

HoA workshop: Tools supporting food chain safety assessments, BfR, 8-9 February 2016



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

Paw Dalgaard

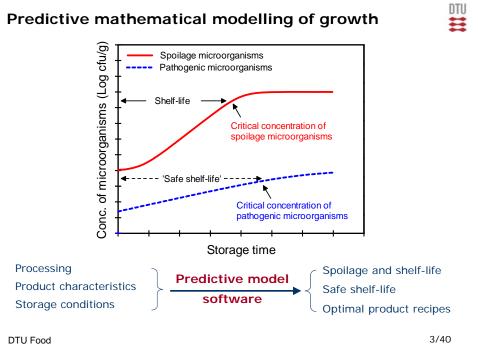
Professor in Predictive Food Microbiology Division of Microbiology and Production Technical University of Denmark (DTU) <u>pada@food.dtu.dk</u> <u>www.staff.dtu.dk/pada</u>

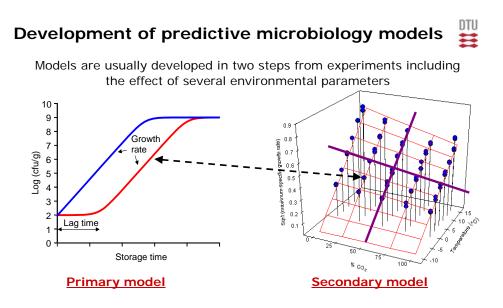
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Food Spoilage and Safety Predictor (FSSP) software – background and applications

- 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

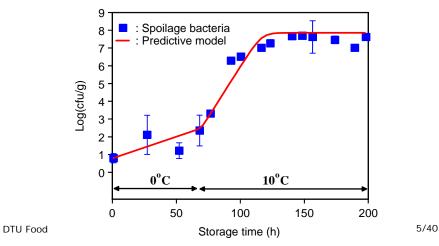




Models are included in software and can be used without detailed knowledge about equations and mathematics

Evaluation/validation of growth models

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

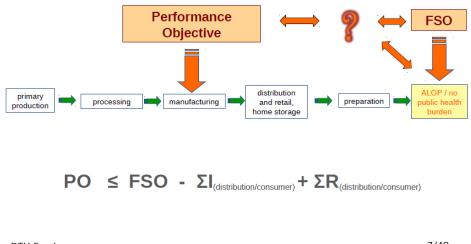


Application of <u>successfully validated</u> predictive microbiology models

- 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



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Ross (2013)

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Food Spoilage and Safety Predictor	DTU
File Options Help	=
Time-Temperature Integration Software	
 Food Spoilage and Safety Predictor (FSSP) Relative rate of spoilage (RRS) models Microbial spoilage models (MSM) Psychrotolerant Lactobacillus spp. (LAB) Histamine formation models Listeria monocytogenes in chilled seafood and meat products Listeria monocytogenes and lactic acid bacteria (LAB) Listeria monocytogenes and lactic acid bacteria (LAB) Generic growth models 	
 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	Response				
	Percent	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						





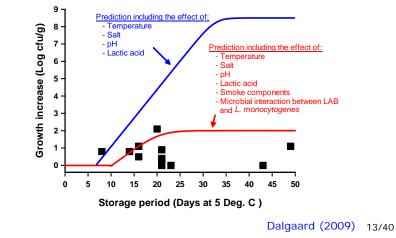
pada@food.dtu.dk - http://fssp.food.dtu.dk

Growth and growth boundary models



Complexity of food $\leftarrow \rightarrow$ Complexity of predictive model

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



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Growth and growth boundary models

