Food Spoilage and Safety Predictor (FSSP) software – background and applications

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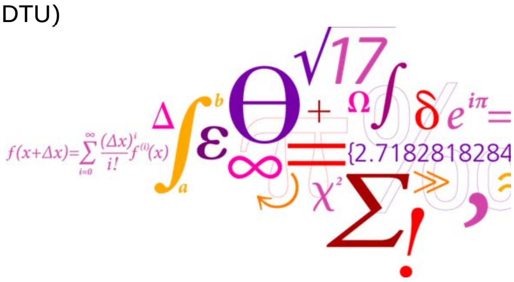

DTU Food
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Food Spoilage and Safety Predictor (FSSP) software – background and applications

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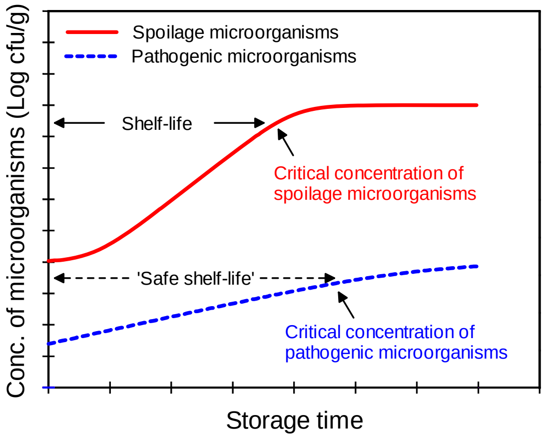
- Predictive microbiology - background
- Food Spoilage and Safety Predictor (FSSP) software
  - *Listeria monocytogenes* – an example
  - Help menu
  - Microbial interaction
  - Stochastic models
  - Documentation of food safety
- Time-temperature integration and food chain assessments
- Conclusions and perspectives

Predictive mathematical modelling of growth



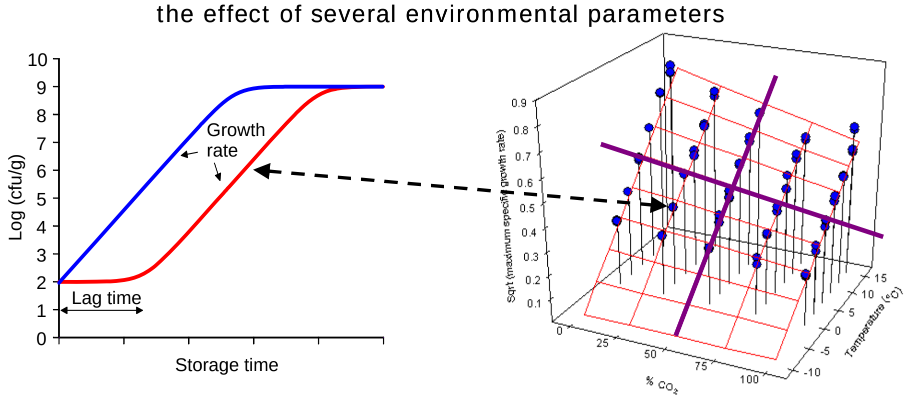
Processing
Product characteristics
Storage conditions

Predictive model software →

Spoilage and shelf-life
Safe shelf-life
Optimal product recipes

Development of predictive microbiology models

Models are usually developed in two steps from experiments including the effect of several environmental parameters

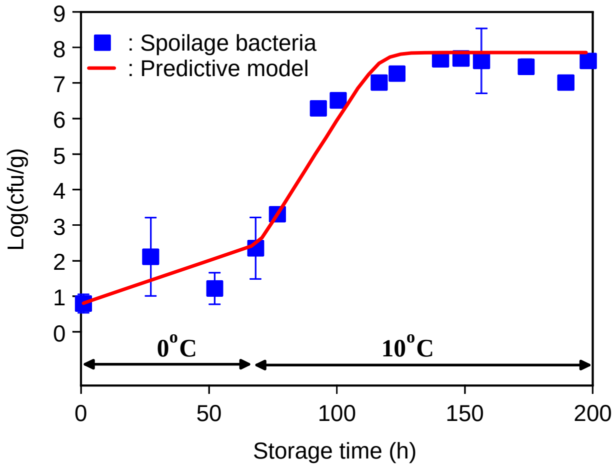


Primary model **Secondary model**

Models are included in software and can be used without detailed knowledge about equations and mathematics

Evaluation/validation of growth models

- Predictive models must be evaluated by comparison of predictions with data from microorganism/food combinations of interest
- With good agreement between observed and predicted data the model is succesfully validated



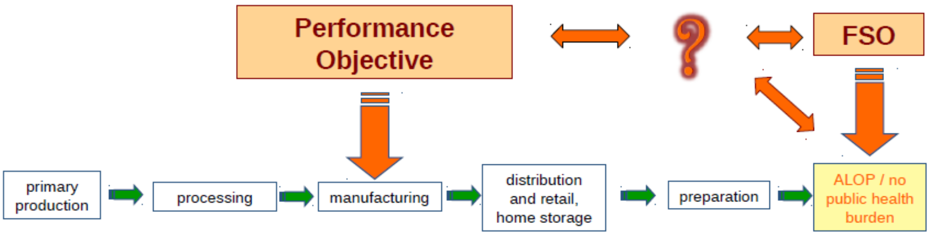
Application of successfully validated predictive microbiology models

- Predict the effect of product characteristics and storage conditions on growth, survival of inactivation of microorganisms
  - Development or reformulation of products
- HACCP plans – establish limits for CCP
- Food safety objectives – equivalence of processes
- Education – easy access to information
- Quantitative microbiological risk assessment (QMRA)

The concentration of microbial hazards in foods may increase or decrease substantially (millions of folds) during processing and distribution

McMeekin et al. (2006)

Application of <u>successfully validated</u> predictive microbiology models



$$PO \leq FSO - \Sigma I_{(distribution/consumer)} + \Sigma R_{(distribution/consumer)}$$

