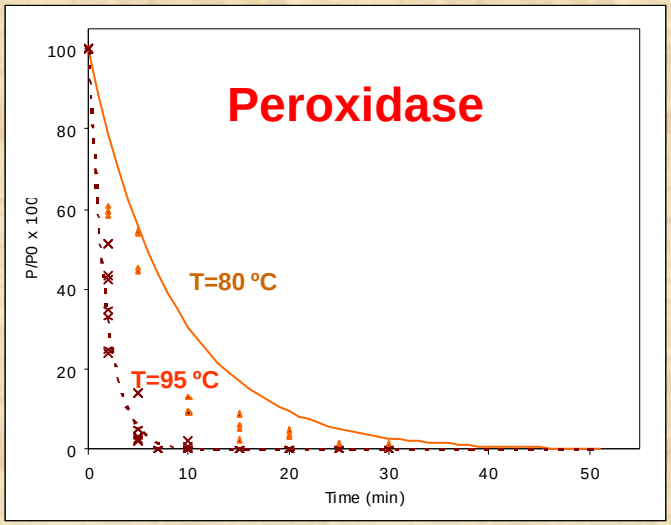


Quality



pumpkin

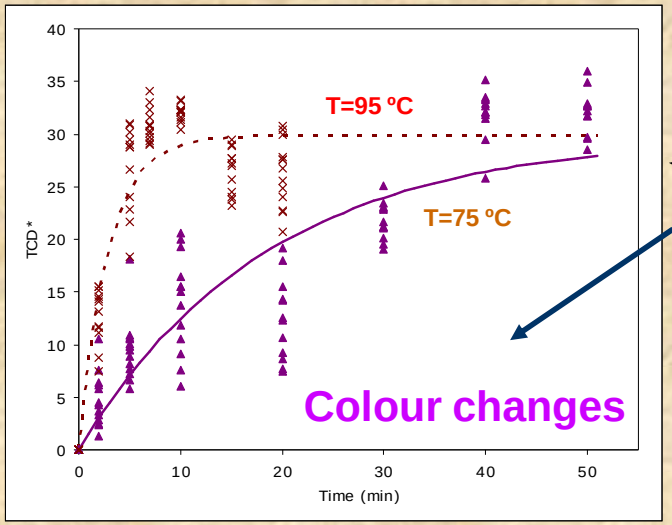
Cucurbita maxima L.



Spectrophotometry (Unicom Ltd, Cambridge, UK)

Heating Foods: *Integrating quality and safety in thermal processes*

1. Heat Processing – effect on food quality and safety



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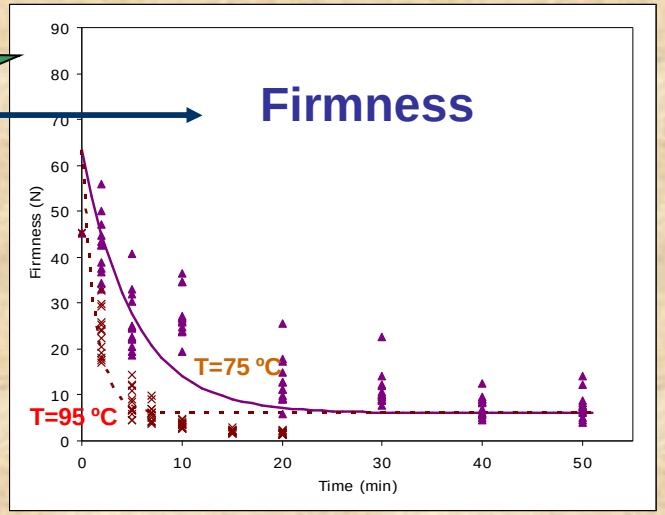


pumpkin

Cucurbita maxima L.

Peroxidase

First order kinetics

$$\frac{P}{P_0} = e^{-kt}$$

k(T) → Arrhenius

Heating Foods: *Integrating quality and safety in thermal processes*

1. Heat Processing – effect on food quality and safety

Modelling the kinetics of **peroxidase** inactivation and **colour** and **texture** changes of pumpkin during blanching, will allow convenient design of thermal processes

⇩

Stabilisation of enzymatic deterioration

Minimisation of quality losses

pumpkin

Cucurbita maxima L.

Blanching conditions

5.8 min at 90 ºC
and
3.9 min at 95 ºC

… are recommended to decrease 90% of peroxidase activity, ensuring a good retention of colour. Unavoidably, texture is greatly affected (~ 14% was retained).

Heating Foods: *Integrating quality and safety in thermal processes*

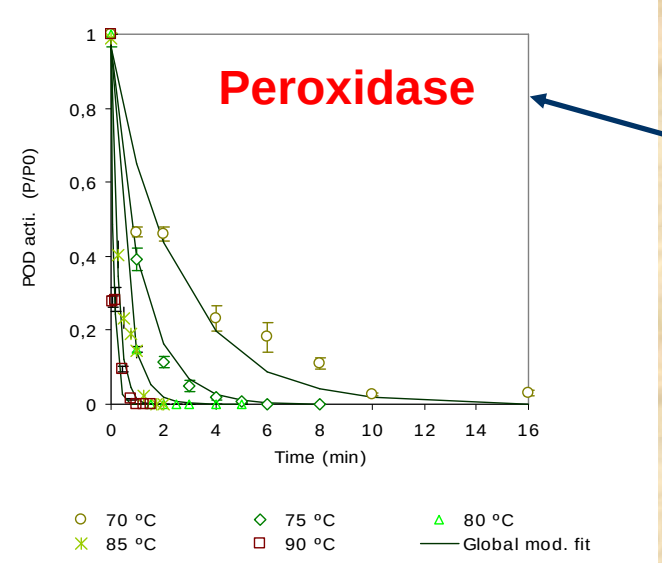
1. Heat Processing – effect on food quality and safety

broccoli

Brassica oleracea L.

Heating Foods: *Integrating quality and safety in thermal processes*

1. Heat Processing – effect on food quality and safety



Spectrophotometry (Unicom Ltd, Cambridge, UK)

Quality

Texture

Phenolic content

broccoli

Brassica oleracea L.

Heating Foods: *Integrating quality and safety in thermal processes*

1. Heat Processing – effect on food quality and safety

Peroxidase

First order kinetics

$$\frac{P}{P_0} = e^{-kt}$$

k(T) → Arrhenius

Quality

Texture

Phenolic content

broccoli

Brassica oleracea L.

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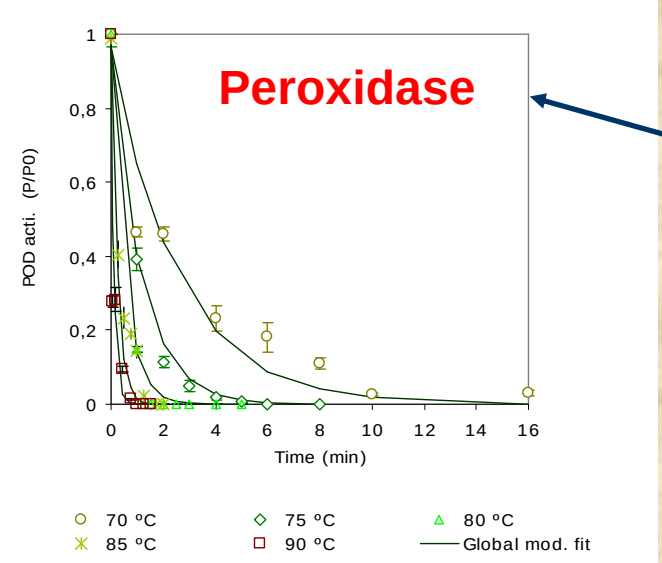

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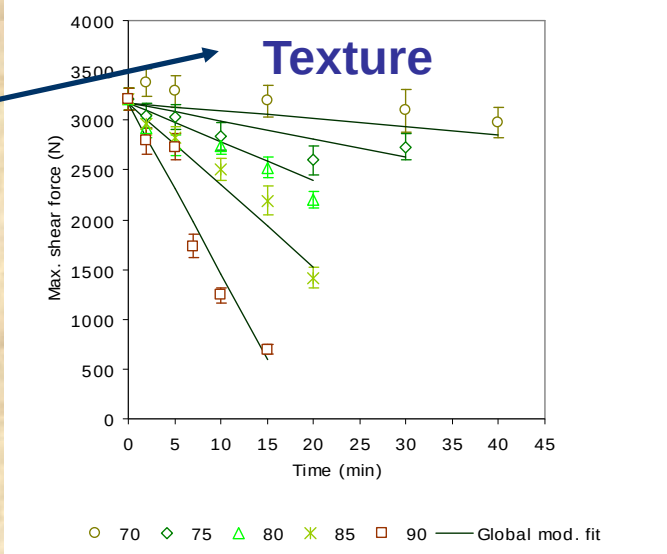


Texture Analyser (Stable Micro-System Ltd, Godalming, UK)
maximum shear force , test speed 8 mm s^{-1} , full-scale load 500 N

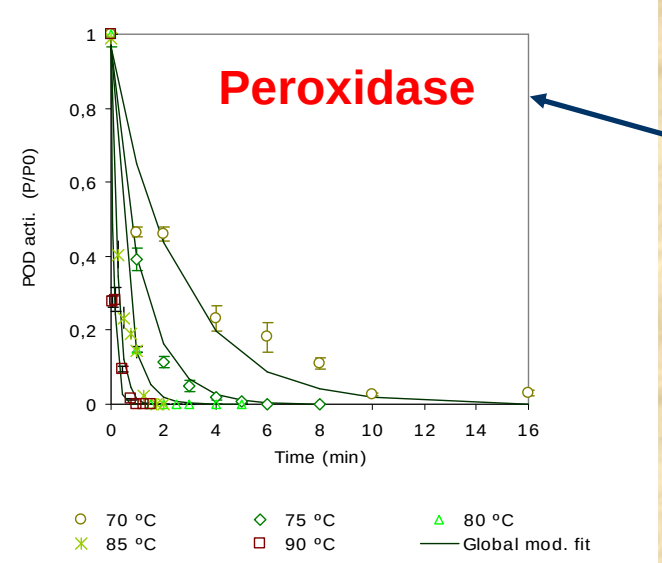
Phenolic content

broccoli

Brassica oleracea L.

Heating Foods: *Integrating quality and safety in thermal processes*

1. Heat Processing – effect on food quality and safety



Quality

Texture

Zero order kinetics

$$Maxshearforce = (Maxshearforce)_0 - kt$$

k(T) → Arrhenius

Phenolic content

broccoli

Brassica oleracea L.

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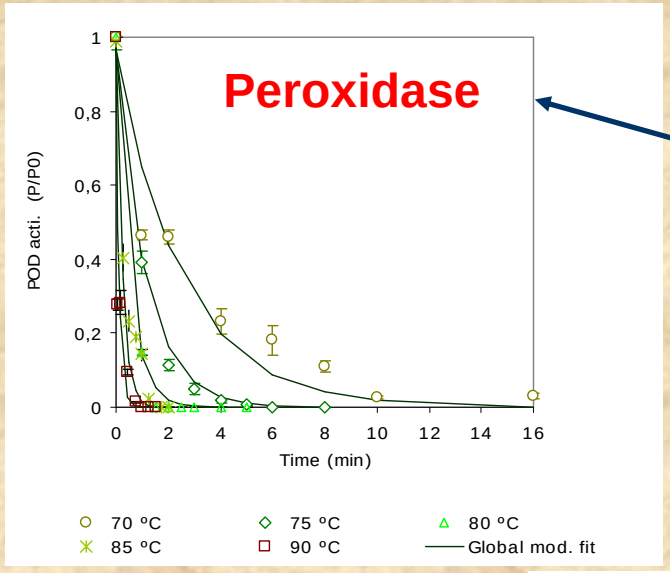
1. Heat Processing – effect on food quality and safety



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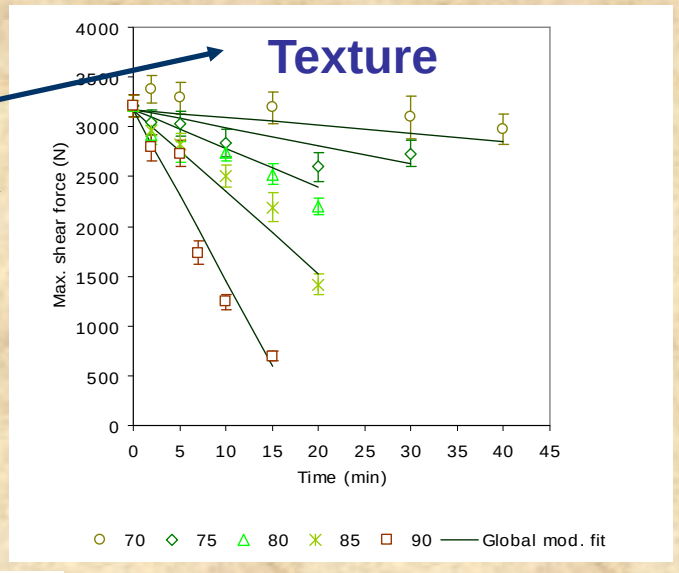

Spectrophotometry
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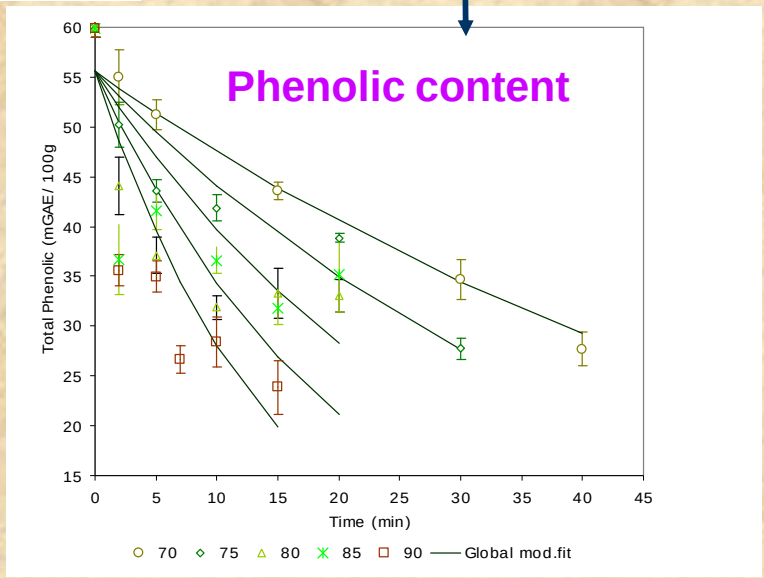

broccoli

Brassica oleracea L.

