Contribution of Predictive Microbiology to Control Dry-Fermented Sausage Safety

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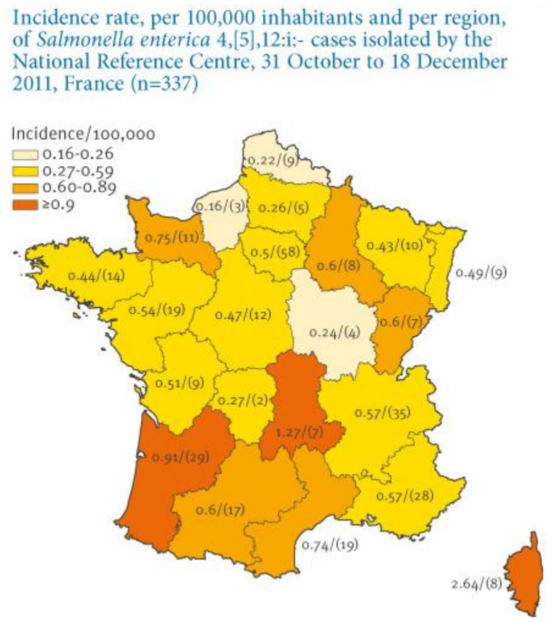
Contribution of Predictive Microbiology to Control Dry-Fermented Sausage Safety



EFSA Journal 2013;11(4):3129. [250 pp.].

Gossner, C.M., et al.. (2012). Eurosurveillance, 17 (5), 19-22

- **Fermented sausages are reported contaminated with *Salmonella***
  - Two main outbreaks in France associated with consumption of dried pork sausages
    - 2010: 132 cases
    - 2011: 337 cases
- **Technological strategies ensure the food safety of fermented sausages**
  - Formulation, bioprotective cultures, processing conditions, …

➲ **Quantitative aspects of the microbial behaviour in dry-fermented sausages**
- Association with challenge testing
- Relevance of the factors and design control measures.

Process of Dry-Fermented Sausages

1) **80% pork lean meat**

   20% derinded backfat

   Meat ingredients **minced**

   @ low temperature (-2°C to 0°C)

2) **Blending minced meats with other ingredients**

   ± Salt
   ± Lactose
   ± Dextrose
   ± Starter

Process of Dry-Fermented Sausages

3) Stuffing batter in casing

with a vacuum hopper

4) Ripening

- Climatic chamber

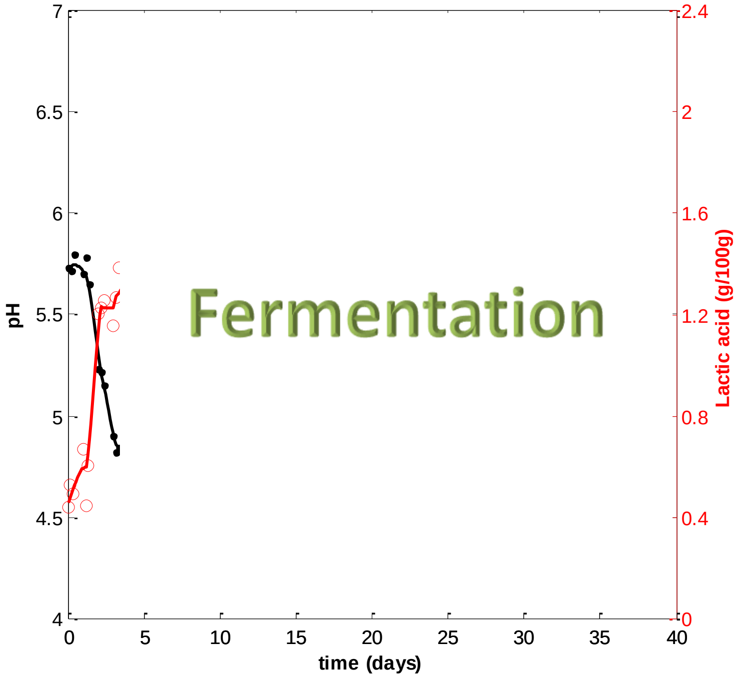
@ controlled Temperature

@ controlled Relative humidity

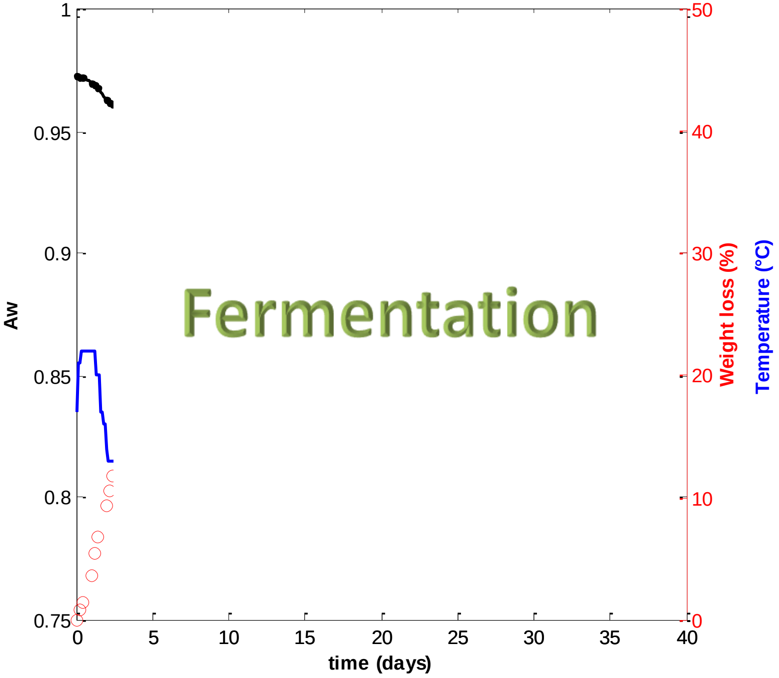
- Fermentation (48h)

- Drying (4 weeks)