Ross (2013)

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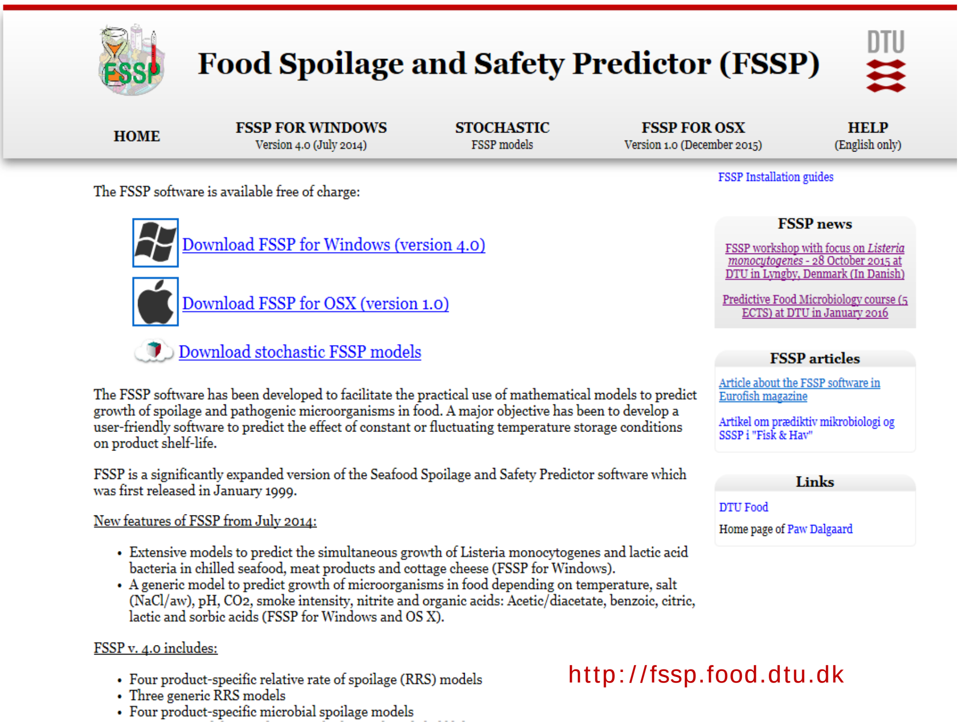
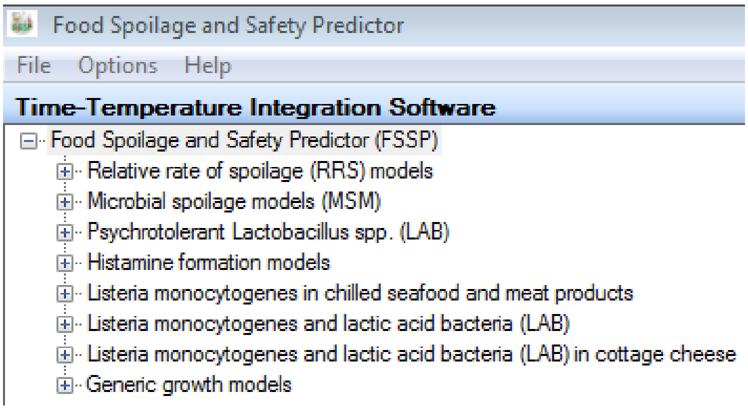


http://fssp.food.dtu.dk



- Seafood, meat and dairy products
- Generic growth model
- Improved models for microbial interaction
- Stochastic models from FSSP homepage

http://fssp.food.dtu.dk

FSSP from 2014 is a new and expanded version of the Seafood Spoilage and Safety Predictor (SSSP) from 1999

4. For what types of food have you been using the SSSP software? Create Chart Download

	Response Percent	Response Count
Fish products	76.1%	35
Meat products	37.0%	17
Vegetables	6.5%	3
Dairy products	17.4%	8
Fresh products	10.9%	5
Processed or lightly preserved products	30.4%	14
Products in modifiede atmosphere or vacuum packaging	30.4%	14

In your opinion has the SSSP software been easy to apply?

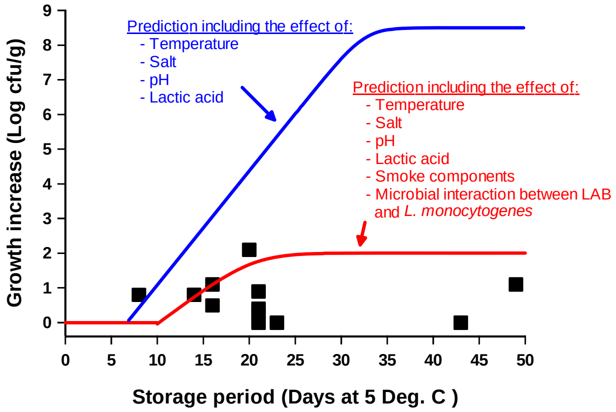
Yes	91.3%	42
No	8.7%	4
If 'No' then please expalin the type(s) of problems you have experienced Show Responses		7

Software workshops worldwide (~ 1000 participants)

Growth and growth boundary models

Complexity of food ←→ Complexity of predictive model

Example with *L. monocytogenes* in naturally contaminated vacuum packed cold-smoked salmon