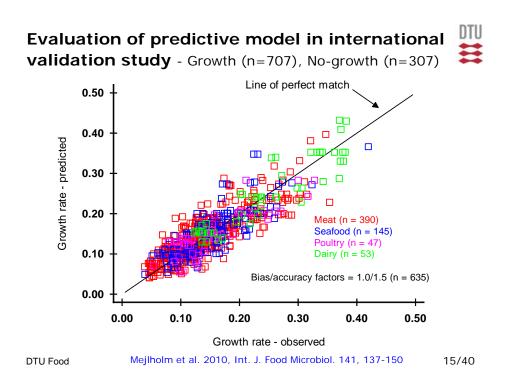


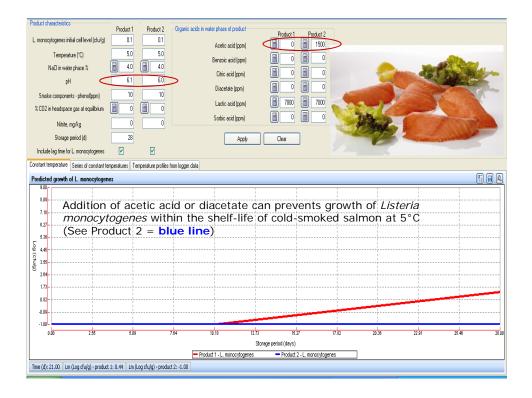
Example for *L. monocytogenes*

- Temperature
- pH
- NaCl/water activity
- Smoke components (phenol)
- Nitrite
- CO₂
- Acetic acid
- Benzoic acid
- Citric acid
- Diacetat
- Lactic acid
- Sorbic acid
- Interactions between all these factors

Mejlholm & Dalgaard 2009, J. Food Prot. 72 (10), 2123-2143

12 parameters

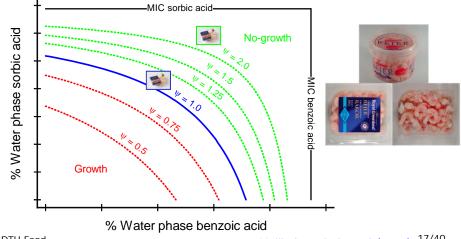






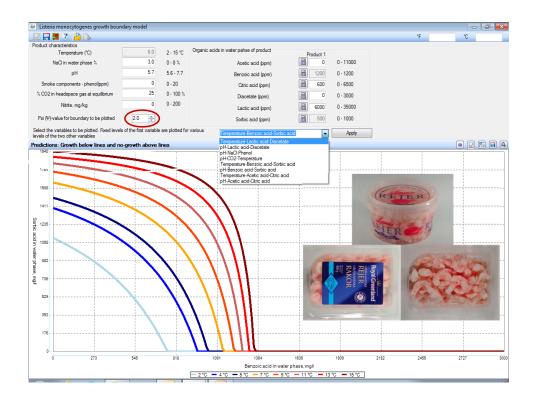


Software predicts combinations of product characteristics that prevent growth of L. monocytogenes in an appropriate distance from the growth boundary

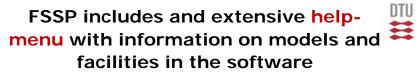


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Mejlholm & Dalgaard (2009) 17/40