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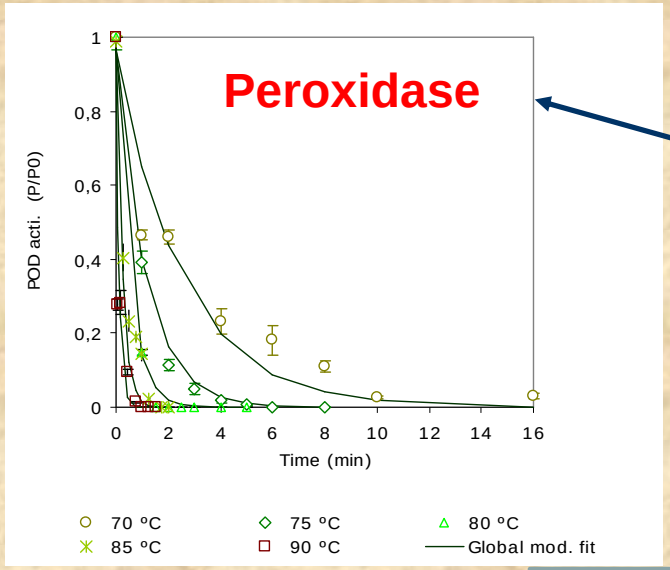
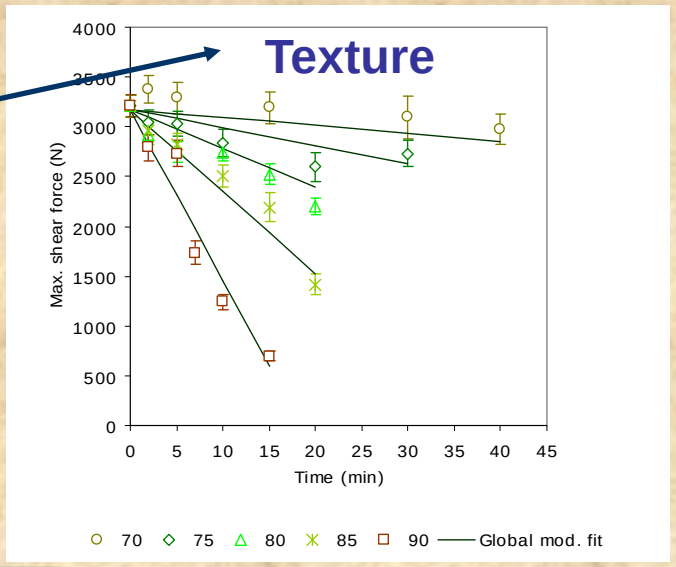
1. Heat Processing – effect on food quality and safety



Quality



Phenolic content

First order kinetics

$$P = P_0 e^{-kt}$$

k(T) → Arrhenius

broccoli

Brassica oleracea L.

Heating Foods: *Integrating quality and safety in thermal processes*

1. Heat Processing – effect on food quality and safety

Modelling the kinetics of peroxidase inactivation and phenolic content and texture changes of broccoli during blanching, will allow convenient design of thermal processes

⇩

Stabilisation of enzymatic deterioration

Minimisation of quality losses

broccoli

Brassica oleracea L.

Blanching conditions

6.5 min at 70 ºC
and
0.4 min at 90 ºC

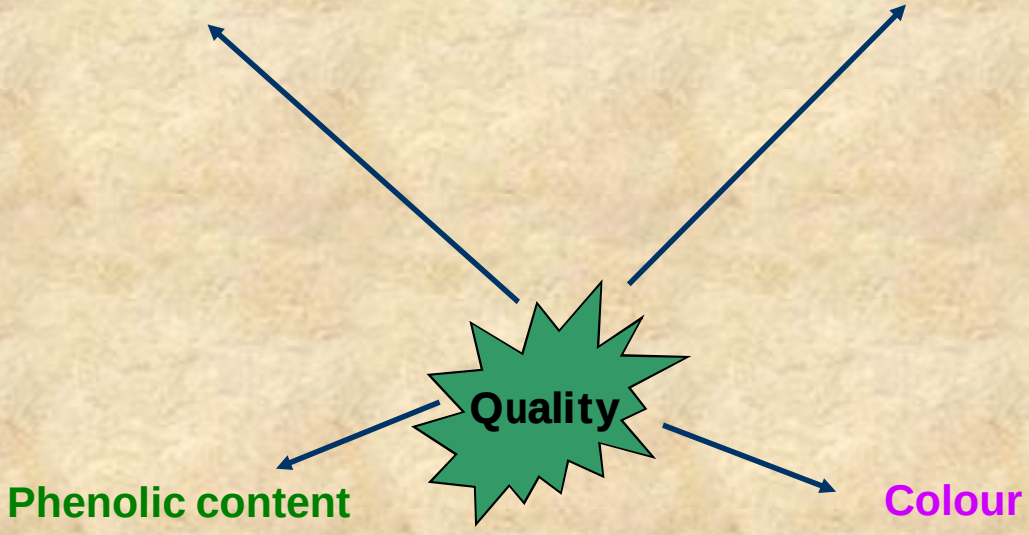
… are recommended to decrease 90% of peroxidase activity.
Texture was the most temperature sensitive parameter. Thus, attention should be given to texture against other quality parameters for optimizing thermal processes of broccoli.

Heating Foods: *Integrating quality and safety in thermal processes*

1. Heat Processing – effect on food quality and safety

carrots

Daucus carota L.



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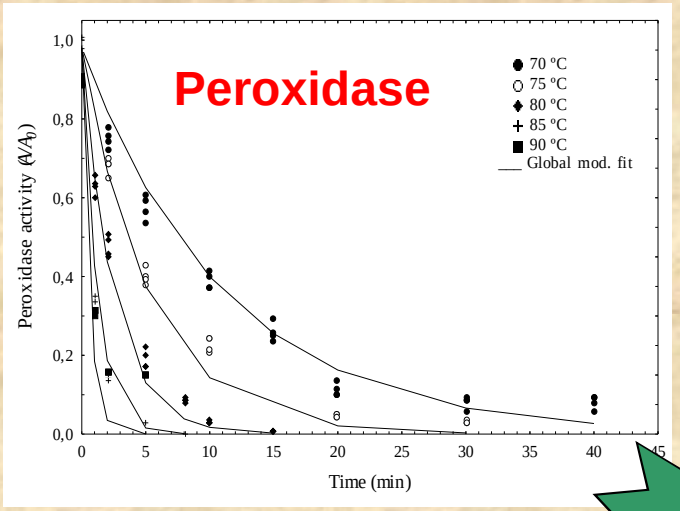
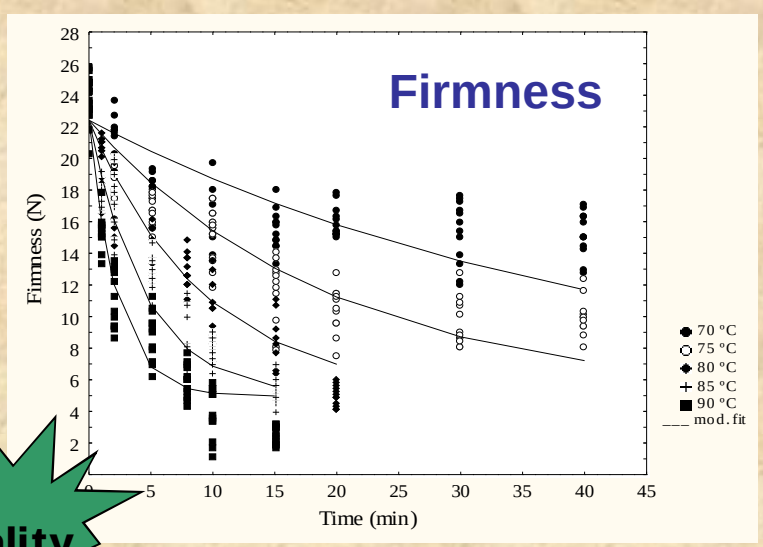
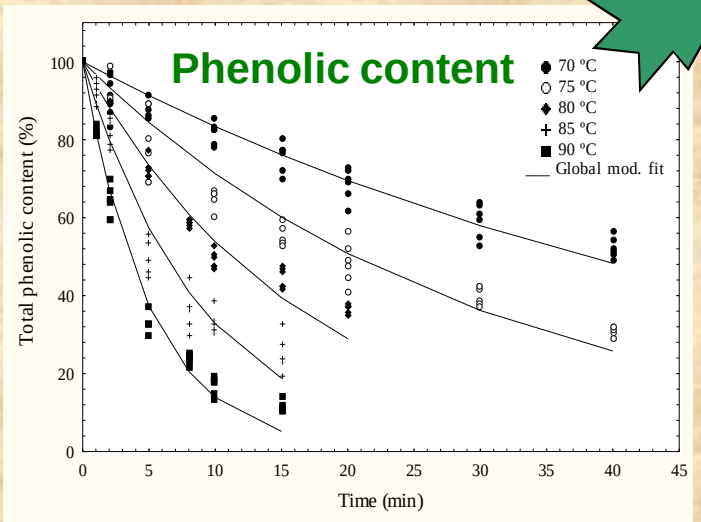
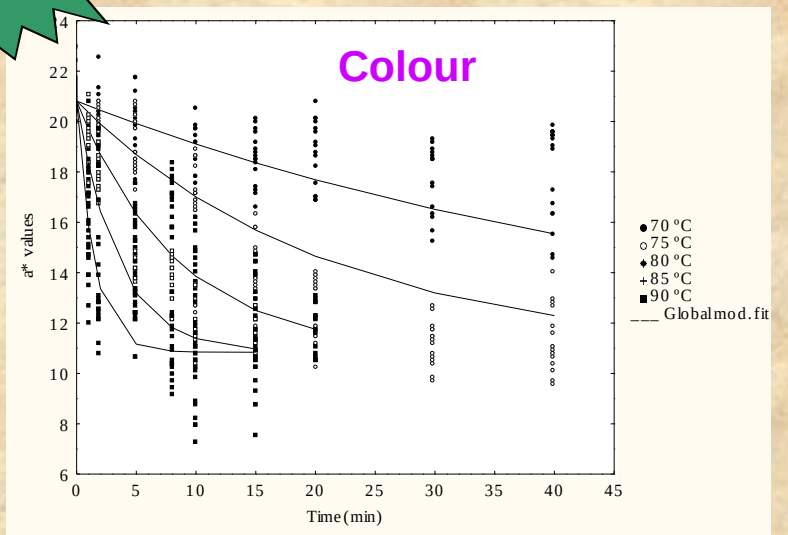




Quality





carrots

Daucus carota L.

Heating Foods: *Integrating quality and safety in thermal processes*

1. Heat Processing – effect on food quality and safety

carrots

Daucus carota L.

Quality

Peroxidase

First order kinetics

$$\frac{P}{P_0} = e^{-kt}$$

k(T) → Arrhenius

Firmness

Fractional conversion model

$$\frac{Firmness - Firmness_{eq}}{Firmness_0 - Firmness_{eq}} = e^{-kt}$$

k(T) → Arrhenius

Phenolic content

First order kinetics

$$\frac{P}{P_0} = e^{-kt}$$

k(T) → Arrhenius

Colour

Fractional conversion model

$$\frac{C - C_{eq}}{C_0 - C_{eq}} = e^{-kt}$$

k(T) → Arrhenius

Heating Foods: *Integrating quality and safety in thermal processes*

1. Heat Processing – effect on food quality and safety

carrots

Daucus carota L.

Modelling the kinetics of peroxidase inactivation and phenolic content, colour and texture changes of carrots during blanching, will allow convenient design of thermal processes

Stabilisation of enzymatic deterioration

Minimisation of quality losses

Blanching conditions 6.0 min at 80 ºC

… is recommended to decrease 90% of peroxidase activity, ensuring a good retention of phenolic content (70%). Colour was the most temperature sensitive parameter. Thus, attention should be given to colour against other quality parameters for optimizing thermal processes of carrots.

