Predicting the shelf life of chilled products

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International Workshop
Quality Management of the Chill Chain
Athens 2005

Predicting the shelf life of chilled products

Shelf life of chilled foods

Spoilage	Safety
Organoleptically accepted by consumers	Provide an appropriate level of protection-ALOP

Models for shelf life prediction. Why?

- Is there a problem today?
- Profit for Industry?
- Benefits for consumers?

Predicting the shelf life of chilled products

- Is there a problem today?

$1 billion in the United States and $200 million in Canada are lost each year as a result of beef spoilage
source: The National Cattlemen's Beef Association

4 billion EUROS per year annual health care costs, traced to few selected foodborne pathogens in meat products
source:WHO 7th report covering 1993-1998 period

Predicting the shelf life of chilled products

Models for shelf life prediction. Why?

- Identification and quantification of factors affecting shelf life
- Shelf life extension
- Effective "expiration dating"
- Development of effective chill chain management systems (decision support)

Predicting the shelf life of chilled products

- Profit for Industry?

- Decrease "external failure cost" of quality (minimizing spoiled products before expiration date)
- Increase "value" of products (providing higher quality, increased safety)
- Lower production cost (exploiting the total shelf life of products)

Predicting the shelf life of chilled products

- Benefits for consumers?

  - Higher quality
  - Increased level of safety
  - Better price?

Predicting the shelf life of chilled products

Presentation Outline

- Spoilage of chilled food products
- Microbial spoilage models
- Applications of spoilage models
- Spoilage modeling in risk assessment

Outline

Spoilage

Spoilage modeling

Applications

Spoilage modeling vs Risk Assessment

Principles of chilled products Spoilage

ONLY A FRACTION OF THE TOTAL MICROFLORA IS RESPONSIBLE FOR SPOILAGE (Specific Spoilage Organisms:SSO)

THIS FRACTION (SSO) IS RESPONSIBLE FOR SPOILAGE ONLY WITHIN A CERTAIN RANGE OF ENVIRONMENTAL CONDITIONS (Spoilage Domain: SD)

SPOILAGE IS CAUSED BY THE PRODUCTION OF A CERTAIN AMOUNT OF METABOLIC PRODUCTS (Chemical Spoilage Index: CSI)

SPOILAGE IS OBSERVED WHEN THE SSO REACH A CERTAIN LEVEL (Spoilage level-SL)

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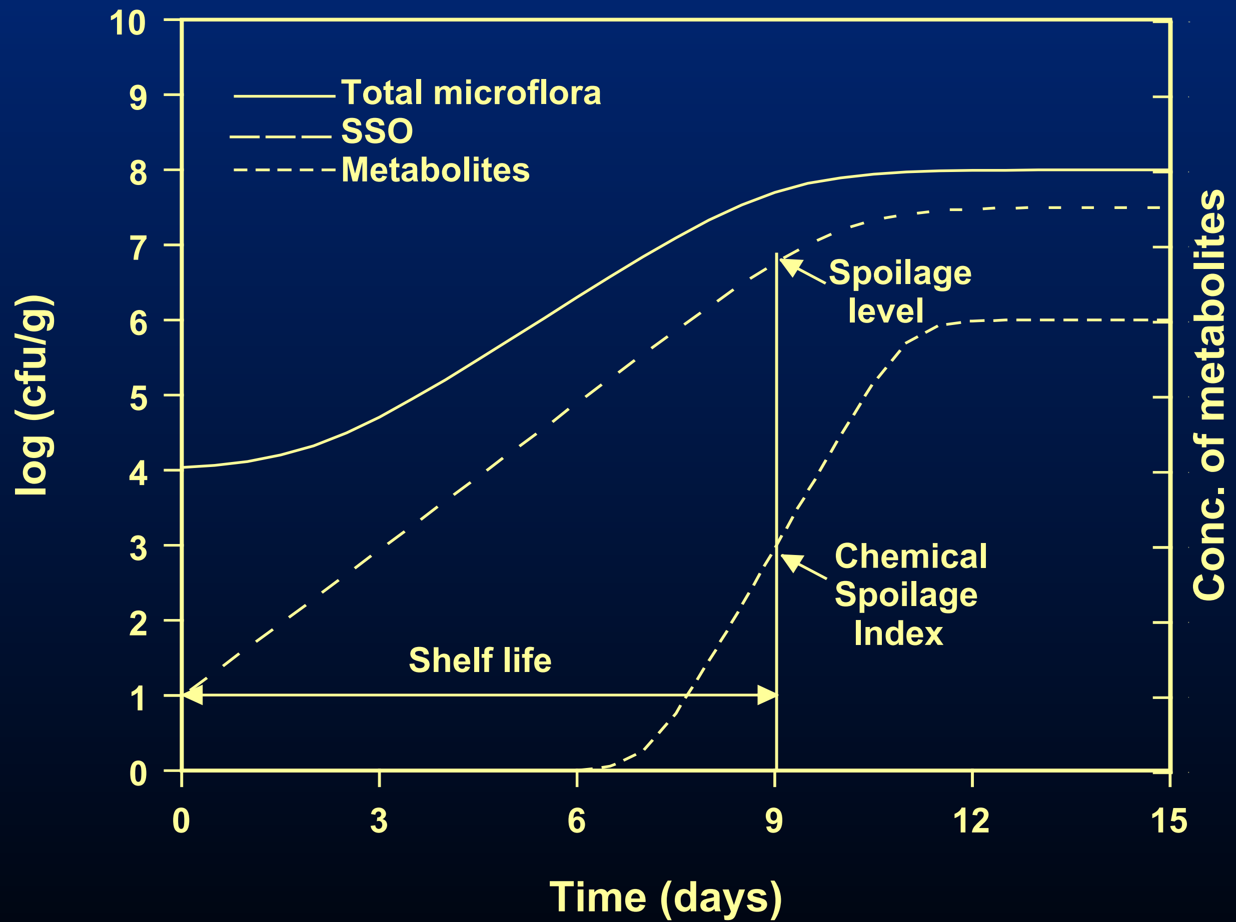
Principles of chilled products Spoilage

