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

Clémence Rigaux^a, Catherine M.G.C. Renard^b, Christophe Nguyen-the^b, Isabelle Albert^a, Frédéric Carlin^b

^aINRA, UR 1204 Met@risk, Méthodologies d'analyse de risque alimentaire, F-75005 Paris, France (e-mail : clemence.rigaux@paris.inra.fr)

^bINRA, Université d'Avignon et des Pays de Vaucluse, UMR 408 Sécurité et Qualité des Produits d'Origine Végétale, F-84000 Avignon, France



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.

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

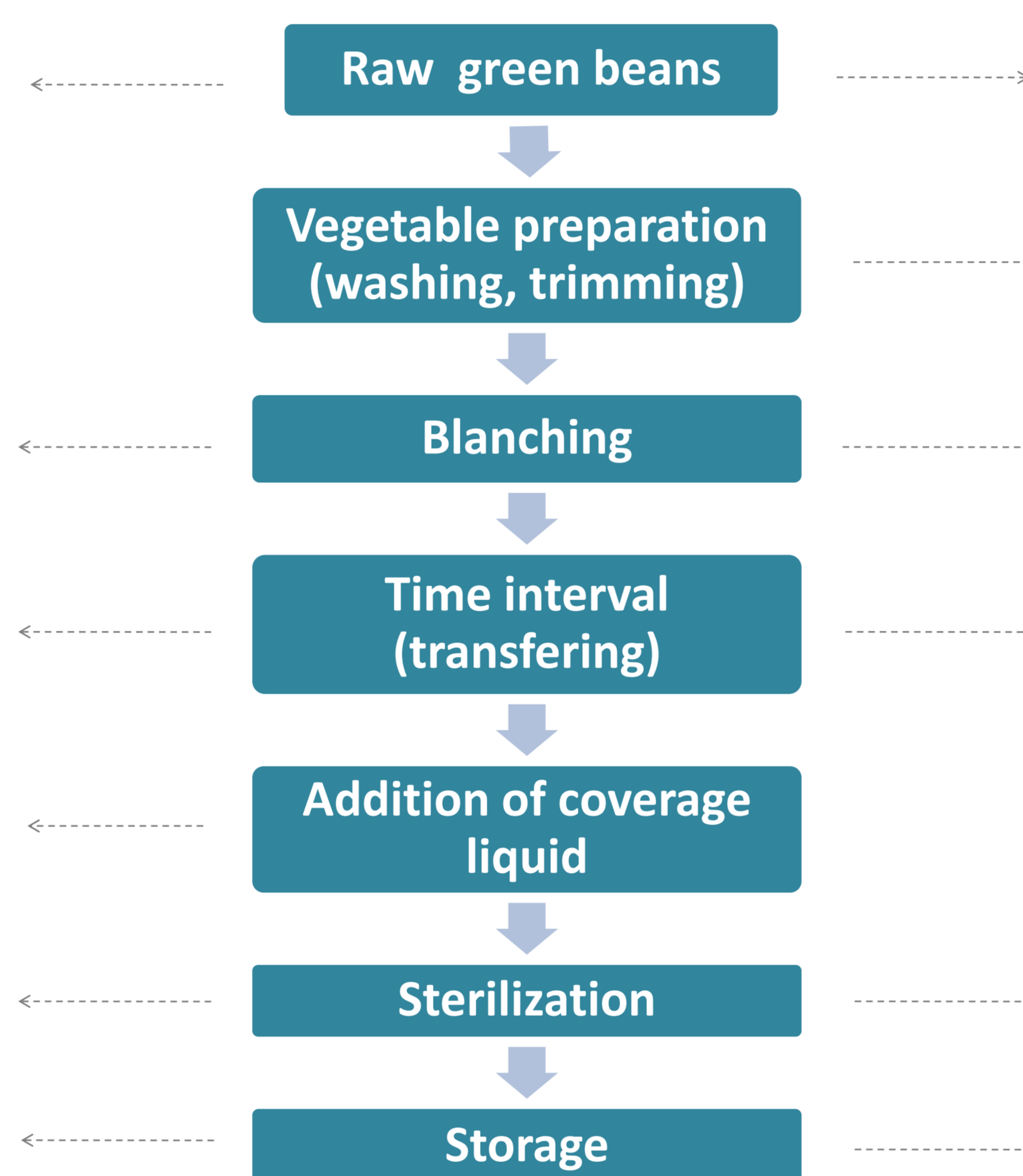
- Possibility of cross-contamination by green bean debris