Product 1 Product 2 L monocytogenes initial cell level (cfu/g) 1 Temperature ('C) 50 NaCl in water phase % 3 pH 6.1 Sincke components - pheno(ppm) 0 % CD2 in headspace gas at equilibrium 25 Nitrite, mg/kg 0 Nitrite, mg/kg 0 Storage period (d) 40 Apply Clear Constant temperature Temperature profiles from logger data Growth rate, lag time and growth boundary parameter (pri) Pril(V) Product 1 0 Product 2 0.0038 13.33 0.5474					
L monocytogenes initial cell level (cluv) Temperature (°C) NaCin water phase % pH Smoke components - phenolipm) % C02 in headspace gas at equilibrium D to 25 (0) 20 (0) 0 % C02 in headspace gas at equilibrium D to 25 (0) 0 % C02 in headspace gas at equilibrium D to 25 (0) 0 % C02 in headspace gas at equilibrium D to 25 (0) 0 % C02 in headspace gas at equilibrium D to 25 (0) 0 % C02 in headspace gas at equilibrium D to 25 (0) 0 % C02 in headspace gas at equilibrium D to 25 (0) 0 % C02 in headspace gas at equilibrium D to 25 (0) 0 % C02 in headspace gas at equilibrium D to 25 (0) 0 % C02 in headspace gas at equilibrium D to 25 (0) 0 % C02 in headspace gas at equilibrium D to 25 (0) 0 % C02 in headspace gas at equilibrium D to 25 (0) 0 % C02 in headspace gas at equilibrium D to 25 (0) 0 % C02 in headspace gas at equilibrium Sorbic exist (ppm) D to 25 (0) 0 % Constant temperature protect at constant temperature profiles from logger data Growth ete. lag from ad growth boundary parameter (poil protect 2 00098 12:33 (0) 5574 Product 1 0 PH > 16, is, dessirable, for shrimp, texture, and julicyness but benzoic and sorbic. acids have little inhibitory effect at this pH New, product formulation with pH 6, 1, lactic acid, and acetic acid, prevents growth of <i>L isteria monocytogenes</i> growth of <i>L Listeria monocytogenes</i>	Product characteristics	Product 1 Product 2	Organic acids in water phase of product	0.1.11 0.1.10	
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Constant temperatures Growth rate, lag time and growth boundary parameter (pri)	Storage period (d)	40	Apply	Clear	JEROS
Growth rate, lag time and growth boundary parameter (pri) product 1 Product 1 0 Infinity 1.3334 Infinity	Include lag time for L. monocytogenes	✓✓			and the second s
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Predicted growth of L monocytogenes 900 pH > 6 is desirable for shrimp texture and juicyness but benzoic and sorbic 900 acids have little inhibitory effect at this pH 900 441 New product formulation with pH 6.1, lactic acid and acetic acid prevents 910 920 920 920 920 920 920 920 920 920 920 920 920 920	Product 1 0	Infinity 1.989	4 Not reached		
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 acids have little inhibitory effect at this pH Acids have little inhibitory effect at this pH New product formulation with pH 6.1, lactic acid and acetic acid prevents growth of <i>Listeria monocytogenes</i> acids acid and acetic acid prevents 	pH > 6 is d	esirable for shr	imp texture and juicy	ness but benzoid	and sorbic
New product formulation with pH 6.1, lactic acid and acetic acid prevents					
New product formulation with pH 6.1, lactic acid and acetic acid prevents regrowth of <i>Listeria monocytogenes</i>		netro minisitory	encer at this pri	1	
3.1 Grower or Elsteria monocytogenes 246	§ 4.91				
3.1 Grower or Elsteria monocytogenes 246	Page New produc	:t formulation \	with pH 6.1, lactic aci	d and acetic acid	prevents
	[®] 3.27 growth of L	isteria monocy	togenes		
0.02	2.45				
0.00					
0.00 0.07 1.21 10.01 17.00 10.10 21.02 20.00 32.13 30.30		7 27 10 01	14.55 19.19 21.92	25.45 20.00	32,73 36,36 40,0
Storage period (days)	0.00 0.04	10.01		20.00	52.15 50.50 4 0.0
Product 1 - L. monocytogenes Product 2 - L. monocytogenes		Product 1		nonocytogenes	



SSP

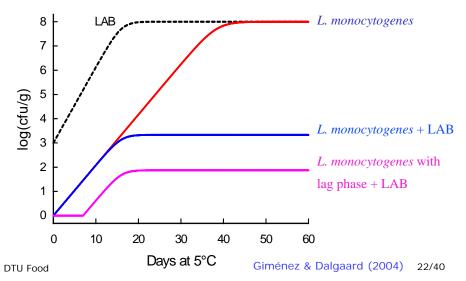
Model	Listeria monocytogenes and lactic acid bacteria (LAB) in lightly preserved seafood including ready- to-eat products				
References	Mejlholm, O. and Dalgaard, P. (2007b). Modeling and predicting the growth of lactic acid bacteria in lightly preserved seafood and their inhibiting effect on <i>Listeria monocytogenes J. Food Prot.</i> 70 (11), 2485-2497.				
	Mejlholm, O., Bøknæs, N., Dalgaard, P. (2014). Development and evaluation of a stochastic model for potential growth of <i>Listeria monocytogenes</i> in naturally contaminated lightly preserved seafood. <i>Food</i> <i>Microbiol.</i> , <u>http://dx.doi.org/10.1016/j.fm.2014.06.006</u>				
	Mejlholm, O., Dalgaard, P. (2015). Modelling the simultaneous growth of <i>Listeria monocytogenes</i> and lactic acid bacteria in seafood and mayonnaise-based seafood salads. <i>Food Microbiol.</i> http://dx.doi.org/10.1016/j.fm.2014.07.005				
Primary growth model	Logistic model with delay and including interaction between <i>Listeria monocytogenes</i> 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 simultaneous growth of <i>L.</i> <i>monoocytogens</i> 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), citic 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 pF below 6.0 (Mejlholm and Dalgaard, 2015).				