Spoilage process



Outline

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Modeling microbiological spoilage

Steps in development of spoilage models

- *IDENTIFICATION OF SSO*
- *DETERMINATION OF SPOILAGE LEVEL*
- *DEVELOPMENT OF A PREDICTIVE MODEL FOR SSO GROWTH*
- *VALIDATION OF THE MODEL*

Step 1&2: Identification of SSO and determination of spoilage level

- Studies with natural contaminated products
- Studies with sterile products inoculated with spoilage bacteria isolated from natural contaminated products

Microbiological analysis

Sensory analysis

Chemical analysis

Outline

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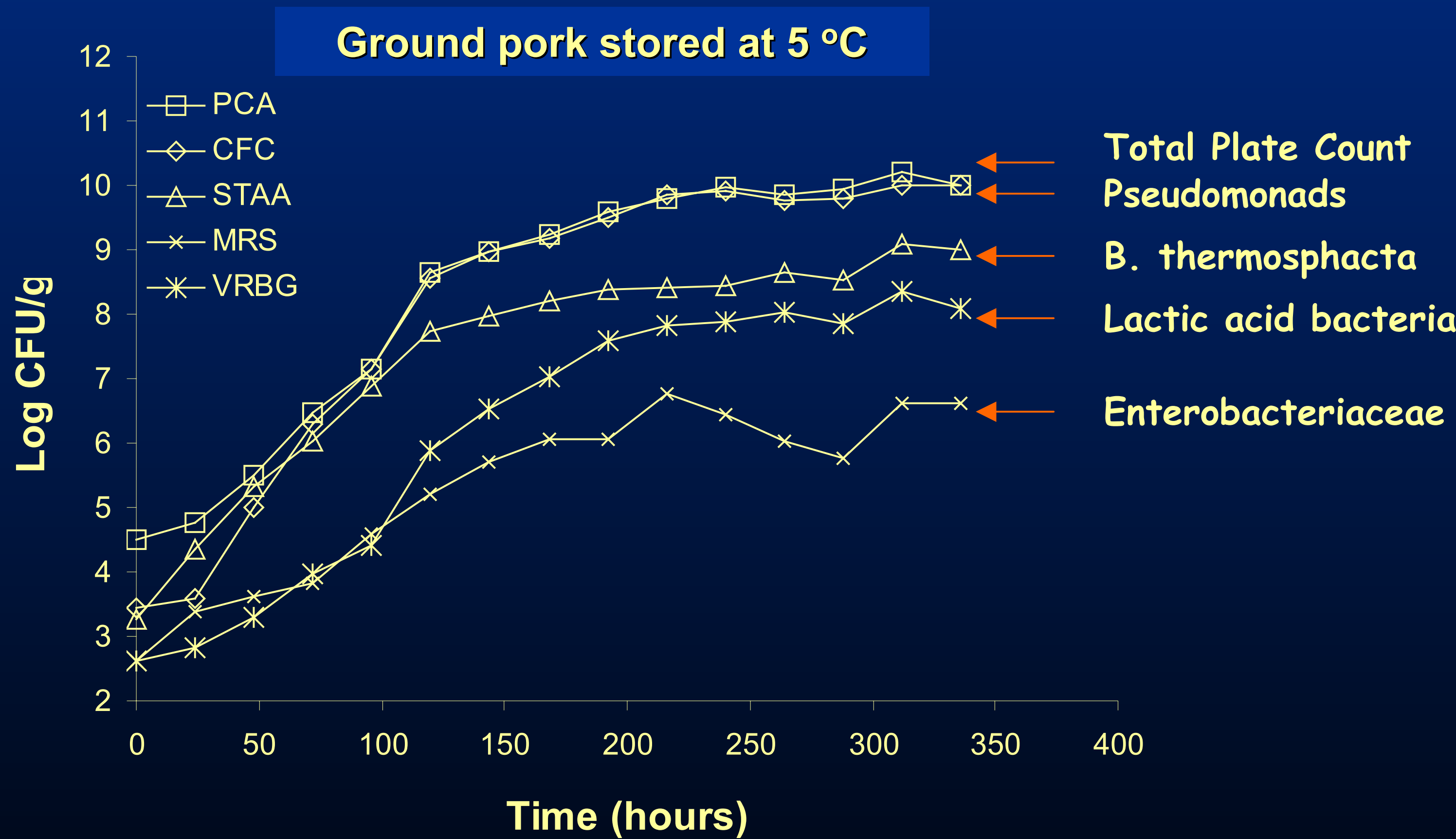
Step 1&2: Identification of SSO and determination of spoilage level