1. Heat Processing – effect on food quality and safety

Blanching

Safety

red bell pepper

Capsicum annuum, L.

parsley

Petroselinum crispum

Heating Foods: *Integrating quality and safety in thermal processes*

1. Heat Processing – effect on food quality and safety

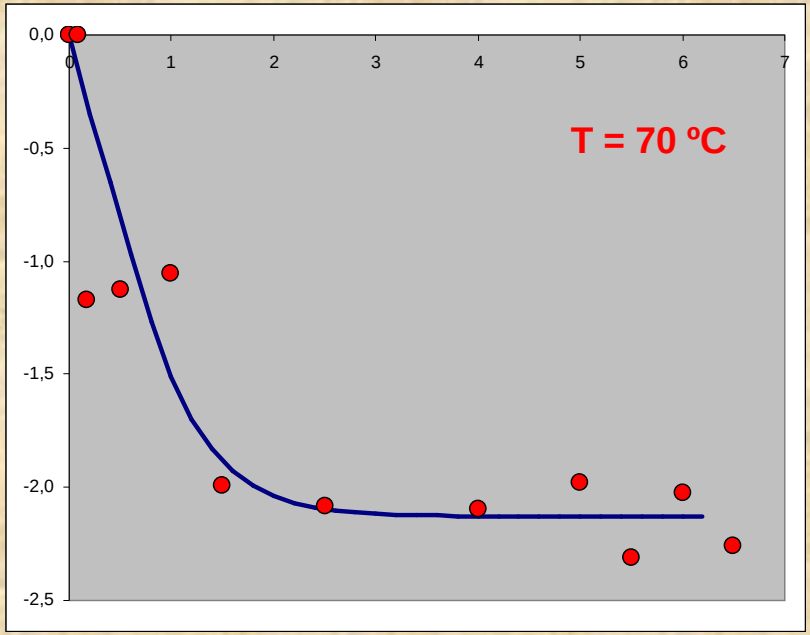
red bell pepper

Capsicum annuum, L.

total mesophiles

PCA

autoctone flora



Initial counts: $N_0 \sim 10^7$ CFU / mg

Heating Foods: *Integrating quality and safety in thermal processes*

1. Heat Processing – effect on food quality and safety

red bell pepper

Capsicum annuum, L.

total mesophiles

PCA

autoctone flora

$\log(N/N_0)$

Gompertz-inspired model

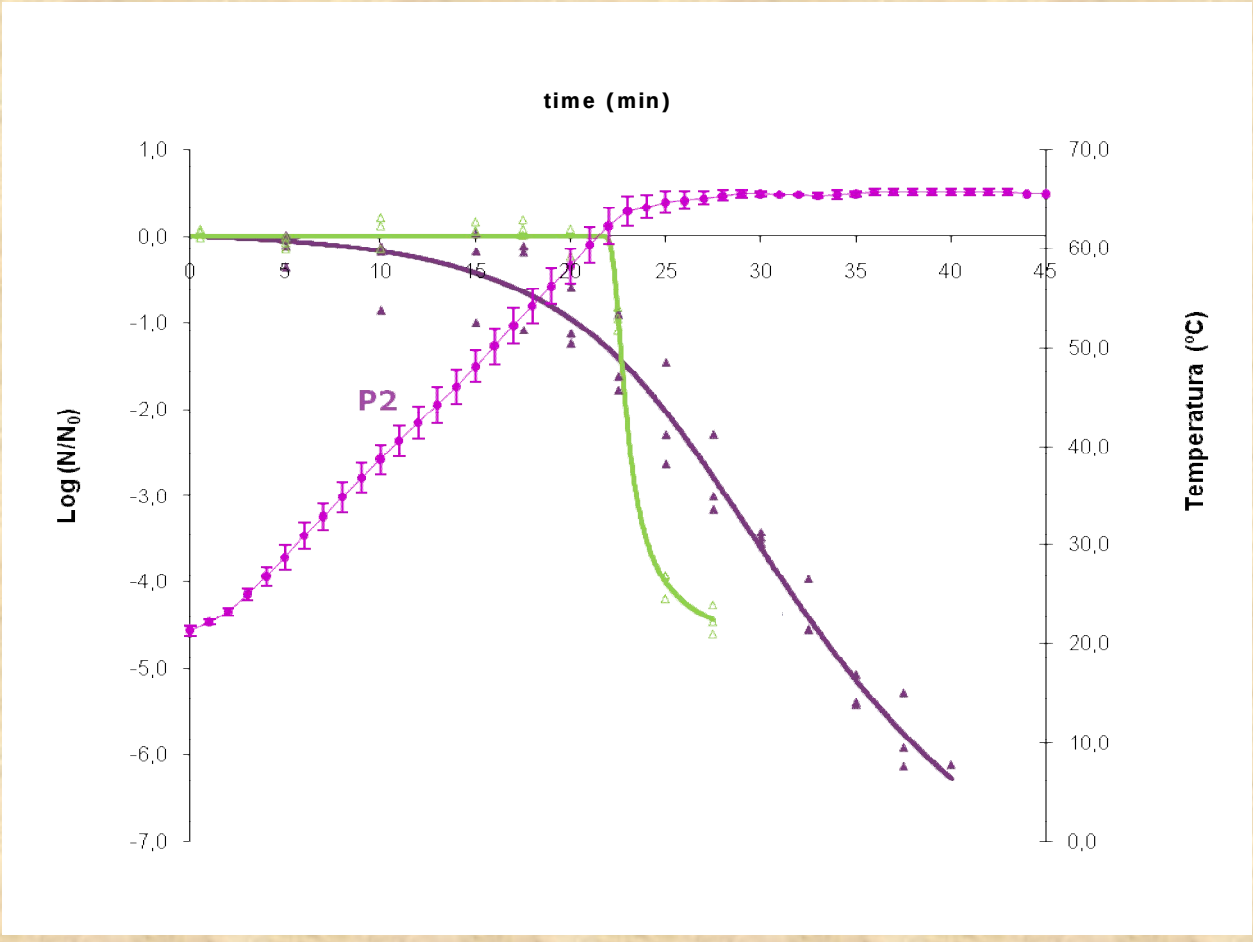
$$\log\left(\frac{N}{N_0}\right) = \log\left(\frac{N_{res}}{N_0}\right)\exp\left(-\exp\left(-\frac{k\,e}{\log\left(\frac{N_{res}}{N_0}\right)}(L-t)+1\right)\right)$$

time (min)

Initial counts: $N_0 \sim 10^7$ CFU / mg

Heating Foods: *Integrating quality and safety in thermal processes*

1. Heat Processing – effect on food quality and safety



Petroselinum crispum

Palcam Agar

Initial counts: $N_0 \sim 10^7$ CFU / mg

Listeria innocua

artificially innoculated

Heating Foods: *Integrating quality and safety in thermal processes*

1. Heat Processing – effect on food quality and safety

Gompertz-inspired model

$$\left(\log\frac{N}{N_0}\right)_{non-isot} = \int_0^t \left[-k(T)e \exp\left(-\frac{k(T)e}{\log\left(\frac{N_{res}}{N_0}\right)}(L(T)-t')+1 \right) \exp\left(-\exp\left(-\frac{k(T)e}{\log\left(\frac{N_{res}}{N_0}\right)}(L(T)-t')+1 \right) \right) \right] dt'$$

Initial counts: $N_0 \sim 10^7$ CFU / mg

Petroselinum crispum

Palcam Agar

Listeria innocua

artificially innoculated

1. Heat Processing – effect on food quality and safety

Modelling the kinetics of microbial inactivation including the effect of relevant variables (temperature, pH and water activity) will allow convenient design of thermal processes

However …

results obtained in broth → can be applied in predicting microbial responses in solid foods ?

Heating Foods: *Integrating quality and safety in thermal processes*

1. Heat Processing – effect on food quality and safety

Microbial content = f (time, temperature, pH, water activity)

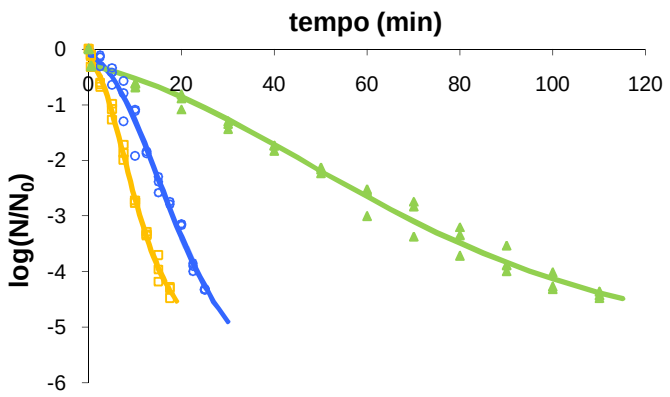
TSB

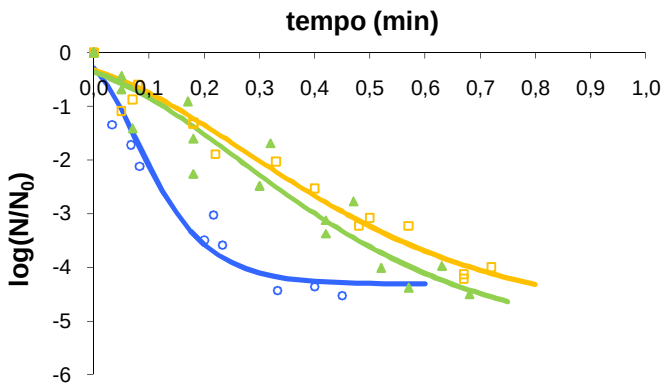
T=52.5 °C

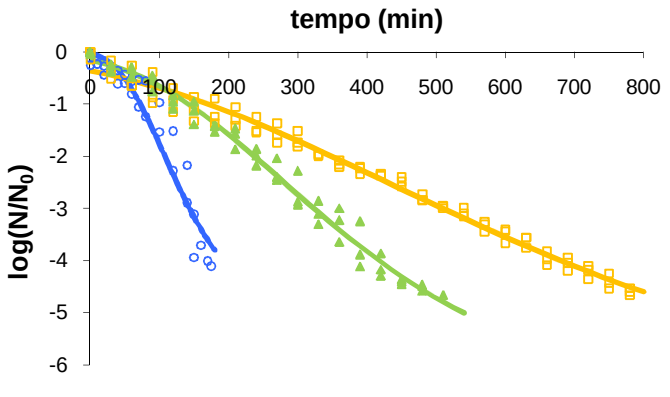
T=65.0 °C

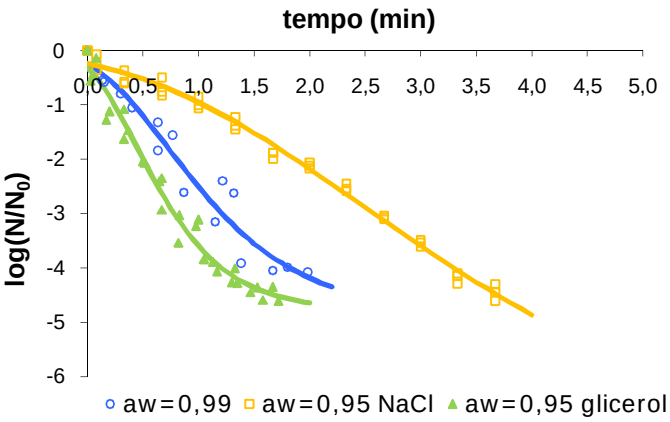
pH=4.5

pH=7.5









Estudos em alimento

Heating Foods: *Integrating quality and safety in thermal processes*

1. Heat Processing – effect on food quality and safety

$$\log\left(\frac{N_{res}}{N_0}\right) = \sum_{i=0}^{n}\sum_{j=0}^{n} G_{Tail_{ij}}\ a_w^{\,k}\ pH^j$$

$$k_{max} = \exp\left(\sum_{i=0}^{n}\sum_{j=0}^{n}\sum_{k=0}^{n} G_{k_{max\,ijk}}\ a_w^{\,k}\ pH^j\ T^i\right)$$

$$L = \exp\left(\sum_{i=0}^{n}\sum_{j=0}^{n}\sum_{k=0}^{n} G_{L_{ijk}}\ a_w^{\,k}\ pH^j\ T^i\right)$$

pH = 6.2

a_w = 0.998

T = 52.5°C to 65.0 °C

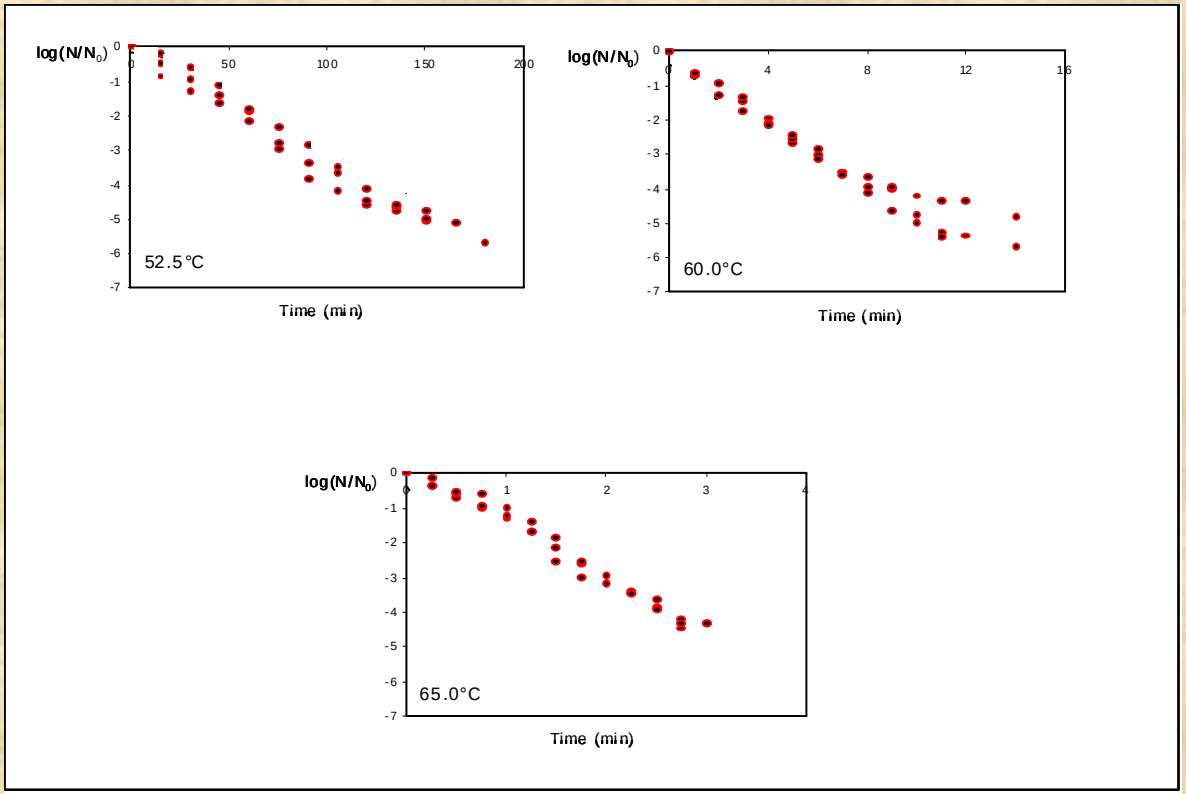
$$\log\left(\frac{N}{N_0}\right) = \log\left(\frac{N_{res}}{N_0}\right)\exp\left(-\exp\left(-\frac{k_{max}\,e}{\log\left(\frac{N_{res}}{N_0}\right)}(L-t)+1\right)\right)$$