pH
lactic acid



a_w
weight loss
temperature



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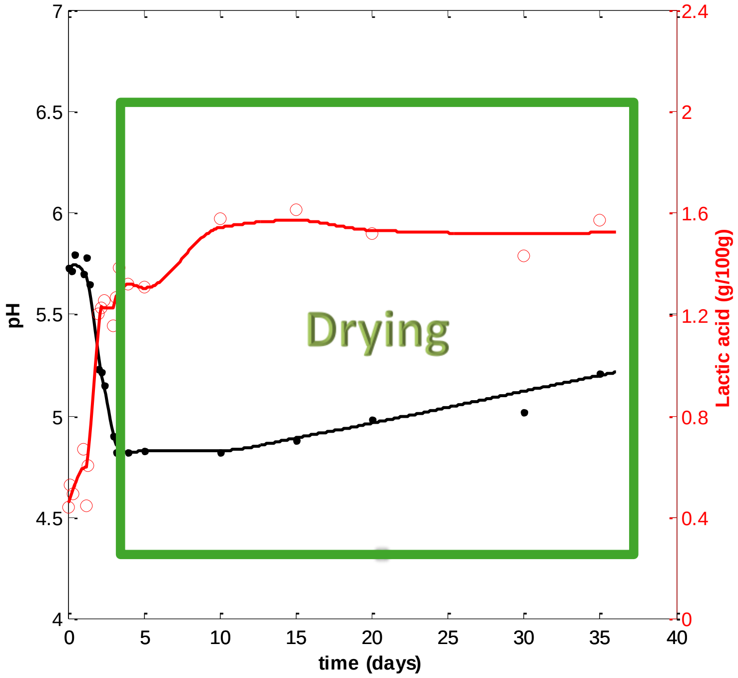
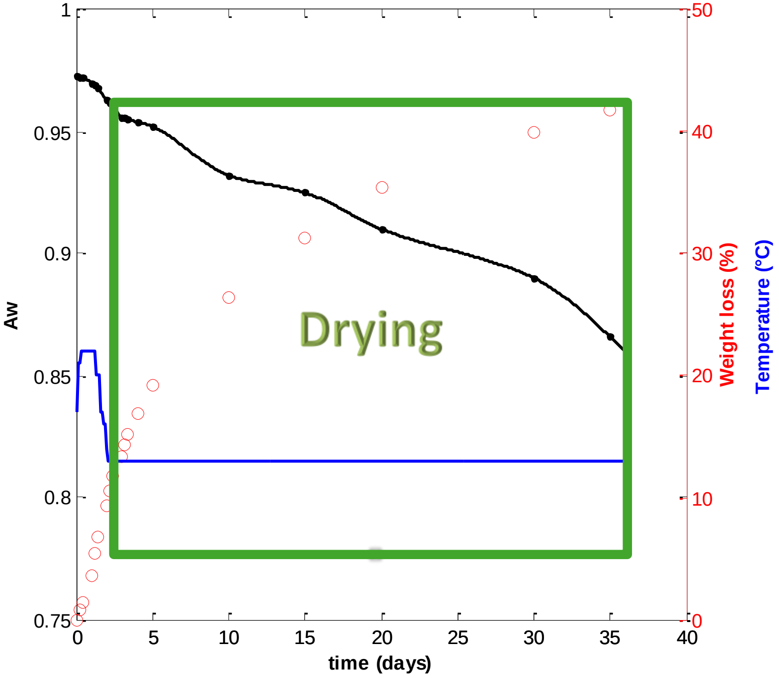
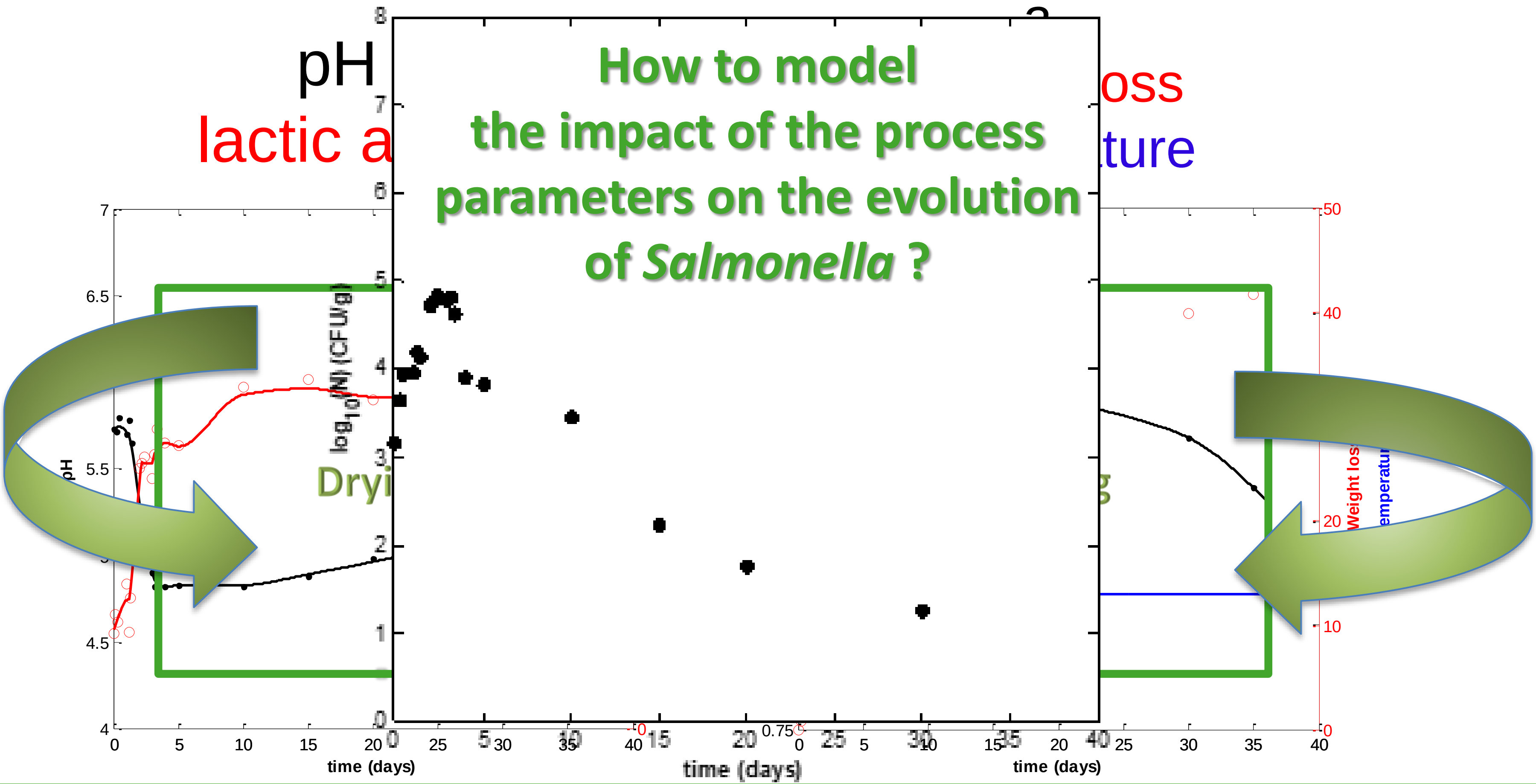
pH
lactic acid



a_w
weight loss
temperature



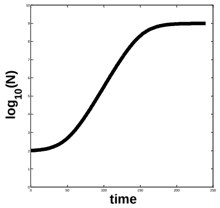
How to model the impact of the process parameters on the evolution of *Salmonella* ?



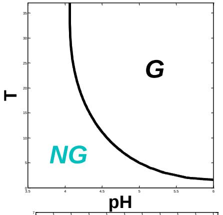
Background - Evolution of pathogen or spoilage microorganisms

Many models exist for:

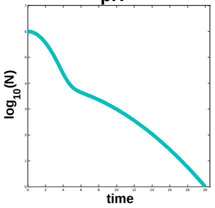
✓ **Bacterial growth**
(meat, milk, vegetable,…)
growth rate (μ), population size (N)



✓ **Growth/no-growth interface**
Growth Probability (p)



✓ **Bacterial inactivation**
(salami, salad dressing, …)
Inactivation rate (μ,k),
Resistance (D, δ, t_{4D}), population size (N)



One combined model for growth and inactivation

- ✓ **Modelling the evolution of *Salmonella* during the process of dried sausages:**

  One parameter

  $$\Delta \log N \big/ \Delta t$$

  - *Variation of bacterial population size for given time of storage*

    increase, decrease, stability

- ✓ **Benefits**
  - *Quantification of microorganism behaviour as a function of process factors*
  - *Mapping of product formulation options*

- ✓ **“Easy to use”**
  - *Biological parameters found in literature, expert opinion,…*
  - *Bacterial behaviour predicted from food properties & vice-versa*
  - *Easy to extend to new environmental factors*

One combined model for growth and inactivation

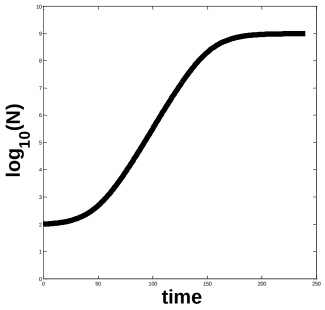
Environment

pH, lactic acid, aw , T

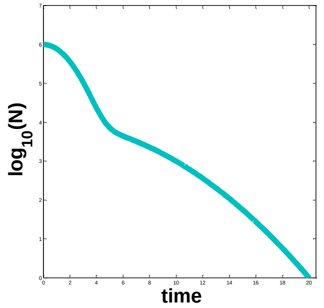
X_i

$$\prod \gamma_i(X_i).\xi$$

> 0 **Growth**



= 0 **Inactivation**



$\gamma(X_i)$ Effect of each factor (X_i)

ξ Effect of the interactions

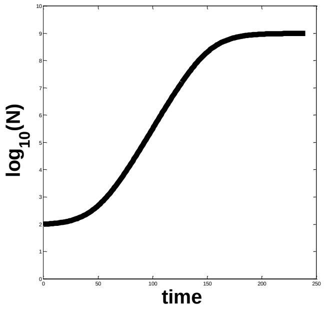
These values are ranged from 0 (no-growth) to 1 (optimal growth)

One combined model for growth and inactivation

Growth

Primary modelling

– Rosso model (1995)



Secondary modelling

– With interactions

$$\mu = \mu_{opt} \cdot \prod \gamma_i (X_i) . \xi$$

Zuliani et al. (2007). Journal of Applied Microbiology

The modular (gamma) concept

Optimal growth rate

The impact of pH

The impact of inhibitor

$$\mu max = \mu opt\ \gamma(T)\ \gamma(pH)\ \gamma(aw)\ \gamma(inhibitor)\ \gamma(interaction)$$

The impact of temperature

The impact of aw

The interaction between factors

Factors which are not modeled by a gamma are summarized in the *μ*opt in this specific product.