Microbiological Analysis



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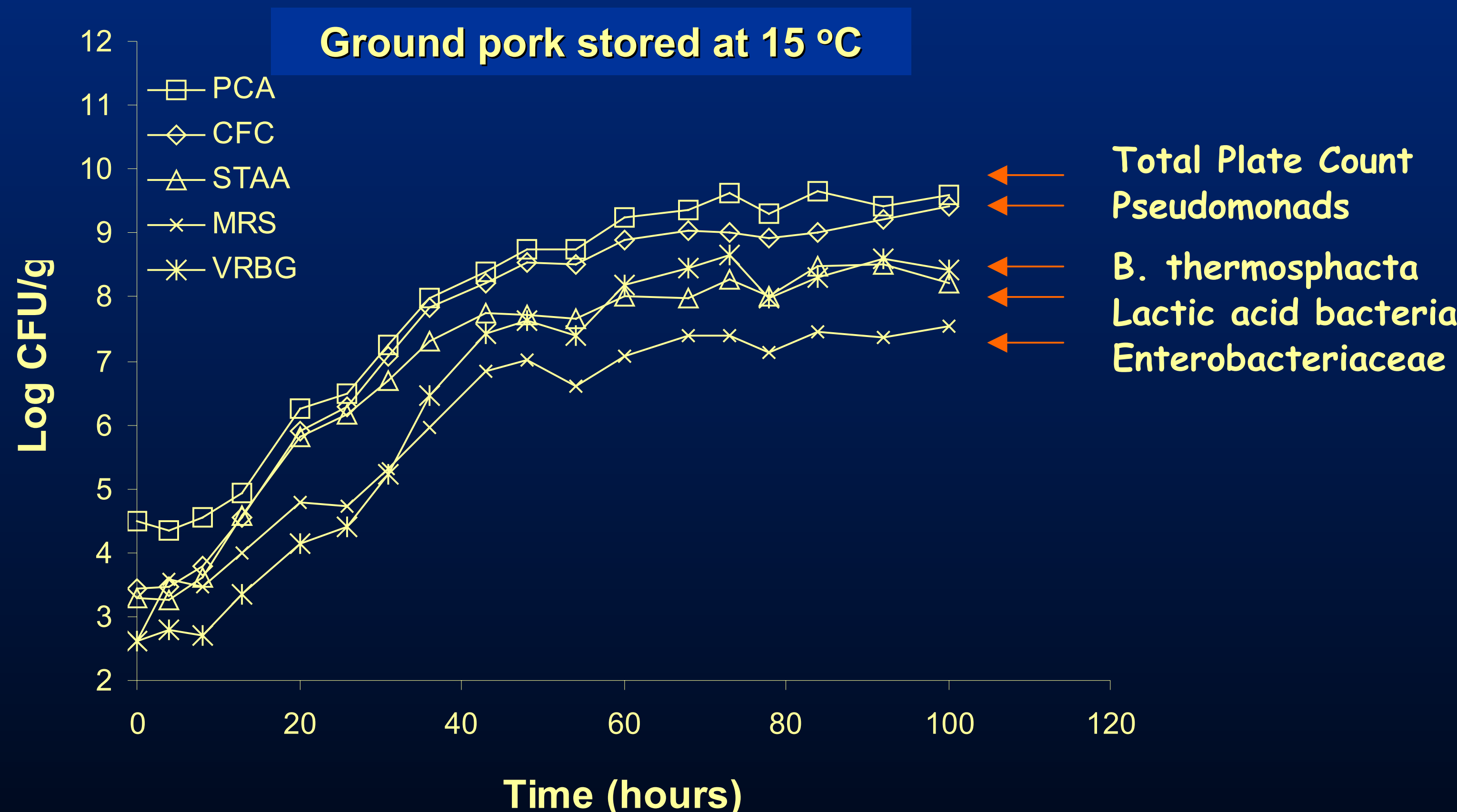
Step 1&2: Identification of SSO and determination of spoilage level