Heating Foods: *Integrating quality and safety in thermal processes*

1. Heat Processing – effect on food quality and safety

Microbial content = f (time, temperature, pH, water activity)

pH=6.2
a_w=0.998



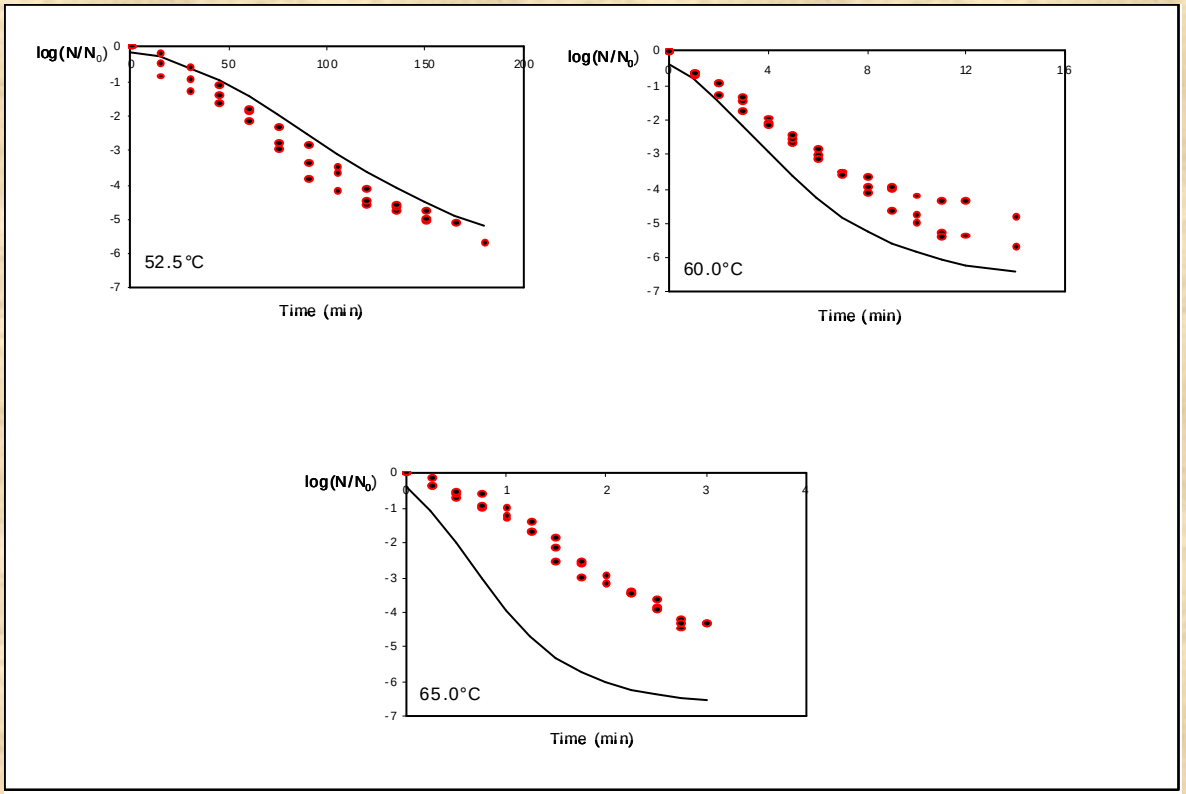
Initial counts: $N_0 \sim 10^7$ CFU / mg

Heating Foods: *Integrating quality and safety in thermal processes*

1. Heat Processing – effect on food quality and safety

Microbial content = f (time, temperature, pH, water activity)

pH=6.2
a_w=0.998



Initial counts: $N_0 \sim 10^7$ CFU / mg

1. Heat Processing – effect on food quality and safety

Can results obtained in broth be applied in predicting microbial responses in solid foods ?

Attention !

Results corroborate that microbial kinetic behaviour in "real" food surfaces differs to the one observed in broth. Consequently, caution should be taken when using the latter ones in food processing predictions.

Heating Foods: *Integrating quality and safety in thermal processes*

Today's Presentation

1. Heat Processing – effect on food quality and safety

2. Combining Heat and other Non-Thermal Technologies to preserve foods 

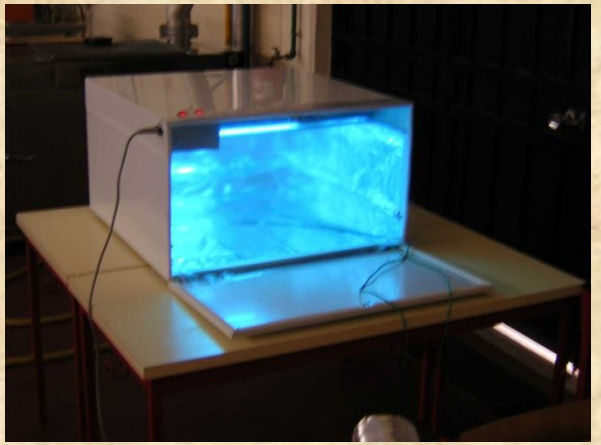
3. New Approaches on Understanding Heat Degradation in Foods

Heating Foods: *Integrating quality and safety in thermal processes*

2. Combining Heat and other Non-Thermal Technologies to preserve foods

UV-C radiation

UV-C chamber (University of Algarve), 4 germicidal UV lamps (TUV G30T8, 16 W, Philips, peak emission at 254 nm), average intensity 12.36 W/m^2



Ozone

ozone generator, concentration measured by potential difference, 0.3 ppm

Ultrasonication / Thermosonication

ultrasound equipment (Bandelin Sonorex RK 100H) operating at 32 kHz

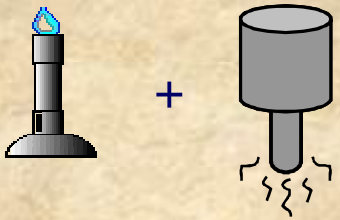
Heating Foods: *Integrating quality and safety in thermal processes*

2. Combining Heat and other Non-Thermal Technologies to preserve foods

watercress

Nasturtium officinale

Types of combined treatments with ultrasound



Heat + Ultrasound

Thermosonication

Heating Foods: *Integrating quality and safety in thermal processes*

2. Combining Heat and other Non-Thermal Technologies to preserve foods

watercress

Nasturtium officinale

Quality

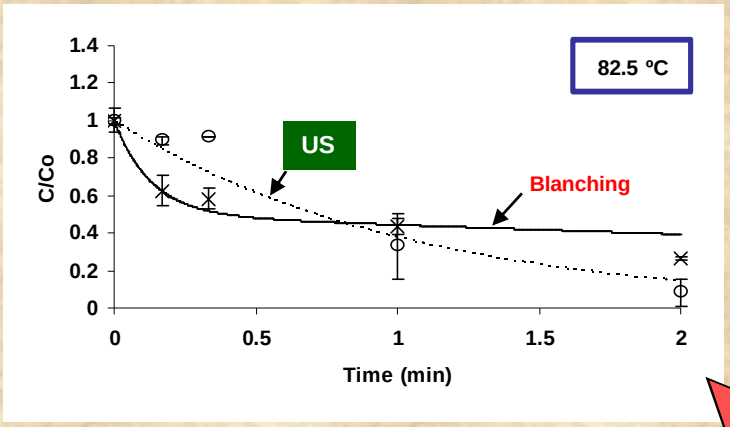
Vitamin C

Colour changes

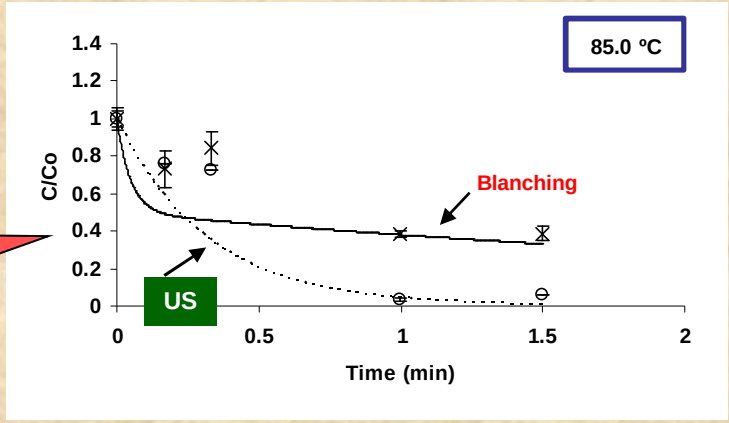
Peroxidase

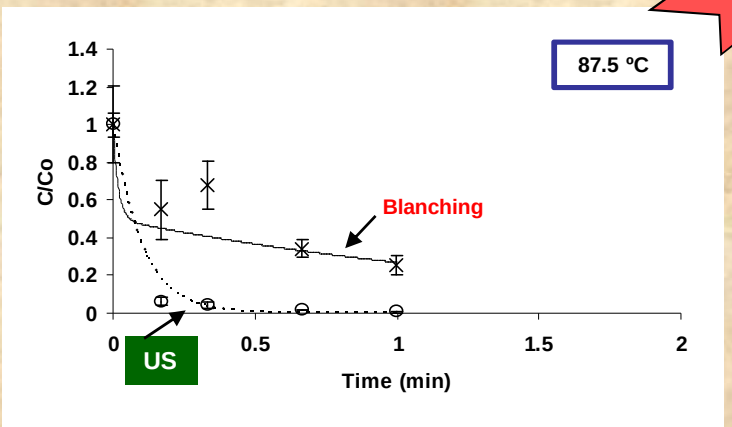
Heating Foods: *Integrating quality and safety in thermal processes*

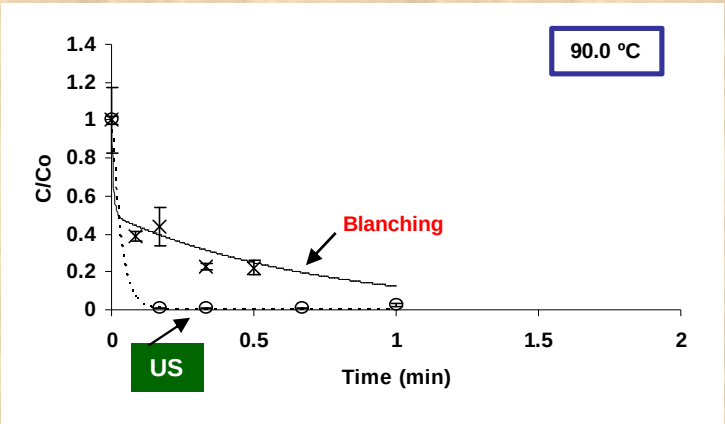
2. Combining Heat and other Non-Thermal Technologies to preserve foods



Peroxidase







2. Combining Heat and other Non-Thermal Technologies to preserve foods

The application of thermosonication

- **temperatures above 85 ºC and for the same blanching times**

led to higher enzyme inactivation when compared to heat blanching processes

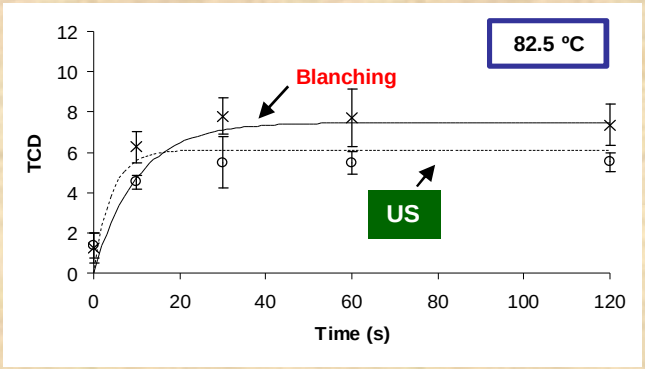
Peroxidase

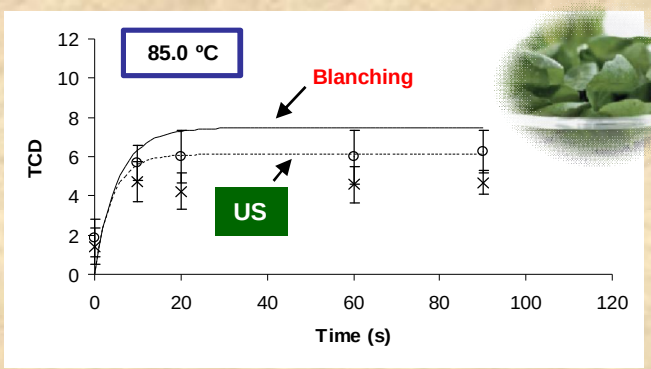
These results allow the application of shorter blanching times at this range of temperatures, leading to a product with a higher quality, or minimized processing

