Seafood Spoilage and Safety Predictor (SSSP) – Version 3 from 2008

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Seafood Spoilage and Safety Predictor (SSSP)

Outline:

- Key features of SSSP v. 2 from 2005
  - Flexible time-temperature integration tool for spoilage and shelf-life evaluation
- Histamine formation in seafood
  - *Morganella psychrotolerans* (0 - 20°C)
  - *M. psychrotolerans and M. morganii* (0 - 44°C)
- *Listeria monocytogenes* and lactic acid bacteria
  - New growth and growth boundary models
- Conclusions and perspectives

Key features of SSSP – relative rates of spoilage (RRS)

Time-Temperature Integration Software

- Seafood Spoilage and Safety Predictor (SSSP)
  - Relative rate of spoilage (RRS) models
    - Fresh seafood from temperate waters
      - Square-root spoilage model
    - Fresh seafood from tropical waters
      - Exponential model for spoilage of fresh tropical seafood
    - Cold-smoked salmon
      - Sliced and vaccum-packed cold-smoked salmon
    - Cooked and brined shrimps
      - Cooked and brined MAP shrimps
    - RRS models with user-defined temperature characteristics
      - RRS models
    - Comparison of observed and predicted RRS data
      - Calculation of values for accuracy factors

Http://www.difres.dk/micro/sssp/

Key features of SSSP – relative rates of spoilage (RRS)

Shelf-life can be predicted at different temperatures when:

1. Shelf-life at a constant temperature is known
2. RRS at different temperatures can be predicted

$$\text{Shelf-life}\,(T\,°C) = \frac{\text{Shelf-life at } T_{ref}\,(°C)}{\text{RRS at } T\,(°C)}$$

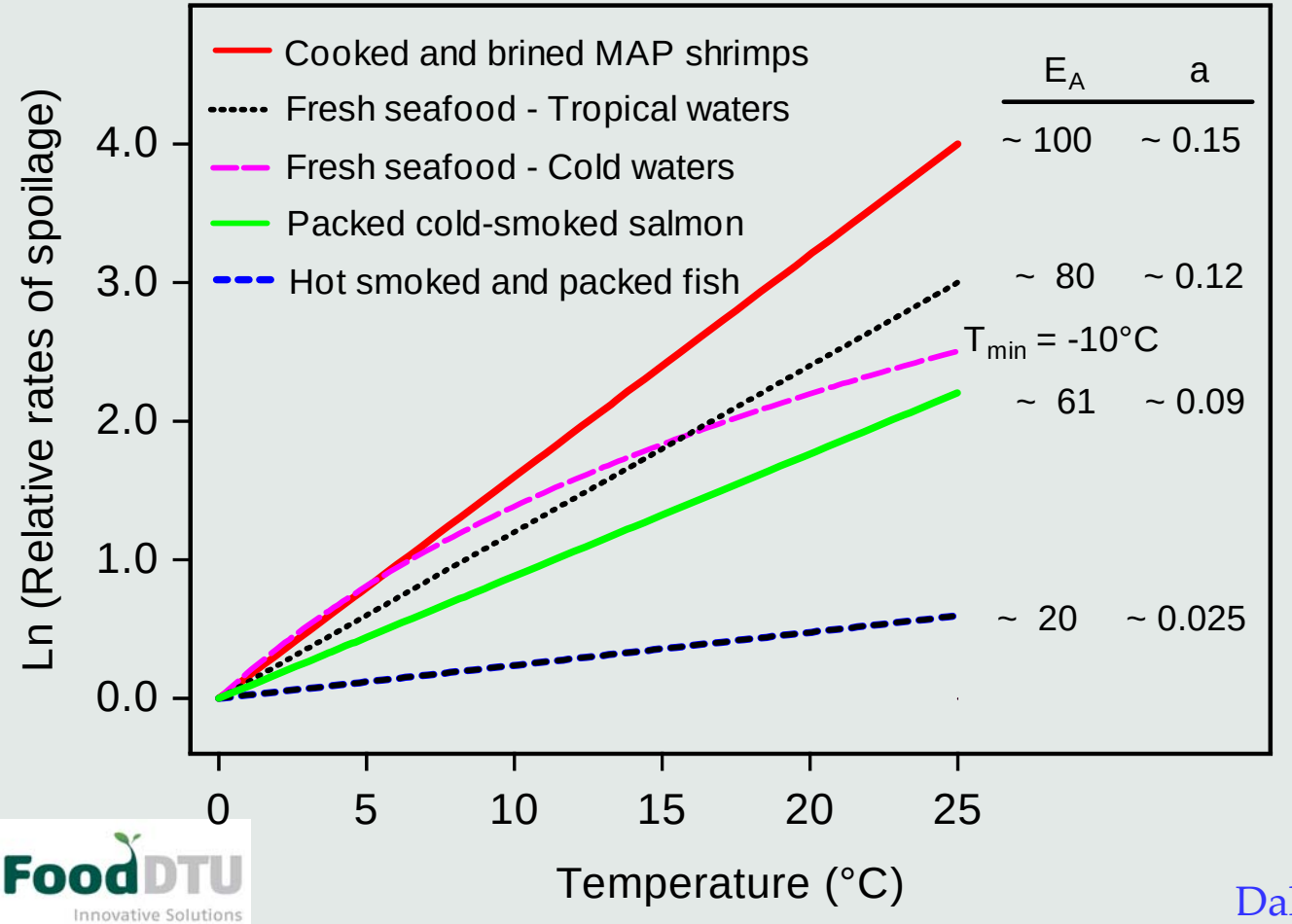
RRS-models can be used:

- Although spoilage microorganisms are not known
- Over wide ranges of storage temperatures

Spencer og Baines (1964), Olley og Ratkowsky (1973)

Key features of SSSP – relative rates of spoilage (RRS)

RRS: Shelf-life at T_{ref} (°C) divided by shelf-life at T°C



- Exponential model
- Square-root model
- Arrhenius model

Dalgaard (2000)

Key features of SSSP – microbial spoilage models

Time-Temperature Integration Software

- Seafood Spoilage and Safety Predictor (SSSP)
  - Relative rate of spoilage (RRS) models
  - Microbial spoilage models (MSM)
    - Photobacterium phosphoreum
      - Fresh MAP cod fillets
      - Fresh MAP plaice fillets
      - Fresh MAP salmon steaks
    - Shewanella putrefaciens
    - MS models with user-defined parameter values
    - Comparison of observed and predicted data
  - Listeria monocytogenes

Http://www.difres.dk/micro/sssp/

Key features of SSSP – microbial spoilage models

Product characteristics

Initial cell density (cfu/g) :	10	Shelf-life (days) :	8.3
Temperature (°C) :	1.8	Growth rate (µmax, 1/h):	0.093
Percentage CO2 :	28	Apply	

Shelf-life prediction for:

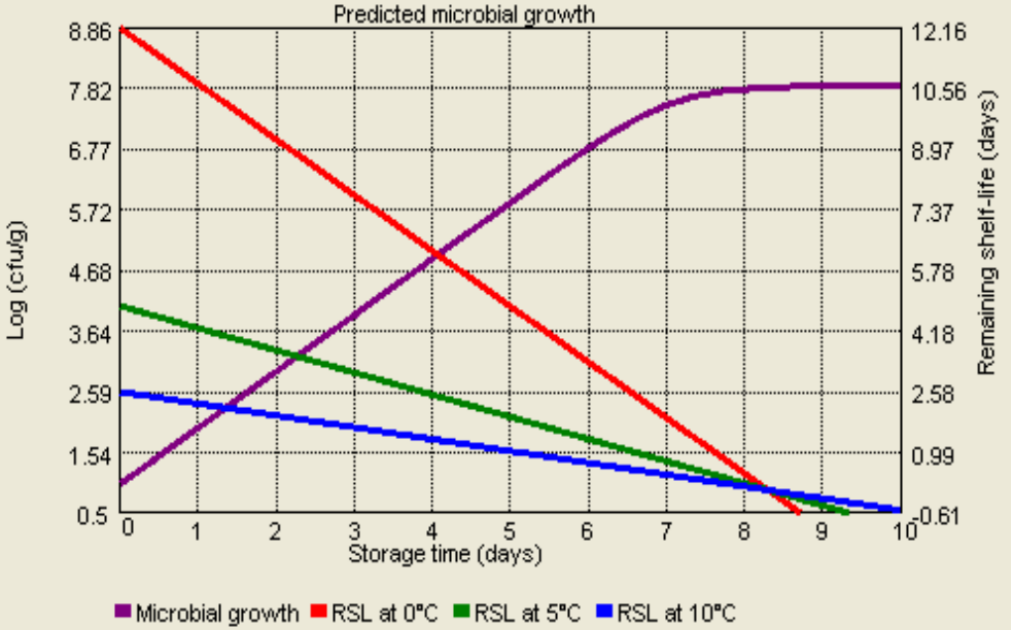
Series of constant temperatures | Temperature profiles from logger data | Calculation of % CO2 i

Remaining shelf-life (hours)

Temperature (°C) 1.8 Storage time (hours) 240

Prediction of remaining shelf-life for a series of constant storage temperatu

Temp. (°C)	Time (h)	0 °C (h)	5 °C (h)	10 °C (h)
0	0	291.8	116.25	62.05
1.8	240	-59.79	-23.82	-12.71

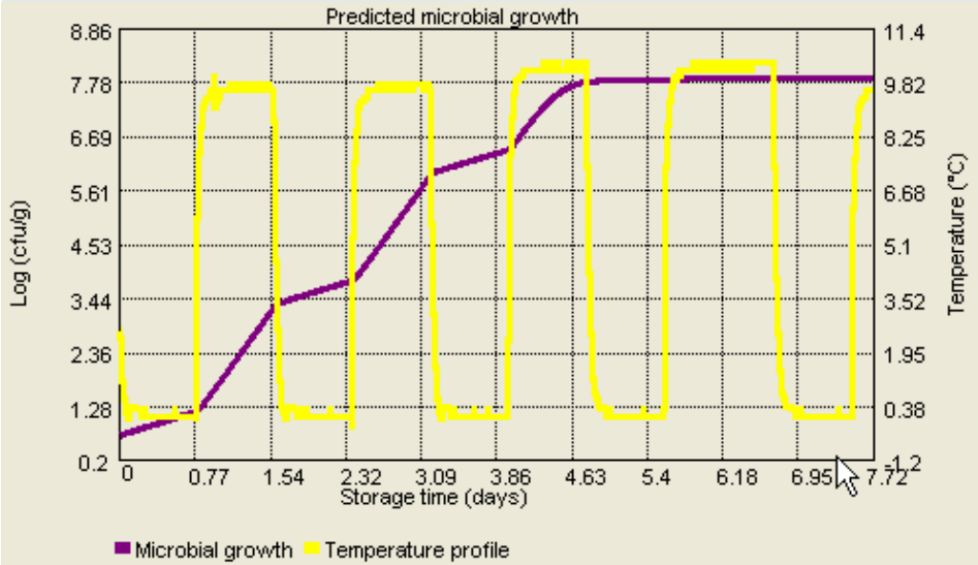


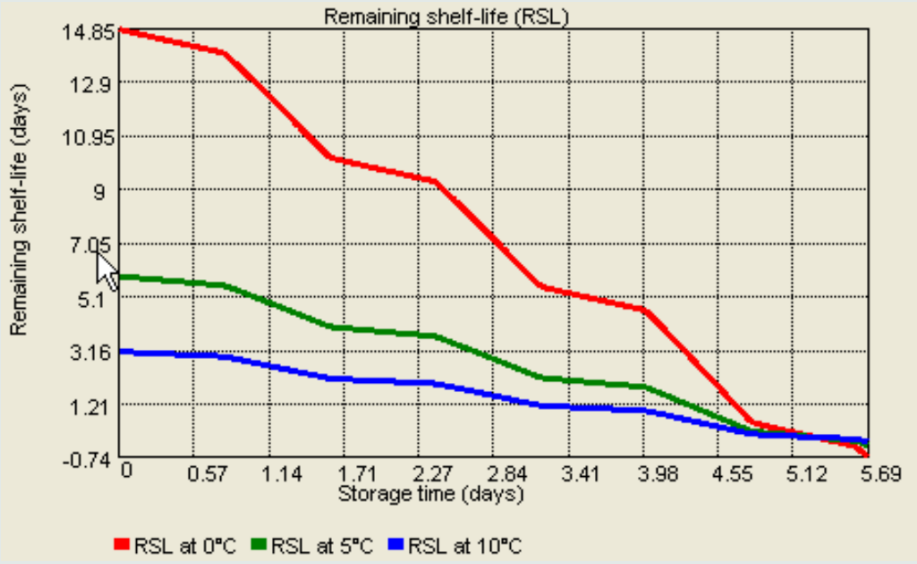
FoodDTU
Innovative Solutions

Key features of SSSP – time-temperature integration

SSSP predicts the effect of product temperature profiles:

- Series of constant temperatures
- Data recorded by temperature loggers





Http://www.difres.dk/micro/sssp/

Key features of SSSP – an extensive help-menu

SSSP help-menu:

- How to use SSSP (e.g. for time-temperature integration)
- Information about individual predictive models:
  - Model development and equations
  - Model evaluation and validation
  - Range of applicability (products, storage conditions)
- Data formats (import, export)
- Other predictive microbiology software

SSSP users

- SSSP has been available since January 1999
  - New versions in 2004, 2005 and 2008
- SSSP is used by more than 3000 people/institutions from more than 100 different countries:
  - Production and distribution of seafood : 33 %
  - Seafood inspection : 19 %
  - Research : 17 %
  - Teaching : 13 %
- SSSP is free and available in 12 different languages
  - www.difres.dk/micro/sssp/

