Modélisation de la fermentation lactique du gowé, une boisson fermentée à base de sorgho

Modeling lactic acid fermentation of Gowé, a sorghum-based fermented beverage

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What is Gowé?

Somewhere between beer and yogurt

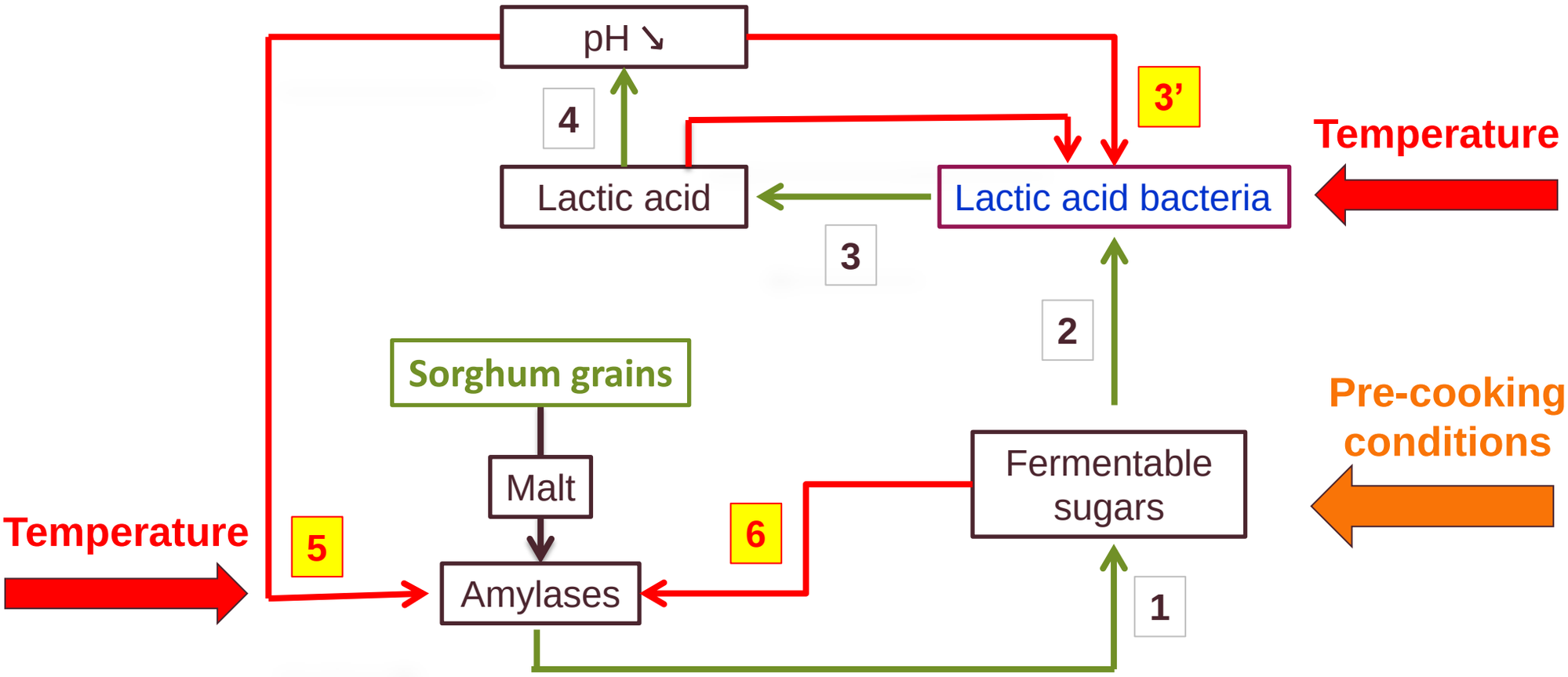
- **Cooked fermented blend of malted and non malted sorghum flours, wrapped in leaves (*Thalia welwichii* or *Tecktona grandis*)**

Photo: J. Hounhouigan

- **Diluted in water (ice) and sugar just before consumption**
- **Quality: slightly acidic, sugary**

- **Exclusively home-made product**
- **Shelf life (1-2 days)**

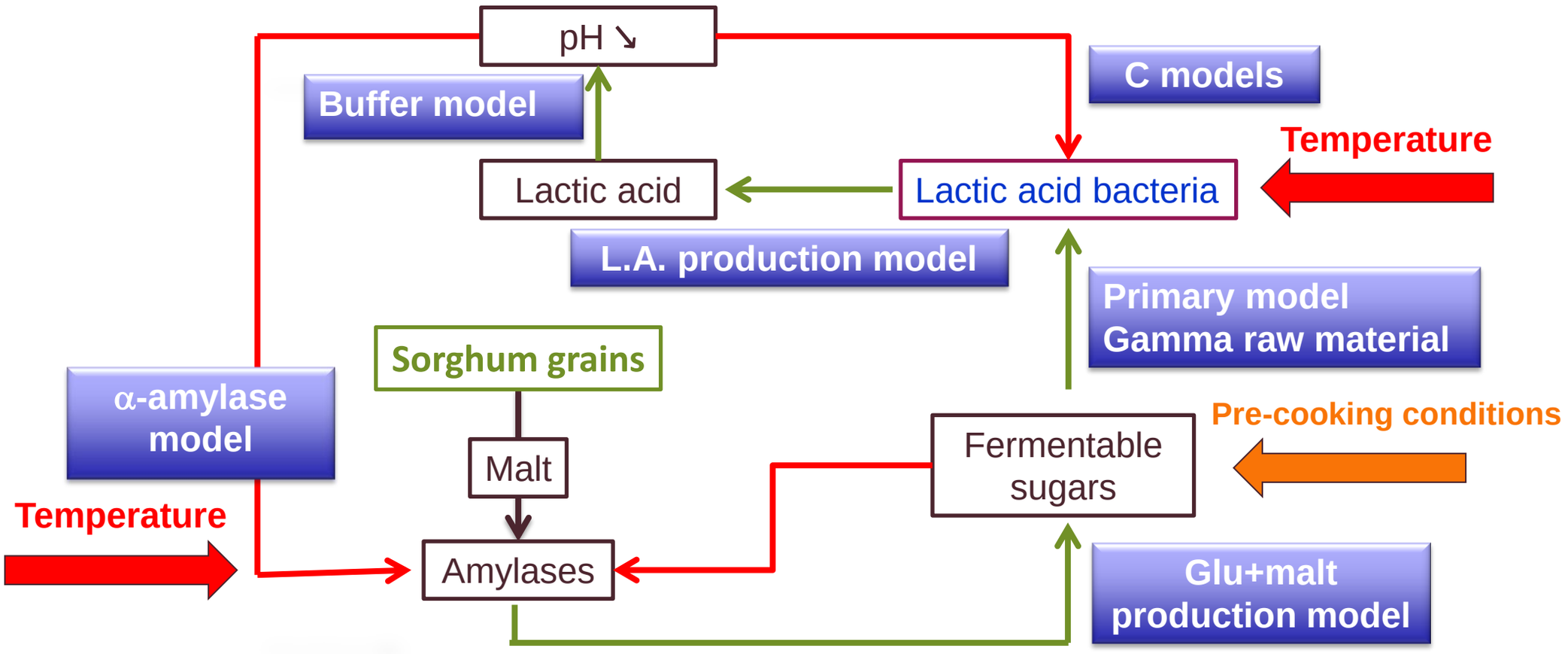
Reaction diagram during gowé processing



- ✓ **numerous factors (inoculation strain & level, temperature, pre-cooking)**
- ✓ **interactions (pH x Lb growth, pH x α-amylase, free sugar x α-amylase)**