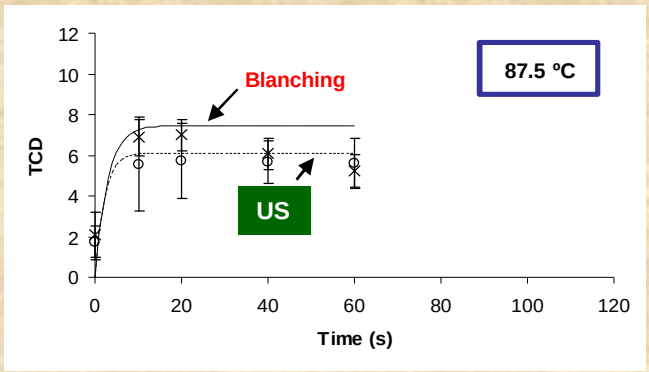
Heating Foods: *Integrating quality and safety in thermal processes*

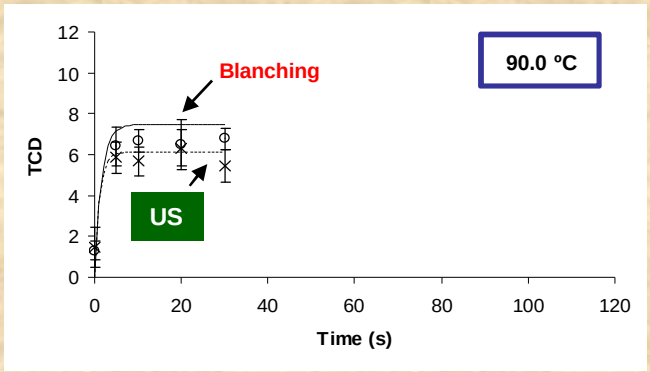
82.5 °C 85 °C

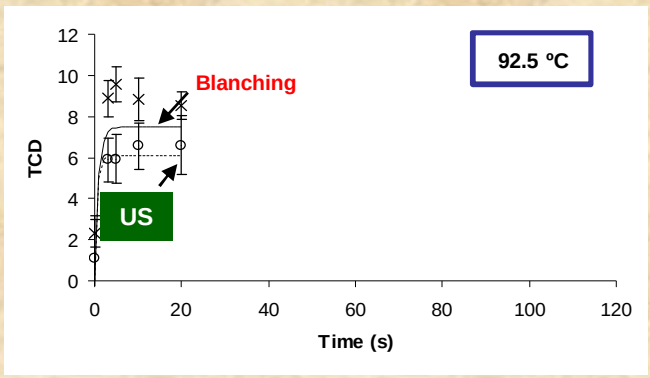
2. Combining Heat and other Non-Thermal Technologies to preserve foods











2. Combining Heat and other Non-Thermal Technologies to preserve foods

The application of thermosonication

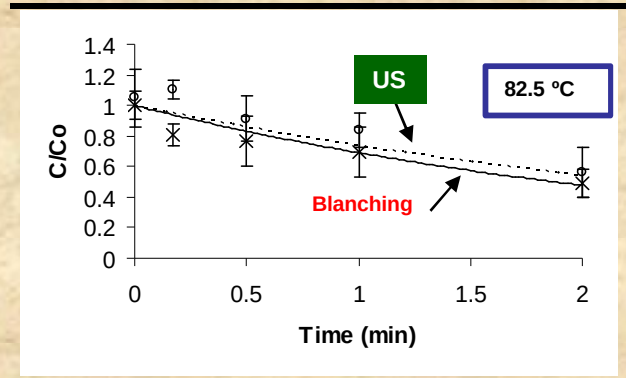


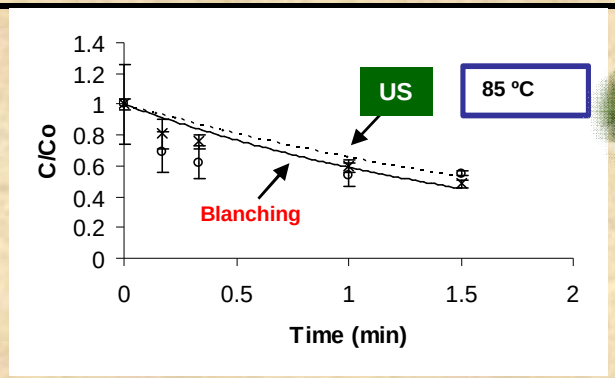
Colour

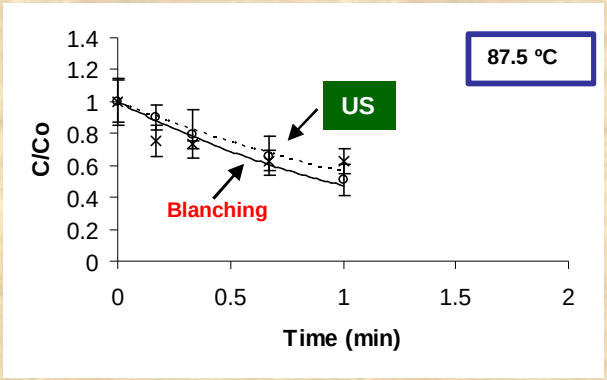
Reaction rates of watercress colour changes due to heat and thermosonication blanchings were not significantly different

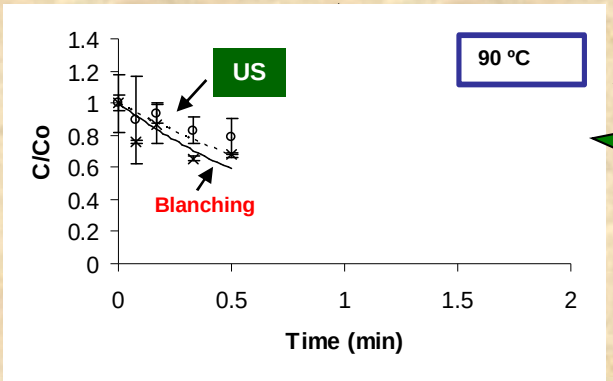
Heating Foods: *Integrating quality and safety in thermal processes*

2. Combining Heat and other Non-Thermal Technologies to preserve foods

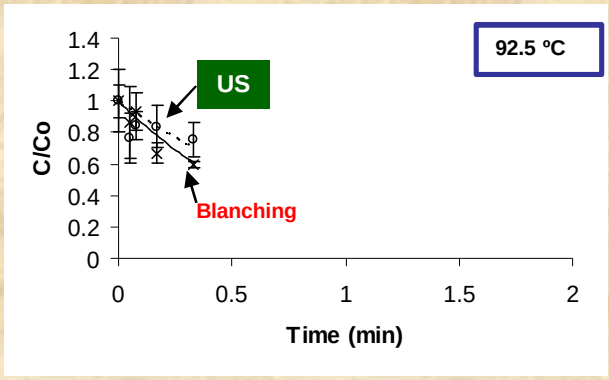








Vitamin C



2. Combining Heat and other Non-Thermal Technologies to preserve foods

The application of thermosonication

Vitamin C

Results showed no significant differences between heat and thermosonication treatments

The treatment will allow good vitamin C retention

2. Combining Heat and other Non-Thermal Technologies to preserve foods

The application of thermosonication

Quality

The thermosonication treatments can be a good alternative to the traditional heat blanching processes, since higher quality products are attained

Heating Foods: *Integrating quality and safety in thermal processes*

2. Combining Heat and other Non-Thermal Technologies to preserve foods

Safety

watercress

Nasturtium officinale

red bell pepper

Capsicum annuum, L.

strawberries

Fragaria ananassa

Heating Foods: *Integrating quality and safety in thermal processes*

2. Combining Heat and other Non-Thermal Technologies to preserve foods

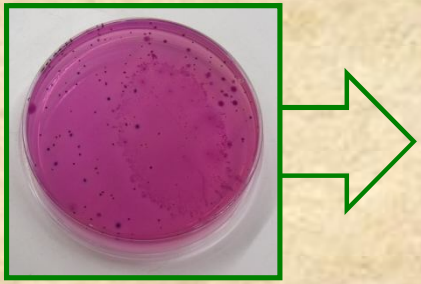
red bell pepper

Listeria innocua

(artificially inoculated)

Palcam Agar

VRBA



watercress

Total coliforms

(autoctone flora)

strawberries

Total mesophiles

(autoctone flora)

PCA

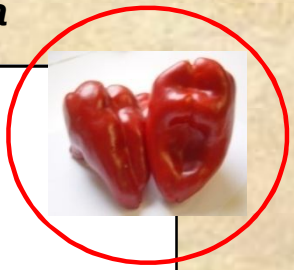
Heating Foods: *Integrating quality and safety in thermal processes*

2. Combining Heat and other Non-Thermal Technologies to preserve foods

Treatment time = 2 min

5 replicates

Listeria innocua



Initial counts: ~ 10^7 CFU / mg

Heating Foods: *Integrating quality and safety in thermal processes*

2. Combining Heat and other Non-Thermal Technologies to preserve foods

Treatment time = 2 min

5 replicates

Total coliforms

Initial counts: ~ 10^8 CFU / mg

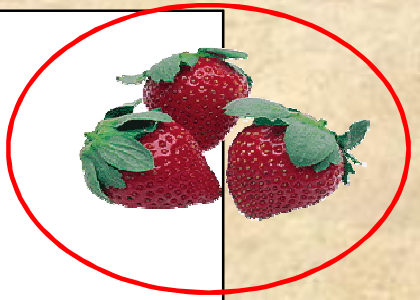
Heating Foods: *Integrating quality and safety in thermal processes*

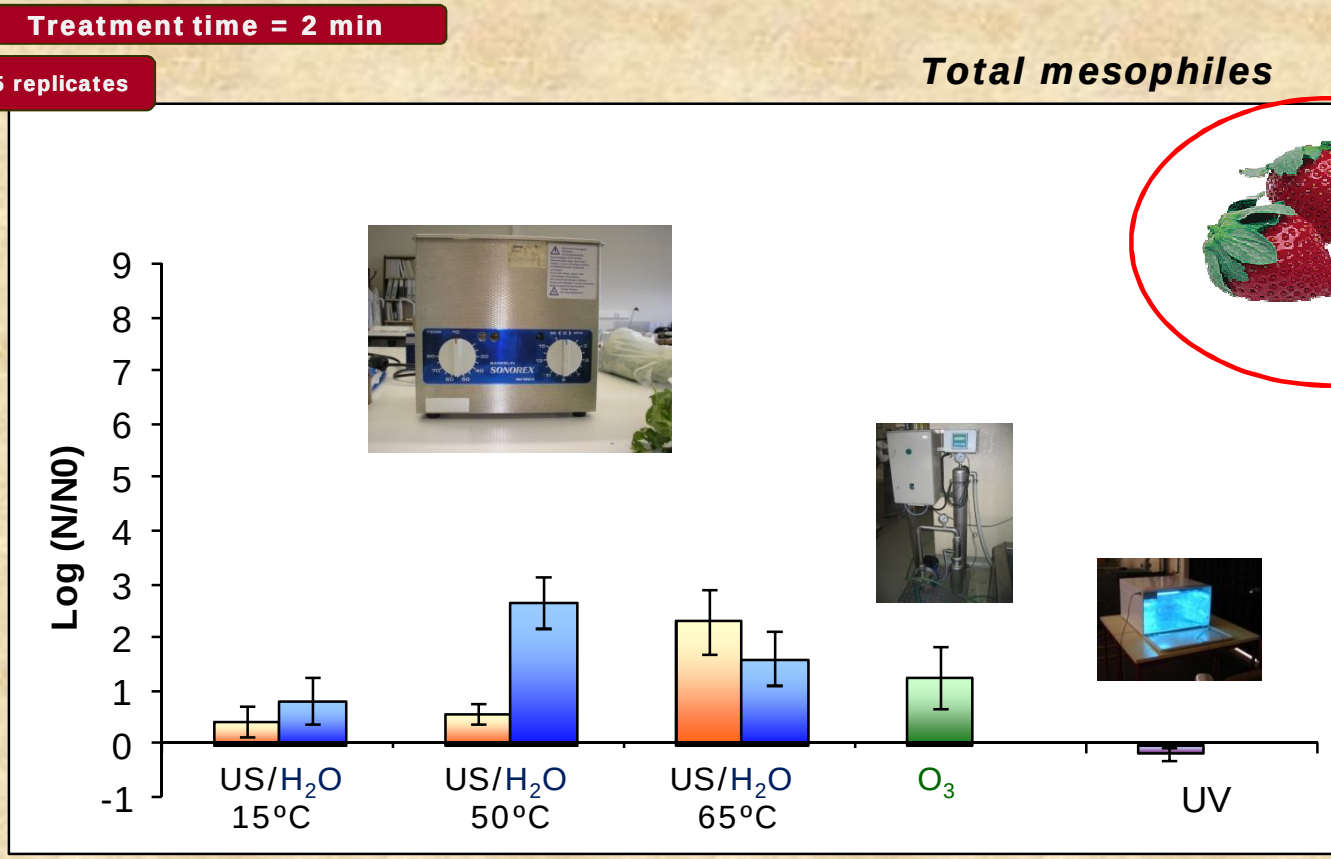
2. Combining Heat and other Non-Thermal Technologies to preserve foods