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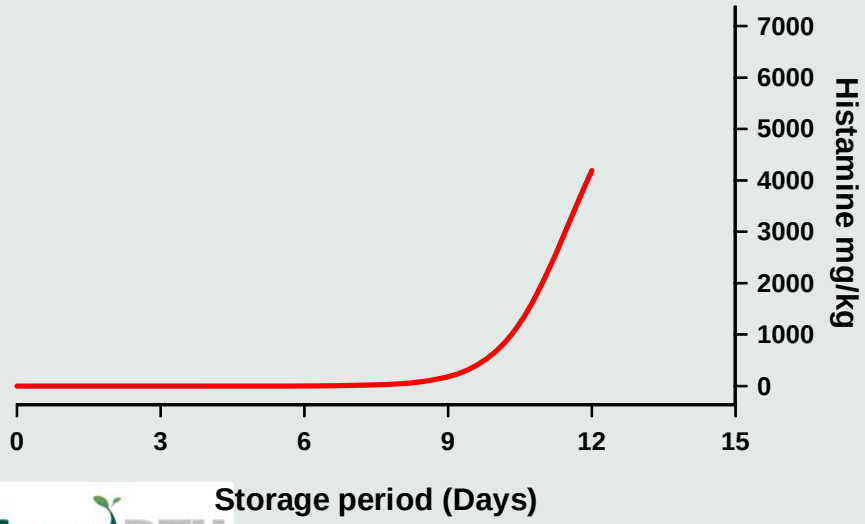
Histamine formation in seafood

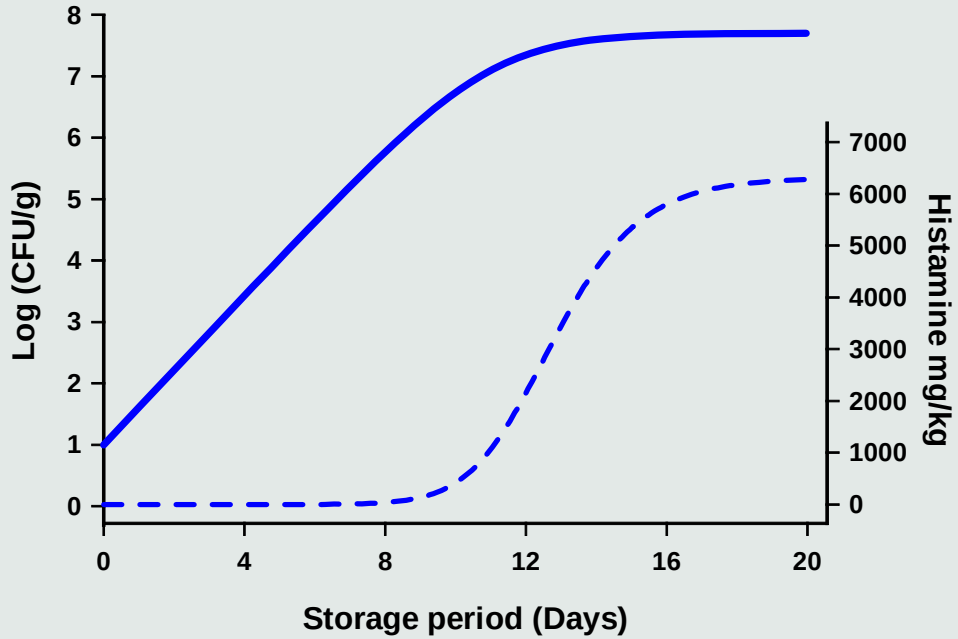
- Histamine fish poisoning (HFP) occurs world wide and is the most common finfish-borne human disease
- HFP is due to marine finfish with >500-1000 mg histamine/kg
- Specific bacteria produce histamine in seafood
  - At above 0°C: *Morganella psychrotolerans, Photobacterium phosphoreum*
  - At above 7-10°C: *Morganella morganii*, *Raoultella planticola*
- EU regulation: 100-200 mg histamine/kg

Dalgaard *et al.* 2008

Histamine formation in seafood

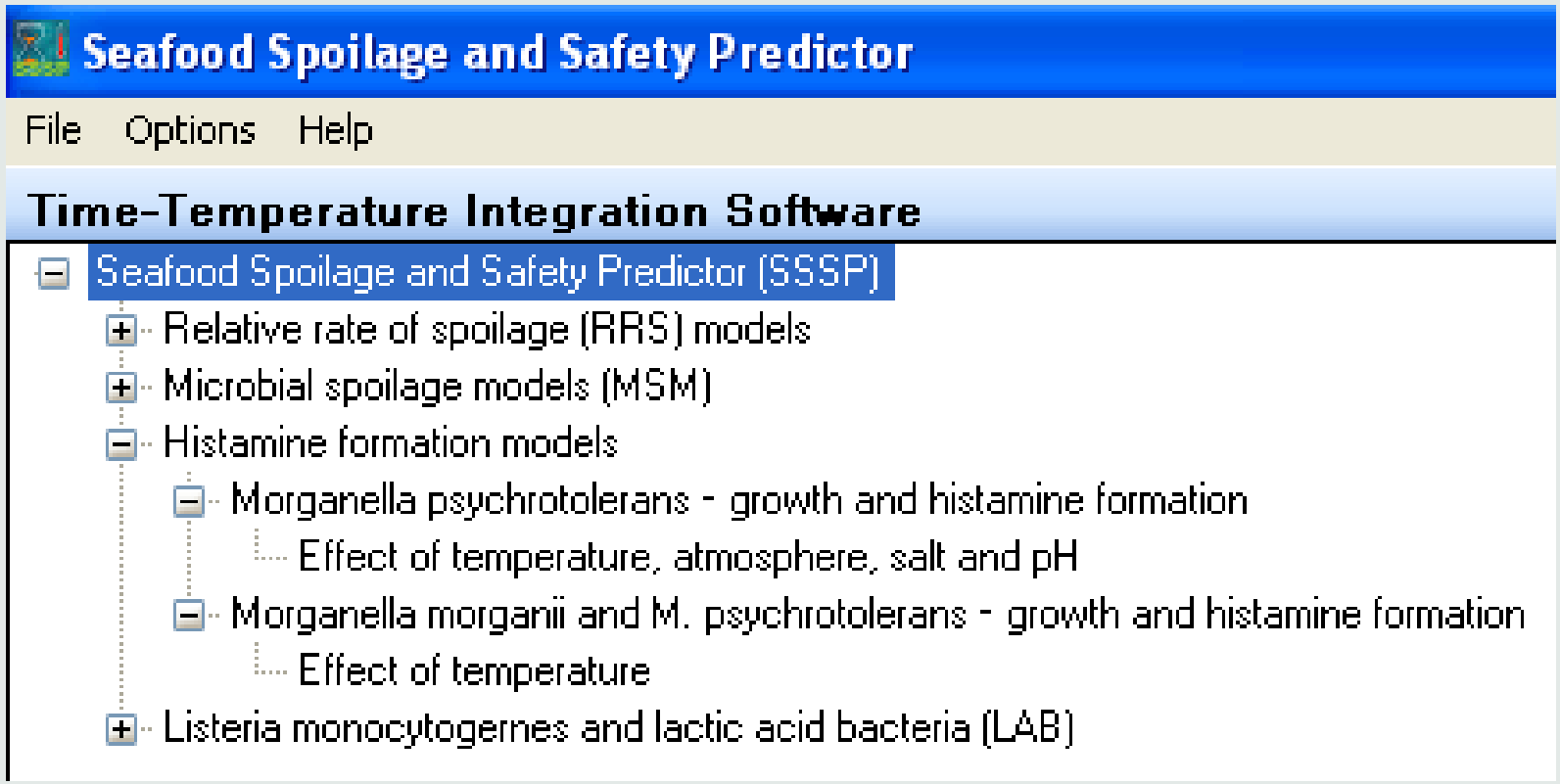
- Models for histamine formation have been available for years:
  - 21.1 – 37.8°C: Frank et al. (1983)
  - -1.1 – 15.6°C: Frank & Yoshinaga (1987)
- Models for bacterial growth and histamine formation are new