Microbiological Analysis



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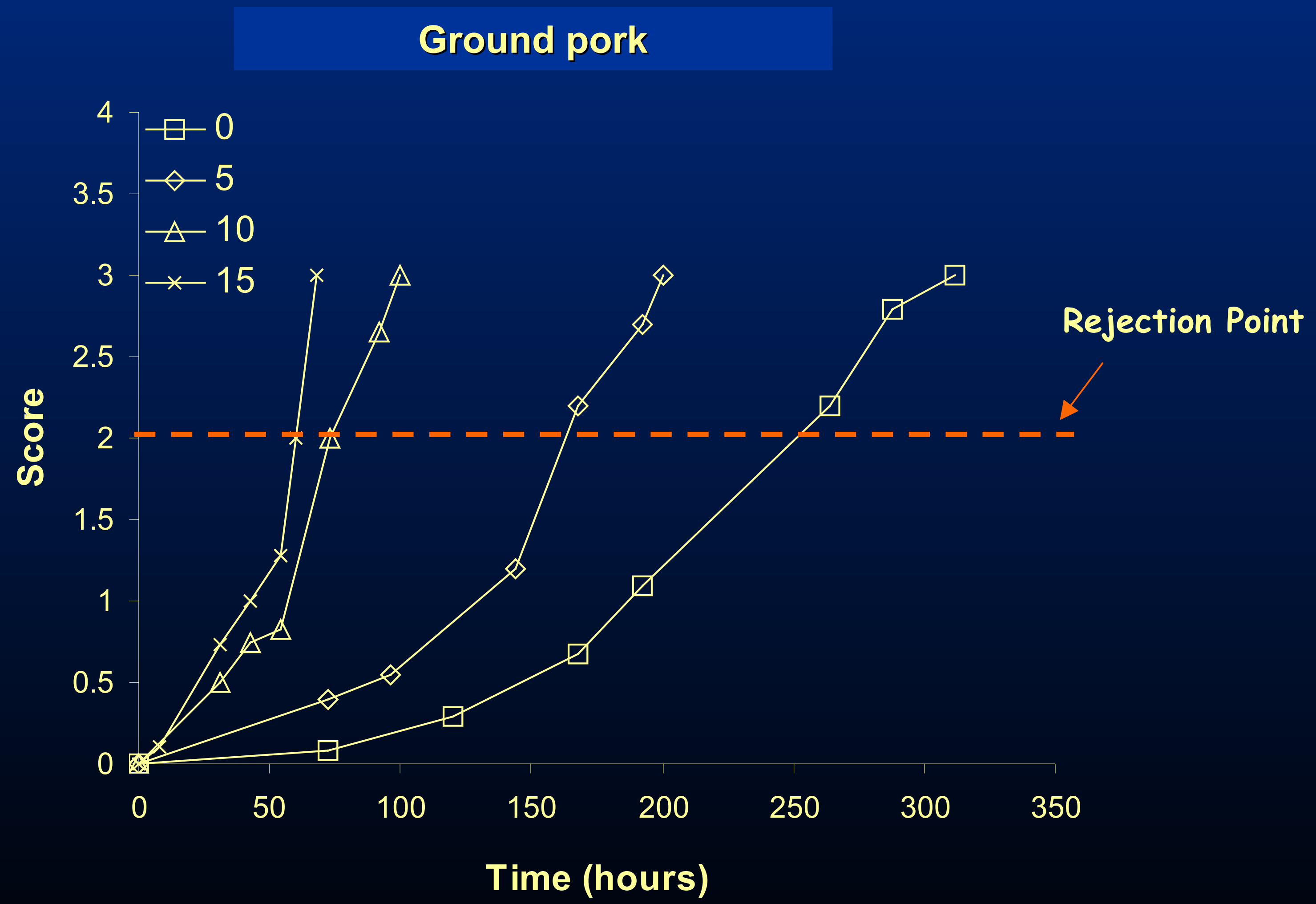
Step 1&2: Identification of SSO and determination of spoilage level

Sensory Analysis



Step 1&2: Identification of SSO and determination of spoilage level

Combining results from microbiological and Sensory Analysis

T (^{o}C)	Shelf life (hours)	CFC Pseudomonads (Log_{10} cfu/g)	STAA B. thermosphacta (Log_{10} cfu/g)	MRS L.A. bacteria (Log_{10} cfu/g)	VRBG Enterobacteria (Log_{10} cfu/g)
0	267.2[a]±5.1[b]	9.2±0.2	8.4±0.2	4.9±0.1	5.1±0.1
5	146.7±9.7	9.1±0.3	8.2±0.1	5.5±0.1	6.4±0.2
10	79.4±3.4	8.8±0.3	8.0±0.2	6.0±0.4	7.0±0.3
15	53.7±6.0	9.0±0.2	8.1±0.1	7.1±0.3	8.0±0.4

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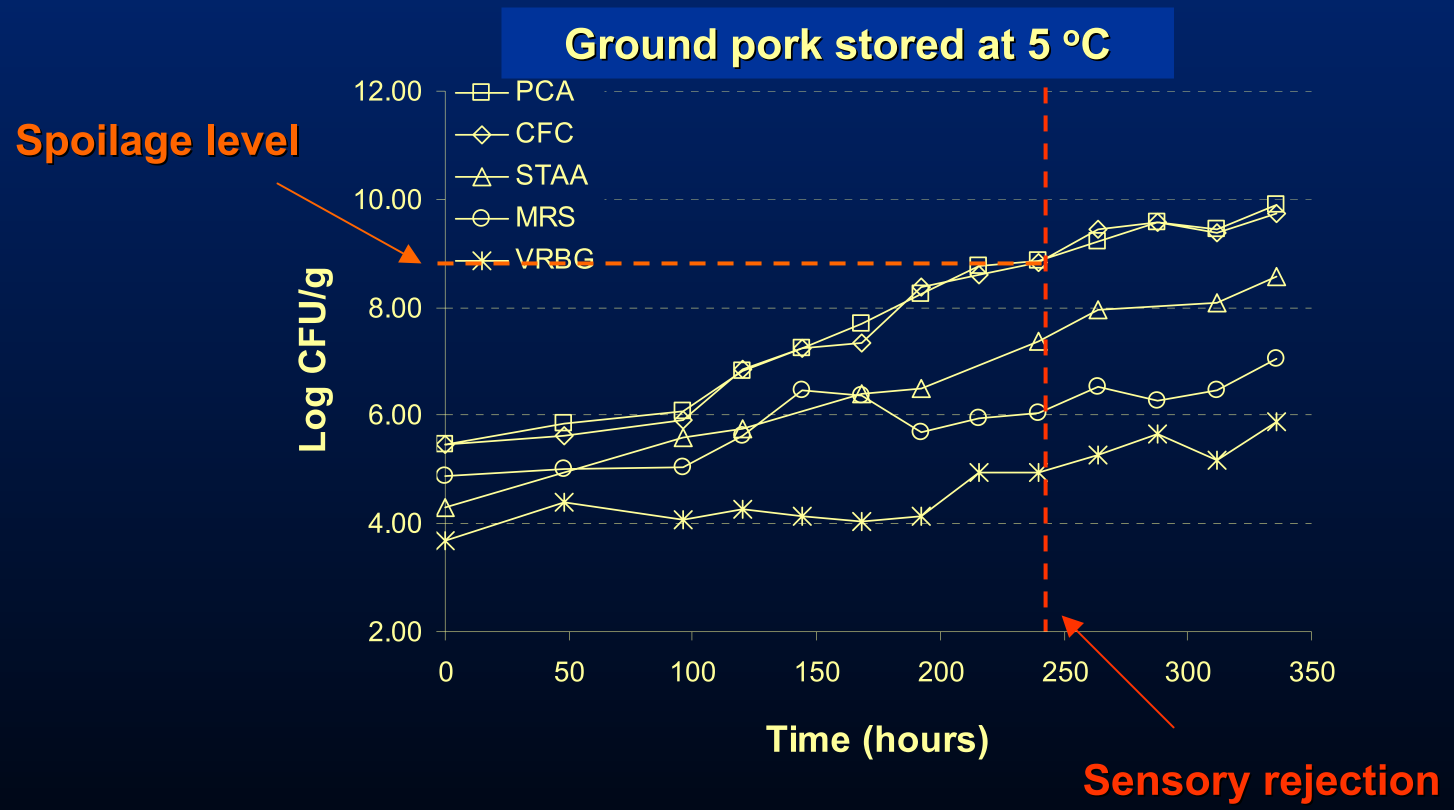
Step 1&2: Identification of SSO and determination of spoilage level