Objective: to model the reactions for optimizing the fermentation

A global model

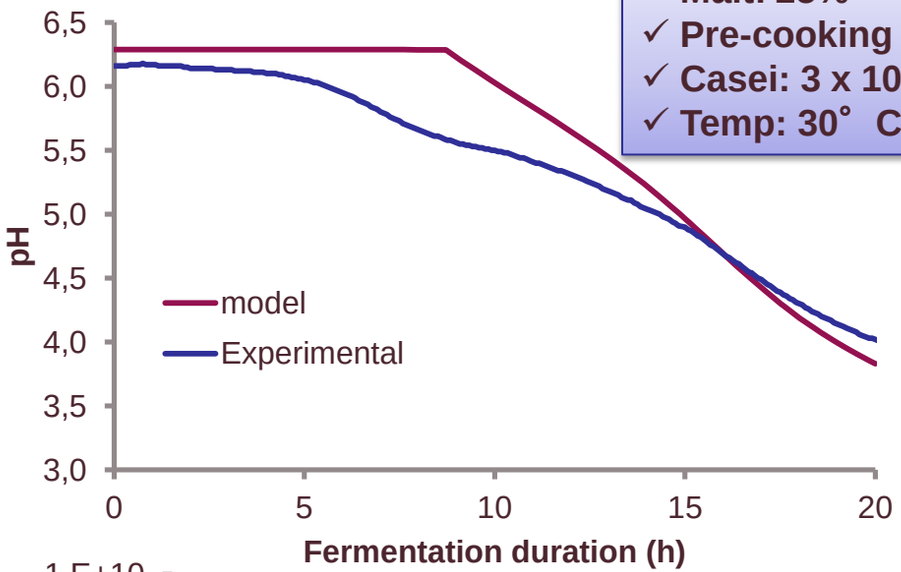


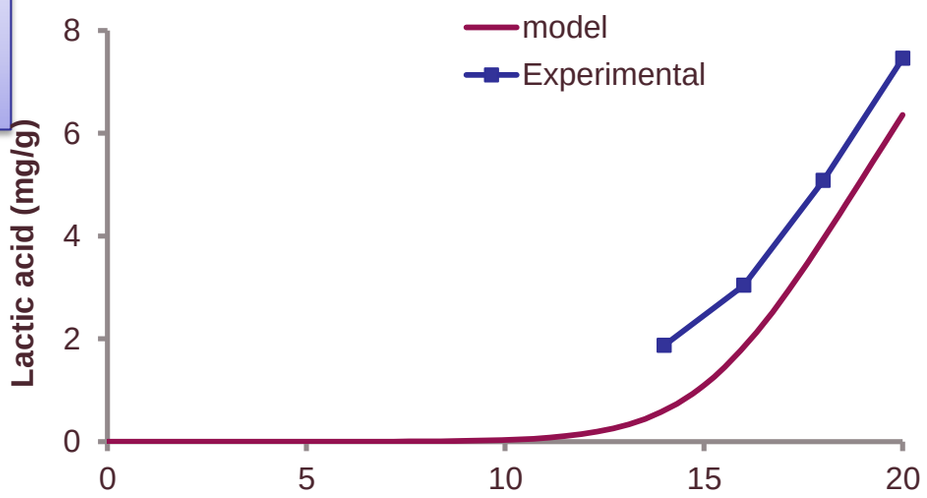
Simulations of various conditions:

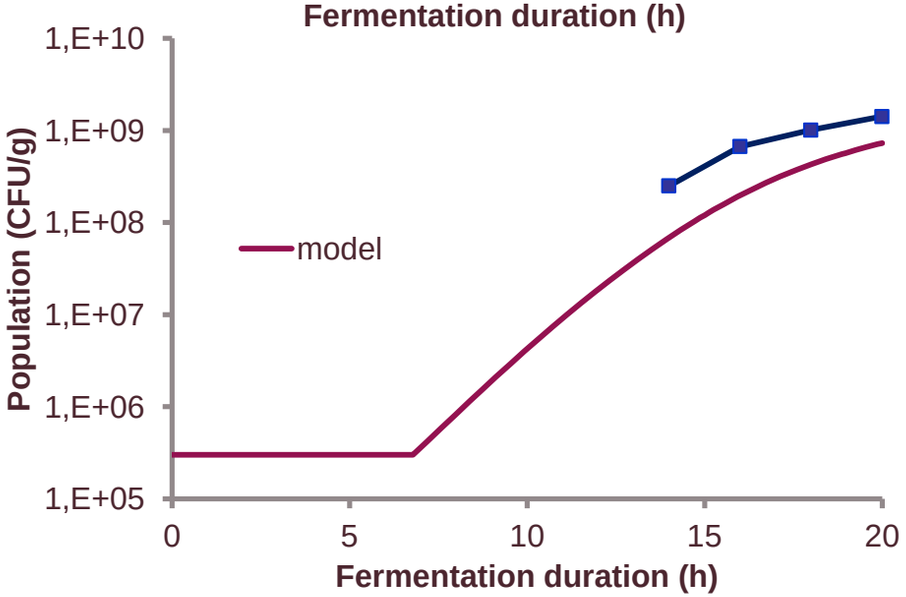
- ✓ **Inoculation strain (*Lb casei, brevis, fermentum*…) & level**
- ✓ **Temperature of fermentation (25-45° C)**
- ✓ **Pre-cooking conditions (proportion, temperature)**