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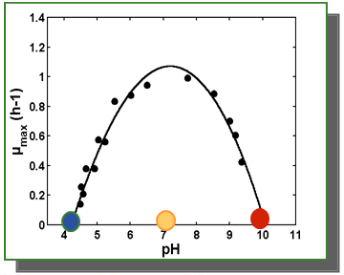
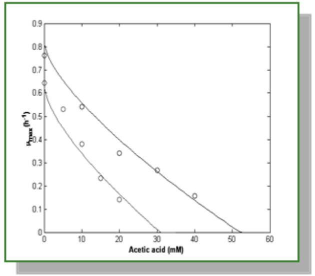
The Modular concept

Optimal
growth rate

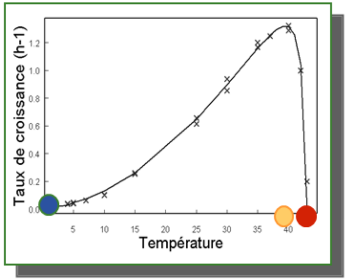


pH_{min} pH_{opt} pH_{max}

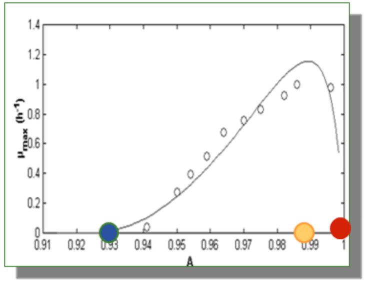


alpha MIC

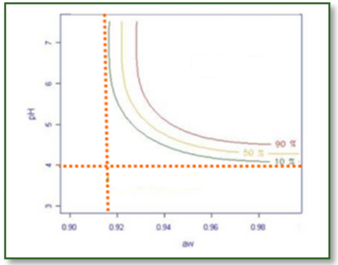
$$\mu max = \mu opt\ \gamma(T)\ \gamma(pH)\ \gamma(aw)\ \gamma(inhibitor)\ \gamma(interaction)$$



T_{min} T_{opt} T_{max}



aw_{min} aw_{opt} aw_{max}



One combined model for growth and inactivation

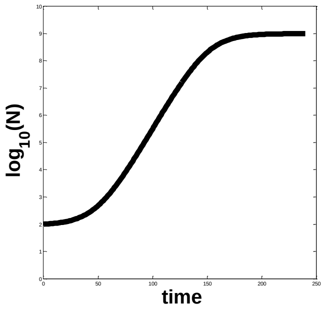
Environment

pH, lactic acid, aw , T

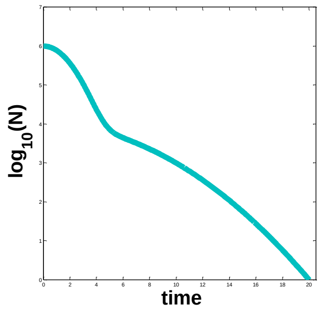
$$X_i$$

$$\prod \gamma_i (X_i).\xi$$

> 0 **Growth**



= 0 **Inactivation**



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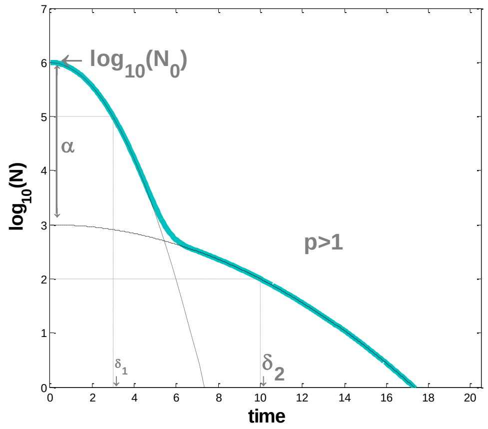
One combined model for growth and inactivation

Inactivation

Primary modelling

Double Weibull model

- 2 subpopulations
- δ_1 and δ_2 : first decimal reduction time
- Compatible with D value



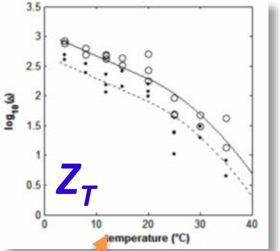
Coroller et al.(2006) AEM
Coroller et al. (2012) IJFM

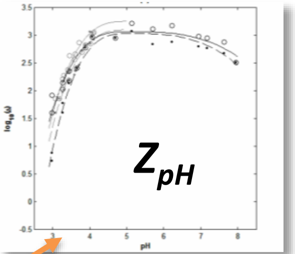
Secondary modelling

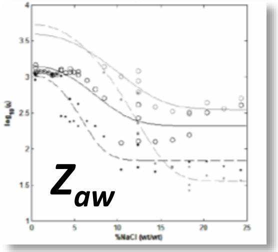
Gamma concept like model

$$\frac{1}{\delta_{T_{HT},pH,aw}} = \frac{1}{\delta_{max}}\lambda_T\ (T_i).\lambda_{pH}\,(pH_i).\lambda_{AH}\,(AH_i).\lambda_{aw}(aw_i)$$

Modular inactivation model

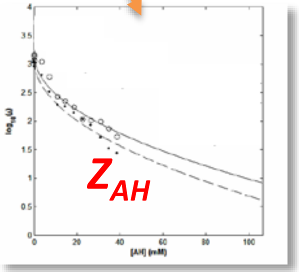






$$\frac{1}{\delta_{T_{HT},pH,aw}} = \frac{1}{\delta_{max}} \lambda_T(T_i).\lambda_{pH}(pH_i).\lambda_{AH}(AH_i).\lambda_{aw}(aw_i)$$

δ_{max} : first decimal reduction
@reference conditions (T, pH, aw…)
Media/strain dependant



One combined model for growth and inactivation

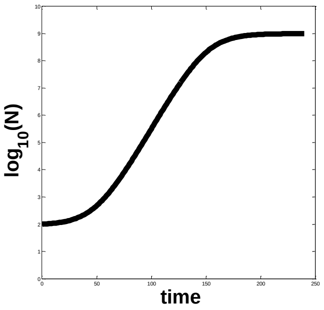
Environment

pH, lactic acid, aw , T

X_i

$$\prod \gamma_i (X_i).\xi$$

> 0 **Growth**



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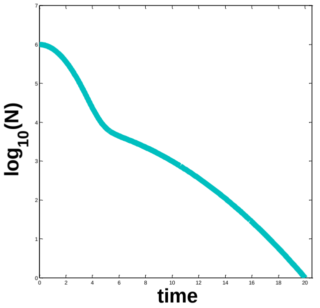