Emborg & Dalgaard 2007

SSSP v. 3 includes models for histamine formation in seafood



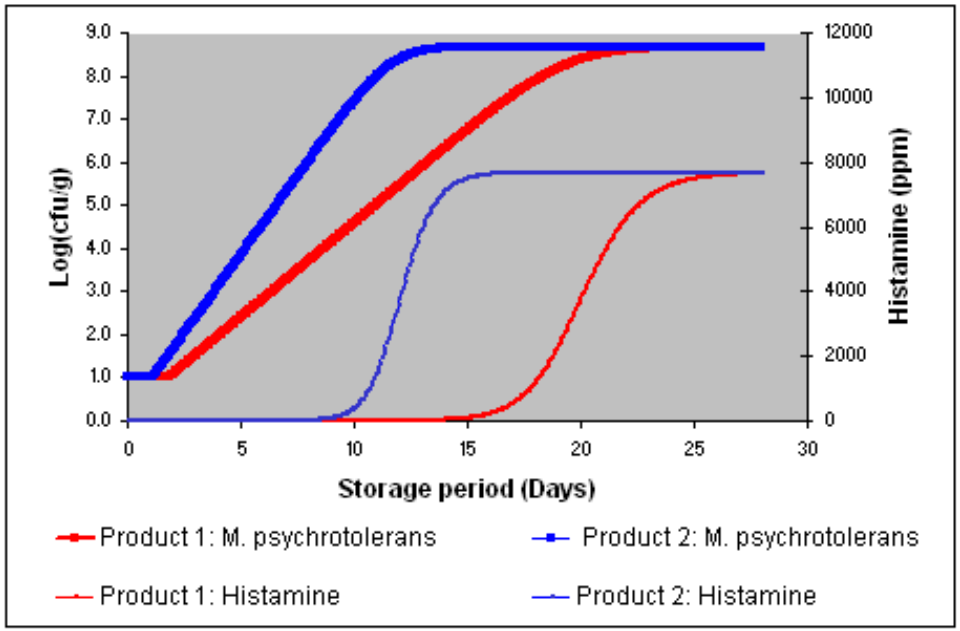
Http://www.difres.dk/micro/sssp/

Histamine formation in seafood

Chilled tuna

Product characteristics and storage conditions

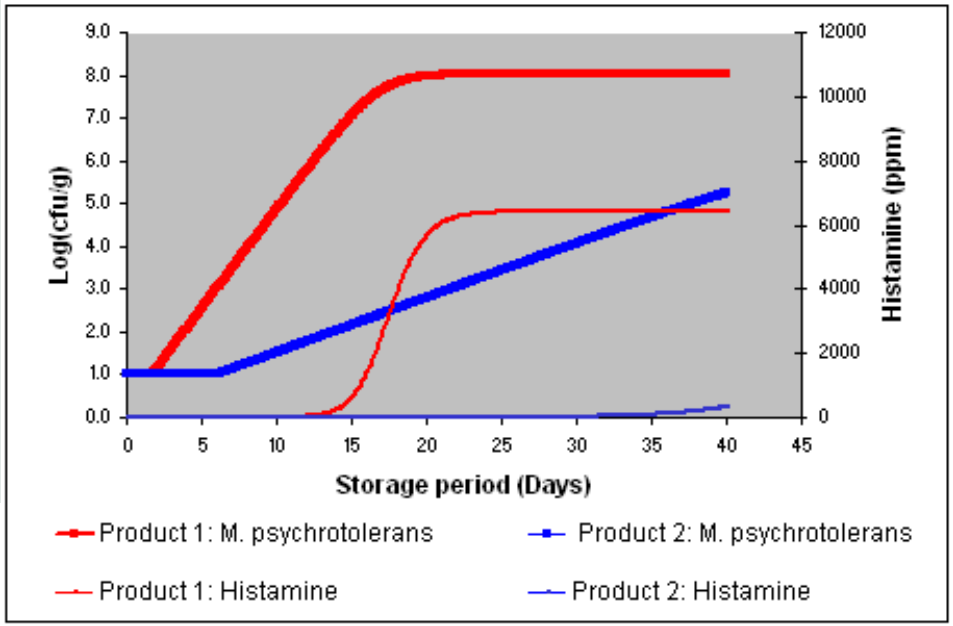
	Product 1	Product 2
Morganella psychrotolerans, cfu/g	10	10
Temperature, °C	2.00	4.40
Water phase salt in product, %	0.30	0.30
pH	5.90	5.90
% CO_2 in headspace gas equllibrium	0.0	0.0
Storage period (Days)	28	28
Initial concentrtation of histamine (ppm)	0	0
Initial concentration of histidine (ppm), Max. 10750 ppm	10750	10750