Combining results from microbiological and Sensory Analysis



Step 1&2: Identification of SSO and determination of spoilage level

SSO: *pseudomonads*

SPOILAGE DOMAIN: *Aerobic storage from 0 to 20 °C*

SSO SPOILAGE LEVEL: *10^9 cfu/g*

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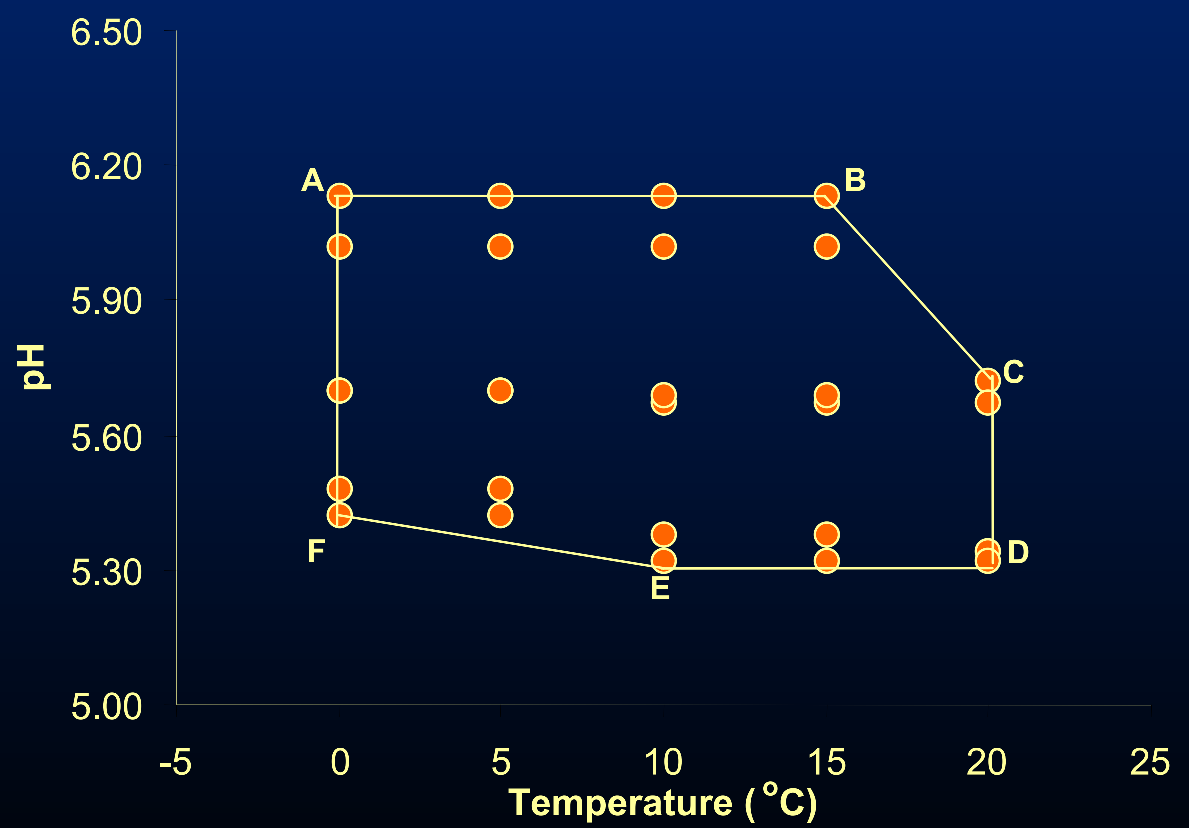
Step 3: Development of a model for SSO growth

Experimental Design

Factors:

1. Storage temperature
2. Meat pH



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Step 3: Development of a model for SSO growth

Modified arrhenius model for the combined effect of temperature and meat pH

$$\ln(\mu_{\max}) = \ln(\mu_{ref}) - d_{\mu} * (pH_{ref} - pH) + \frac{E_{A\mu}}{R} * \left(\frac{1}{T} - \frac{1}{T_{ref}}\right)$$

$$\ln(1/\lambda) = \ln(1/\lambda_{ref}) - d_{\lambda} * (pH_{ref} - pH) + \frac{E_{A\lambda}}{R} * \left(\frac{1}{T} - \frac{1}{T_{ref}}\right)$$