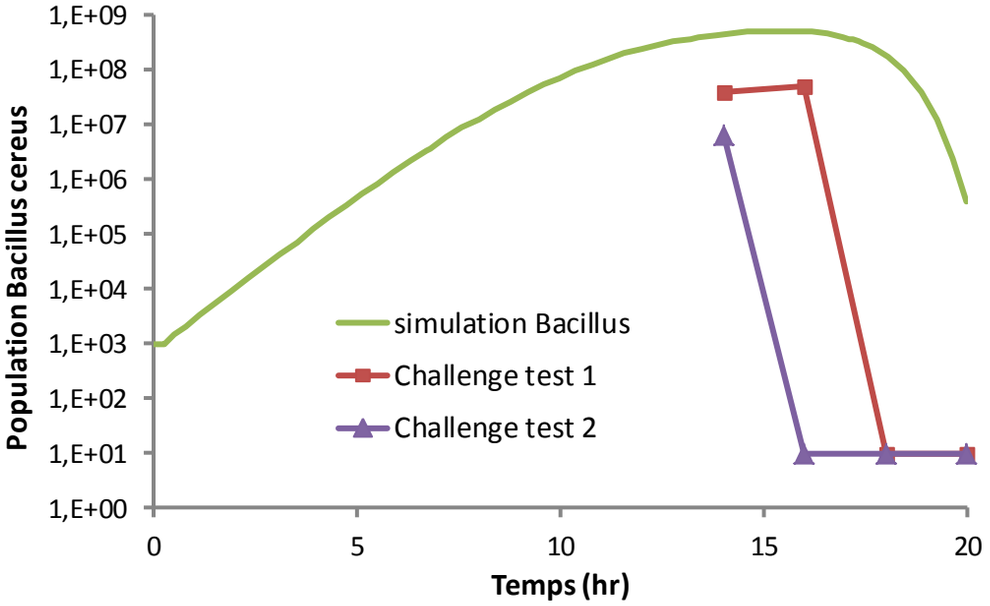
Modeled control panel for *Lb casei* fermentation

- ✓ Malt: 25%
- ✓ Pre-cooking (70° C, 15%)
- ✓ Casei: 3 x 10^5 CFU/g
- ✓ Temp: 30° C



