Adjusting the control parameters of the diced bacon process according to food safety targets for *Listeria monocytogenes*

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1. Introduction

Diced bacon consists in processed pork breasts tumbled with brine and then steamed, diced and packed under modified atmosphere. *L. monocytogenes* can be present on pork breasts. According to the physico-chemical characteristics of diced bacon growth of the pathogen is possible. Diced bacon is a product usually used in home cooked preparations but occasionally consumed as a ready-to-eat by about 10% of the consumer population in France.

In this context, a probabilistic model was developed (Billoir et al. in press) to assess the impact of the manufacturing process on the fate of *L. monocytogenes* and lactic acid bacteria (LAB). Contamination evolution was modeled in the adequate units (breasts, dices, or packaging units) through the successive process steps (arrival, brining, steaming, dicing and packaging). This model did not consider growth during process.

Recently, additional data have been acquired. This concerns (i) *L. monocytogenes* (detection and enumeration) on pork breasts just after tumbling (Commeau et al. 2009), (ii) fate of inoculated *L. monocytogenes* in packed diced bacon (Cornu et al., in press) and (iii) temperatures at the breast's surfaces and in the surrounding air during steaming.

Figure 1. Diced bacon process chain

2. Objectives

The objectives of this work were:

- To refine the process model according to new data collected
- To extend the model for the storing step
- To link the controllable parameters of the diced bacon process according to food safety targets

3. Methods

Refinement of the process model

The modeling approach of *L. monocytogenes* concentration at arrival was modified. The Bayesian model used to describe contamination at arrival is composed of two parts: the process part and the data one, the latter being composed of detection and enumeration (Commeau et al., 2009). The previous model presented in Billoir et al. (in press) described concentration on breasts (c_i^A) at arrival with a log-lognormal distribution. In the new model, c_i^A depends on the logarithm the concentration in a batch (lconcB). lconcB follows a normal distribution of parameter μ^A and σ^A.

Flat priors were set because very few information about breast contamination at arrival was available. Bayesian estimation of the posterior distributions of the parameters was performed using the software OpenBugs (3.0.3) (100,000 iterations, 1 chain, thinning of 1,000) and the R package Brugs. The new model of simulation of the contamination is presented in Figure 2.

Growth during heat-up phase of the steaming phase was considered in the new process model. The same primary and secondary growth models as used for post-processing were used to predict growth of LAB and *L. monocytogenes*.

Extension of the model to post-processing

The model was extended to the post-process storage until consumption. Temperature was assumed to be constant at 8°C throughout it. Growth and competition between *L. monocytogenes* and LAB were considered. For primary growth model, a model that takes into account Jameson effect was used. The growth competition was considered at the dice level.

For LAB and *L. monocytogenes*, secondary growth models of Mejlholm and Dalgaard (2007) and Mejlholm et al. (2010) were considered respectively. The following environmental factors were considered for prediction of growth rate: temperature, pH, water activity, lactate, diacetate, CO_2. Between batch variability was taken into account (e.g. for acid content).

Link between control parameters and food safety targets

Several process parameters are directly controllable by the manufacturer: for example temperature and duration of the steaming step. For these parameters we tested different possible values in order to exemplify the link between process control measures and food safety targets. Five scenarios were tested in their ability to comply with different food safety target levels (Table 1). For each, we checked the compliance of diced bacon packages at the end of the storage step with three different food safety targets (1 cfu/100 g, 1 cfu/10 g, 1 cfu/g and 100 cfu/g).