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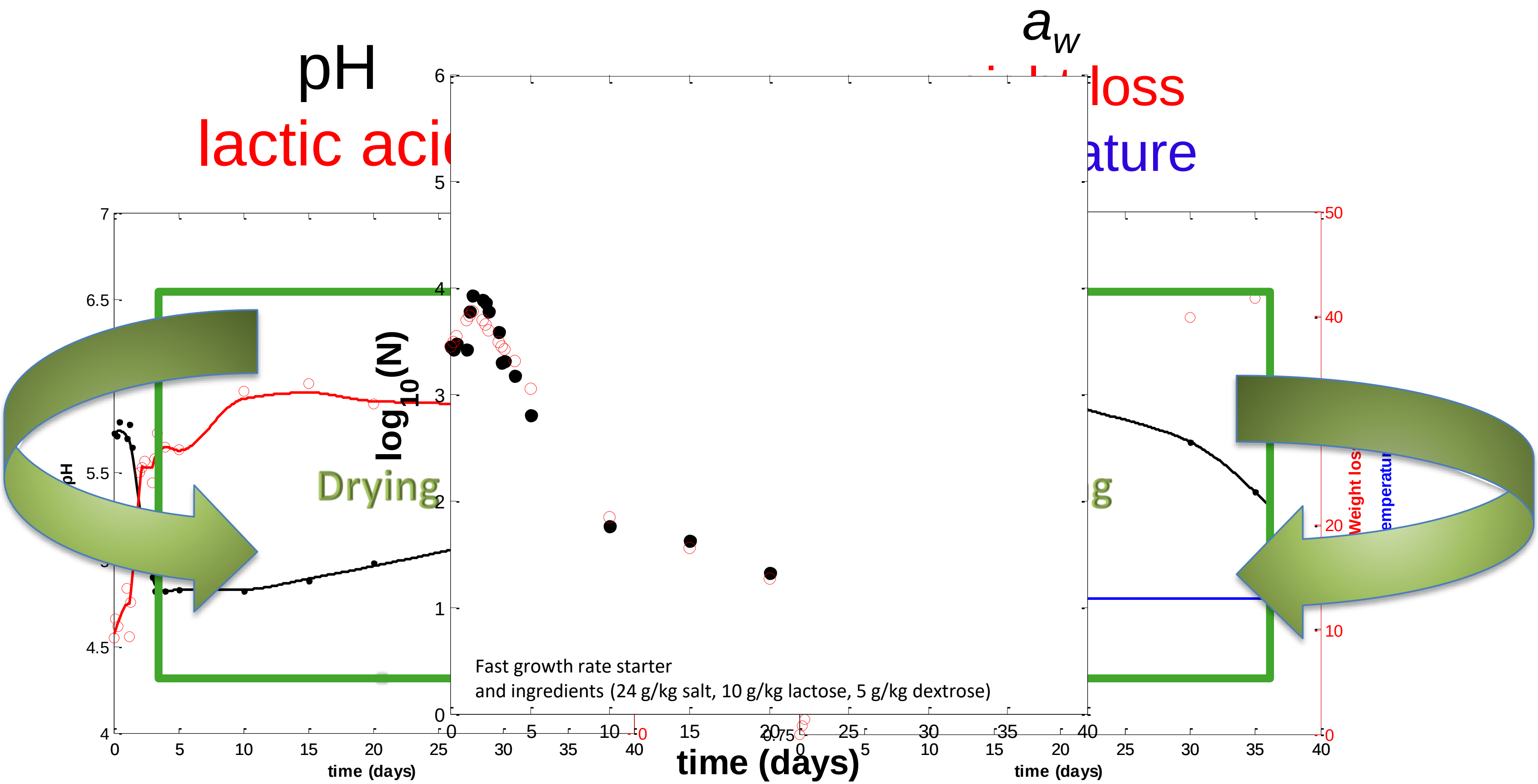
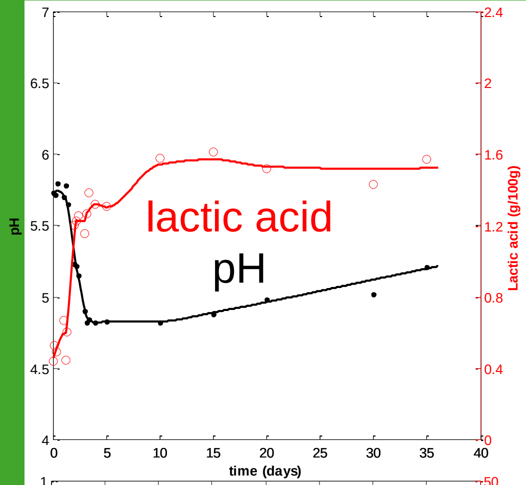
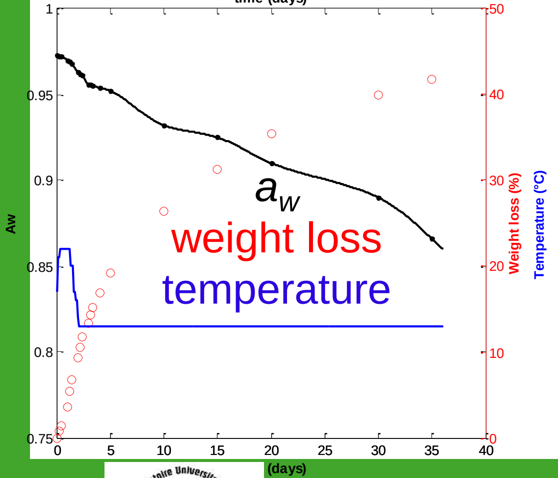


pH
lactic aci
a_w
loss
ature
Drying
g
$\log_{10}(N)$
time (days)
time (days)
time (days)
pH
Weight los
emperatu
Fast growth rate starter
and ingredients (24 g/kg salt, 10 g/kg lactose, 5 g/kg dextrose)



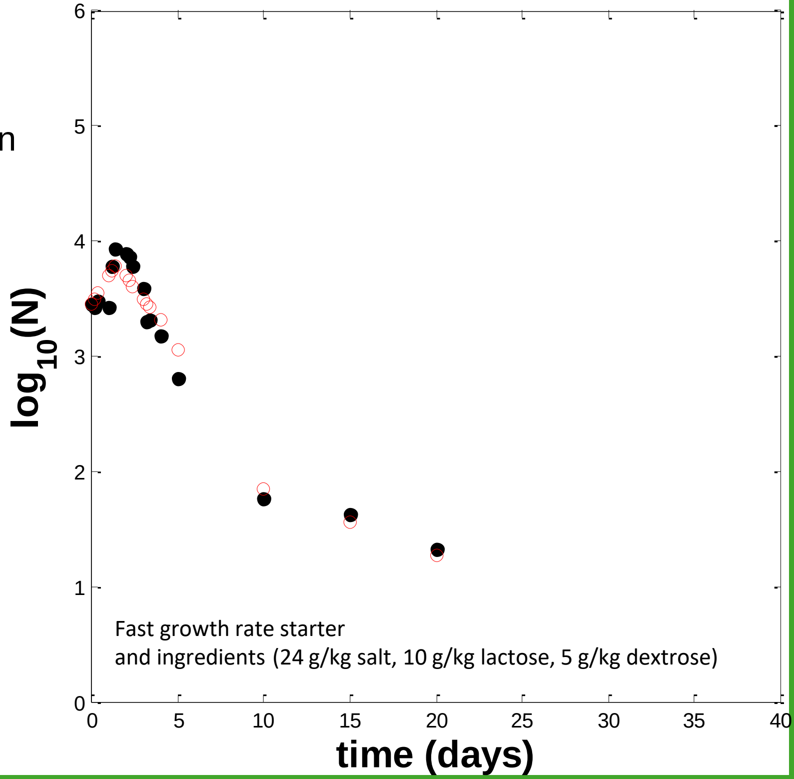


Growth/Inactivation transition

~ second day of ripening

- Temperature shift 20°C / 13°C
- Decrease of water activity
- Decrease of pH
- Increase lactic acid concentration