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

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

Growth models:

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

Secondary model of Zwietering: $\mu_{max} = \mu_{opt} \cdot \gamma(T) \cdot \gamma(pH)$

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

(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⁾:

$$\frac{d[AA]}{dt} = -k_1 \cdot [AA] \cdot [O_2]^\theta$$

$$\text{Arrhenius law : } k_1, k_3 = k_{ref} \cdot \exp\left(-\frac{E_a}{R} \left(\frac{1}{T} - \frac{1}{T_{ref}}\right)\right)$$

$$\frac{d[DHA]}{dt} = k_1 \cdot [AA] \cdot [O_2]^\theta - k_3 \cdot [DHA]$$

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.stearothermophilus* and vitamin C concentrations:

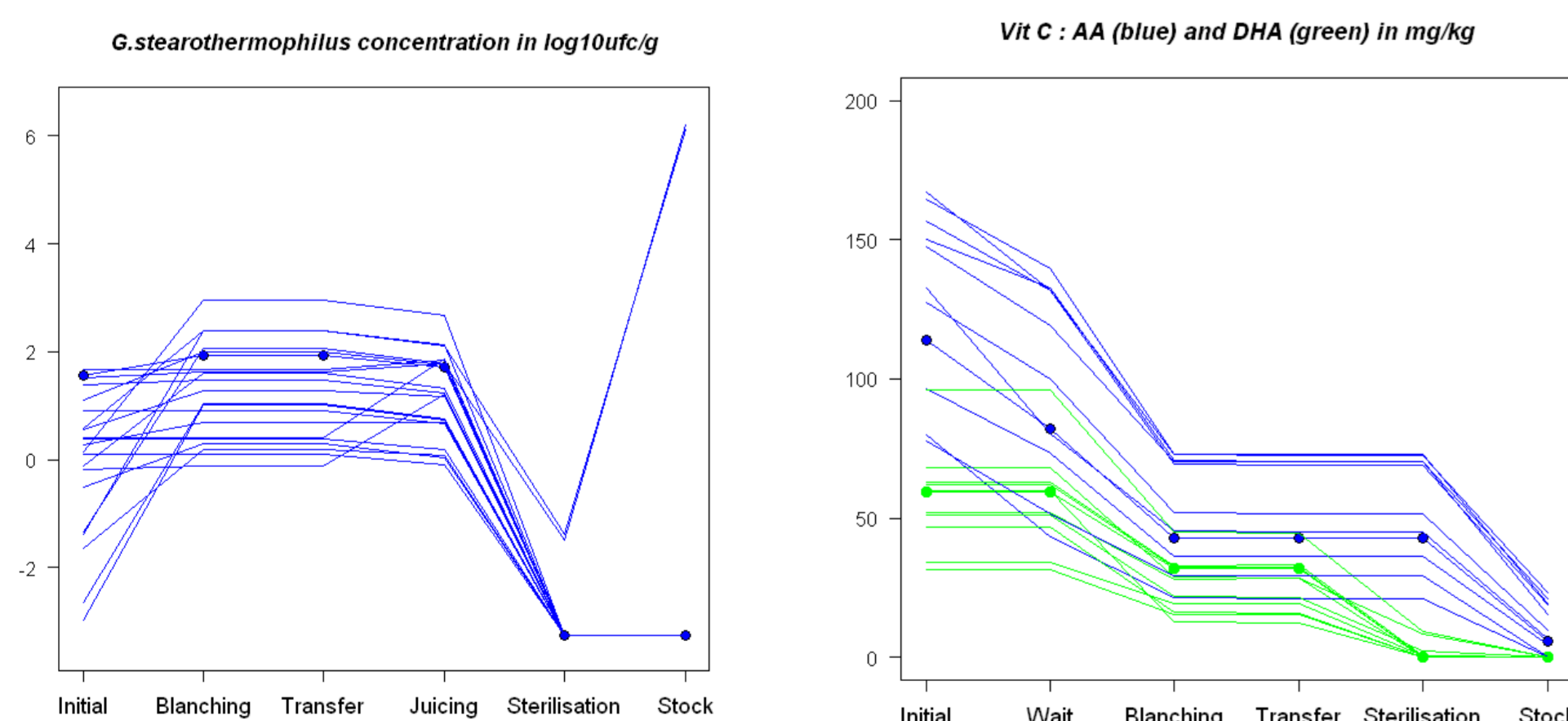
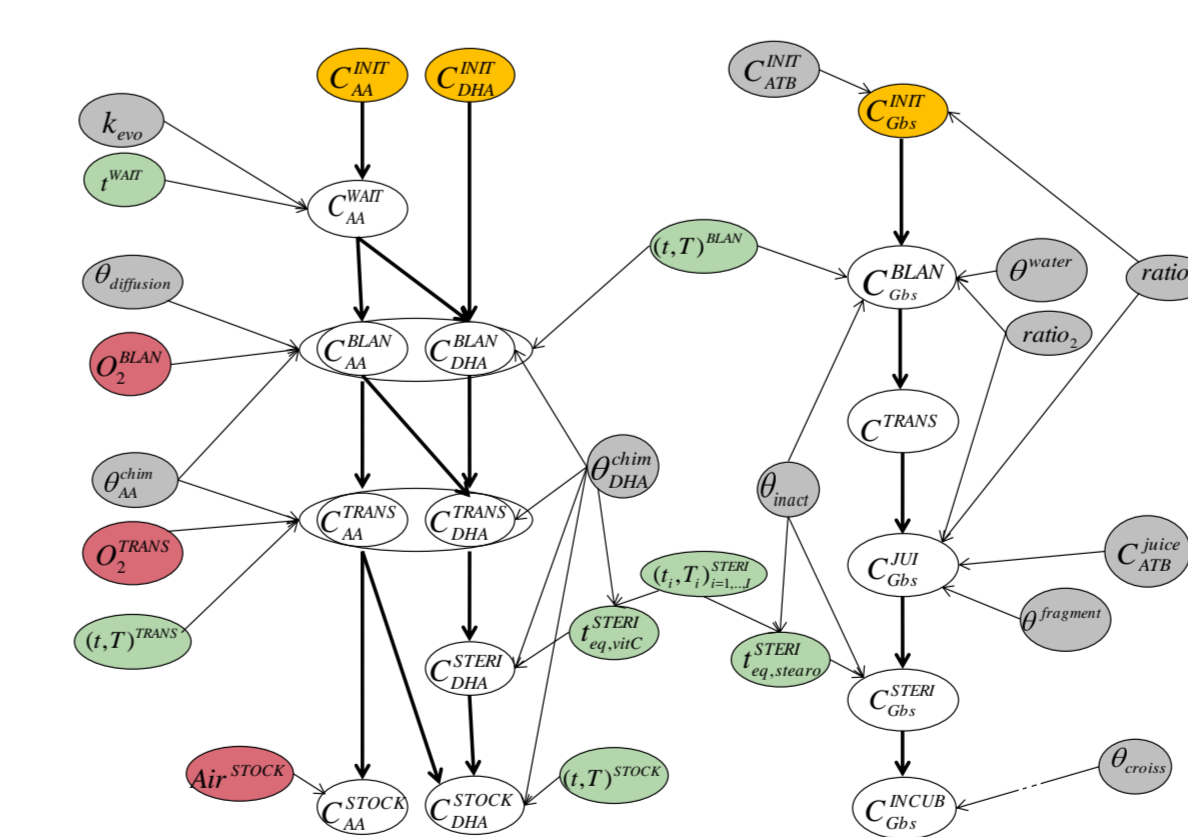


Figure 1. Several evolution scenarios in some green bean cans (obtained from different random variability and uncertainty values)

Figure 2. Simultaneous risk-benefice 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.stearothermophilus* 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 sensivity analysis will permit to find the most impacting factors and possibly an optimization bivariate criteria.

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