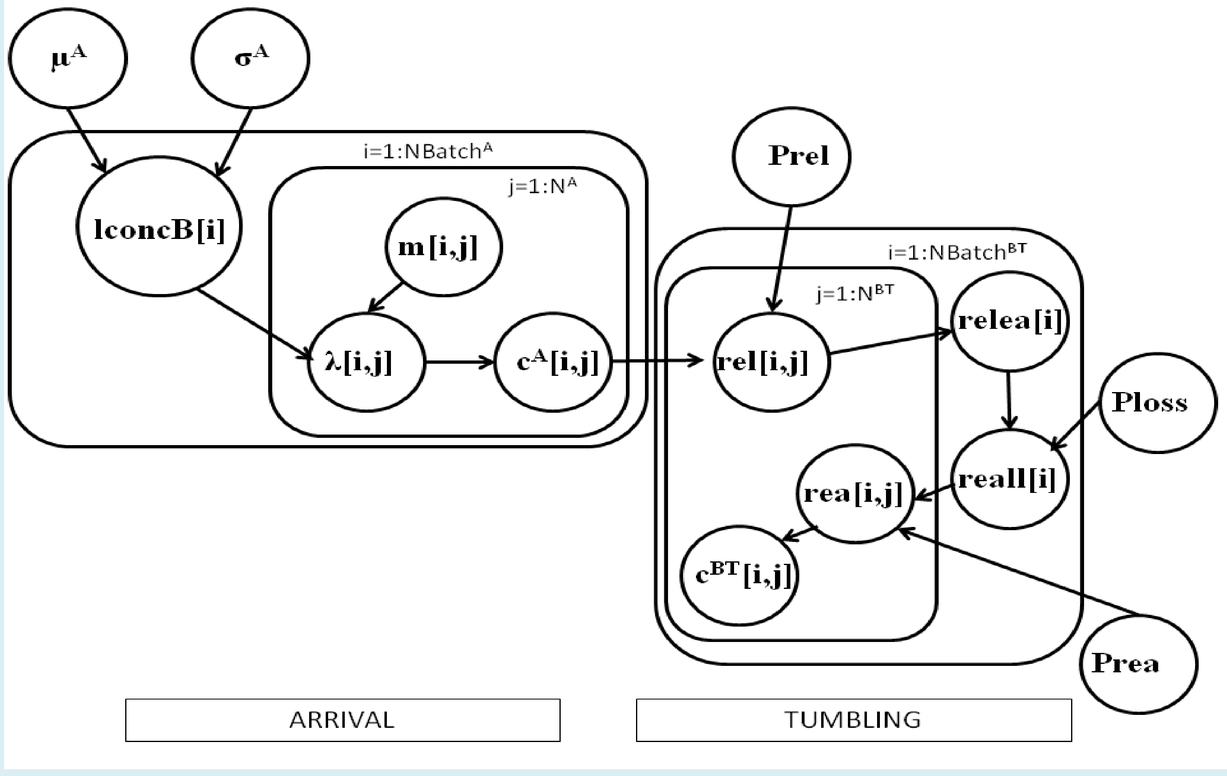

Figure 2. Diagram of the model describing the first two steps of the process.

Prel: probability for a bacterium to be released; rel[i,j]: part of bacteria released from a breast; relea[i]: total number of bacteria released; reall[i]: total number of bacteria reallocated; rea[i,j]: number of bacteria reallocated to a breast; Prea: probability for a bacterium to be reallocated; and cBT is the contamination at the end of the tumbling step.

5. Conclusions

- Modelling approach confirms experimental results of challenge test
- Growth is sparse during refrigerated storage of diced bacon and according to levels at the end of the process step. Probability to reach high levels of *L. monocytogenes* at the end of the shelf-life is low
- Model can be used to adjust process parameters in order to comply with different food safety objectives