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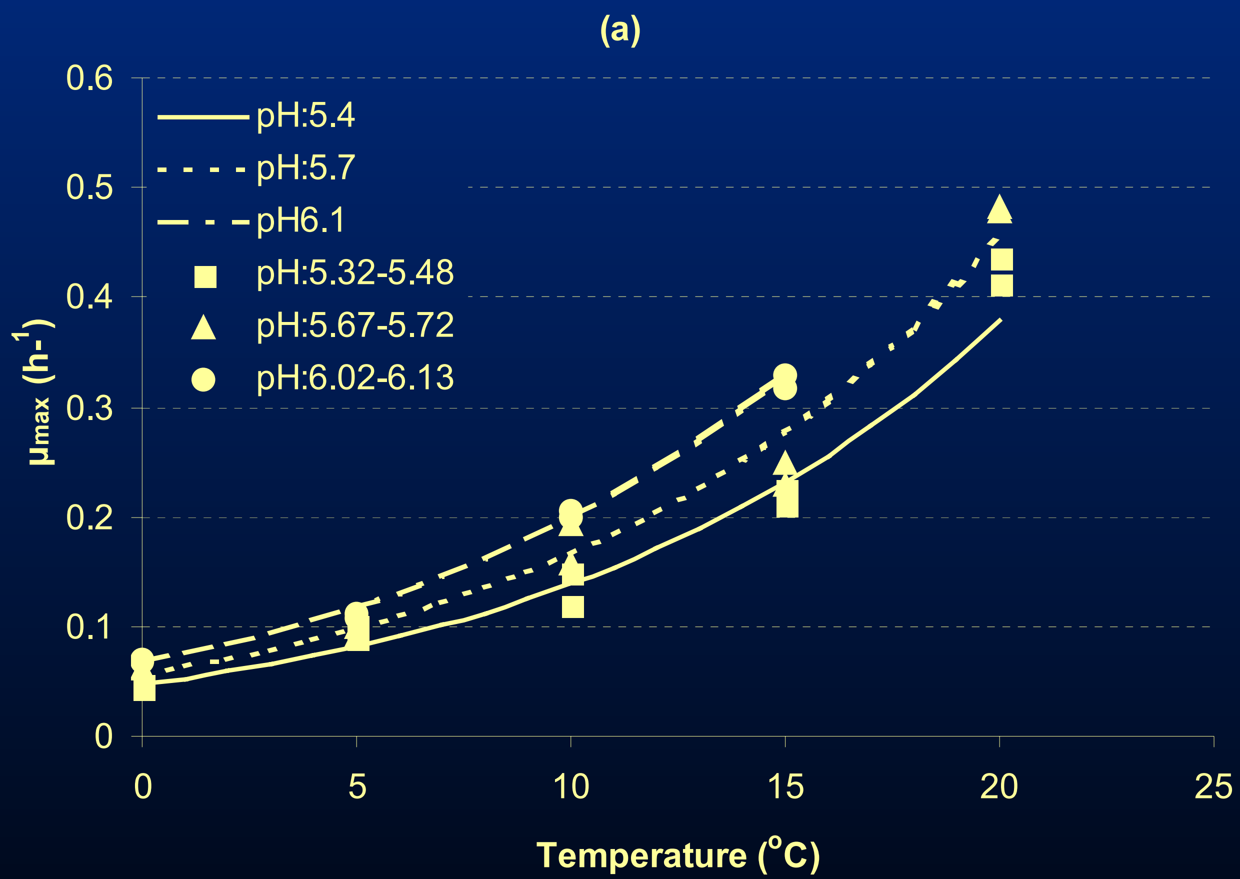
Step 3: Development of a model for SSO growth

Modified arrhenius model for the combined effect of temperature and meat pH



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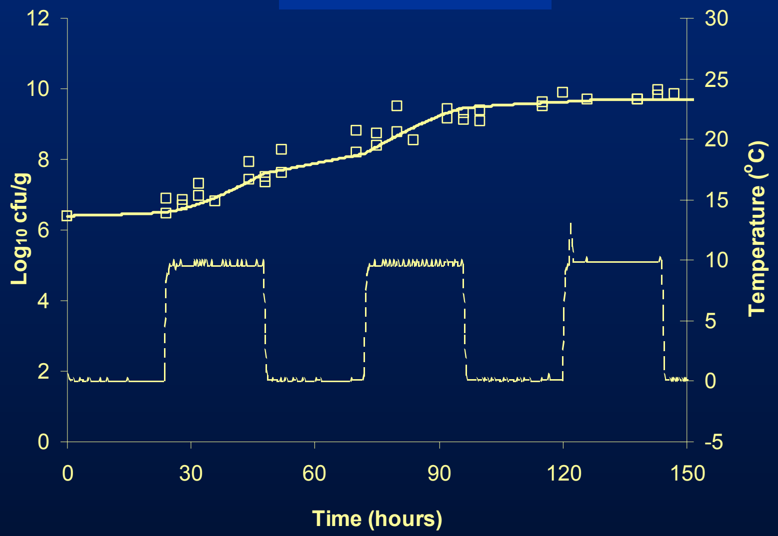
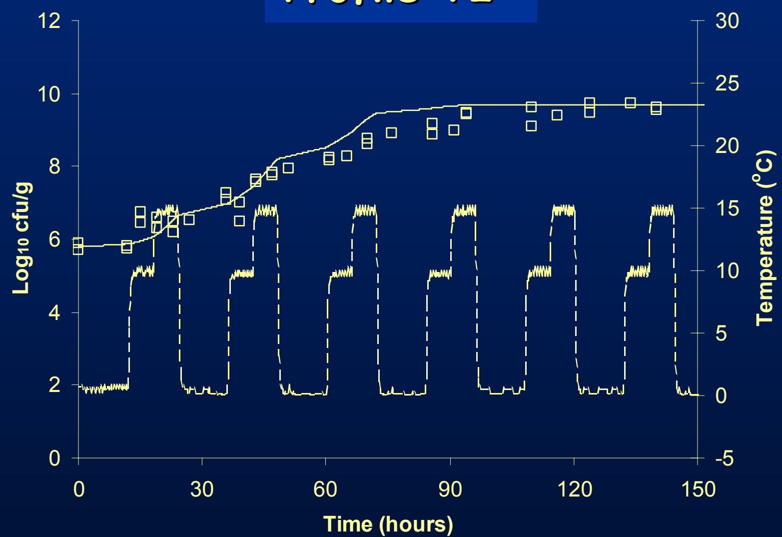
Step 4: Validation of the model