Growth and growth boundary models

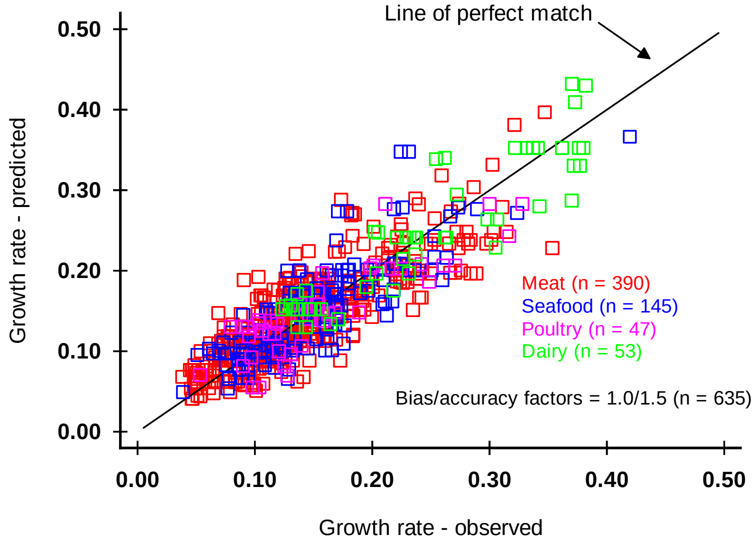
Example for *L. monocytogenes*

- Temperature
- pH
- NaCl/water activity
- Smoke components (phenol)
- Nitrite
- CO_2
- Acetic acid
- Benzoic acid
- Citric acid
- Diacetat
- Lactic acid
- Sorbic acid
- Interactions between all these factors

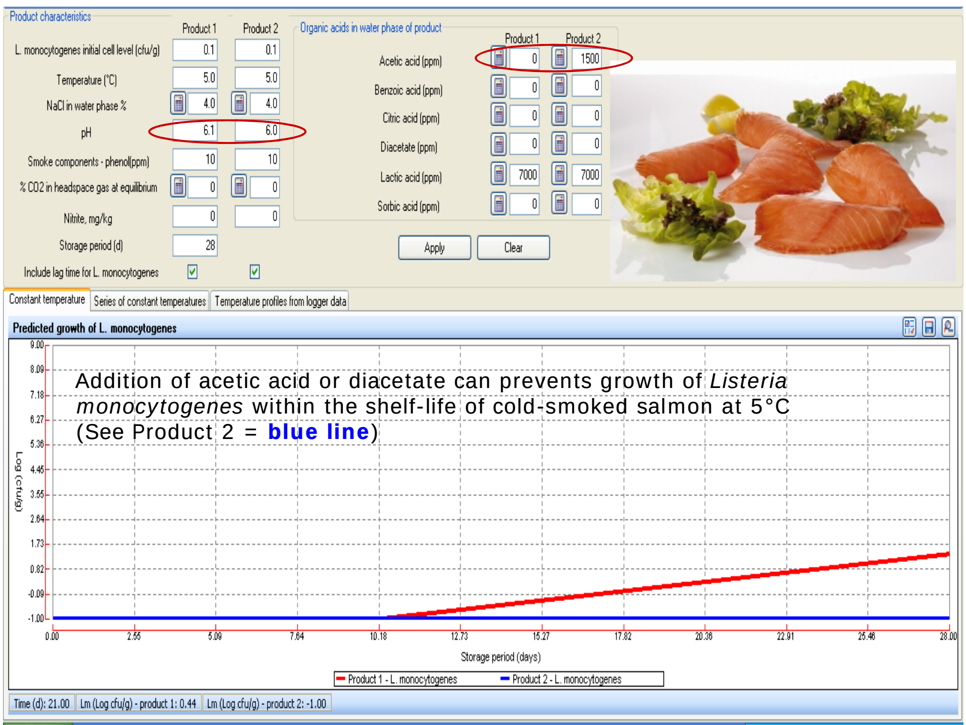
12 parameters




Evaluation of predictive model in international validation study - Growth (n=707), No-growth (n=307)