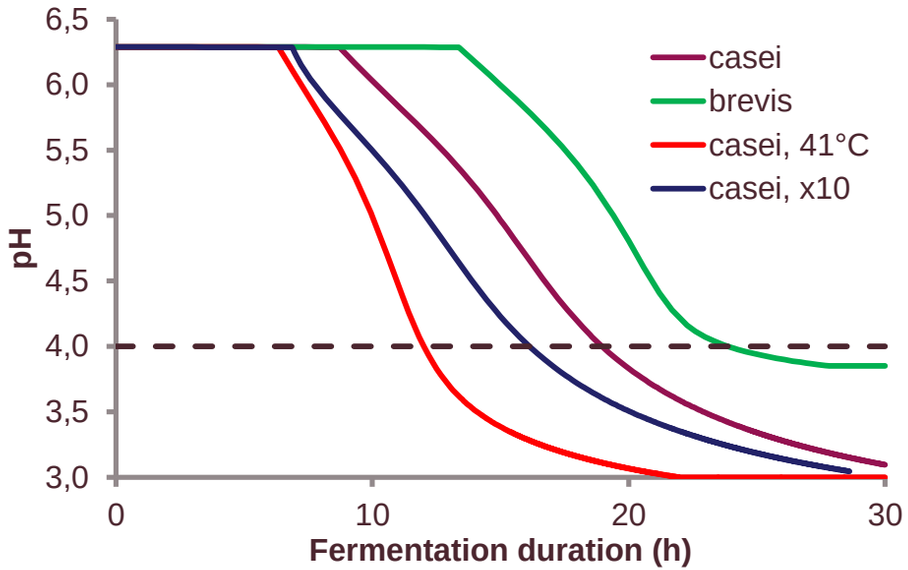


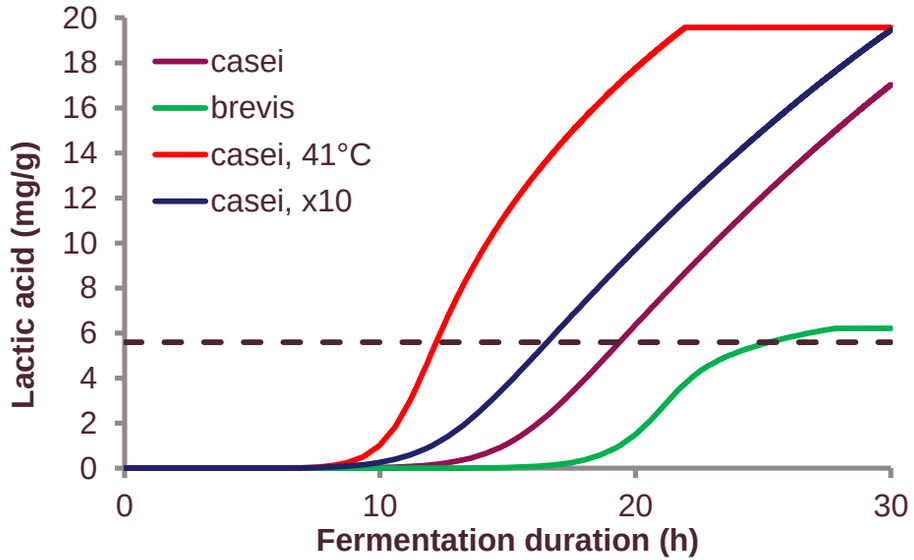


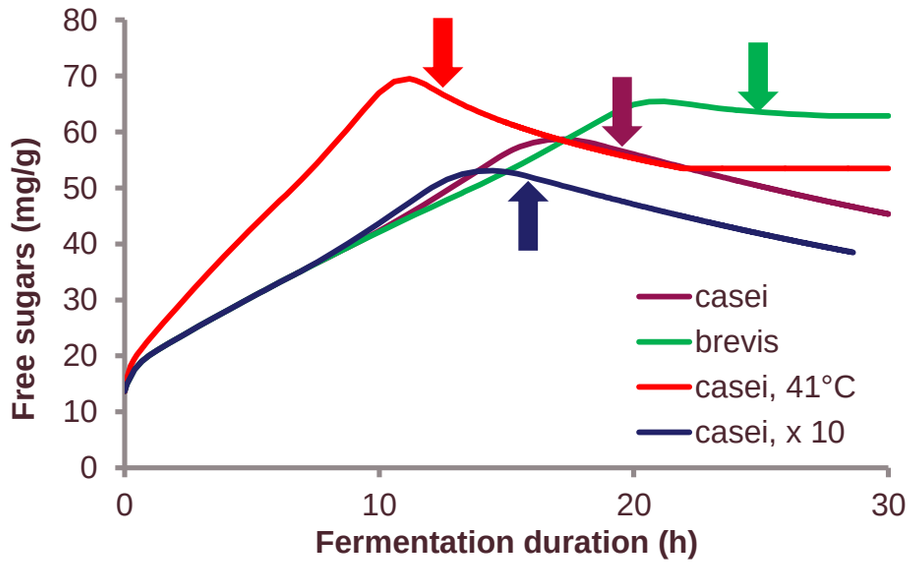


➢ **Validated; incidence of indigenous flora**

Modeled control panel: simulations of various conditions







➢ **Specific conditions can be tailored for different applications**

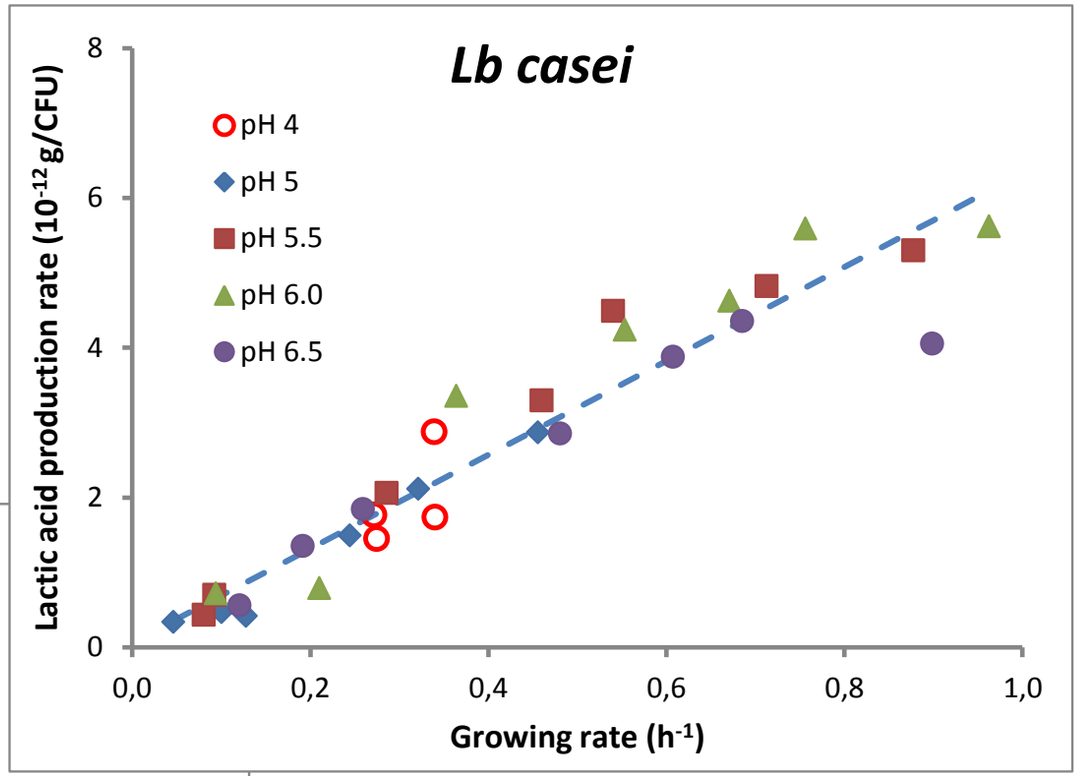
Conclusion and perspectives

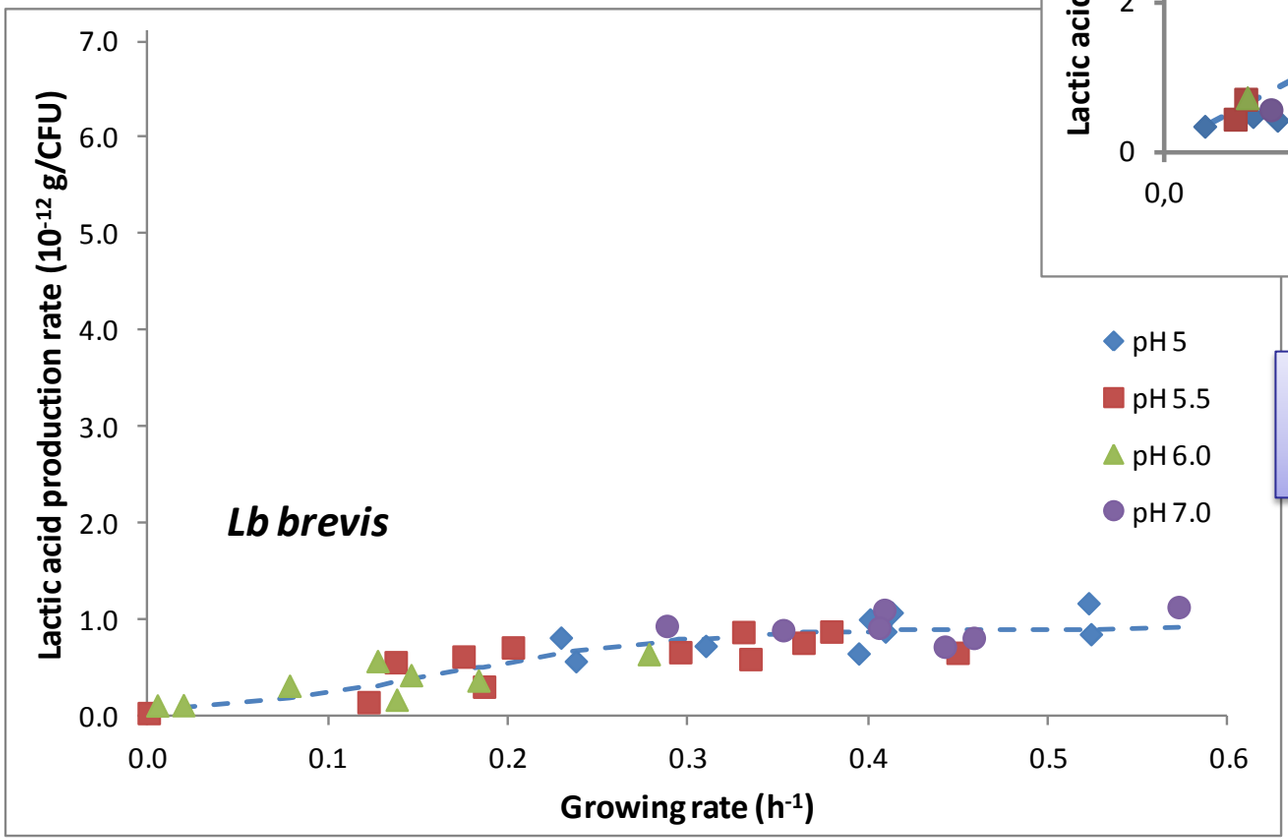
✓ Coupling predictive microbiology & biochemical modeling; a tool for tailoring a fermentation process

✓The model is under development (more strains – yeasts…)