➲ **Synergetical effect**



Growth/Inactivation transition

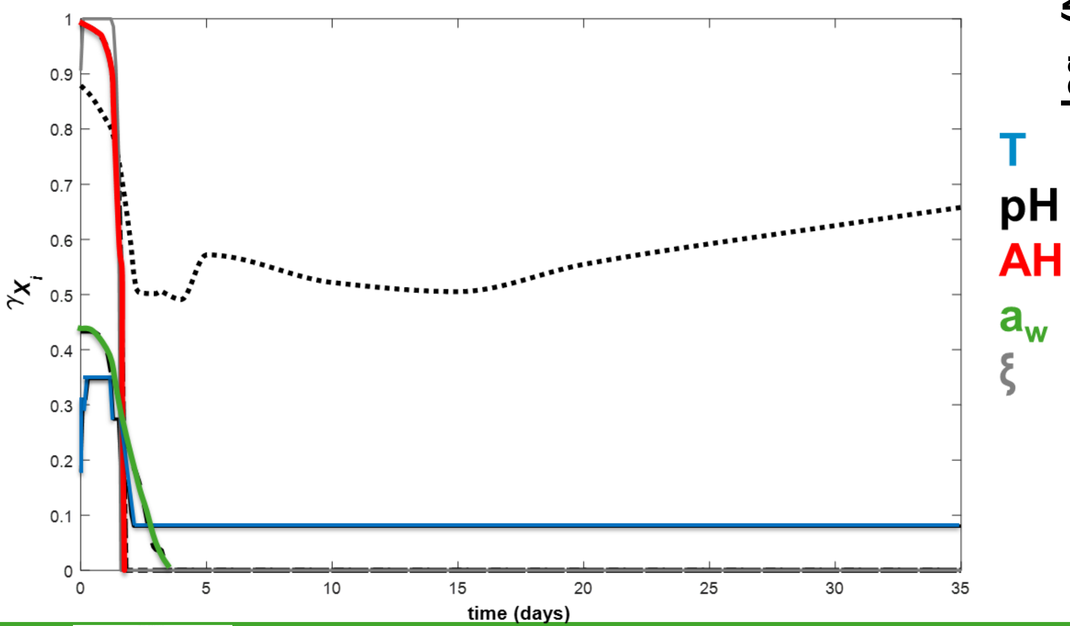
~ second day of ripening

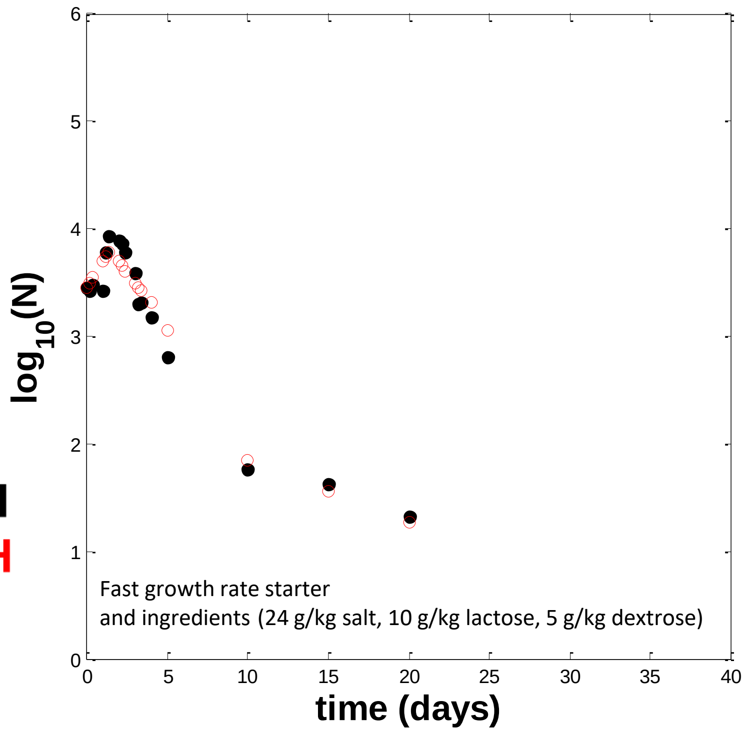
Temperature shift from 20°C to 13°C

Decrease of water activity

Decrease of pH

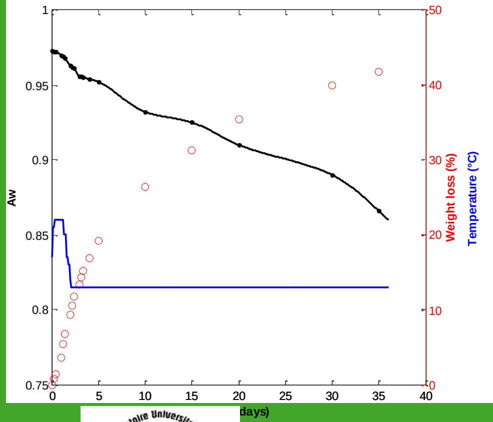
Increase lactic acid concentration





What are the relevant process parameters to control the *Salmonella* population ?

- **pH** associated with increasing **lactic acid** **concentration**
- **Low temperature**
- Decrease of **water activity** ⇔ **Weigth loss**



$$W=C1 + C2 \ln(1 - aw)$$

Moisture sorption isotherm (Smith 1947, Andrade et al. 2011)

W the water content (g of water/g of dried weight),
C1 the quantity of water of the first sorbed fraction
C2 the quantity of water in the multilayer humidity fraction.

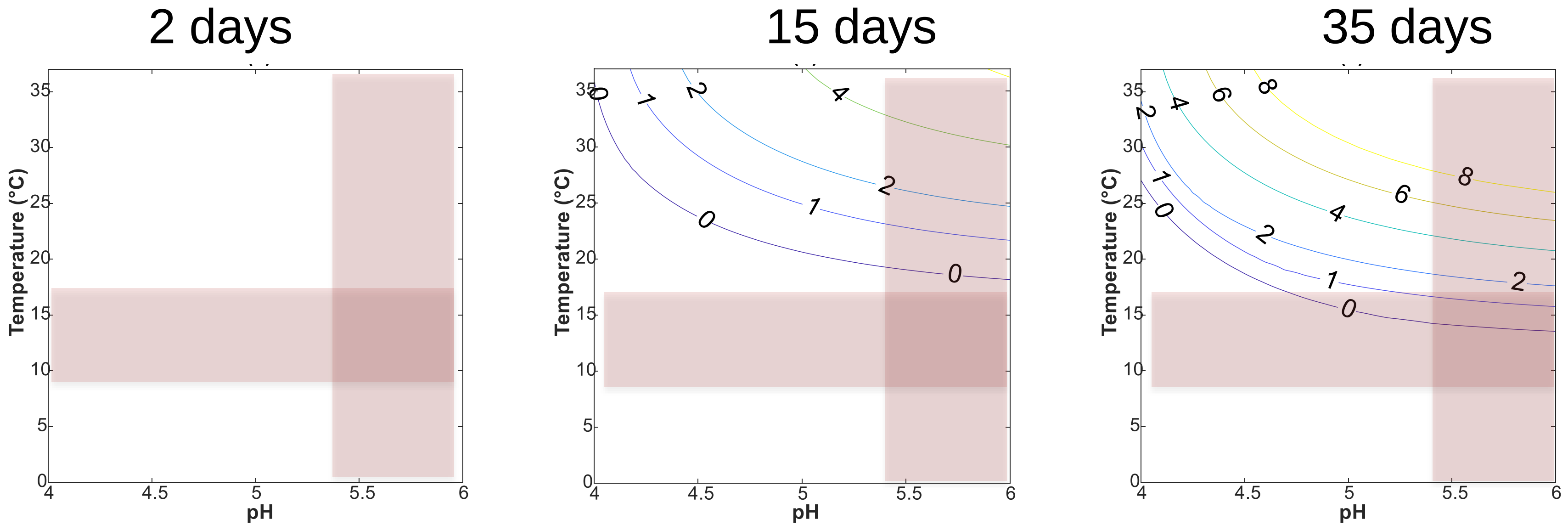
What are the relevant process parameters to control the *Salmonella* population ?