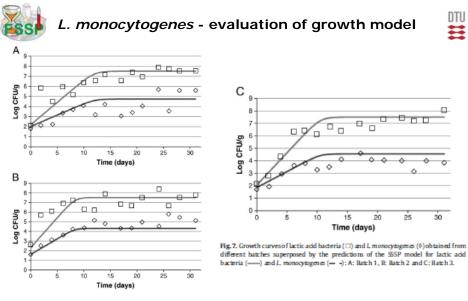
Food Spoilage and S	Safety Predictor (FSSP)
Calculator	Calculator
Dry matter, % 35.0 NaCl in product, % 2.70 Water phase salt in product, % 3.99 @	Dry matter, % 35 Acetic acid and acetate in product, % 0.098 () OR Sodiumacetate in product, % 0.13 () Water phase acetic acid and acetate, % 0.15 Water phase sodiumacetate, % 0.2
Calculator	Acetic acid in water phase of product, mg/l 1505
Temperature (°C) 5.0 Initial gas/product ratio 2 Initial %CO2 in headpace gas 50 % CO2 in headspace at equilibrium 34.1 Apply Cancel	Build-in FSSP calculators facilitates determination of relevant water- phase concentrations of NaCl, CO ₂ and organic acids

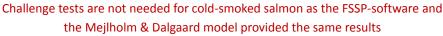


Primary models for microbial interaction

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

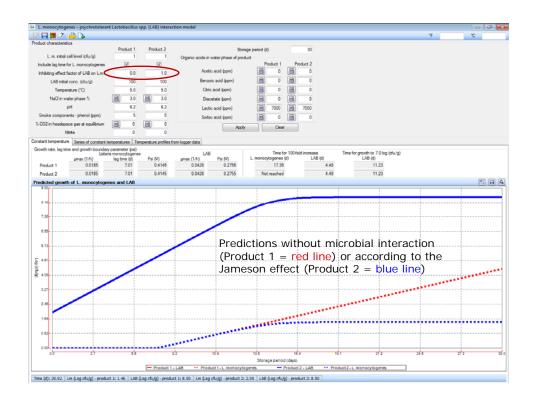




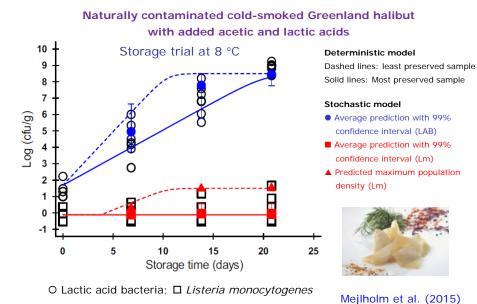


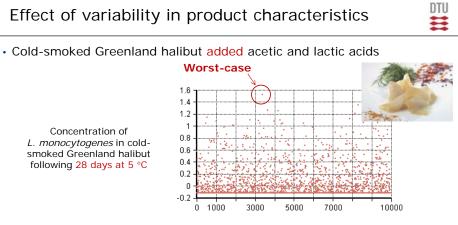
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Vermeulen et al. 2011 23/40



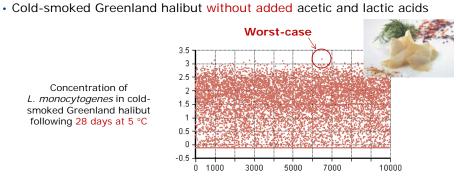
Durability study and evaluation of stochastic lactic acid bacteria - *L. monocytogenes* interaction model





- 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)

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- 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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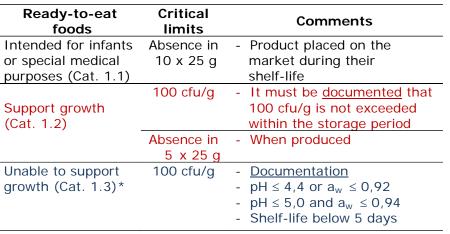
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Listeria monocytogenes - microbiological criteria



