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Modeling risk-benefit in a food chain: nutritional benefit versus microbial spoilage risk in canned green beans

Clémence C. Rigaux, Catherine C. Renard, Christophe C. Nguyen The, Isabelle I. Albert, Frederic F. Carlin

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Introduction

The same factors such as time, temperature, pH and O₂ concentration, affect both microbial changes and nutrient degradation in a food processing line. Microbial risk assessment is increasingly performed to evaluate the effect of processing fresh and processed foods on the microbial fate. A similar approach could be used to evaluate vitamin degradation during food

processing operations. We therefore propose to model simultaneously the evolution of some bacteria and vitamin concentrations in a real food chain: a canned green bean processing chain. We aim to find a compromise on process parameters that optimizes nutritional benefit while keeping risk at an acceptable level.

Methodology

A risk and benefit second order Monte-Carlo simulation model was built, using literature data, data from a real green bean processing line, and expert opinions. Uncertainty and/or variability distributions were adjusted to model parameters using bayesian inference or maximum likelihood method, and performing a meta-analysis on heat resistance parameters.

Basic microbial and biochemical processes determining changes in bacterial and vitamin concentrations were defined at each step of the industrial process, as well as the most relevant chemical and physical environmental factors affecting those changes.

Results

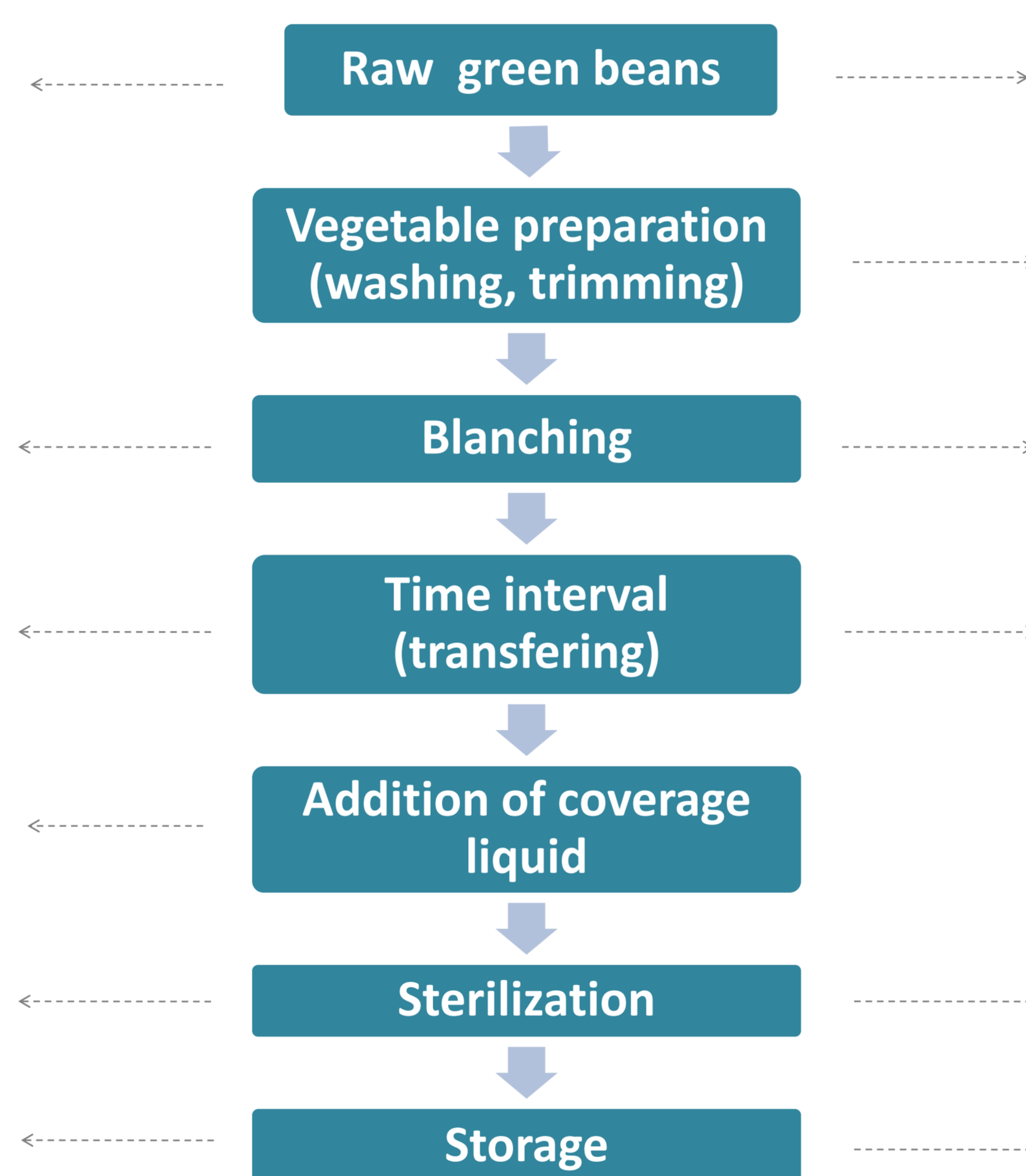
The risk: *Geobacillus Stearotherophilus*