✓ It can be adapted for many cereal acidic fermentation processes

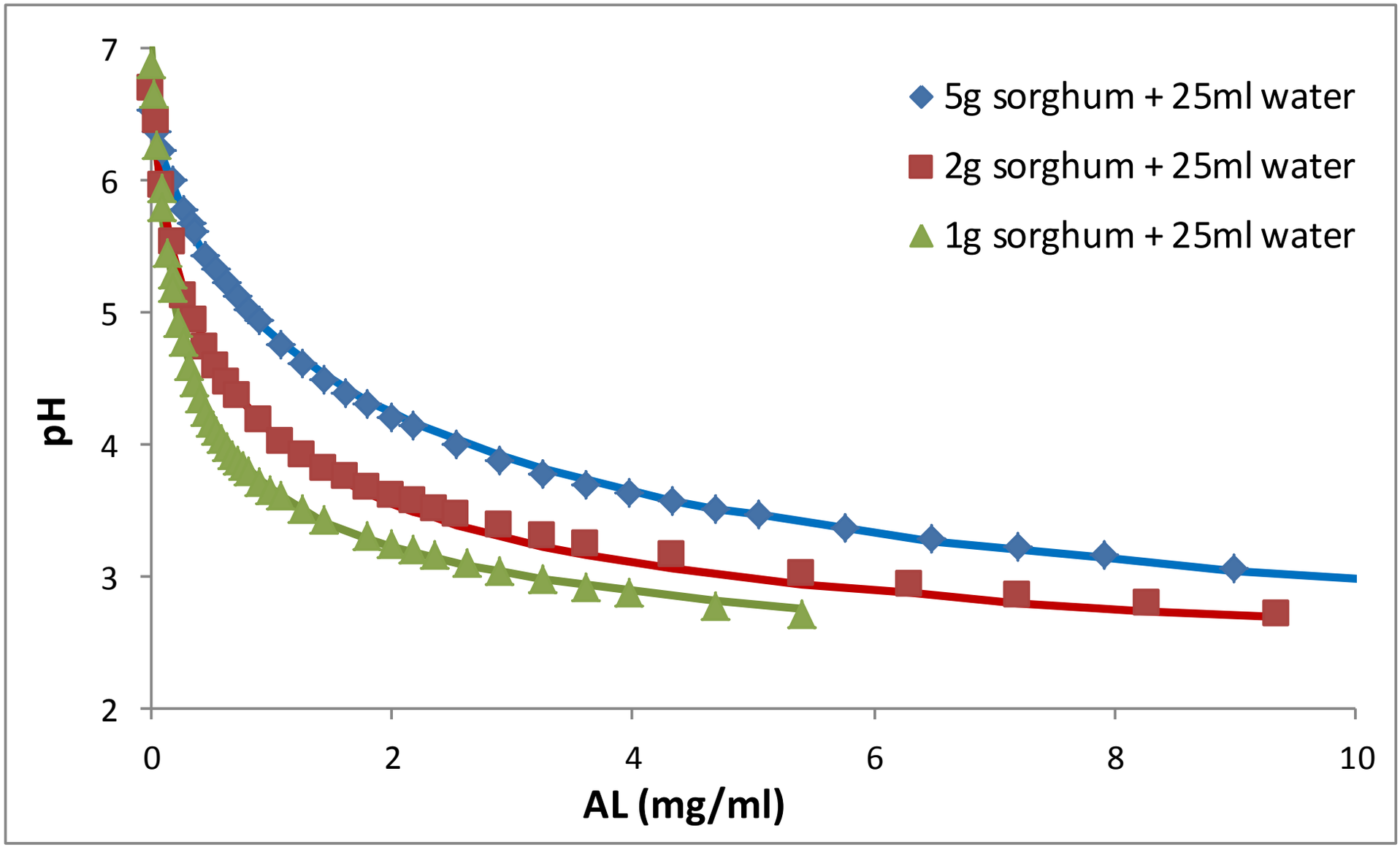
Lactic acid production



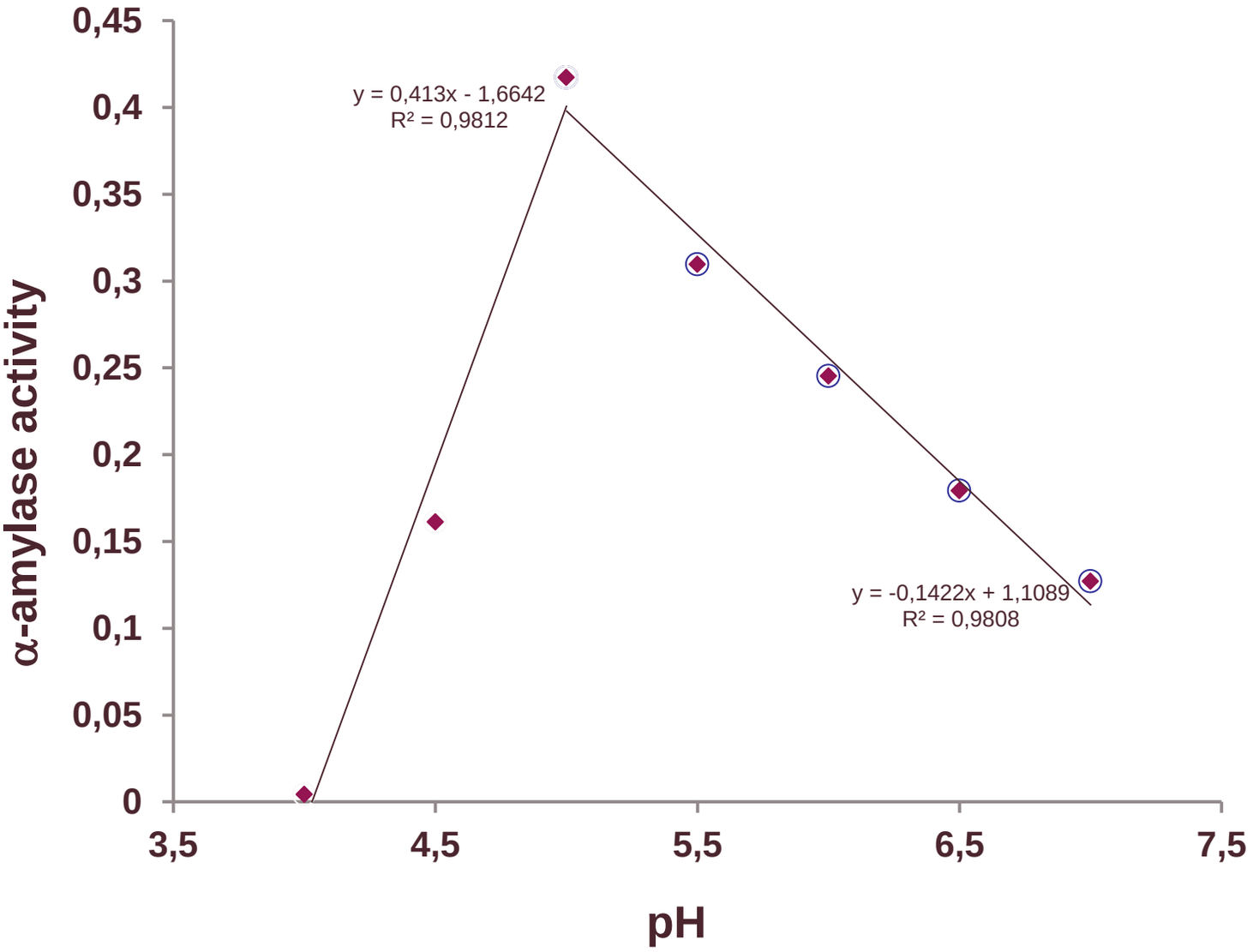


➢ **Lactic acid production <u>only</u> depends on physiological state (μ)**