Chilled cold-smoked tuna

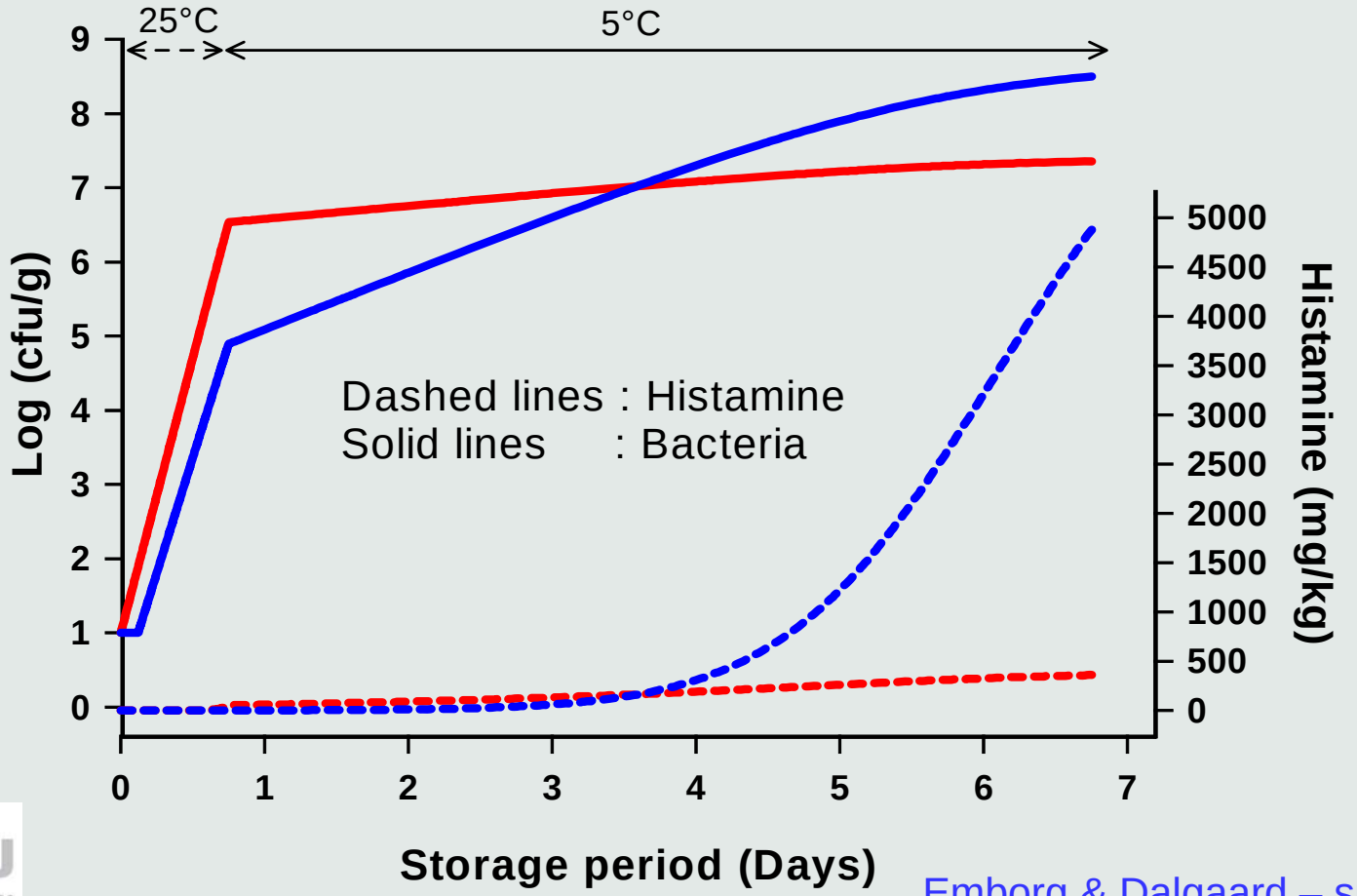
Product characteristics and storage conditions

	Product 1	Product 2
Morganella psychrotolerans, cfu/g	10	10
Temperature, °C	5.00	5.00
Water phase salt in product, %	3.00	5.00
pH	5.90	5.90
% CO_2 in headspace gas equllibrium	0.0	40.0
Storage period (Days)	40	40
Initial concentrtation of histamine (ppm)	0	0
Initial concentration of histidine (ppm), Max. 10750 ppm	10750	10750



Histamine formation in seafood

A combined *M. psychrotolerans* and *M. morganii* model allows growth and histamine formation to be evaluated for a wide range of temperatures



Emborg & Dalgaard – submitted

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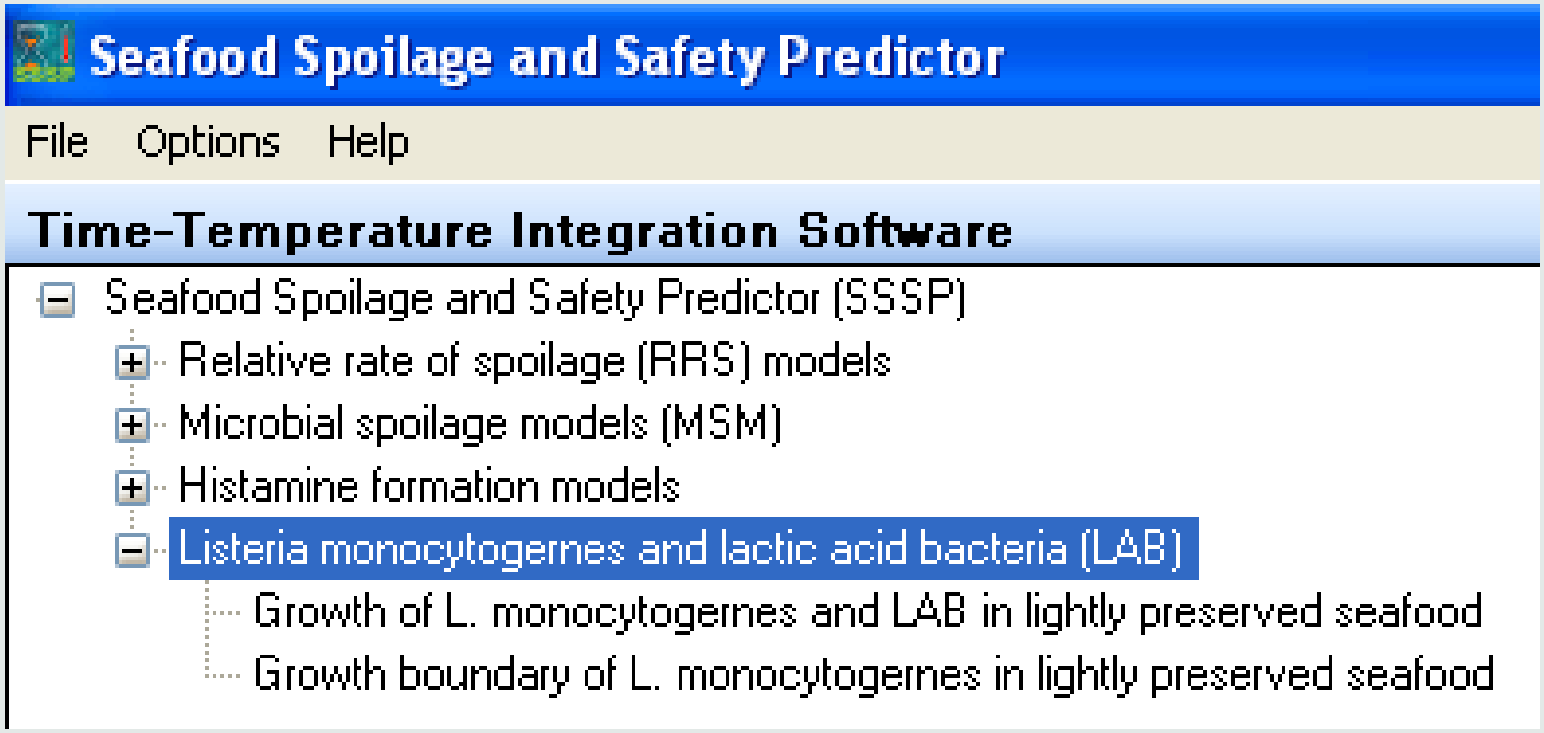
Listeria monocytogenes and lactic acid bacteria