« Fast acidifying » starter

10g/kg lactose & 8g/kg dextrose

➡ Slower growth

➡ Lower resistance



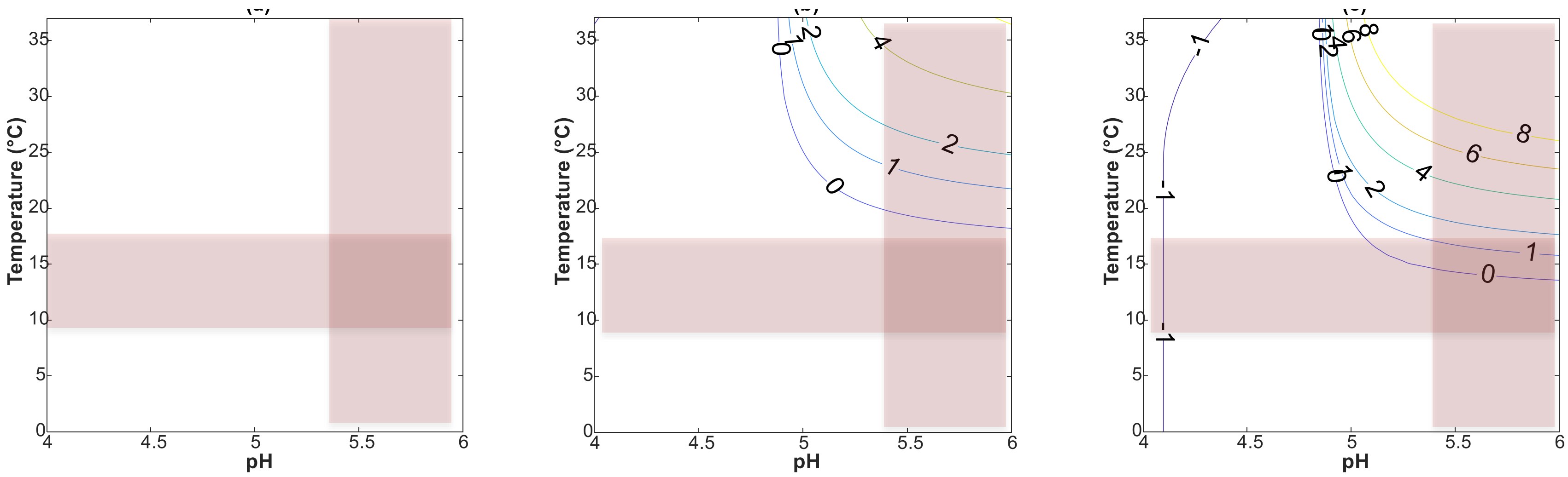
AH=**0.0** % lactic acid

aw=0.97 ⇔ 0 % Weigth loss

2 days

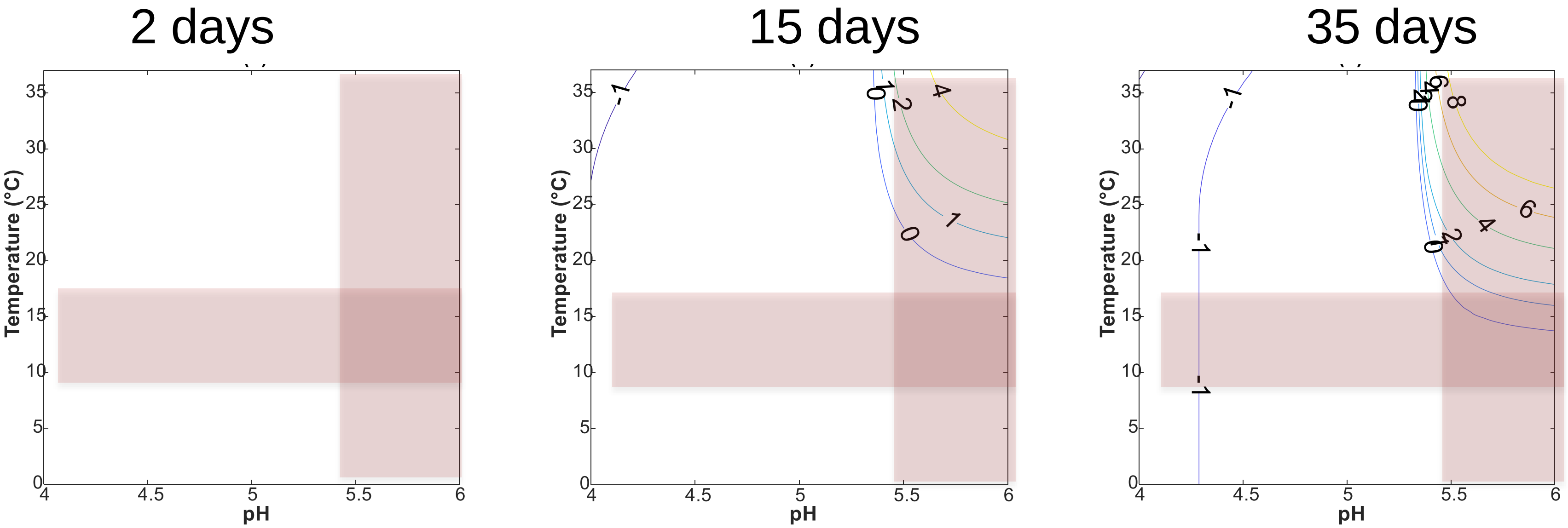
15 days

35 days



AH=**0.5** % lactic acid

aw=0.97 ⇔ 0 % Weigth loss



AH=**1.5** % lactic acid

aw=0.97 ⇔ 0 % Weigth loss

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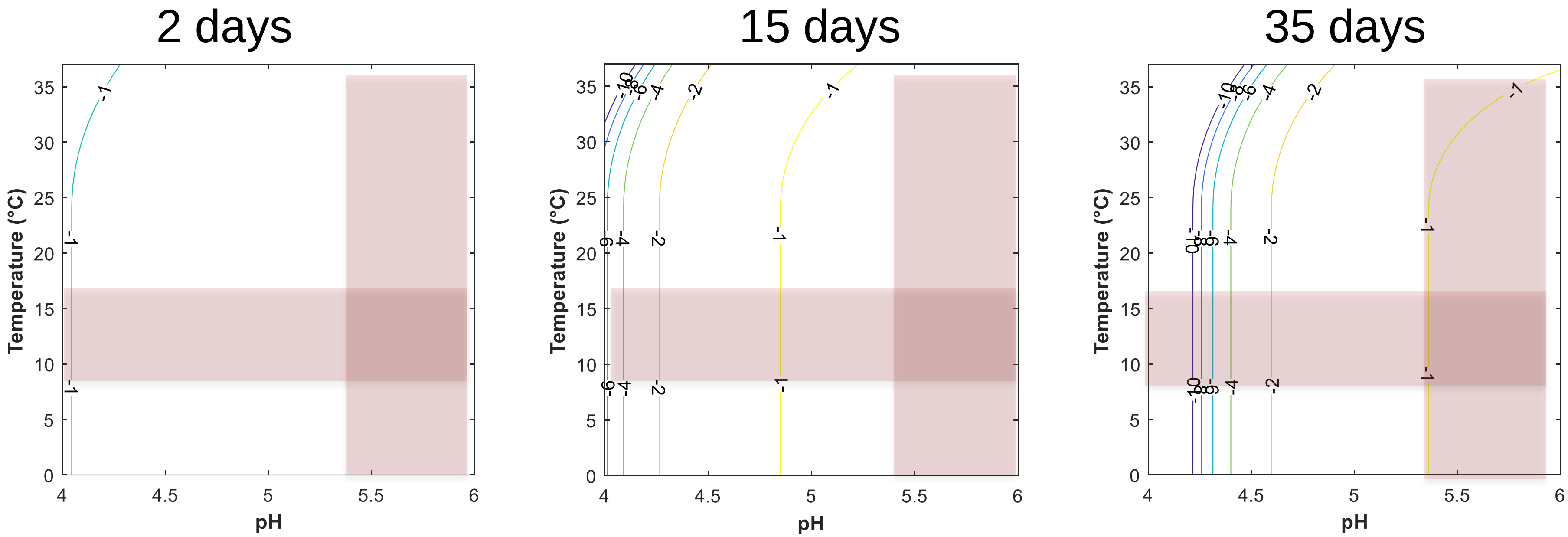


AH=**1.5** % lactic acid

aw=**0.95** ⇔ 10 % Weigth loss

What are the relevant process parameters to control the *Salmonella* population ?