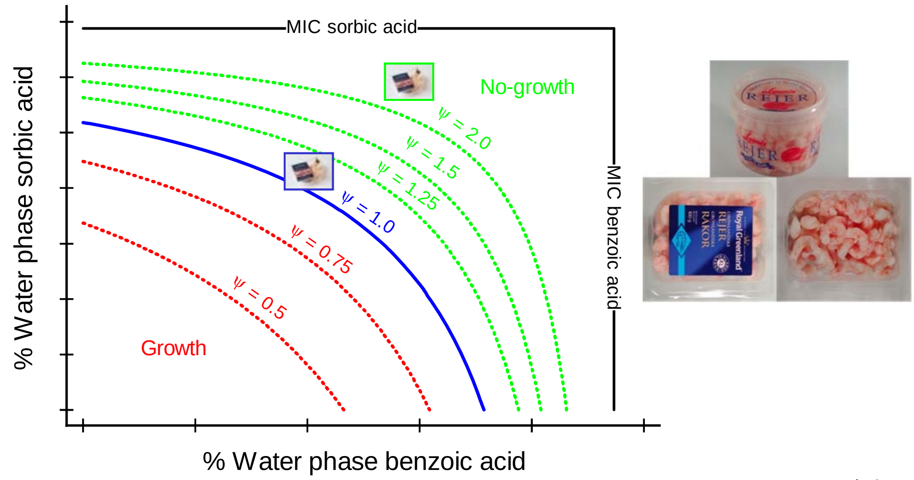


Mejlholm et al. 2010, Int. J. Food Microbiol. 141, 137-150

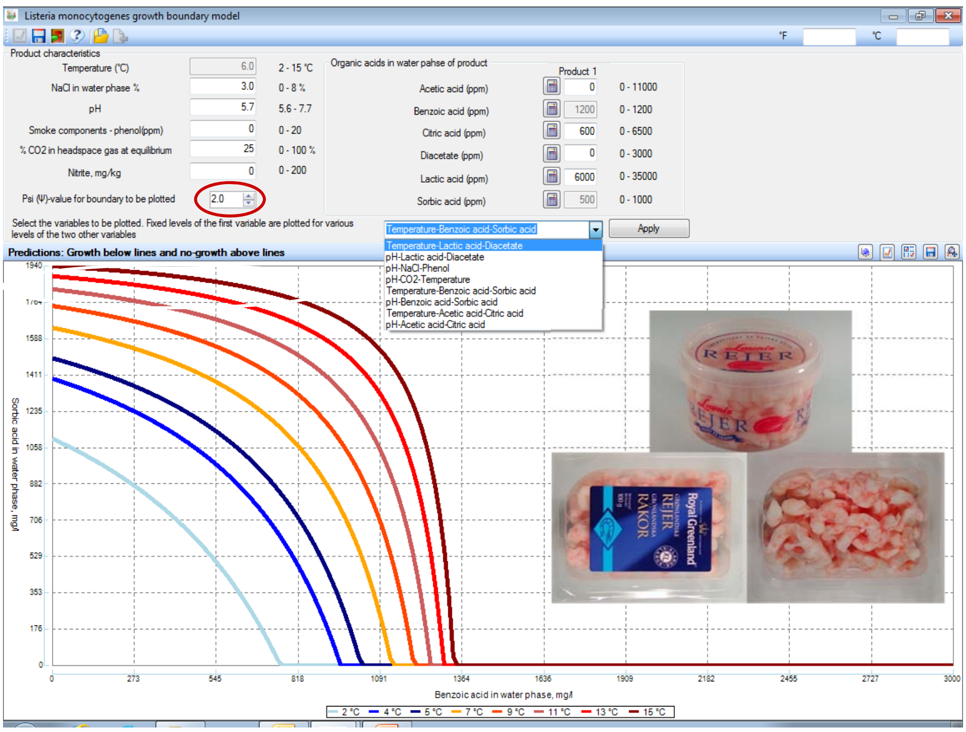


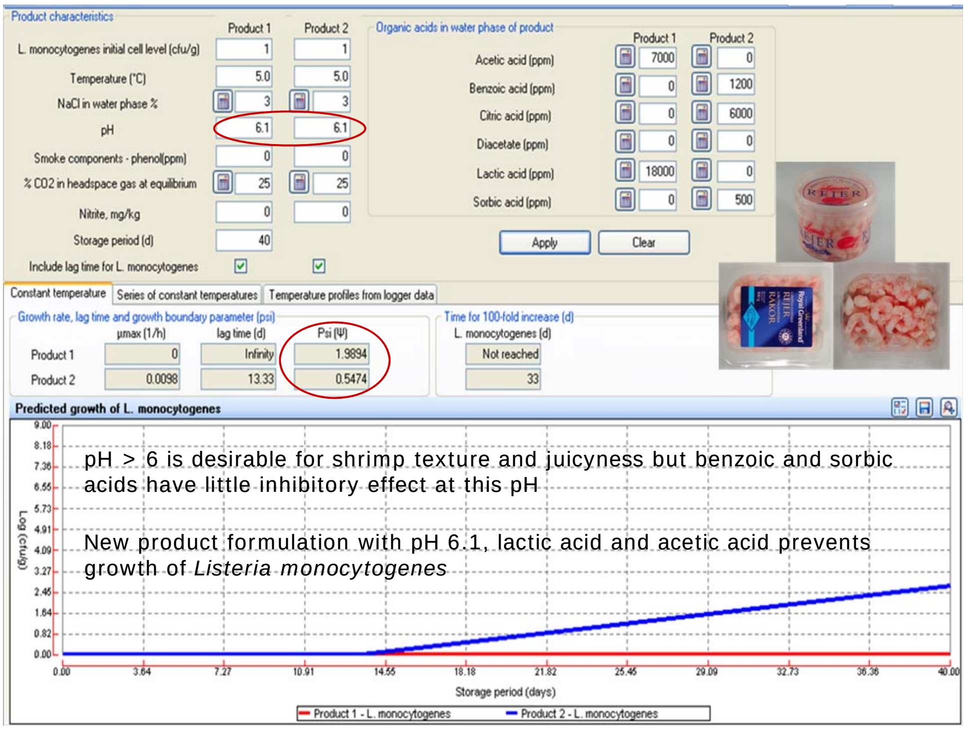
Prediction of growth boundary

Software predicts combinations of product characteristics that prevent growth of *L. monocytogenes* in an appropriate distance from the growth boundary



Mejlholm & Dalgaard (2009)

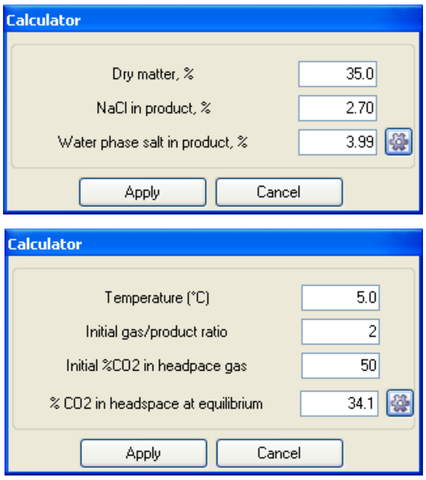


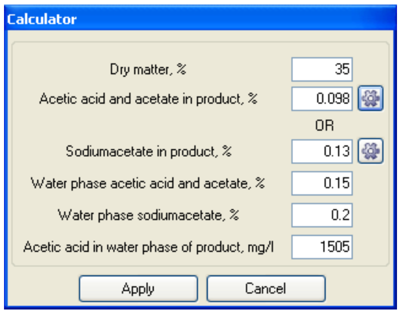


FSSP includes and extensive help-menu with information on models and facilities in the software