Treatment time = 2 min

5 replicates

Total mesophiles





Initial counts: ~ 10^7 CFU / mg

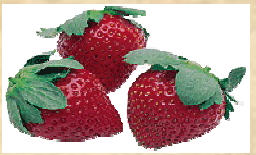
Heating Foods: *Integrating quality and safety in thermal processes*

2. Combining Heat and other Non-Thermal Technologies to preserve foods

Thermosonication

Ozone in aqueous solution

UV-C radiation



Safety

- Thermosonication is a promising technique
- Ozonated water-washings are equivalent to simple water-washings
- UV-C radiation is not efficient

Heating Foods: *Integrating quality and safety in thermal processes*

Today's Presentation

1. Heat Processing – effect on food quality and safety

2. Combining Heat and other Non-Thermal Technologies to preserve foods

3. **New Approaches on Understanding Heat Degradation in Foods**

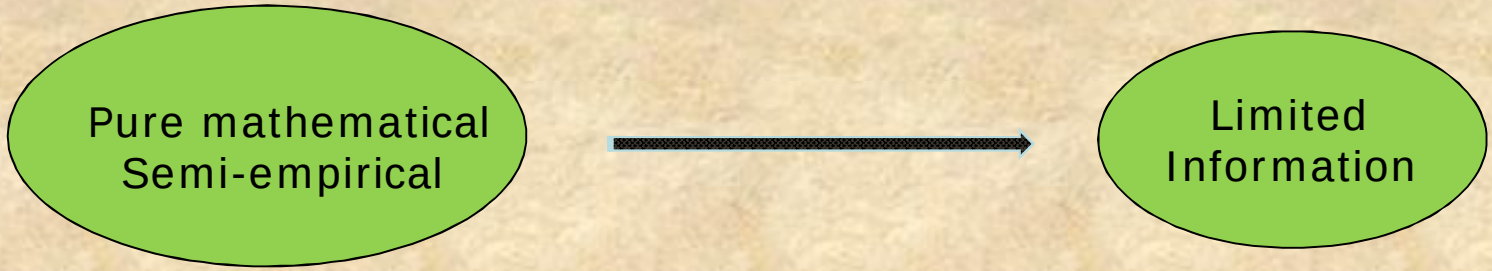
Heating Foods: *Integrating quality and safety in thermal processes*

3. New Approaches on Understanding Heat Degradation in Foods

Food reactions often do not occur isolated but rather within a chain of complex reactions, all dependent on several different environmental conditions

3. New Approaches on Understanding Heat Degradation in Foods

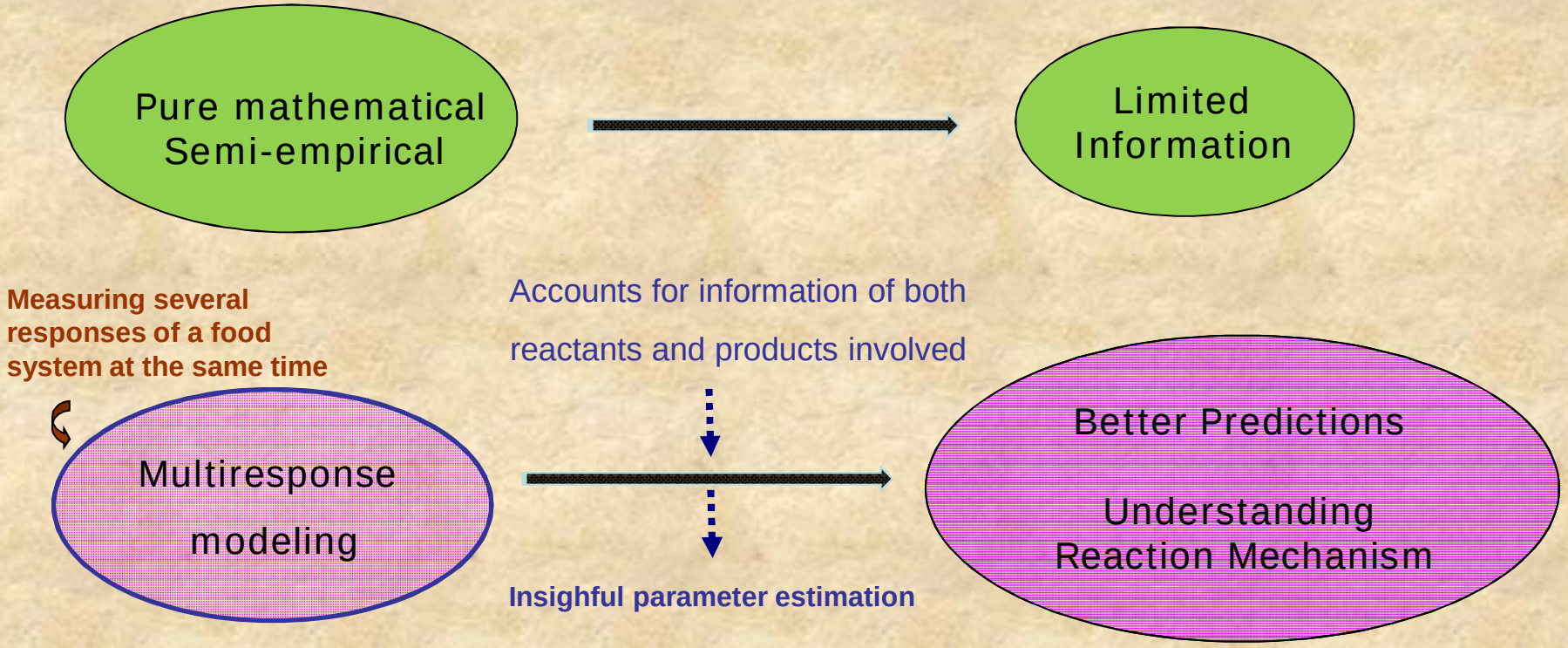
Food reactions often do not occur isolated but rather within a chain of complex reactions, all dependent on several different environmental conditions



Heating Foods: *Integrating quality and safety in thermal processes*

3. New Approaches on Understanding Heat Degradation in Foods

Food reactions often do not occur isolated but rather within a chain of complex reactions, all dependent on several different environmental conditions



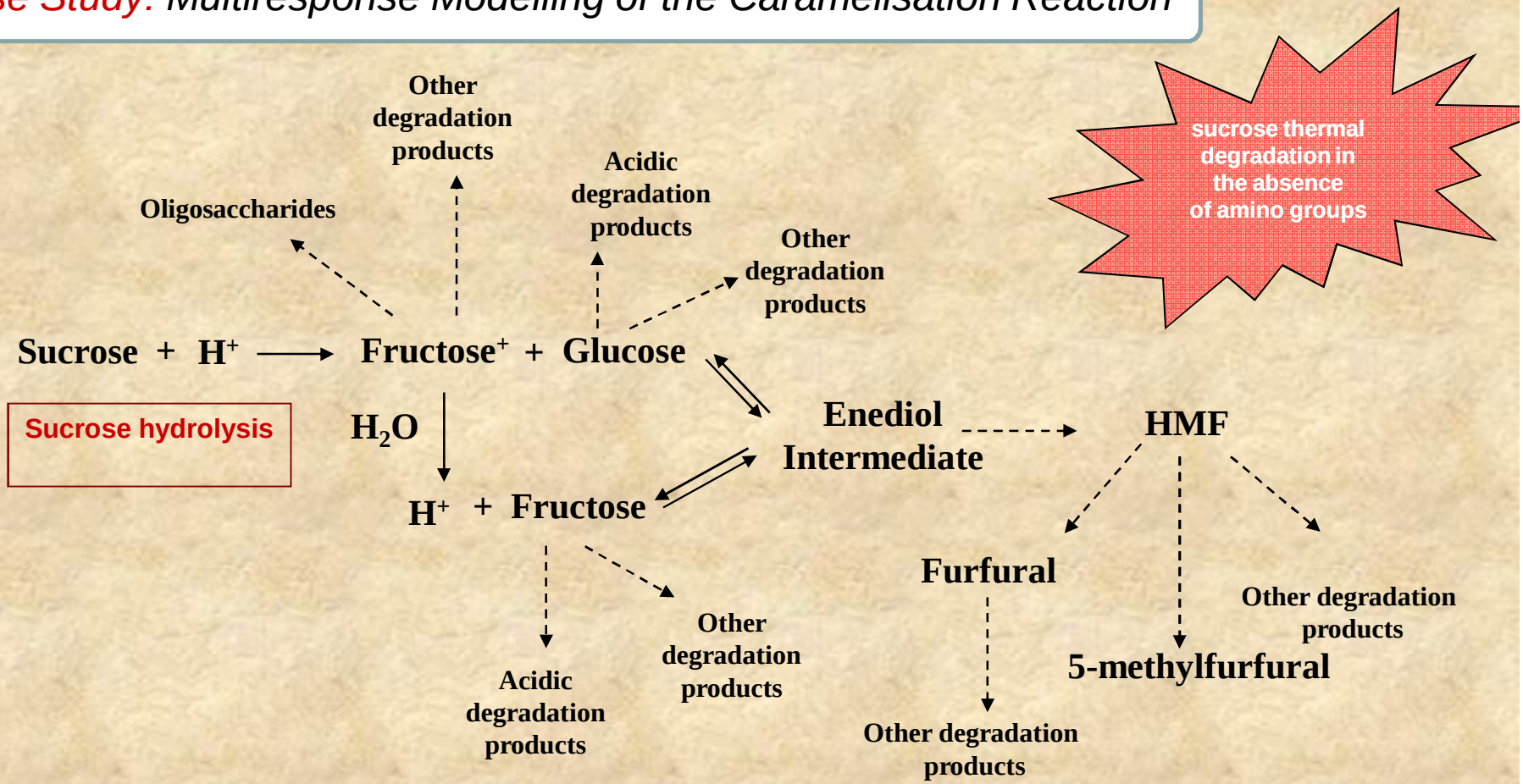
3. New Approaches on Understanding Heat Degradation in Foods

Examples of multiresponse modelling in food systems

- enzymatic reactions *(Torres, Lessard & Hill, 2003; Barros & Malcata, 2004)*
- chlorophyll degradation in foods *(van Boekel, 1999)*
- lactic fermentation during pickled carrot manufacture *(Nabais & Malcata, 1997)*
- Maillard reaction *(van Boekel, 1998)*
- acrylamide formation *(Knol, Van Loon, Linssen, Ruck, Van Boekel & Voragen, 2005)*

3. New Approaches on Understanding Heat Degradation in Foods

Case Study: *Multiresponse Modelling of the Caramelisation Reaction*



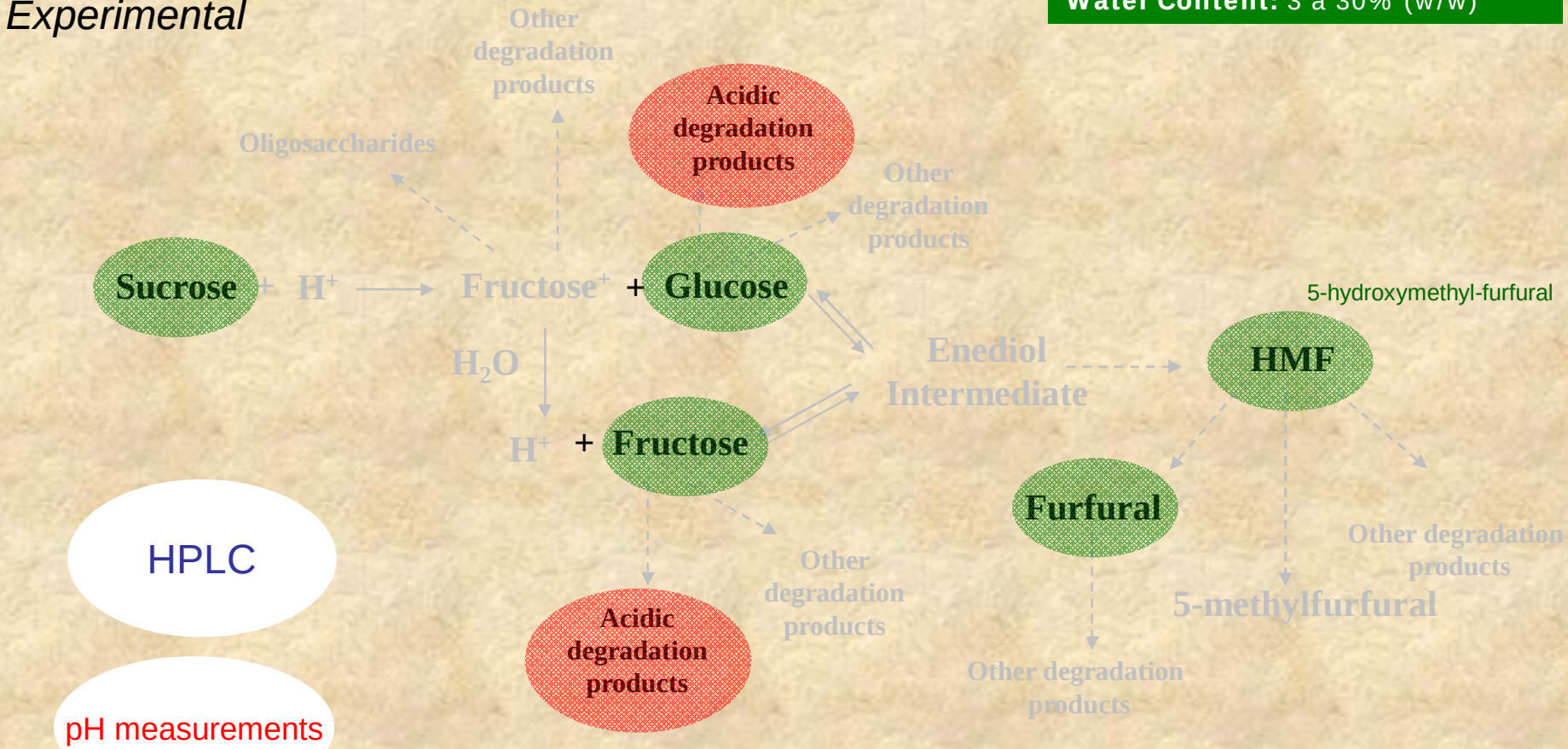
Heating Foods: *Integrating quality and safety in thermal processes*