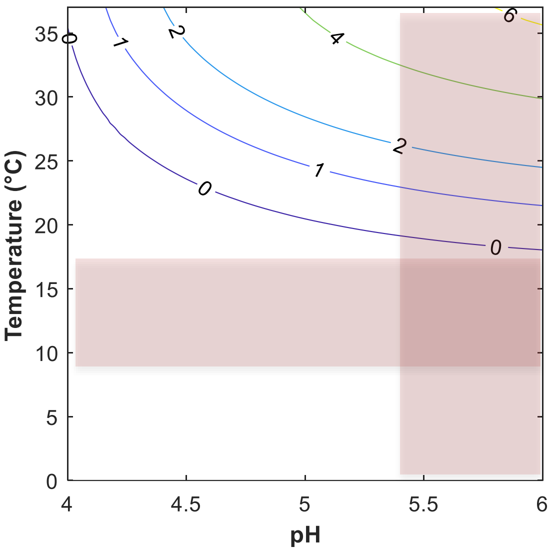
« moderate acidifying » starter

10g/kg lactose & 8g/kg dextrose

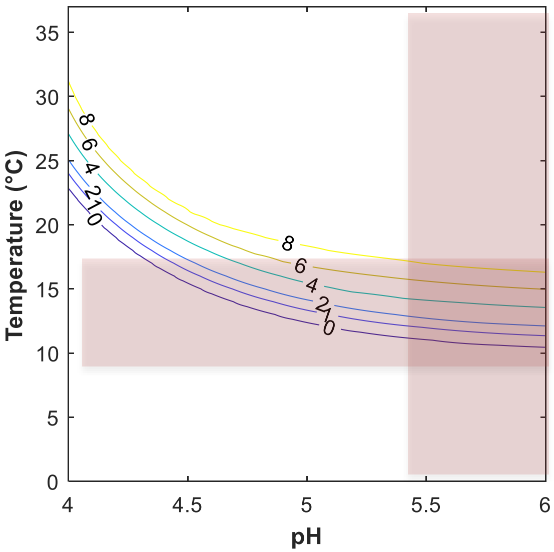
➲ higher growth potential

➲ higher resistance

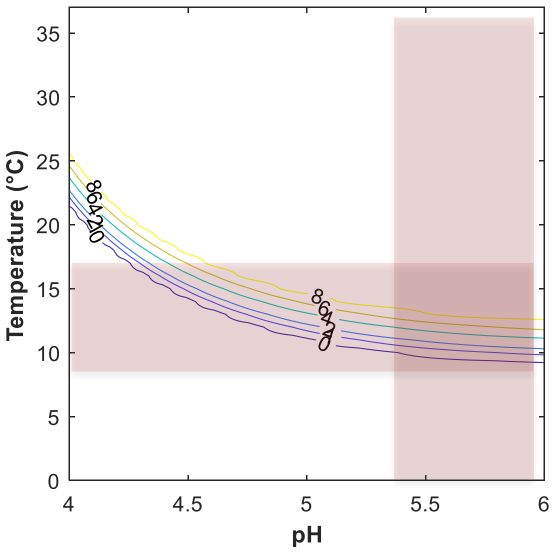
2 days



15 days



35 days



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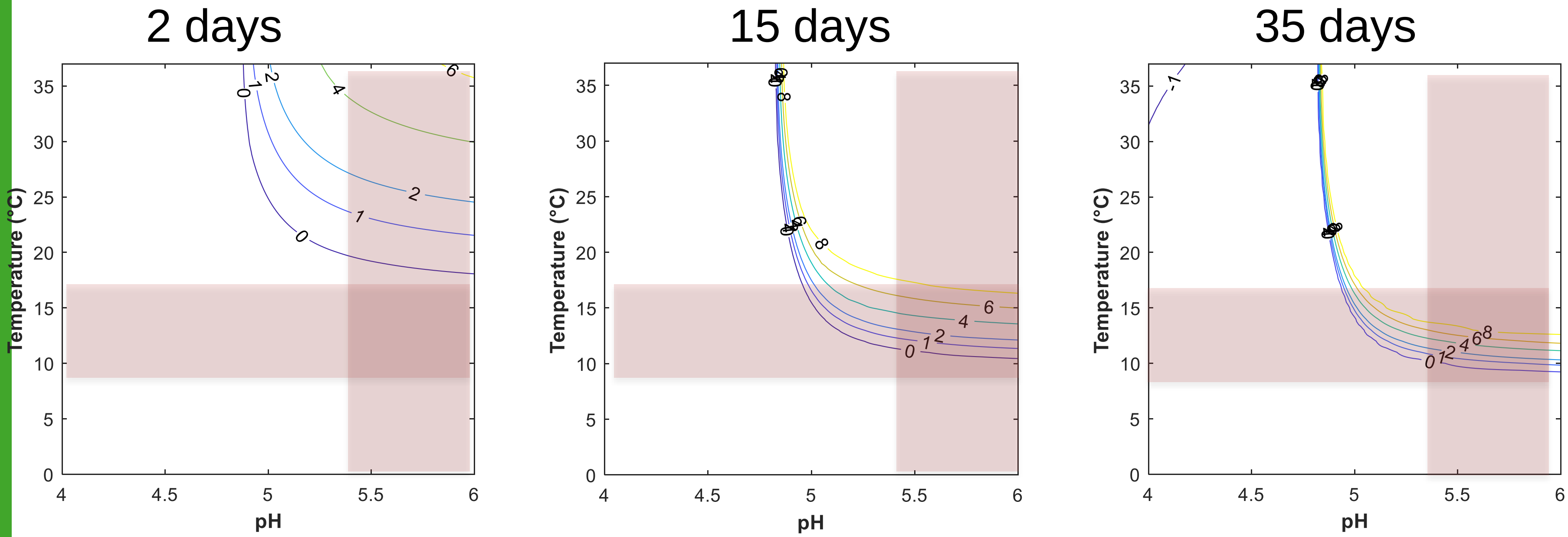

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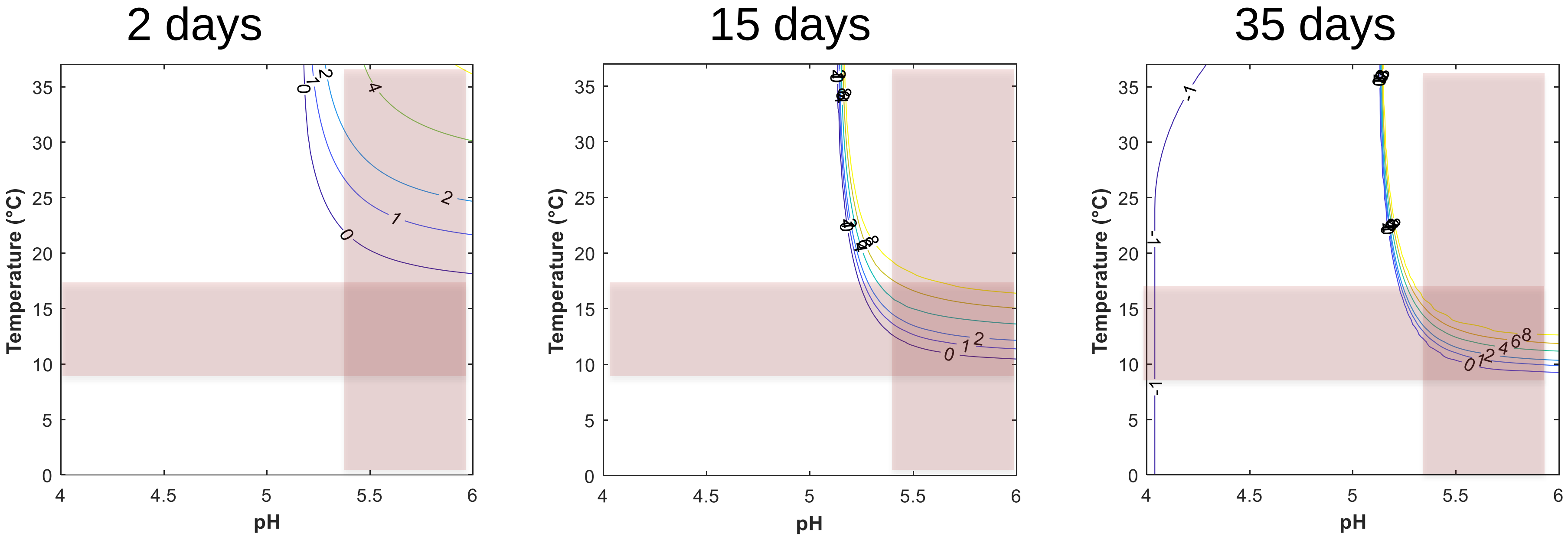

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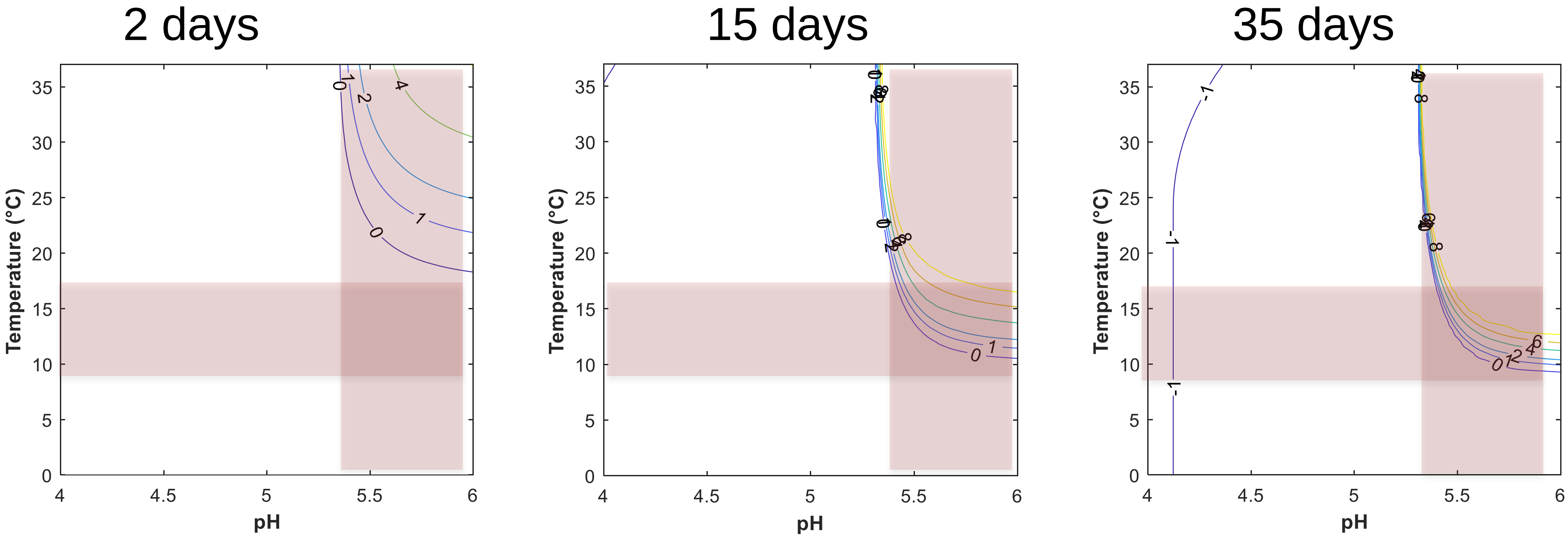