EU-regulation (EC 2073/2005) distinguish between ready-to-eat foods able or unable to support growth of *Listeria monocytogenes*

Ready-to-eat foods	Critical limit	Comments
Support growth	None in 25 g	- When produced
Support growth	100 cfu/g	- It must be documented that 100 cfu/g is not exceeded within the storage period
Unable to support growth	100 cfu/g	- Documentation - pH $\leq$ 4,4 or a_w $\leq$ 0,92 - pH $\leq$ 5,0 and a_w $\leq$ 0,94 - Shelf-life below 5 days

Listeria monocytogenes and lactic acid bacteria

SSSP v. 3 includes extensive growth and growth boundary models for *Listeria monocytogenes* and lactic acid bacteria



Mejlholm and Dalgaard (2007a,b) - *J. food Prot*, **70**, 70-84 and 2485-2497

L.monocytogenes - LAB interaction model

°F °C

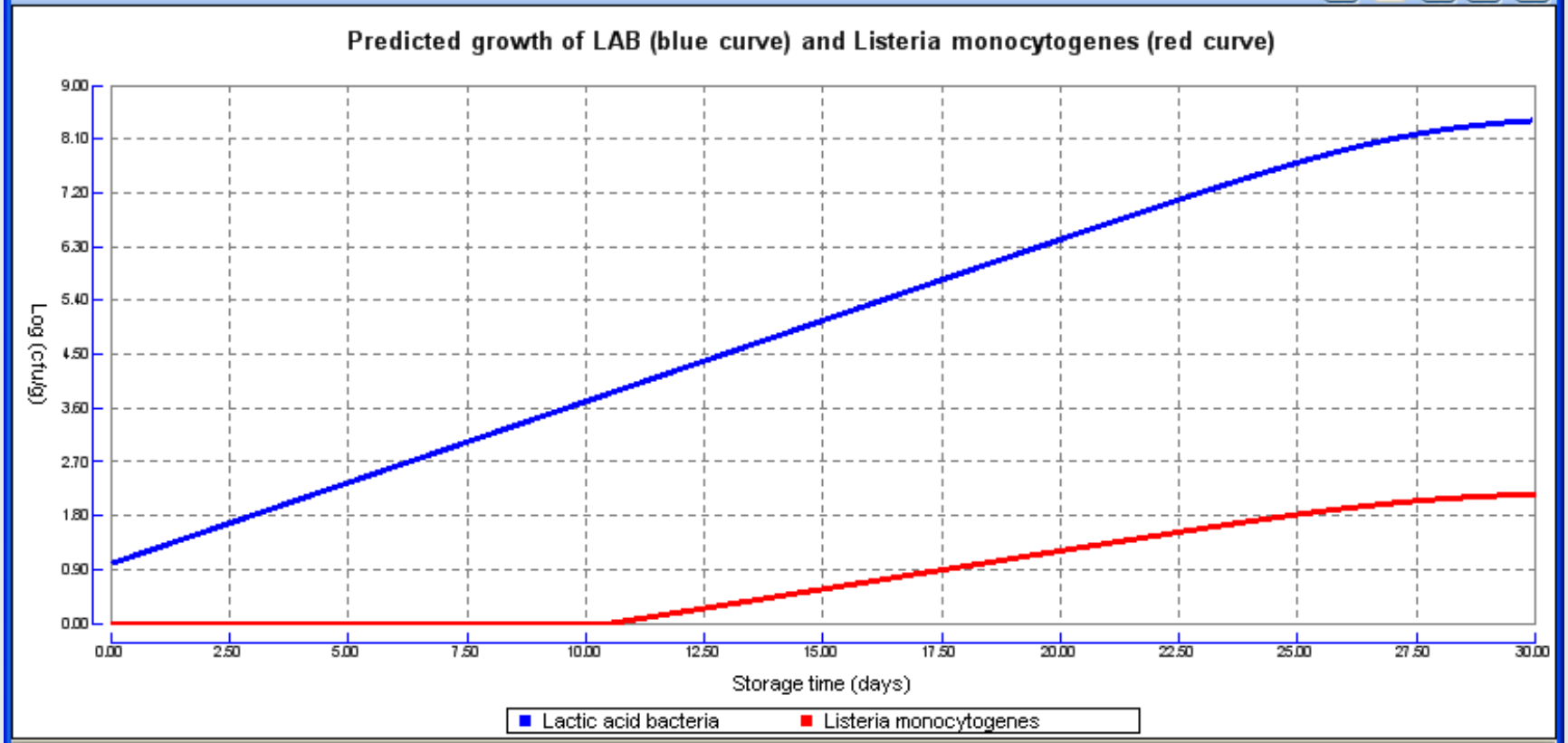
Product characteristics and storage conditions

Storage period (d)	30	
Temperature (°C)	5.0	2 - 15 °C
NaCl in water phase (%)	4.5	2.5 - 8
pH	6.1	5.8 - 7.0
Lactic acid in water phase (ppm)	8000	< 30000
Smoke components/phenol (ppm)	8	< 20
% CO2 in headspace gas equilibrium	0	0 - 80
Diacetate in water phase of product, mg/l	0	< 2000

Predicted microbial growth

Apply

	L. monocytogenes	LAB
Initial cell density (cfu/g)	1	10
Include lag time	☑	☐
µmax (1/h)	0.0123	0.026
Lag time (d)	10.54	0
Time for 100-fold increase (d)	26.85	7.37



Time (d):20.16 | Lactic acid bacteria, Log(cfu/g):7.43 | L. monocytogenes, Log(cfu/g):1.22