Performance of the model in predicting SSO growth under dynamic temperature conditions

Profile T1



Profile T2



Step 4: Validation of the model

Performance of the model in predicting shelf life under dynamic temperature conditions

Shelf life prediction

TIME REQUIRED BY THE SSO TO MULTIPLY FROM THE INITIAL TO SPOILAGE LEVEL

Step 4: Validation of the model

Performance of the model in predicting shelf life under dynamic temperature conditions

Temperature profile	SL observed (h)	SL predicted(h)
T1	85.3	85.5
T2	98.0	66.8
T3	68.8	53.6
T4	71.5	70.5

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Components of a "ready to use" Spoilage Model

PRODUCT:	Ground meat (beef and pork)
CONDITIONS OF APPLICABILITY:	Aerobic storage from 0 to 20 ^{o}C, Meat pH: 5.3-6.2
SSO:	Pseudomonads
SSO SPOILAGE LEVEL:	10^9 cfu/g
PREDICTIVE MODEL:	Modified arrhenius model for the effect of temperature and pH
VALIDATION:	Static and Dynamic conditions
APPLICATION:	User-friendly software

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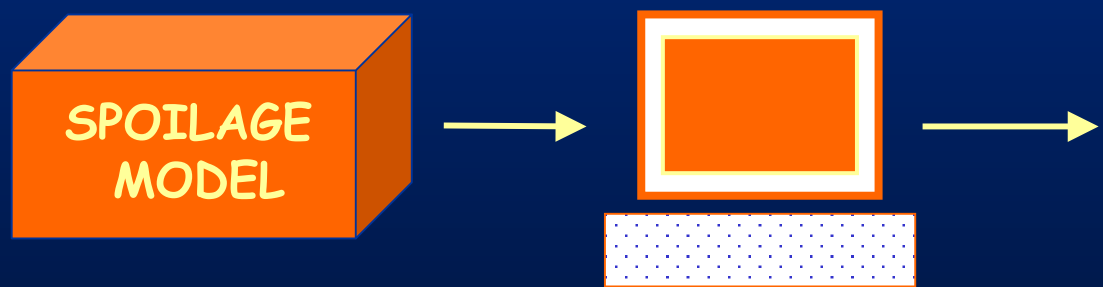
Components of a "ready to use" Spoilage Model

Tertiary Model

Application of spoilage models by the Food Industry using a user-friendly computer software



Shelf life prediction

user-friendly computer software

Components of a "ready to use" Spoilage Model

Application of spoilage models by the Food Industry using a user-friendly computer software

®MicroSPred v 1.0-pro

MICROBIAL SPOILAGE PREDICTOR

- Models targeted to specific food products (fish, meat, poultry, dairy)
- Lag is included
- Organoleptic data
- Information on the relation microbial growth vs shelf life (SSO, Spoilage level)
- Application of the rapid method for SSO enumeration
- Applicable and well validated models at static and dynamic conditions

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Use of spoilage modeling for effective expiration dating

"Expiration Dating"

Current method for expiration dating: Challenge tests

Problems with Challenge tests

Estimation of shelf life based on Challenge tests is valid only for the conditions tested while any changes to these conditions require the repetition of the test.

Furthermore, no information is provided on the magnitude of influence of the controlling factors on microbial growth and product shelf life.

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Challenge Experiments on ground pork

Storage Temperature °C	Shelf life (days)
0	11.1
5	6.1
10	3.3
15	2.2

Expiration date?