AH=**1.5** % lactic acid

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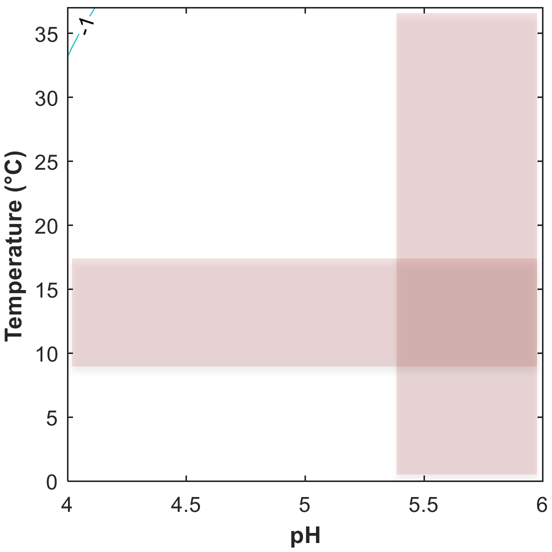
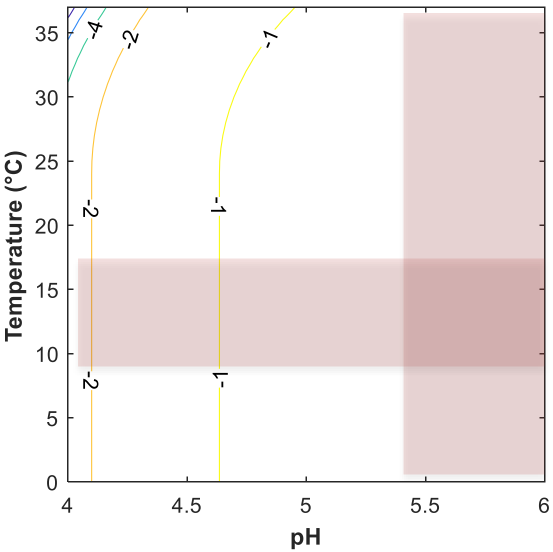
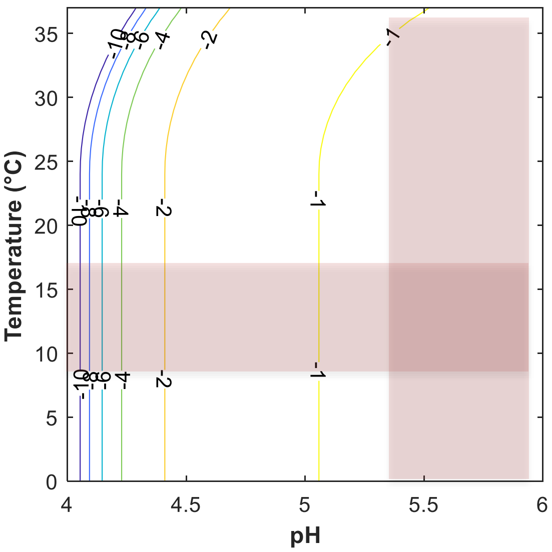
2 days



15 days



35 days



AH=**1.5** % lactic acid

aw=**0.95** ⇔ 10 % Weigth loss

Conclusions

Whatever dynamic of the process parameters,

the growth rate or the resistance of *Salmonella* is:

- **not dependent on the salt content**
  - the salt content impacts the pH, acid, and a_w kinetics but not the growth potential or the resistance.
- **dependent on the sugar contents**
  - High sugar contents could be linked to a higher *Salmonella* growth
- **dependent on the starter type**
  - Moderate growth rate starter could be linked to higher *Salmonella* growth rate and resistance

Conclusions

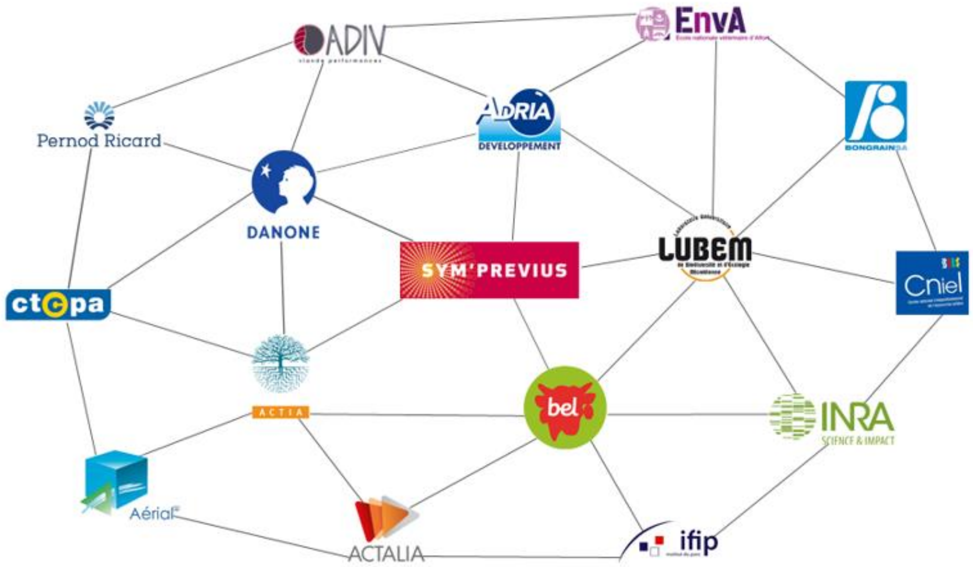
One combined model for growth and inactivation

- « Easy to use » ☺
    - Biological parameters, expert opinions…
- Specificity of the food effect ☺
- Parameters consuming ☹
    - Parameters must be known for growth and inactivation

– Improvements: physiological states of cells, link between resistance and growth potential, specie, strain and cellular variability…

The consortium

A network of Food Business Operators, Food Technology Institutes and Academics



HACCP Assistant

Growth/ No Growth Interface

Growth Simulation

Thermal inactivation

Available in English, Spanish and French

symprevius@adria.tm.fr

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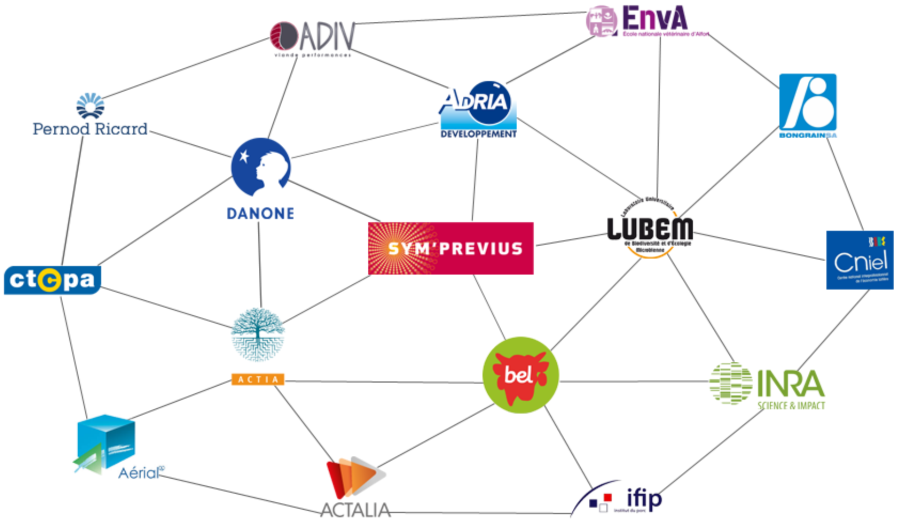

Thank you for your attention