Non pathogenic thermophilic bacteria, responsible of spoilage

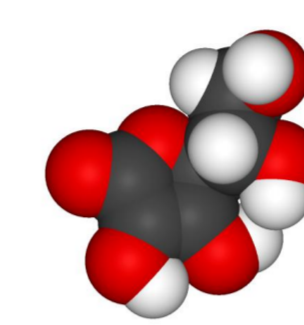
- Contamination
- Low inactivation due to high temperature (80-90°C)
- Cross-contamination by water
- Possibility of cross-contamination by green bean debris
- Cross-contamination via coverage liquid
- High inactivation due to high temperature processing (120-130°C)
- Germination and possibility of growth, leading to food spoilage

The canning process



The benefit: Vitamin C (AA and DHA)

Useful for immunity, cicatrization, antioxydant capacity



- Initial concentrations of vitamin C
- Loss due to physiological evolution (green beans still "alive")
- Loss due to chemical reactions (destructured membranes)
- Loss due to diffusion in the blanching water
- Loss due to chemical reactions
- Loss due to chemical reactions
- Loss due to chemical reactions
- Loss due to diffusion in the juice

Inactivation models:

Weibull primary model⁽¹⁾:

Bigelow secondary model: $D = D_{ref} \cdot 10^{(T_{ref}-T)/z} \cdot 10^{(pH-pH_{ref})/z_{pH}}$

$$\log_{10}\left(\frac{N_t}{N_0}\right) = -\left(\frac{t}{D}\right)^p$$

Growth models:

Logistic primary model with delay $\lambda=0$:

Secondary model of Zwietering:

$$N_t = \frac{N_{max}}{1 + \left(\frac{N_{max}}{N_0} - 1\right) \exp(-\mu_{max} \cdot t)}$$

$$\mu_{max} = \mu_{opt} \cdot \gamma(T) \cdot \gamma(pH)$$

(N_t: contamination in cfu at time t, T: temperature, D: decimal reduction time, z: increase in temperature causing to a 10-fold reduction of D, p: shape parameter, μ_{max} and μ_{opt} : maximal and optimal growth rates)

Physiological evolution models:

$$\frac{d[AA]}{dt} = -k \quad \text{and} \quad \frac{d[DHA]}{dt} \approx 0$$

Chemical reaction models⁽²⁾:

$$\frac{d[AA]}{dt} = -k1 \cdot [AA] \cdot [O2]^\beta$$

$$\text{Arrhenius law : } k1, k3 = k_{ref} \cdot \exp\left(-\frac{E_a}{R} \left(\frac{1}{T} - \frac{1}{T_{ref}}\right)\right)$$

$$\frac{d[DHA]}{dt} = k1 \cdot [AA] \cdot [O2]^\beta - k3 \cdot [DHA]$$

Diffusion at blanching: Fick law

(AA, DHA and CGA: Ascorbic, Deshydroascorbic and Ketoglutaric acids, O₂: oxygen, []: concentrations, k, k1, k2: speed reaction coefficients, t: duration, T: temperature, E_a: activation energy, R: universal gaz constant)