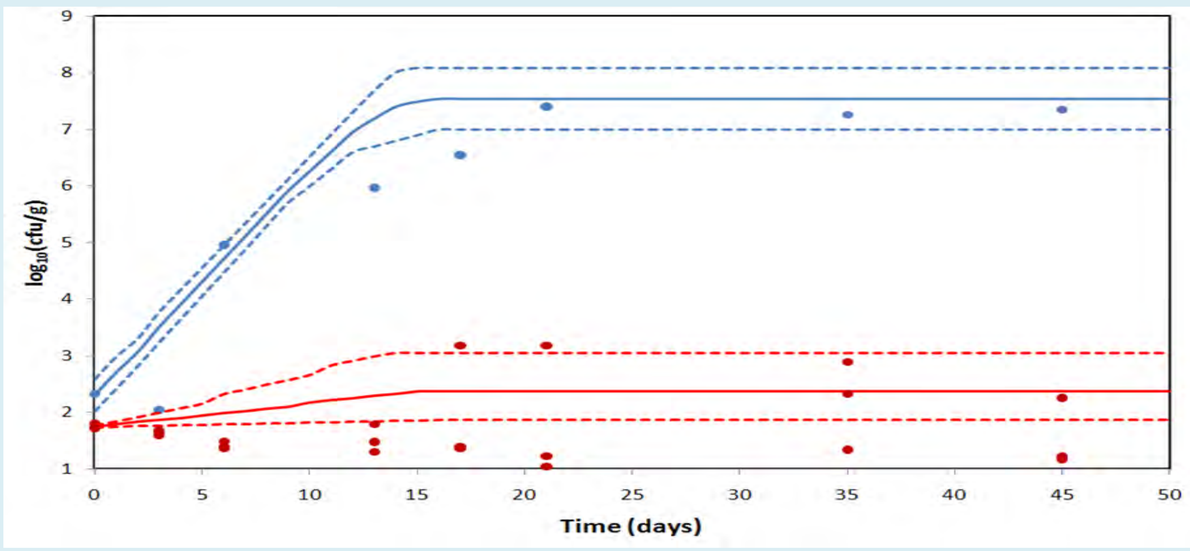

Figure 3. Observed (●) and predicted (–) growth of LAB (blue) and *L. monocytogenes* (red) in diced bacon at 8°C (aw=0.96, pH=5.8, 1.52% of lactate, 40% of CO_2). (--) represent 95% confidence intervals of predictions.

4. Results

The means of posterior distributions for μ^A and σ^A were respectively of -2.33 and 0.93.

Primary model associated with secondary growth models for LAB and *L. monocytogenes* satisfactorily predict the observed data of challenge-testing (Figure 3). These two models were thus incorporated in the storing step of the model.

For all the different sets of process parameters or for a reduced salt level, the probabilities to surpass level higher than 1 cfu of *L. monocytogenes* /g at the end of the shelf life is small (Figure 4).

Figure 5 illustrates the impact on changing process parameter or diced bacon composition on compliance with a food safety objective.

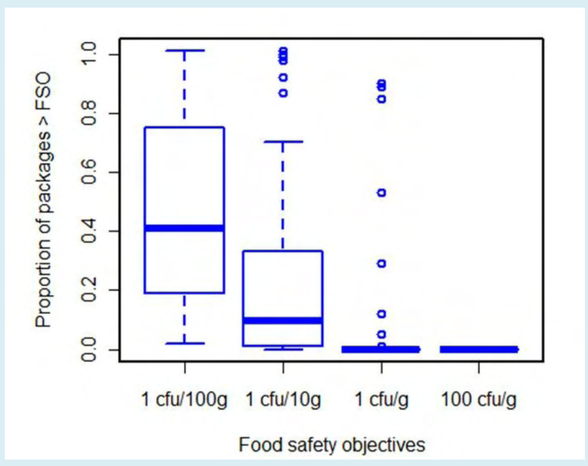

Figure 4. Probability to comply with different food safety objectives at the end of the shelf-life for scenario S5

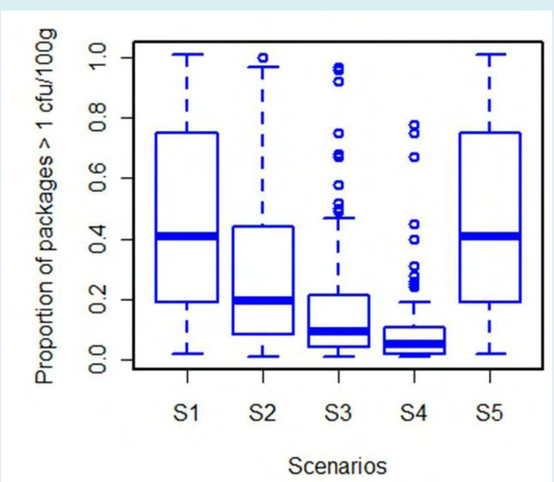

Figure 5. Probability to comply with a food safety target of 1 ufc/100g at the end of the shelf-life for the different scenarios

Table 1. Parameter values for different scenarios of diced bacon processing

Scenario	Maximum temperature after heat-up step during steaming	Duration of exposing at maximum temperature	Water activity
S1	45°C	1h30	0.96
S2	50°C	0h30	
S3	50°C	1h00	
S4	50°C	1h30	
S5	45°C	1h30	0.965

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