Model	***Listeria monocytogenes*** **and lactic acid bacteria (LAB) in lightly preserved seafood including ready-to-eat products**
References	Mejlholm, O. and Dalgaard, P. (2007b). Modeling and predicting the growth of lactic acid bacteria in lightly preserved seafood and their inhibiting effect on *Listeria monocytogenes*. *J. Food Prot.* **70** (11), 2485-2497. Mejlholm, O., Bøknæs, N., Dalgaard, P. (2014). Development and evaluation of a stochastic model for potential growth of *Listeria monocytogenes* in naturally contaminated lightly preserved seafood. *Food Microbiol.* http://dx.doi.org/10.1016/j.fm.2014.06.006 Mejlholm, O., Dalgaard, P. (2015). Modelling the simultaneous growth of *Listeria monocytogenes* and lactic acid bacteria in seafood and mayonnaise-based seafood salads. *Food Microbiol.* *http://dx.doi.org/10.1016/j.fm.2014.07.005*
Primary growth model	Logistic model with delay and including interaction between *Listeria monocytogenes* and LAB (Giménez and Dalgaard, 2004)
Secondary growth model	Simplified cardinal parameter type model
Environmental parameters in model	Temperature, atmosphere (CO2), water phase salt/aw, pH, smoke components/phenol, nitrite and organic acids in water phase of product (acetic acids, benzoic acid, citric acid, diacetate, lactic acid and sorbic acids)
Product validation studies	Cold-smoked and marinated (including 'gravad') salmon, Greenland halibut and trout (Mejlholm & Dalgaard 2007b). Brined shrimp and mayonnaise-based seafood salads (Mejlholm and Dalgaard, 2015). Importantly, this model has been shown to accurately predict the simuultaneous growth of *L. monoocytogens* and lactic acid bacteria in naturally contaminated cold-smoked salmon and naturally contaminated cold-smoked Greenland halibut (Mejlholm et al. 2014).
Range of applicability	Temperature (2-25°C), atmosphere (0-100 % CO_2), water phase salt (0.7-9.0 %), pH (5.6-7.7), smoke components/phenol (0-20 ppm), nitrite (0-150 ppm in product), acetic acid (0-11000 ppm in water phase), benzoic acid (0-1800 ppm in water phase), citric acid (0-6500 ppm in water phase), diacetate (0-3000 ppm in water phase), lactic acid (0-60000 ppm in water phase) and sorbic acid (0-1300 in water phase). For mayonnaise-based seafood salads the model included in FSSP should not be used for products with pH below 6.0 (Mejlholm and Dalgaard, 2015).

Food Spoilage and Safety Predictor (FSSP)



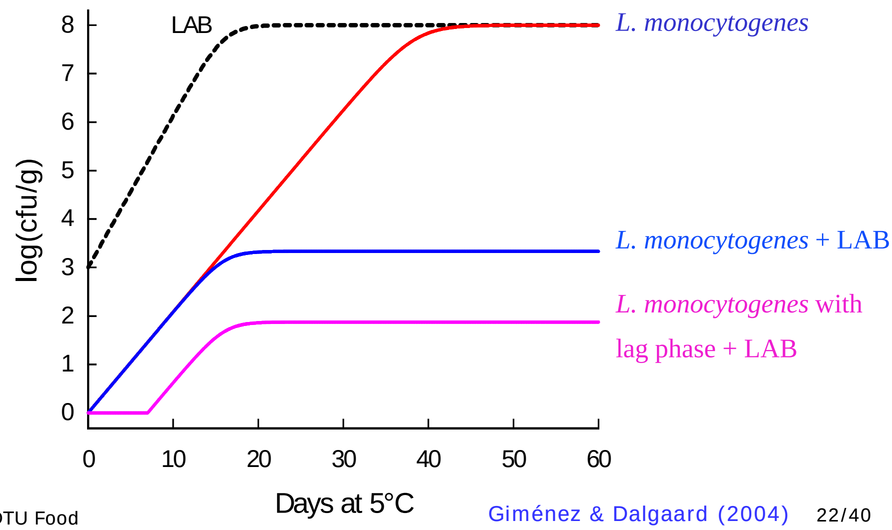


Build-in FSSP calculators facilitates determination of relevant water-phase concentrations of NaCl, CO_2 and organic acids

http://fssp.food.dtu.dk

Primary models for microbial interaction

Models are available to predict the inhibiting effect of high concentrations of lactic acid bacteria (LAB) on growth of *Listeria monocytogenes*



Giménez & Dalgaard (2004)

L. monocytogenes - evaluation of growth model

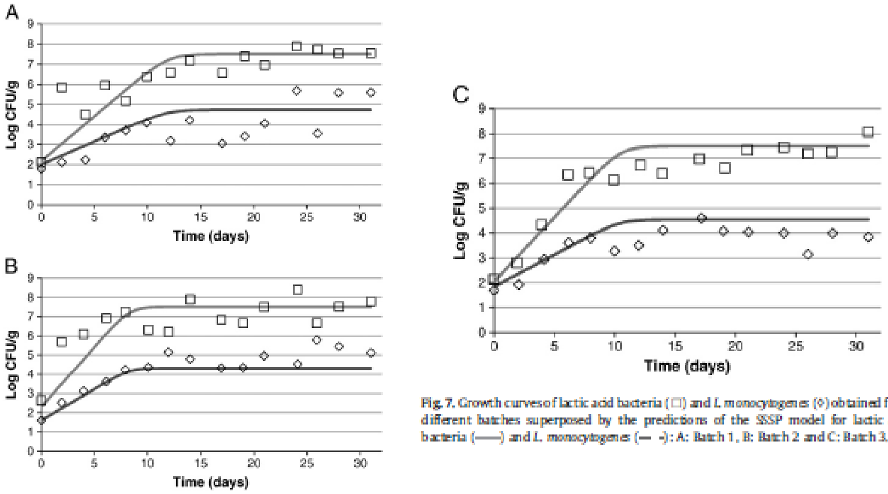
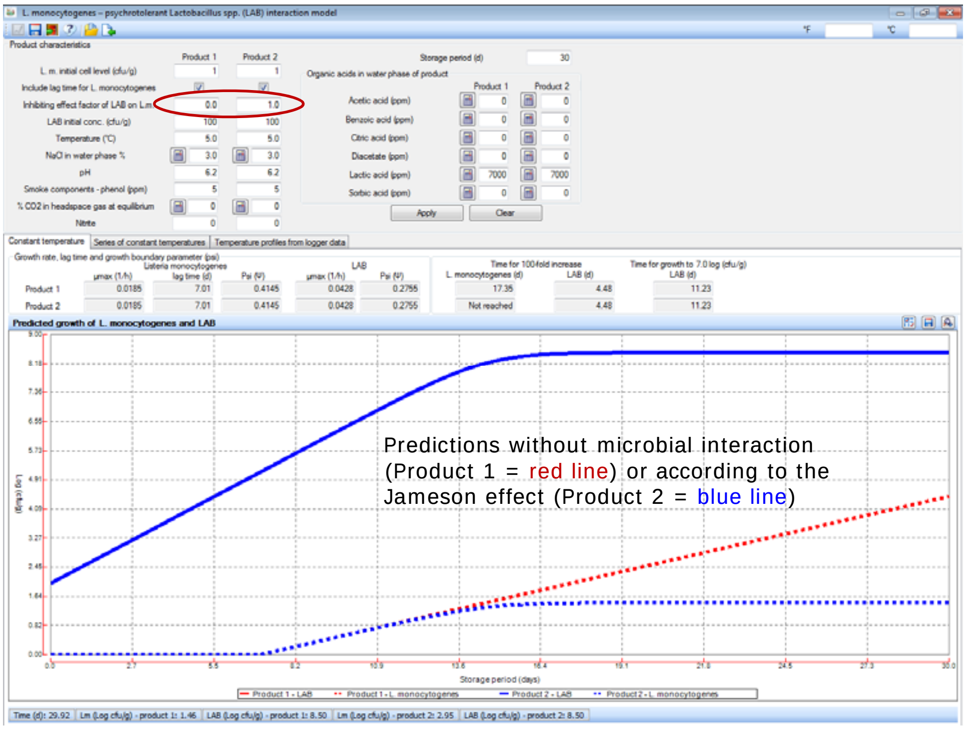