Predicted evolution of *G.stearotherophilus* and vitamin C concentrations:

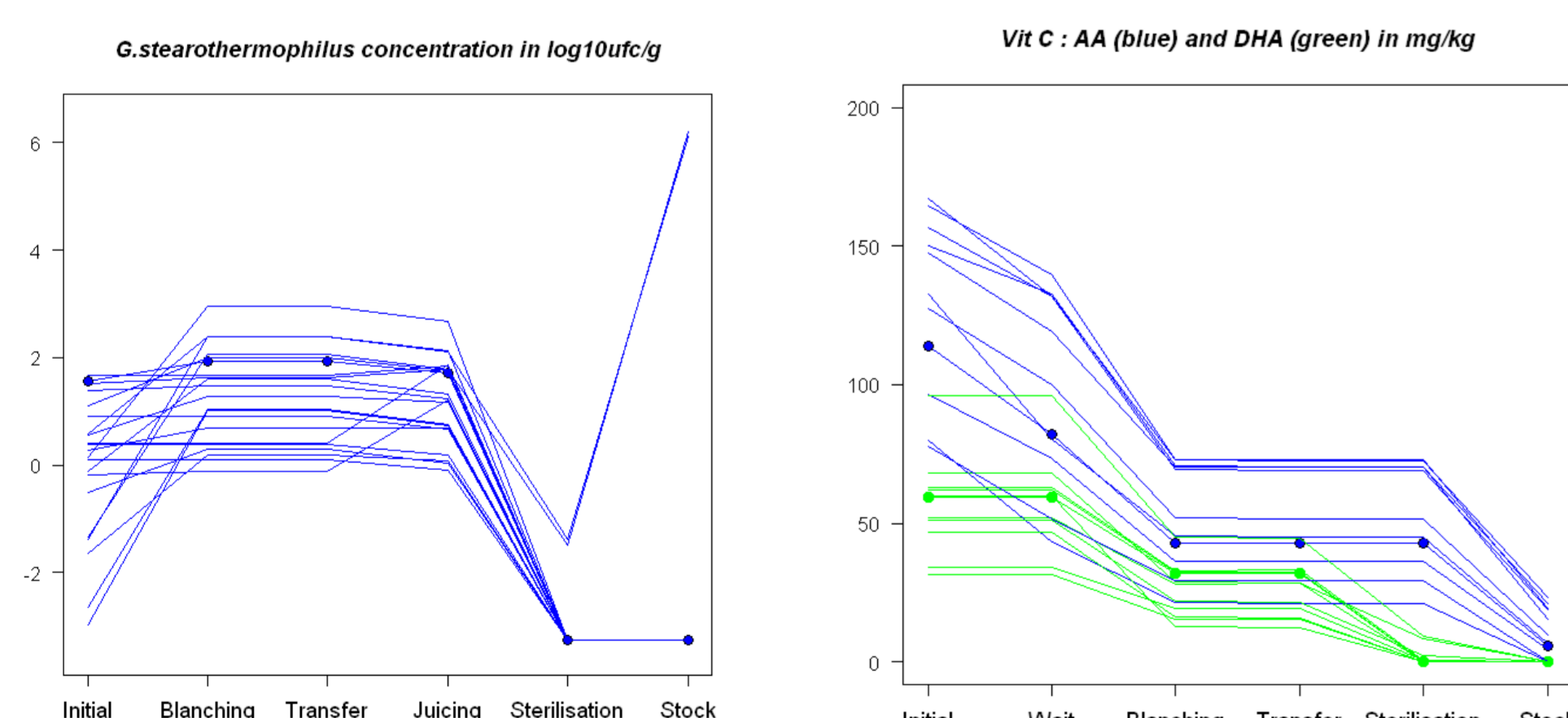
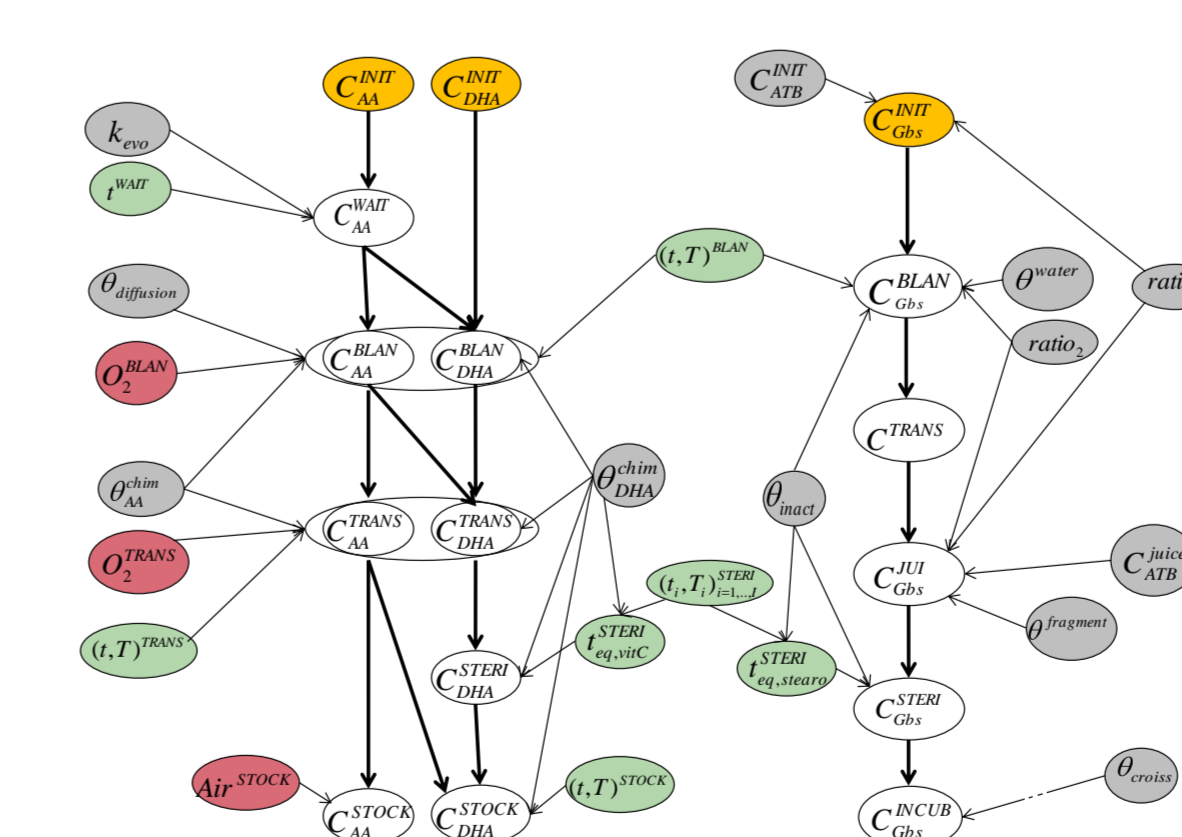


Figure 1. Several evolution scenarios in some green bean cans (obtained from different random variability and uncertainty values)

Figure 2. Simultaneous risk-beneficial model graph, confrontation to reality:



The only commands common to bacterial inactivation and to vitamin degradation are the blanching and sterilisation times and temperatures.

- Non stability predicted rate: $\approx 6\%$
→ rather high compared to industrial data
- Predicted vit C concentration: $\approx 12\text{mg/kg}$
→ to be compared to $\approx 30\text{mg/kg}$ in litterature

Discussion and perspectives

- The model is still in progress, but only few parameters seem to have an important impact on both vitamin C and *G.stearotherophilus* final concentrations.
- The prediction of changes in vitamin concentrations and spoilage rate will be analysed and compared to measured data to validate the model. A more detailed sensitivity analysis will permit to find the most impacting factors and possibly an optimization bivariate criteria.

References

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(2) Penicaud, C., Etude et modélisation du couplage entre le transfert d'oxygène et les réactions d'oxydation dans les aliments au cours de leur conservation, PhD Thesis, University of Montpellier 2 Sciences et Techniques, France, nov 2009.

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