3. New Approaches on Understanding Heat Degradation in Foods

Temperature range: 100 to 180ºC

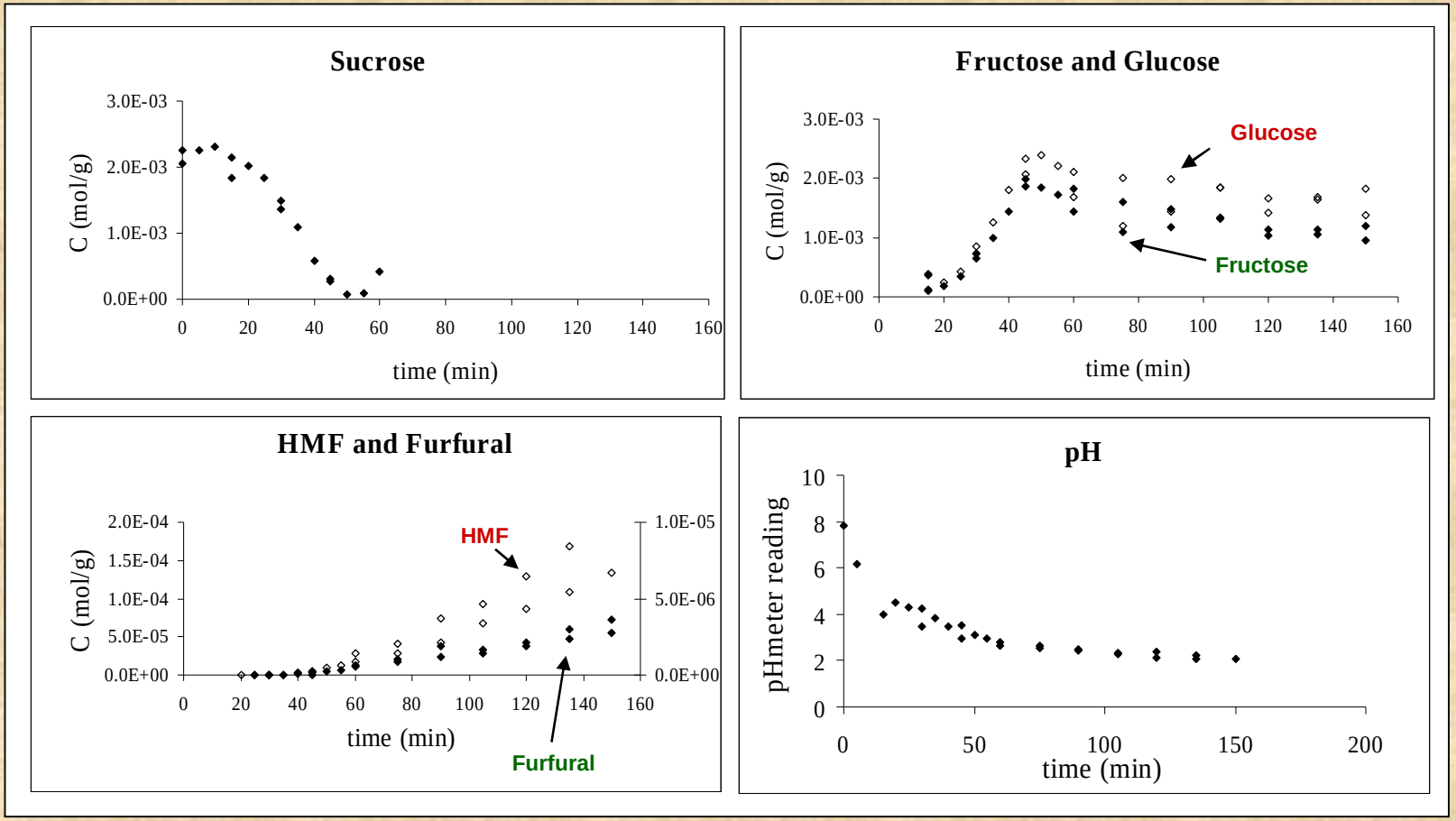
Water Content: 3 a 30% (w/w)

Experimental



Heating Foods: *Integrating quality and safety in thermal processes*

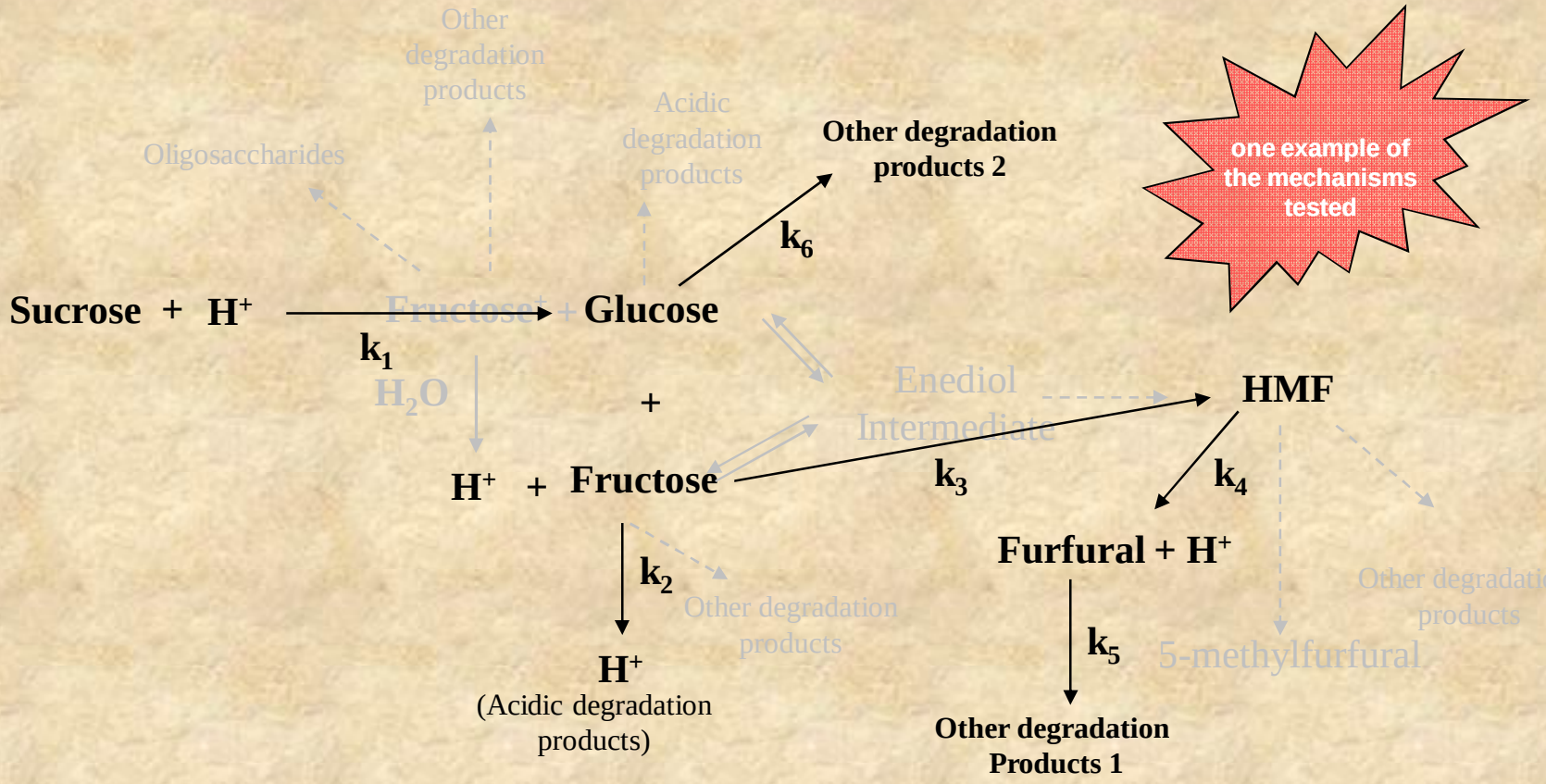
3. New Approaches on Understanding Heat Degradation in Foods



Supercooled sucrose solution (25.30 (w/w)% water content)
T= 140°C

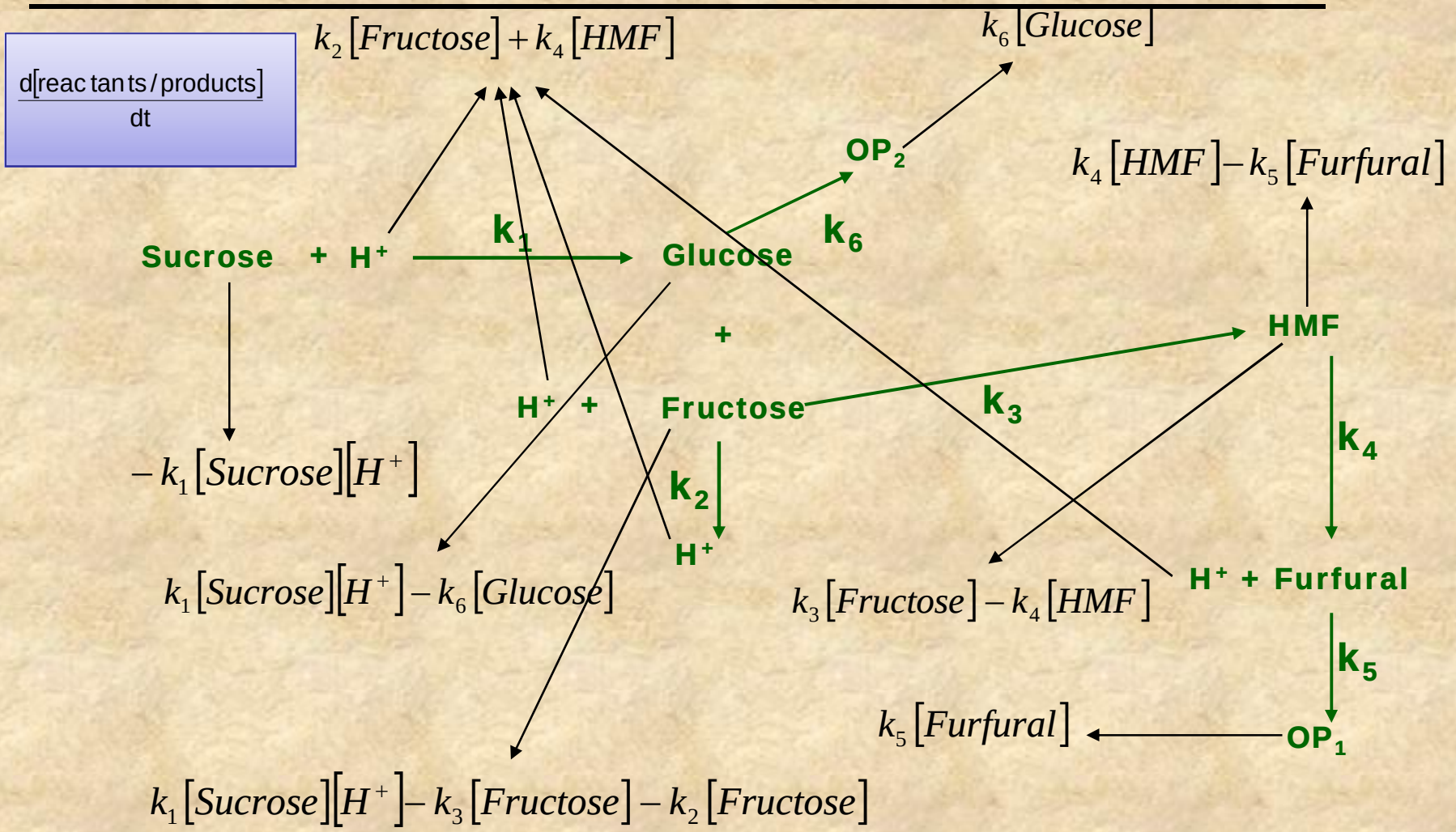
Experimental Results

3. New Approaches on Understanding Heat Degradation in Foods



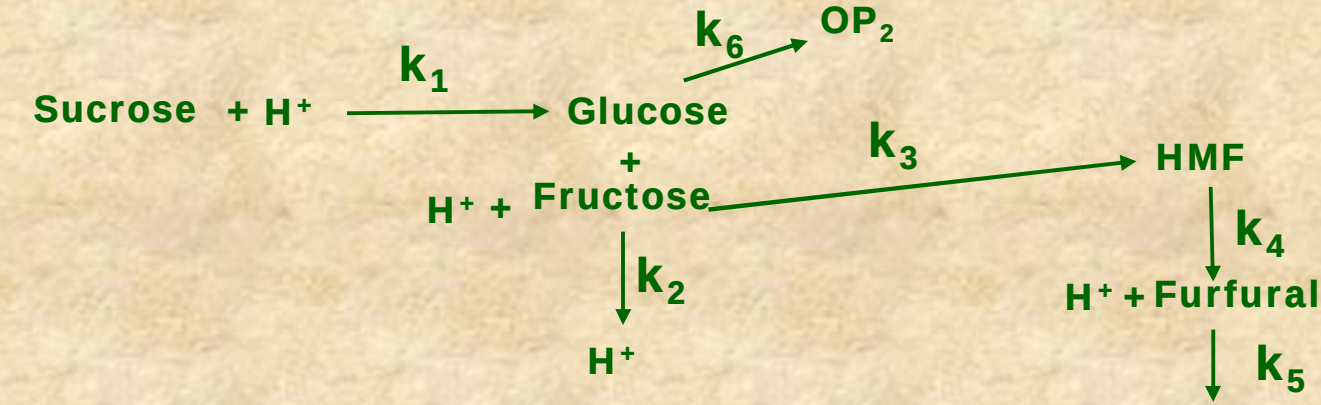
Observed in 12.20 to 30.03 (w/w)% water content solutions at all tested temperatures