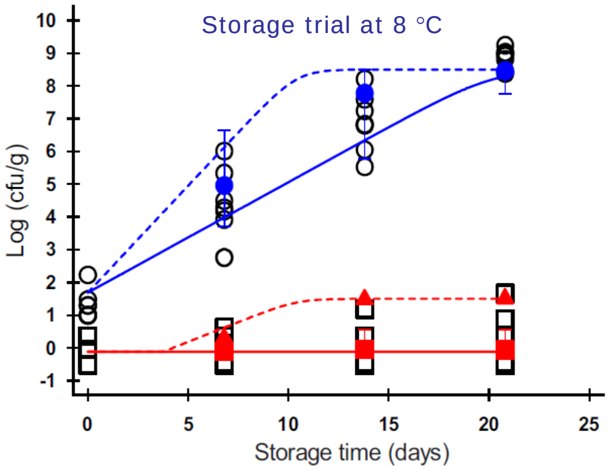
Fig. 7. Growth curves of lactic acid bacteria (□) and *L. monocytogenes* (◇) obtained from different batches superposed by the predictions of the SSSP model for lactic acid bacteria (——) and *L. monocytogenes* (— -): A: Batch 1, B: Batch 2 and C: Batch 3.

Challenge tests are not needed for cold-smoked salmon as the FSSP-software and the Mejlholm & Dalgaard model provided the same results



Durability study and evaluation of stochastic lactic acid bacteria - *L. monocytogenes* interaction model

Naturally contaminated cold-smoked Greenland halibut with added acetic and lactic acids



○ Lactic acid bacteria; □ *Listeria monocytogenes*

Deterministic model

Dashed lines: least preserved sample

Solid lines: Most preserved sample

Stochastic model

● Average prediction with 99% confidence interval (LAB)

■ Average prediction with 99% confidence interval (Lm)

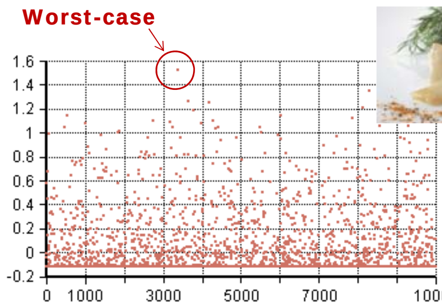
▲ Predicted maximum population density (Lm)

Mejlholm et al. (2015)

Effect of variability in product characteristics

- Cold-smoked Greenland halibut added acetic and lactic acids

Concentration of *L. monocytogenes* in cold-smoked Greenland halibut following 28 days at 5 °C

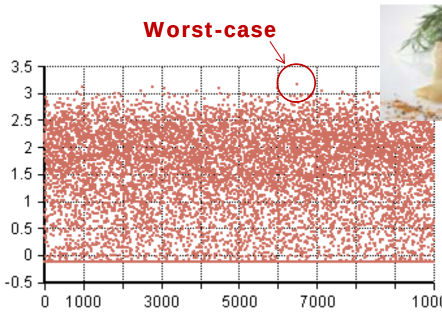


- Predicted maximum cell concentration of *L. monocytogenes*: 1.5 log (cfu/g)
  - In compliance with the EU-regulation
  - 99.9% of the repetitions were lower than 1.1 log (cfu/g)

Effect of variability in product characteristics

- Cold-smoked Greenland halibut without added acetic and lactic acids

Concentration of *L. monocytogenes* in cold-smoked Greenland halibut following 28 days at 5 °C



- Predicted maximum cell concentration of *L. monocytogenes*: 3.2 log (cfu/g)
  - Not in compliance with the EU-regulation
  - 31% of the repetitions were higher than 2.0 log (cfu/g)

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Listeria monocytogenes - microbiological criteria

EU regulation (EC 2073/2005 and EC 1441/2007)

Ready-to-eat foods	Critical limits	Comments
Intended for infants or special medical purposes (Cat. 1.1)	Absence in 10 x 25 g	- Product placed on the market during their shelf-life
Support growth (Cat. 1.2)	100 cfu/g	- It must be documented that 100 cfu/g is not exceeded within the storage period
	Absence in 5 x 25 g	- When produced
Unable to support growth (Cat. 1.3)*	100 cfu/g	- Documentation - pH ≤ 4,4 or a_w ≤ 0,92 - pH ≤ 5,0 and a_w ≤ 0,94 - Shelf-life below 5 days