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

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

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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

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

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Listeria monocytogenes

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

I praksis

- \rightarrow Tag 1 filet fra 5 forskellige produktionsdage.
- ightarrow 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.
- $\rightarrow\,$ Find det datasæt med mest vækst. Dette datasæt afgør, om produktet placeres i kategori 1.3 eller 1.2 i Mikrobiologiforordningen.
- ightarrow Punkterne bør gentages mindst én gang om året og ved hver ændring i fremstillingsprocessen.

http://www.foedevarestyrelsen.dk/SiteCollectionDocuments/25_PDF_word_filer%20til%20d ownload/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%20d DTU Food ownload/04kontor/Mikro%20zoonose/Listeria/Listeria%20fisk%20end.pdf 32/40



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

Batch	Product characteristics Values for five different fillets and average ± standard deviation					
	I	Ш	ш	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
pН	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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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 level¹

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.

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

A challenge for handling of temperature data



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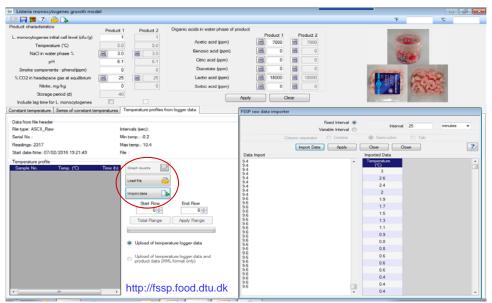
Product characteristics	Product 1 Product 2	Organic acids in water phase of product		
L. monocytogenes initial cell level (cfu/g)	1 1	Acetic acid (ppm)	Product 1 Product 2	
Temperature (*C)	5.0 5.0	Benzoic acid (ppm)	0 1200	
NaCl in water phase %		Citric acid (ppm)		
pH	6.1 6.1	Diacetate (ppm)		
Smoke components - phenol(ppm)	0 0			
% CO2 in headspace gas at equilibrium	25 🖬 25	Lactic acid (ppm)		RETER
Nitrite, mg/kg	0 0	Sorbic acid (ppm)		A LINE W
Storage period (d)	40	Apply	Clear	ELER C
Include lag time for L. monocytogenes			100	
Constant temperature Series of constant te	emperatures Temperature profile:	s from logger data	I I I I I I I I I I I I I I I I I I I	I A A A A A A A A A A A A A A A A A A A
Growth rate, lag time and growth boundary		Time for 100-fold increase (d)		
Product 1 0	lag time (d) Psi(Ψ)	L. monocytogenes (d) 94 Not reached		1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Product 2 0.0098	13.33 0.54		N	
Predicted growth of L. monocytoger				17 🗐 🔒
9.00	10.0		1 1	
8.18 nH > 6 is d	logirable for sh	rimp texture and juic	vness but benzoic	and sorbic
		effect at this pH	yriess but benzoic	
5.73	intrie initiationy	eneccar mis pri		
8 401				
Rew produc		with pH 6.1, lactic ac	id and acetic acid	prevents
327GI-OW-(I-F-OF-2	isteria monocy	ytogenes		
2.45		·····		1
0.82-				
0.00				
0.00 3.64	7.27 10.91	14.55 18.18 21.82 Storage period (days)	25.45 29.09	32.73 36.36 40.00
	- Product 1		monocytogenes	

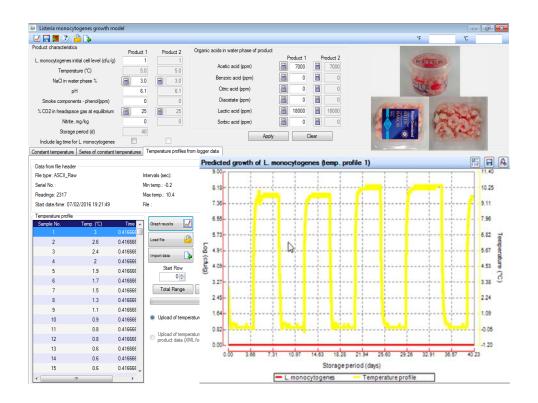


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To facilitate evaluation of product temperature profiles FSSP includes a module to import data (copy/paste) from spreadsheets







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

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