L.monocytogenes - LAB interaction model

°F °C

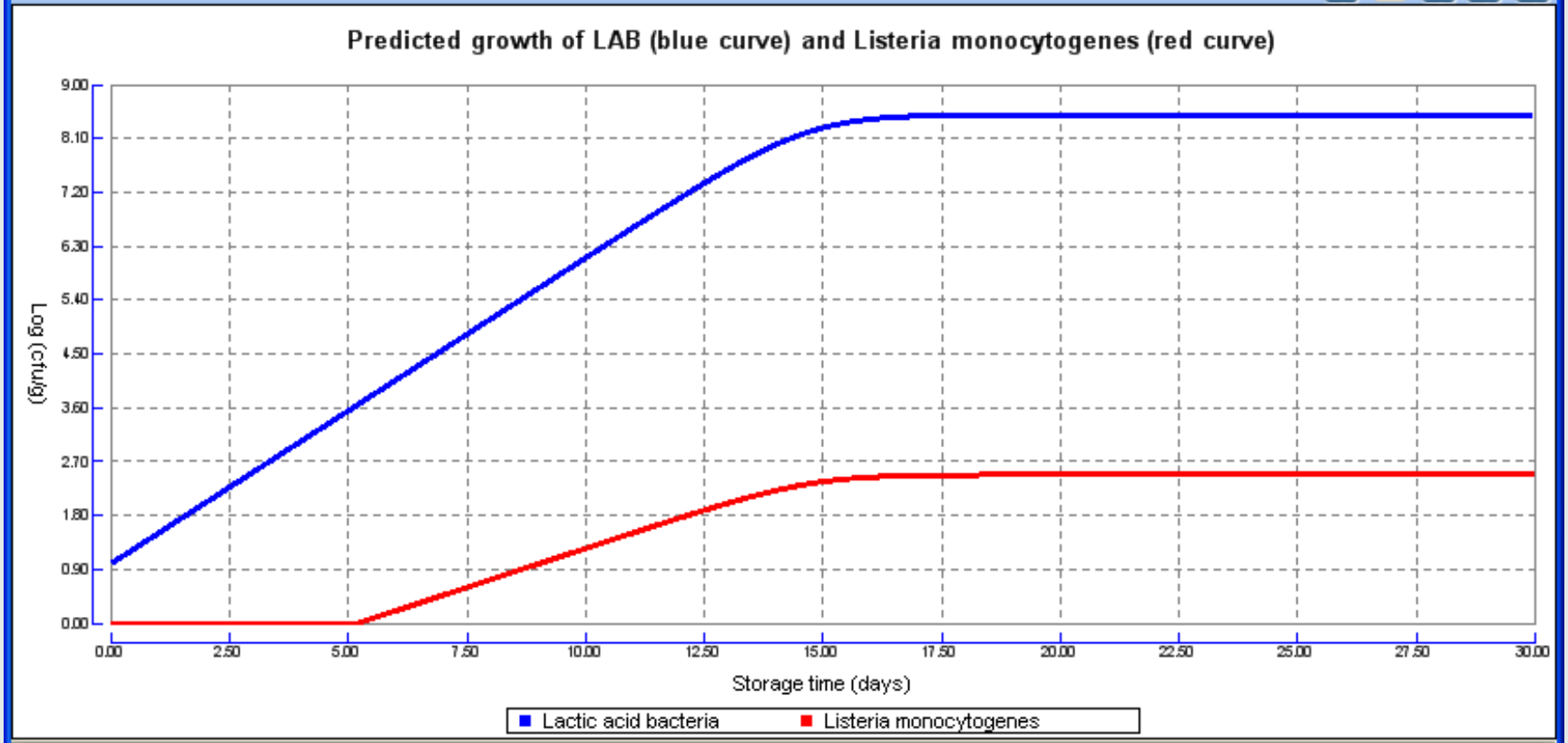
Product characteristics and storage conditions

Storage period (d)	30	
Temperature (°C)	8.0	2 - 15 °C
NaCl in water phase (%)	4.5	2.5 - 8
pH	6.1	5.8 - 7.0
Lactic acid in water phase (ppm)	8000	< 30000
Smoke components/phenol (ppm)	8	< 20
% CO2 in headspace gas equilibrium	0	0 - 80
Diacetate in water phase of product, mg/l	0	< 2000

Predicted microbial growth

Apply

	L. monocytogenes	LAB
Initial cell density (cfu/g)	1	10
Include lag time	☑	☐
µmax (1/h)	0.0251	0.049
Lag time (d)	5.18	0
Time for 100-fold increase (d)	12.98	3.91



Time (d):20.05 | Lactic acid bacteria, Log(cfu/g):8.5 | L. monocytogenes, Log(cfu/g):2.48

L.monocytogenes - LAB interaction model

°F °C

Product characteristics and storage conditions

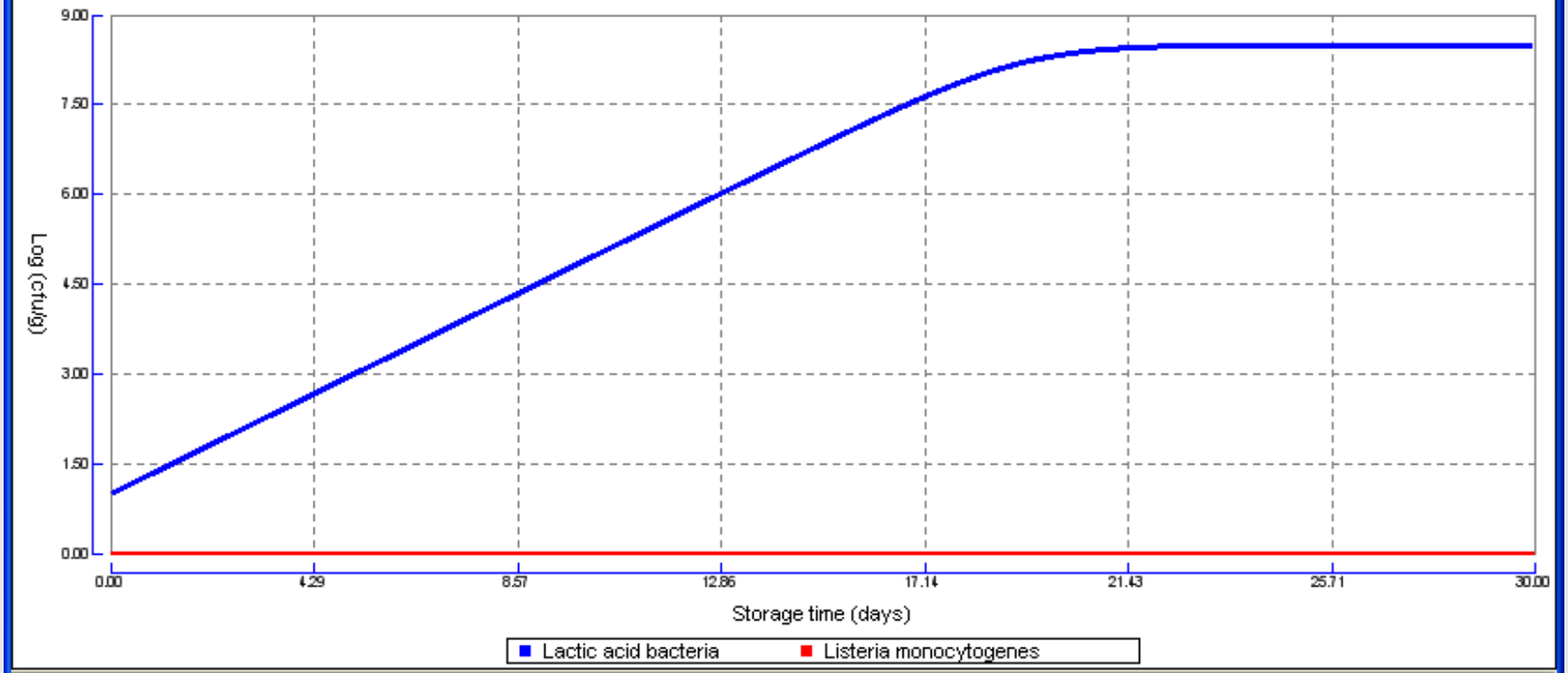
Storage period (d)	30	
Temperature (°C)	8	2 - 15 °C
NaCl in water phase (%)	4.5	2.5 - 8
pH	6.0	5.8 - 7.0
Lactic acid in water phase (ppm)	8000	< 30000
Smoke components/phenol (ppm)	8	< 20
% CO2 in headspace gas equilibrium	25	0 - 80
Diacetate in water phase of product, mg/l	1500	< 2000