[*] Growth should not exceed 0.5 log (cfu/g) ~ 3 cfu/g during the shelf-life

EU regulation (EC 2073/2005 – Annex II):

Documentation shall include specifications for:

- Physico-chemical product characteristics
- Storage and processing conditions
- Contamination and foreseen shelf-life

When necessary additional studies may include:

- Predictive mathematical modelling for food in question
- Tests to investigate the ability to grow or survive

Studies shall take into account variability for products, microorganisms, processing and storage conditions

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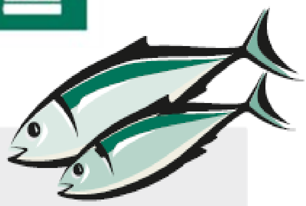
- Predictive food microbiology models
- Challenge testing - inoculated
- Durability studies – naturally contaminated

Listeria monocytogenes

Sådan vurderer du, om L. monocytogenes kan vokse i spiseklare og letkonserverede fiskeprodukter – brug edb-modeller



I praksis

- → Tag 1 filet fra 5 forskellige produktionsdage.
- → 5 cm fra forreste ende af hver filet udtages 100 g fiskekød, som blendes.
- → Brug det blendede fiskekød til at bestemme produktets egenskaber (pH, NaCl i vandfasen, røgkomponenter målt som phenol, tørstof og organiske syrer).
- → Brug Seafood Spoilage and Safety Predictor (SSSP) programmet til at bestemme vækst af L. monocytogenes ud fra produktegenskaberne for hver af de 5 datasæt.
- → Find det datasæt med mest vækst. Dette datasæt afgør, om produktet placeres i kategori 1.3 eller 1.2 i Mikrobiologiforordningen.
- → Punkterne bør gentages mindst én gang om året og ved hver ændring i fremstillingsprocessen.

http://www.foedevarestyrelsen.dk/SiteCollectionDocuments/25_PDF_word_filer%20til%20download/04kontor/Mikro%20zoonose/Listeria/Listeria%20fisk%20end.pdf

Documentation of control for growth of *Listeria monocytogenes* in RTE seafood

- Use of FSSP software has been adapted by the Danish Veterinary and Food Administration
- Detailed characteristics are determined for samples from five independent production batches: pH, NaCl, dry matter, food preservatives (including naturally occurring lactate) and smoke components as relevant
- Predictions at relevant temperatures for each samples using the Mejlholm & Dalgaard (2009) model with lag phase for *L. monocytogenes*

http://www.foedevarestyrelsen.dk/SiteCollectionDocuments/25_PDF_word_filer%20til%20download/04kontor/Mikro%20zoonose/Listeria/Listeria%20fisk%20end.pdf

Documentation of control for growth of *Listeria monocytogenes* in RTE seafood

	Product characteristics Values for five different fillets and average ± standard deviation					
Batch	**I**	**II**	**III**	**IV**	**V**	**Average ± Standard deviation**
Salt in water phase of the product, %	4.7	3.4	4.2	4.7	4.0	4.19 ± 0.55
pH	6.16	6.22	6.17	6.16	6.22	6.19 ± 0.03
Acetic acid in water phase of the product, mg/L	2772	3617	2801	3359	3117	3133 ± 402
Lactic acid in water phase of the product, mg/L	7704	7349	7581	7430	6425	7298 ± 506
Phenol (Smoke intensity), mg/kg	11.8	11.5	10.4	10.8	8.8	10.7 ± 1.2
Predicted growth responses at 5°C:						
Lag time (days)	>90	>90	>90	>90	>50	>90
Growth rate (1/h)	<0.001	<0.001	<0.001	<0.001	<0.0025	<0.001
Increase during 28 days, cfu/g	**0**	**0**	**0**	**0**	**0**	**0**

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European Food Safety Authority

EFSA Journal 2015;13(7):4162

SCIENTIFIC REPORT OF EFSA

Scientific and technical assistance on the evaluation of the temperature to be applied to pre-packed fishery products at retail level[1]

European Food Safety Authority[2,3]

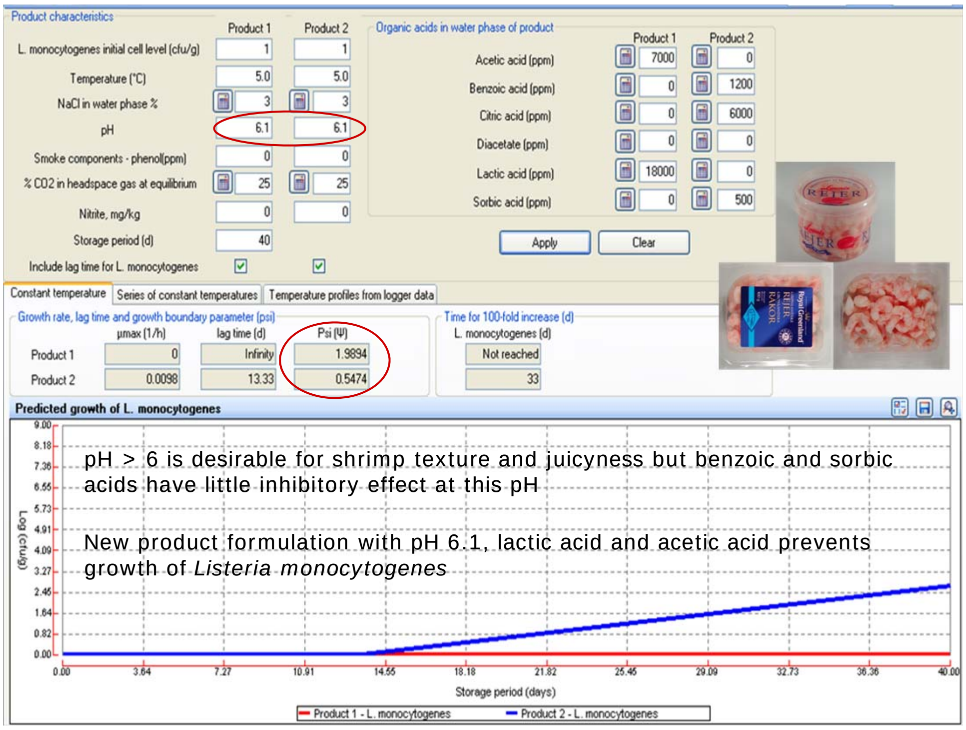
European Food Safety Authority (EFSA), Parma, Italy