Sorghum titration curve

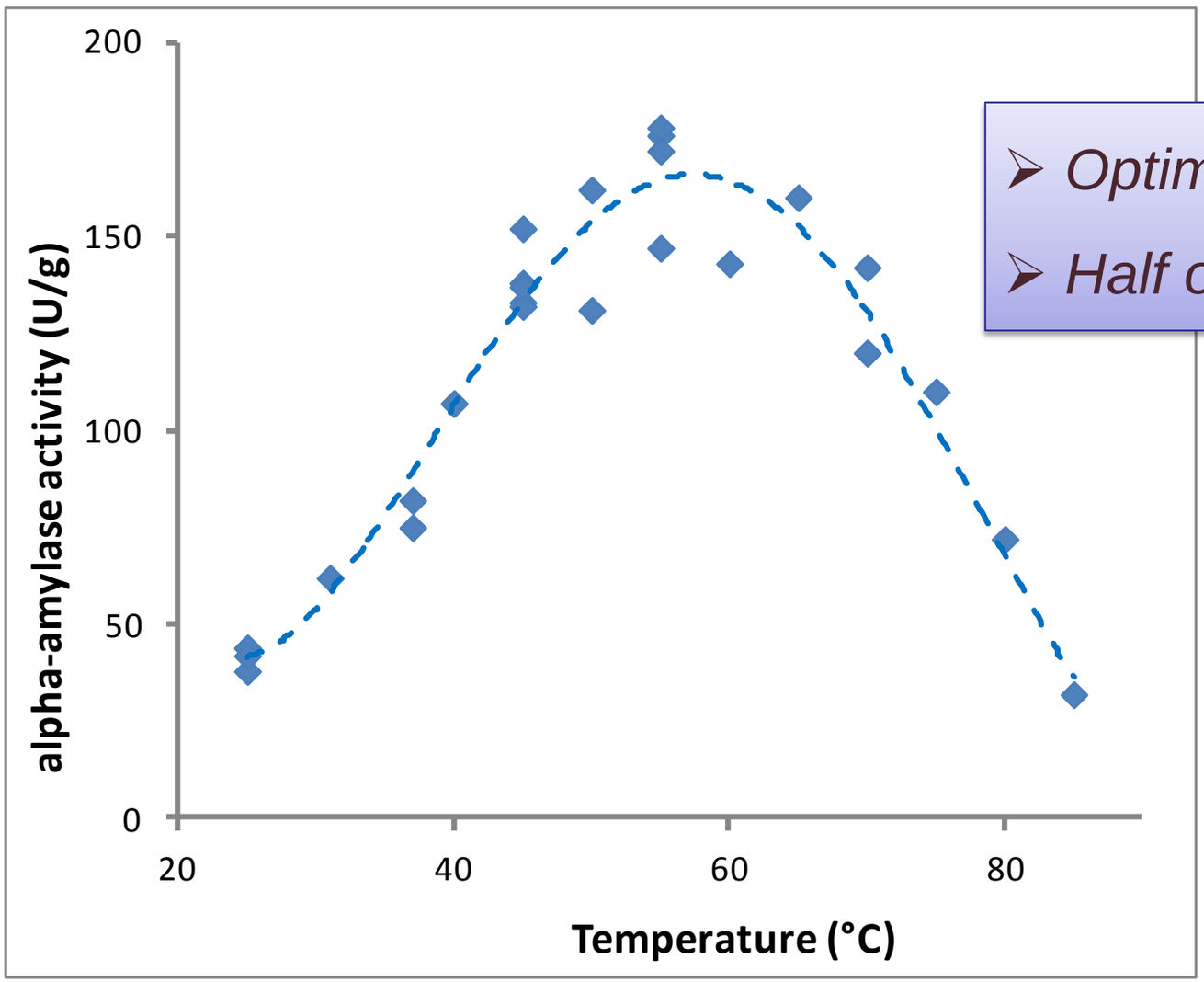


Variation of malt alpha-amylase activity with pH:



➢ α-amylase is completely inhibited at pH ≤ 4.0

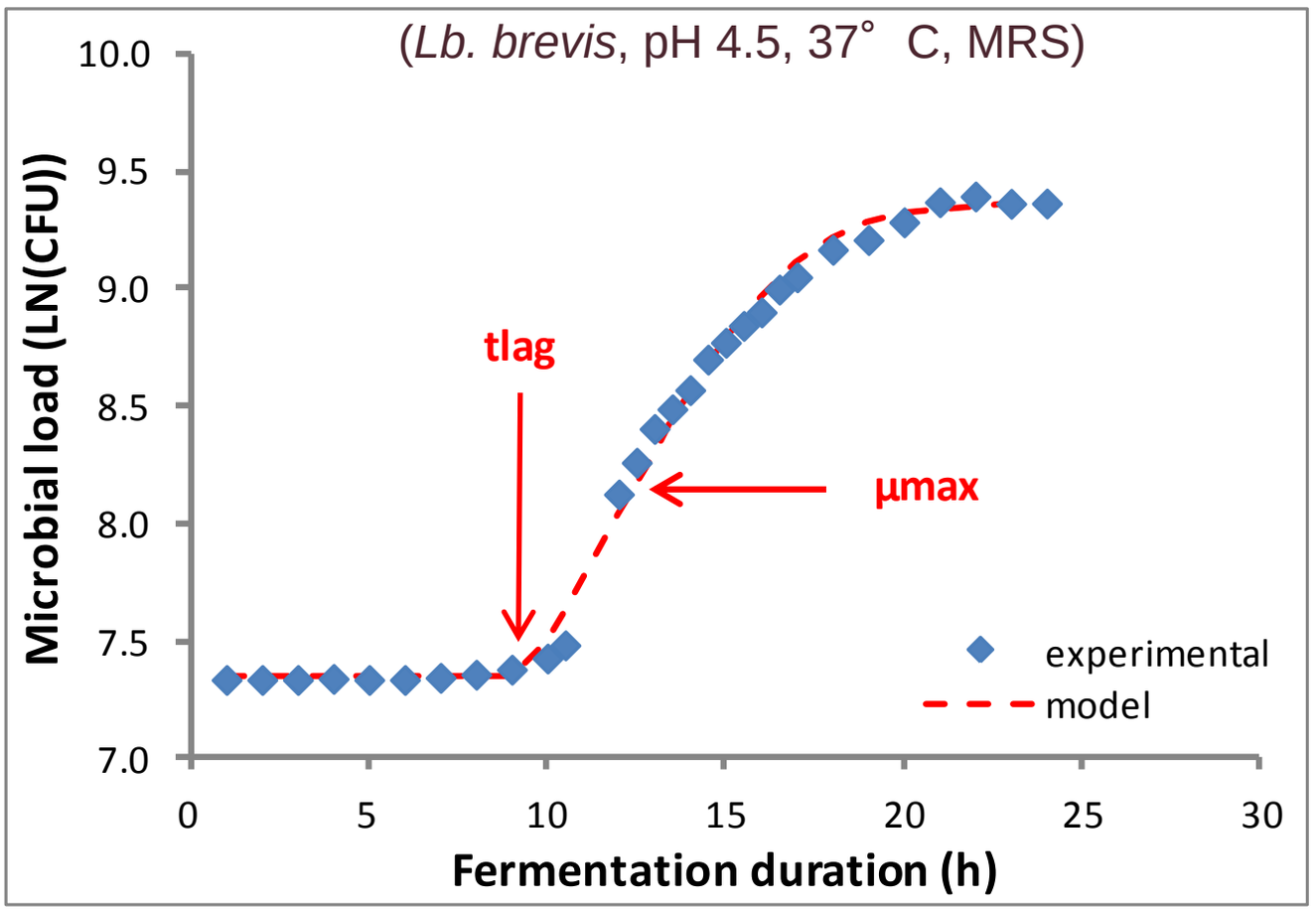
Variation of malt alpha-amylase activity with temperature:



- *Optimum temperature is 55° C*
- *Half of the activity at 80° C!*

Primary model (Rosso type): with standardized conditions (T° , pH, MRS)

$$\begin{cases} \frac{dx}{dt} = o \quad \text{si } t \le t_{lag} \\ \frac{dx}{dt} = \mu_{max} * \left[1 - \frac{x}{x_{max}}\right] * x \quad \text{if } t > t_{lag} \end{cases}$$



Secondary model (gamma concept): *(gamma should be between 0 and 1)*

$$\mu = \mu opt * \gamma_{pH} * \gamma_{malt} * \gamma_{T^o} * \gamma_{aw} \text{ (etc)}$$

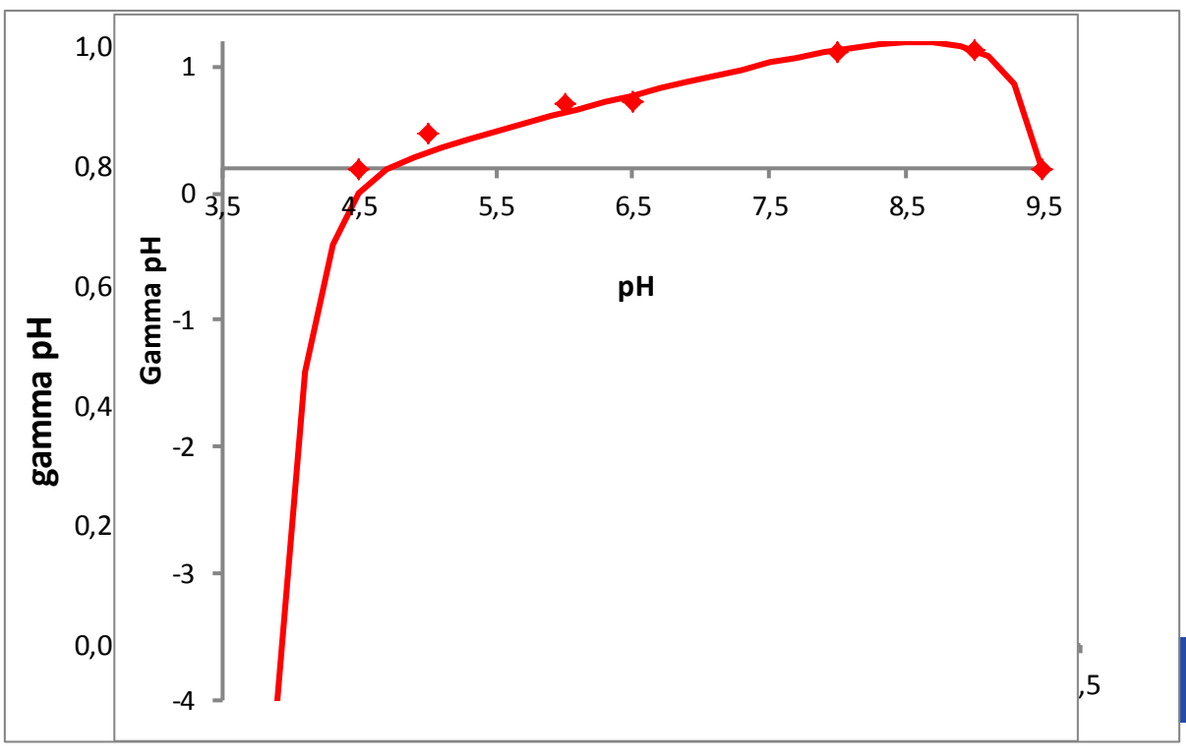
(modèle cardinal)

$$\gamma(pH) = \begin{cases} pH < pH\,min, & 0 \\ pH\,min < pH < pH\,max, & \dfrac{(pH - pHmin)(pH - pHmax)}{(pH - pHmin)(pH - pHmax) - (pH - pHopt)^2} \\ pH > pHmax, & 0 \end{cases}$$

2.0

Bacillus cereus:

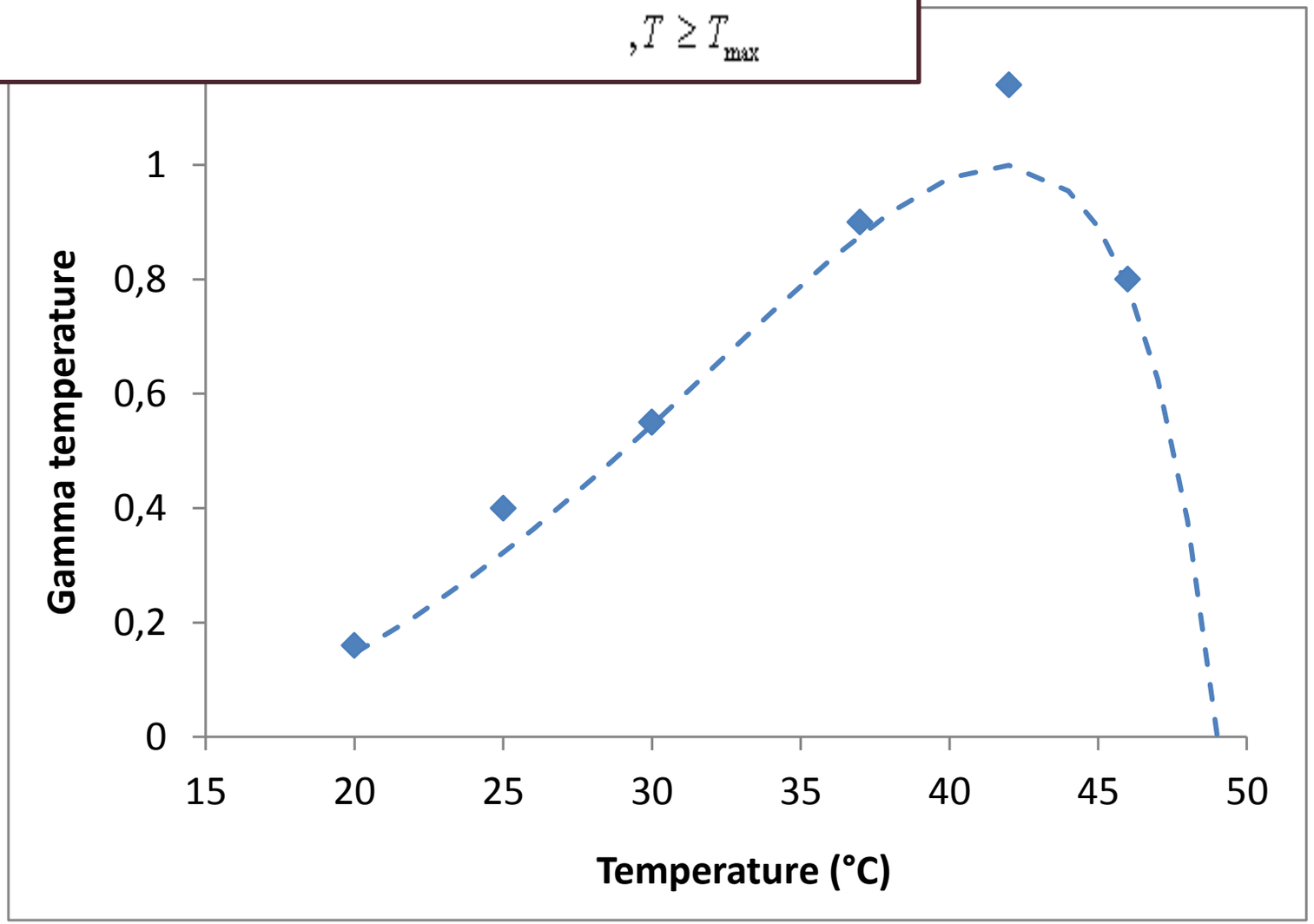
- μ_{opt} = 1.24
- pH_{opt} = 8.6
- pH_{max} = 9.5
- pH_{min} = 4.5
- pH_0 = 3.5
- D* = 0.027
- z_{pH} = 0.46



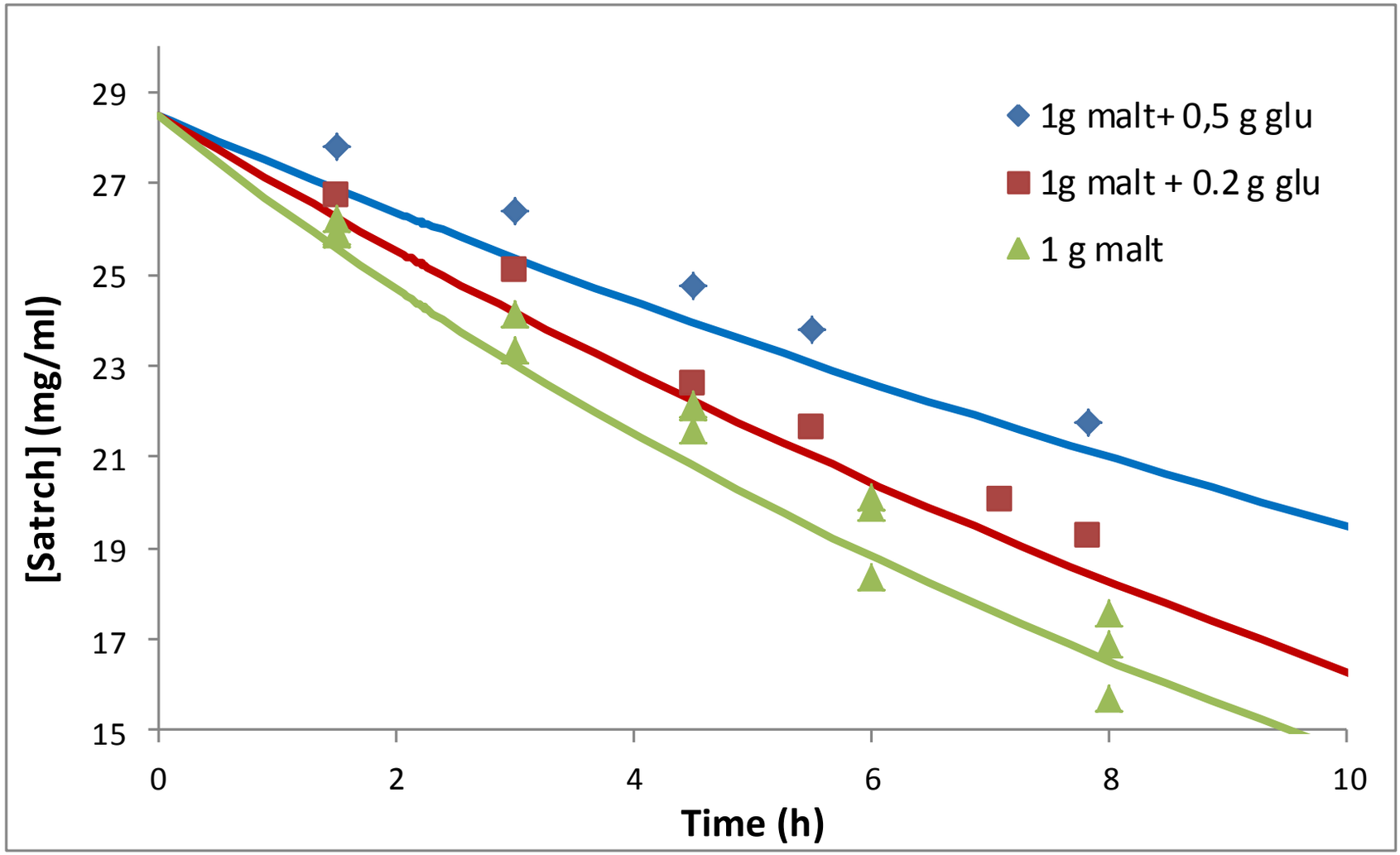
$$\gamma(T) = \begin{cases} 0 & ,T \le T_{min} \\ \dfrac{(T - T_{max})(T - T_{min})^2}{(T_{opt} - T_{min})[(T_{opt} - T_{min})(T - T_{opt}) - (T_{opt} - T_{max})(T_{opt} + T_{min} - 2.T)]} & ,T_{min} < T < T_{max} \\ 0 & ,T \ge T_{max} \end{cases}$$

Lb casei:

- μ_{opt} = 1.06
- T_{opt} = 41.9° C
- T_{max} = 49° C
- T_{min} = 10.1° C



The hydrolysis of starch follows an enzymic kinetic with competitive inhibition by the end-products



$$V = - \frac{[\text{Starch}] * [\alpha \text{ activity}]}{k_1 * (1 + k_2 * [\text{end-products}]) + k_3 * [\text{Starch}]}$$