VALIDATION AND EVALUATION OF PERFORMANCE INDICATORS OF THE CORBION® *LISTERIA* CONTROL MODEL ON READY-TO-EAT MEAT PRODUCTS

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I. INTRODUCTION

Control of *Listeria monocytogenes* throughout shelf life is one of the biggest challenges in preservation of ready-to-eat meat products. Refrigeration temperature and the typical water activity and pH of ready-to-eat meat products do not provide the desired protection and therefore these types of products need an additional hurdle to provide sufficient *L. monocytogenes* control. Predictive microbiology is increasing in popularity to assist product developers in formulating ready-to-eat meat products to inhibit any potential growth of *L. monocytogenes* should the bacterium ever exist in their post-lethality exposed products. Various *L. monocytogenes* predictive growth models are publicly available, one of which is the Corbion® *Listeria* Control Model (CLCM). The CLCM is a predictive growth model based on the widely used Gamma concept [1] and includes over 2500 growth curves, both in broth and food applications, used for model fitting. It is an extended and improved version of the Purac® *Listeria* Control Model 2007, which was evaluated by Mejlholm et al. [2] The model not only takes into account selected values for selected product characteristics (e.g., salt content, product moisture, pH, and whether it was cured not), but it also allows the use of various Corbion *Listeria*-control products to predict the potential growth of *L. monocytogenes*.
This study evaluates model performance for the CLCM model in terms of its ability to realistically predict the observed time-to-growth (time to one log growth (TTG)) of various product samples from four different datasets.

II. MATERIALS AND METHODS

Data from four sources were used for model evaluation. These data sets comprised different ready-to-eat meat products, with different antimicrobials (lactate, acetate, propionate) and contained cured as well as uncured meat products. Predicted TTG was compared to observed TTG. The evaluation of the model was centered around three basic concepts: 1) the bias of the data, i.e., did the model predict more data points to one side or the other of an equivalence line. This bias can be measured using a performance index called Bias Factor (B_f). 2) Measure of the scatter of the data. This was accomplished by using the Accuracy factor (A_f) and the Performance factor (P_f) [3]. 3) An estimate of the number of predictions accurate, the number that were fail-safe, and the number that were fail-hazardous by evaluation of how many of the predictions fall in an Acceptable Zone defined by certain criteria [4] or as % accurate predictions by the method used by Mohr et al. [5]. The data from the four sources were analyzed separately, as well as combined altogether.

III. RESULTS AND DISCUSSION

A total of 66 data points were included in the analysis. Two values were compared – the best fit prediction (CLCM BF) and the 95% line prediction (CLCM 95%) (see Table 1). The best fit prediction represented the most likely or average (50th percentile) time-to-growth (TTG) result from the model while the 95% prediction represented the 95% percentile of the predicted TTG value. The overall bias factor for the best fit predictions was 1.18, with an accuracy factor of 1.57. Bias factors for the individual datasets were ranging from 0.62 to 1.42, indicating that although overall model performance was acceptable, there was significant variation between the different dataset, ranging from fail-dangerous to fail-safe. The variation between the different datasets highlights the importance of including variability in model predictions.

The 95% line predictions, originating from the original data sets, seem to shift some predictions from the acceptable zone and the % accurate classification to the fail safe zone. Consequently, this reduces the number of the predictions that would be deemed to be acceptable or accurate. This is acceptable practice, however, since it should result in challenge study results that have observed TTG values greater than the predicted values. This is also reflected by a very low B_f and a relatively high A_f of the 95% line, indicating that this is a fail-safe prediction. Requiring a high proportion of predictions in the acceptable zone that proves the models to be able to accurately predict TTG is a worthy goal, but it may be unrealistic in actual practice due to the vast number of uncontrolled variables at play in the production of meat products. The use of 95% line predictions should be preferred over the best fit line because the use of the 95% confidence limit takes into account some of the inherent variability that may be observed in the product.

Table 1 Indicators of model performance of the CLCM based on four datasets.

Performance indicators	CLCM 95%	CLCM BF
Bias factor (B_f)	0.56	1.18
Accuracy factor (A_f)	1.89	1.57
Performance factor (P_f)	37.2	27.0
AP Zone indicators	CLCM 95%	CLCM BF
Fail Hazardous	1.5%	39.4%
Fail Safe	55.1%	10.6%
AP Zone	43.5%	50.0%
Fail Safe + AP Zone	98.6%	60.6%

In addition, compared with the previous version of the model, the CLCM has better prediction quality in all of the key performance indicators, especially less fail hazardous predictions and more in the fail safe and acceptable regions (data not shown). Looking across other commercially available *Listeria* models, the CLCM also predicts a longer growth period (up to 150 days), and has the flexibility of specifying different *L. monocytogenes* growth targets (e.g. 0.5 log, 1 log, 2 log outgrowth) which makes it suitable for different geographical regions, each with their own *L. monocytogenes* regulations.

IV. CONCLUSION

The CLCM is a tool to support product developers in formulating ready-to-eat meat products in such a way that sufficient *L. monocytogenes* control is provided throughout shelf life. The model can be used both on the best fit line and the 95% line which can be useful for risk assessment and reflecting strain or product variations. Overall, the best fit line gives a slightly fail-dangerous bias, but this is not the case for all datasets. Using the 95% line is recommended as this results in 98.6% of the predictions to be accurate or safe. However, some accurate predictions are sacrificed for a higher number of fail-safe predictions.

CLCM is open to universities, institutes, governmental agencies as well as food manufacturers and provides food producers with another reliable source of information for *L. monocytogenes* control, enabling a 'check and balance' procedure where predictions are cross-examined. The ultimate purpose is ensuring food safety. The final formulation requires validation in the actual RTE meat product being considered using inoculation-pack challenge studies.

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