3. New Approaches on Understanding Heat Degradation in Foods



3. New Approaches on Understanding Heat Degradation in Foods

Temperature and Water Content effect on reaction kinetics



$$k_S = k_{ref-S} \exp\left(-\frac{Ea_S}{R}\left(\frac{1}{T}-\frac{1}{T_{ref}}\right)\right)$$

constant

$$k_{ref_{1,3,4,5,6}} = a\exp(bC)$$

$$k_{ref_2} = \text{constant}$$

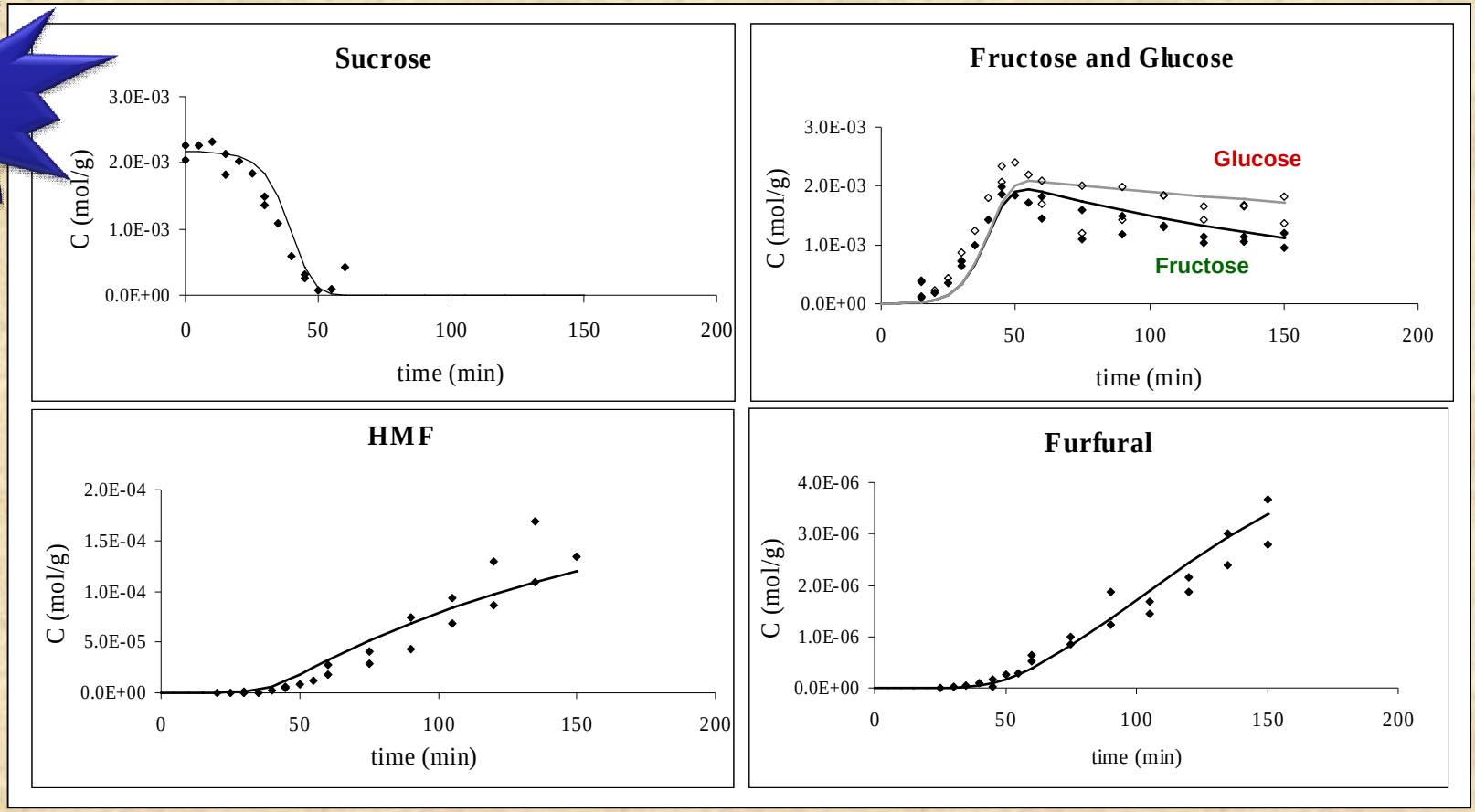
Water content effect

3. New Approaches on Understanding Heat Degradation in Foods

Global Model

Estimates precision: 2 – 45 %
(95%CI /2p)

Higher water content solutions



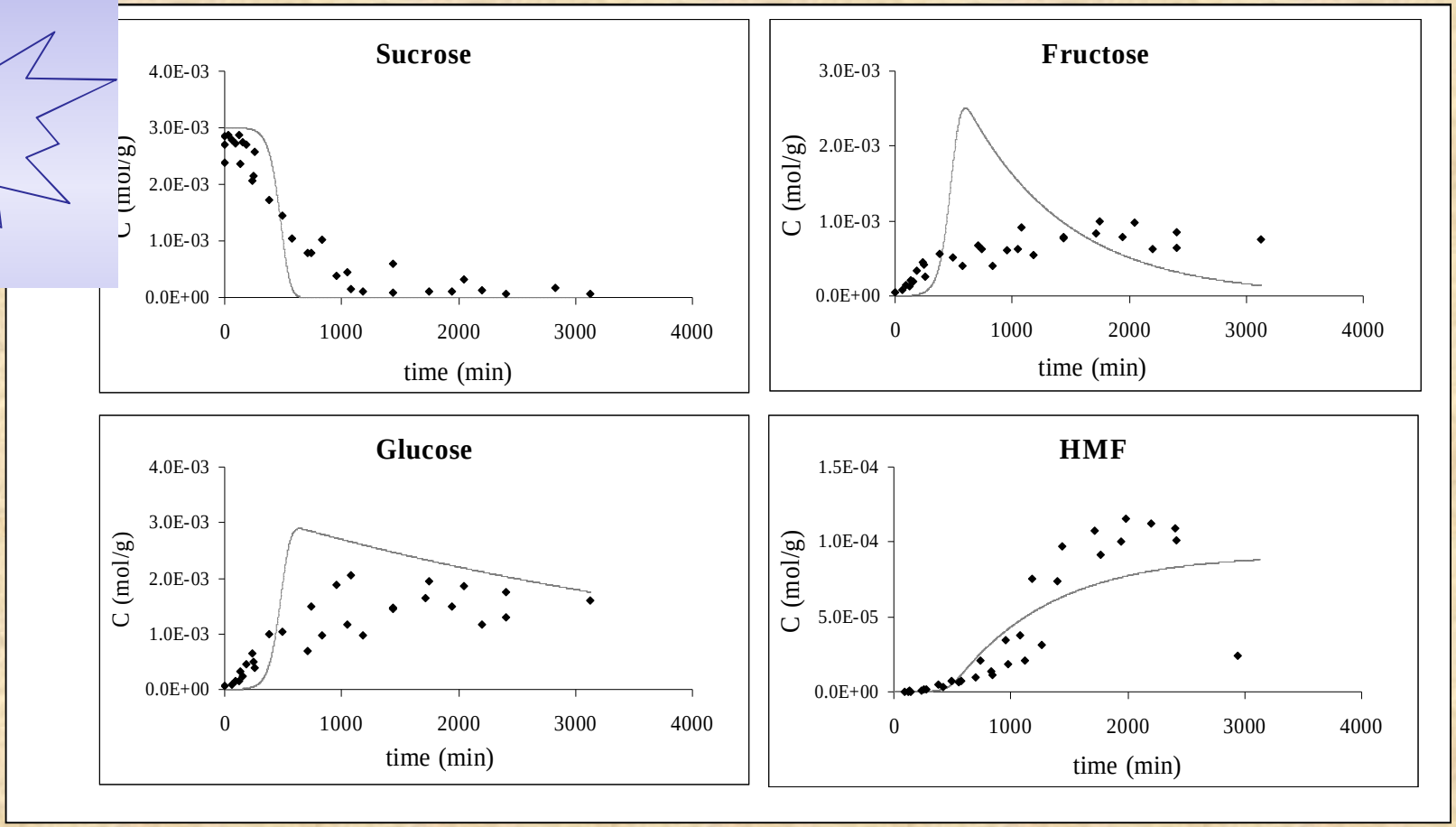
Athena Visual Studio Software

Supercooled sucrose solution (25.30 (w/w)% water content)
T= 140°C

3. New Approaches on Understanding Heat Degradation in Foods

Model Inadequacy for Reactions Occurring at Extremely Low Water Content

Low water content solutions



Athena Visual Studio Software

Supercooled sucrose solution (3.58 (w/w)% water content)
T= 120°C

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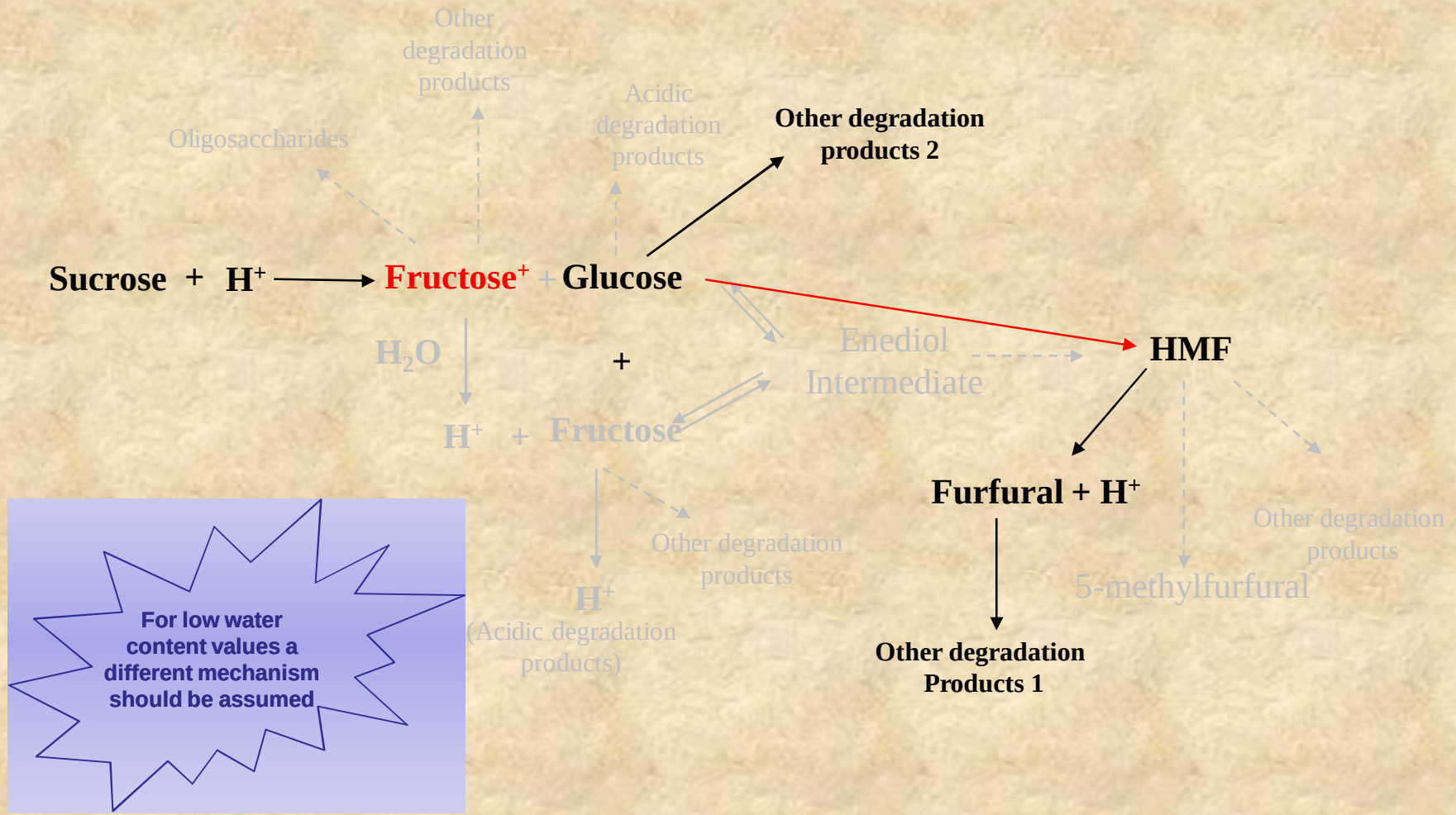

3. New Approaches on Understanding Heat Degradation in Foods

In summary …

This work demonstrates the usefulness of **multiresponse modelling** in understanding reaction mechanisms in food matrices, by elucidating major reaction steps under different conditions and by allowing good prediction of temperature and water content effects

IFTPS
The Institute For Thermal Processing Specialists

2nd European Conference

Harmonization of Standards in Thermal Processing

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Heating Foods

Integrating Quality and Safety in Thermal Processes

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