- Pre-packed fresh fishery products can be stored at refrigeration temperatures above 0 °C (e.g. 3–5 °C) and be compliant with the current EU and international rules.
- Examples of combinations of product durability (maximum shelf-life) and packaging atmosphere that should enable compliance with the safety criteria for various storage temperatures at retail are provided.

Numerous dataloggers are available to record the temperature of food during storage and distribution

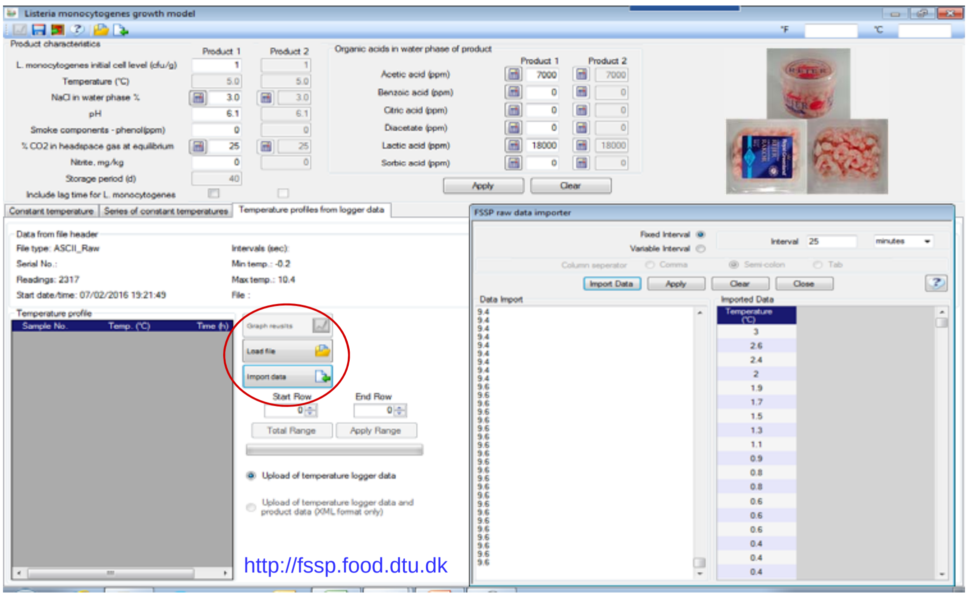
DTU

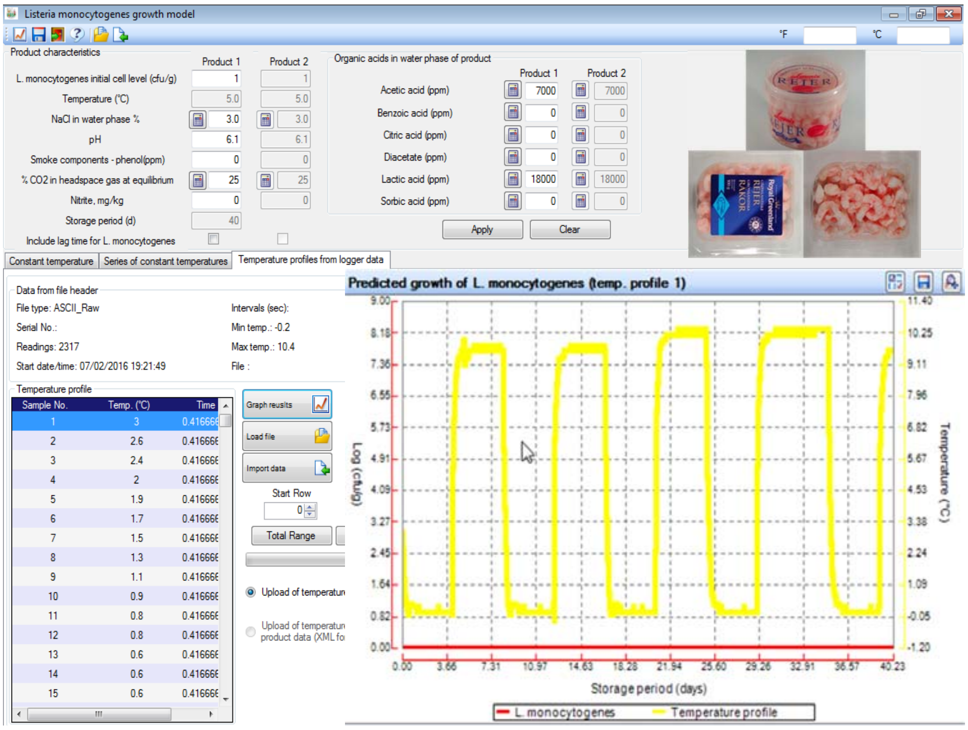
- A challenge for handling of temperature data



Time-temperature integration

To facilitate evaluation of product temperature profiles FSSP includes a module to import data (copy/paste) from spreadsheets





Food Spoilage and Safety Predictor (FSSP) software – background and applications

Conclusions and perspectives

- Complex predictive food microbiology models are often needed for assessment and documentation of food safety
- FSSP facilitate the practical application of validated predictive microbiology models with relevant complexity
- New research and further training is needed to help industry and authorities benefit from predictive microbiology models
- Increased collaboration between industry, authorities and academia is needed to accelerate progress