Predicted microbial growth

Apply

	L. monocytogenes	LAB
Initial cell density (cfu/g)	1	10
Include lag time	☑	☐
µmax (1/h)	0.0054	0.0375
Lag time (d)	24.05	0
Time for 100-fold increase (d)	Not reached	5.12

Predicted growth of LAB (blue curve) and Listeria monocytogenes (red curve)



Time (d):20.05 | Lactic acid bacteria, Log(cfu/g):8.34 | L. monocytogenes, Log(cfu/g):0

Listeria monocytogenes growth boundary model

°F °C

Product characteristics

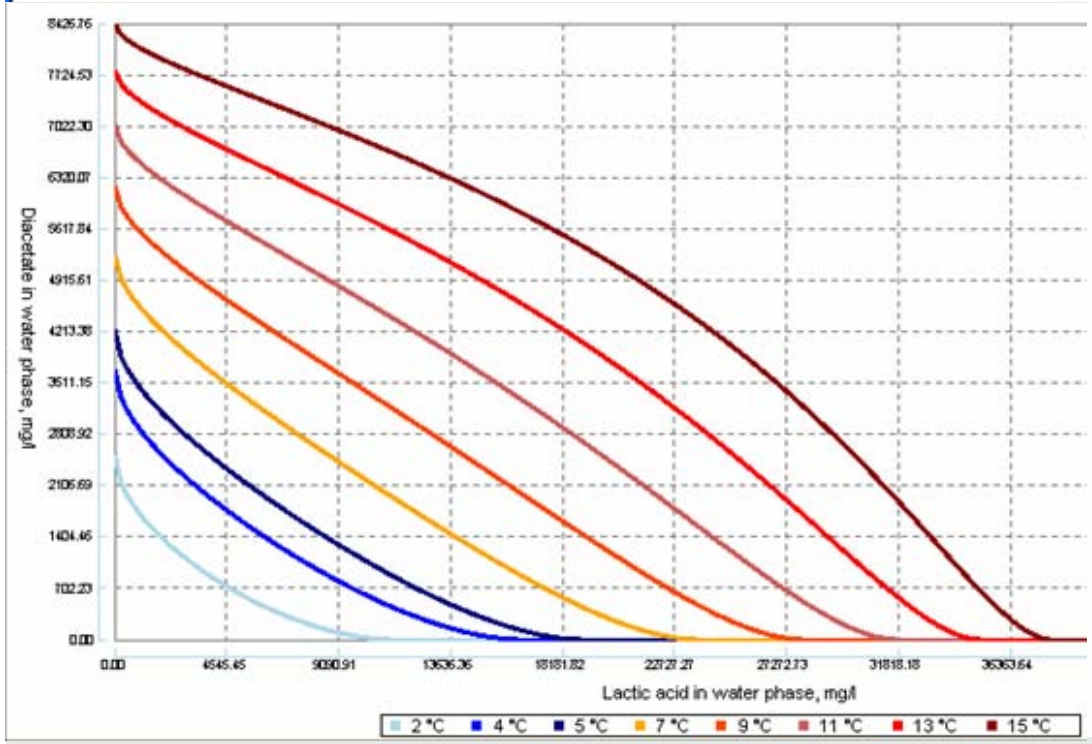
Temperature (°C)	6.0	2 - 15 °C	Smoke components/phenol (ppm)	8	< 20
NaCl in water phase (%)	4.5	2.5 - 8	% CO2 in headspace gas equilibrium	0	0 - 80
pH	6.0	5.8 - 7.0	Diacetate in water phase of product, mg/l	0	< 2000
Lactic acid in water phase (ppm)	6000	< 30000	Nitrite, mg/kg	0	< 350

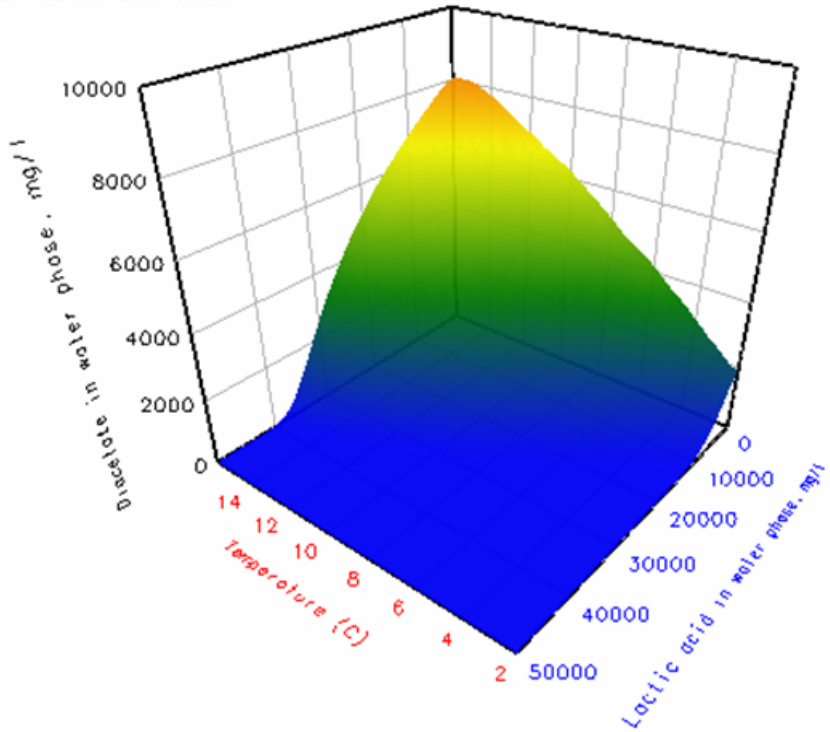
Select the variables to be plotted. The first parameter is fixed, the second two are variable

Temperatute-Lactic Acid-Diacetate

- Temperatute-Lactic Acid-Diacetate
- pH-Lactic Acid-Diacetate
- pH-NaCl-Phenol
- pH-CO2-Temperature

Apply





Temperature (°C): 4.98 | Lactic acid in water phase, mg/l: 7963.71 | Diacetate in water phase, mg/l: 1524.41

Conclusions and perspectives

- SSSP has stimulated the use of predictive models and time-temperature integration within the seafood sector
- SSSP v. 3 includes new seafood safety models for:
  - Time-temperature integration
  - Product development and quality control
  - Documentation of seafood safety
- Future developments of SSSP may include:
  - Product specific e-learning modules
  - Improved links to other freeware

Thanks

- Colleagues at DTU Aqua
- Financial support
- Industry collaboration

Last but not least

I thank you for your attention