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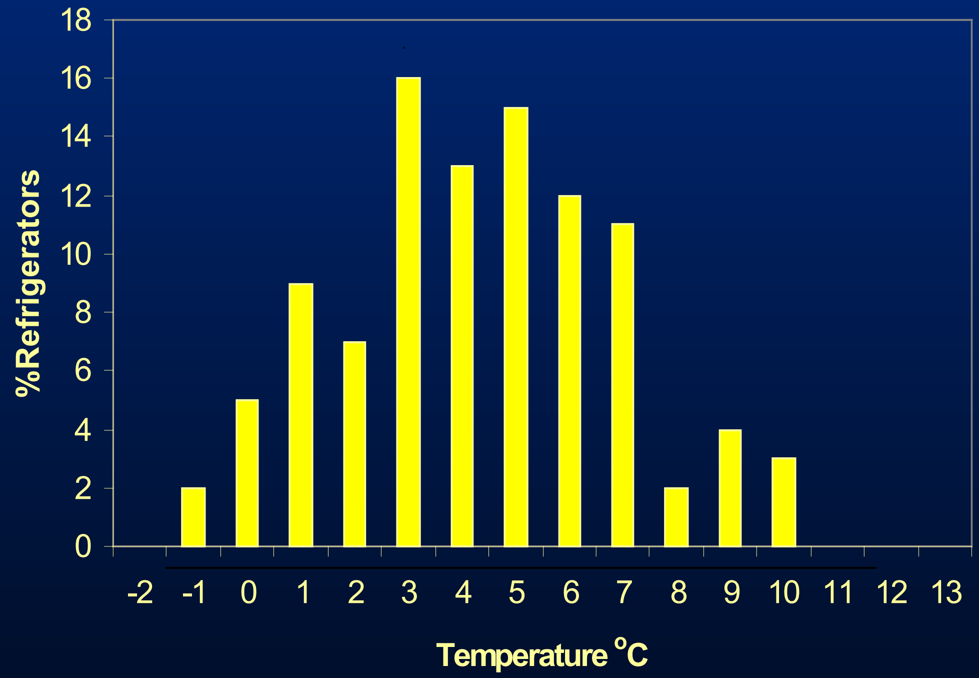
Temperature in Retail Stores



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Challenge Experiments on ground pork

Challenge Experiment 1

Temperature: 5 °C
Initial pseudomonads level: 2.5 log cfu/g
pH: 5.7

→ Self life: 7.0 days

Challenge Experiment 2

Temperature: 5 °C
Initial pseudomonads level:5.8 log cfu/g
pH: 6.4

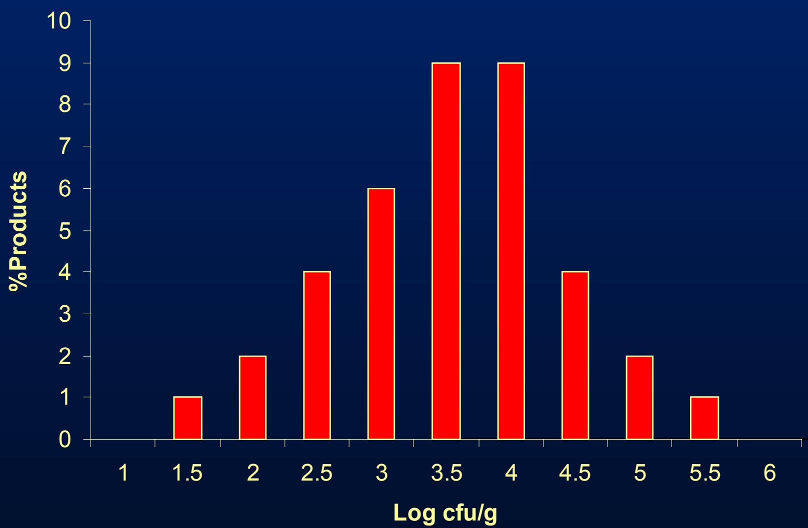
→ Self life: 2.8 days

Expiration date?

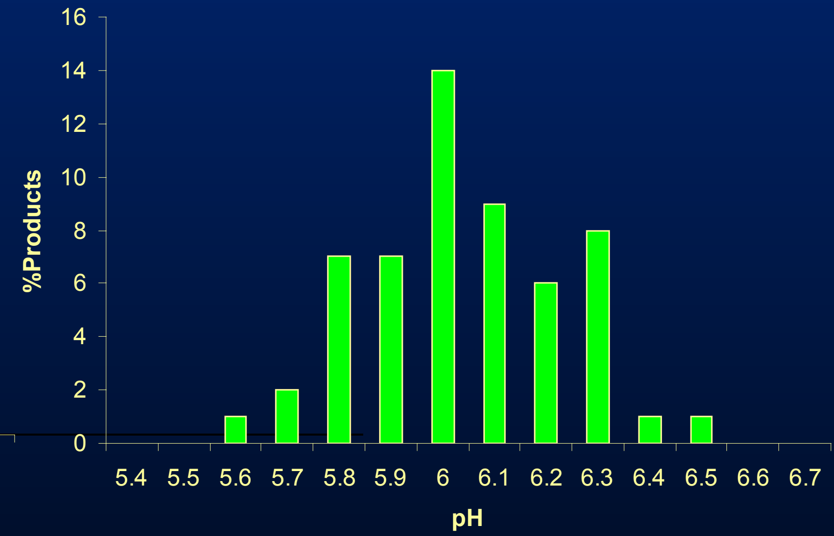
Use of spoilage modeling for effective expiration dating

Ground pork

Initial pseudomonads level



pH



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Use of spoilage modeling for effective expiration dating

"Expiration Dating"

Current method for expiration dating: Challenge tests

- **Disadvantages:**

(-) Ignores variations in initial Quality (level of SSO)

(-) Ignores variations in product characteristics (pH, a_w, etc)

(-) Ignores chill chain characteristics

→

Shelf life loss

Spoiled products

↓

Significant economic losses for Food Industry

"Quantitative Spoilage Assessment (QSA): a probabilistic approach for effective "expiration dating" of chilled products"

QSA components

Spoilage Characterization

- SSO identification
- Determination of Spoilage domain
- Determination of Spoilage level

Spoilage Quantification

- Model development for SSO
- Model Validation

Chill Chain Mapping

- Databases of temperature characteristics of the chill chain

Self life Assessment

- Estimation of self life distribution
- Establishment of expiration date

"Quantitative Spoilage Assessment (QSA)

QSA algorithm

Product characteristics (Initial quality SSO, pH)

Chill chain characteristics

Spoilage model

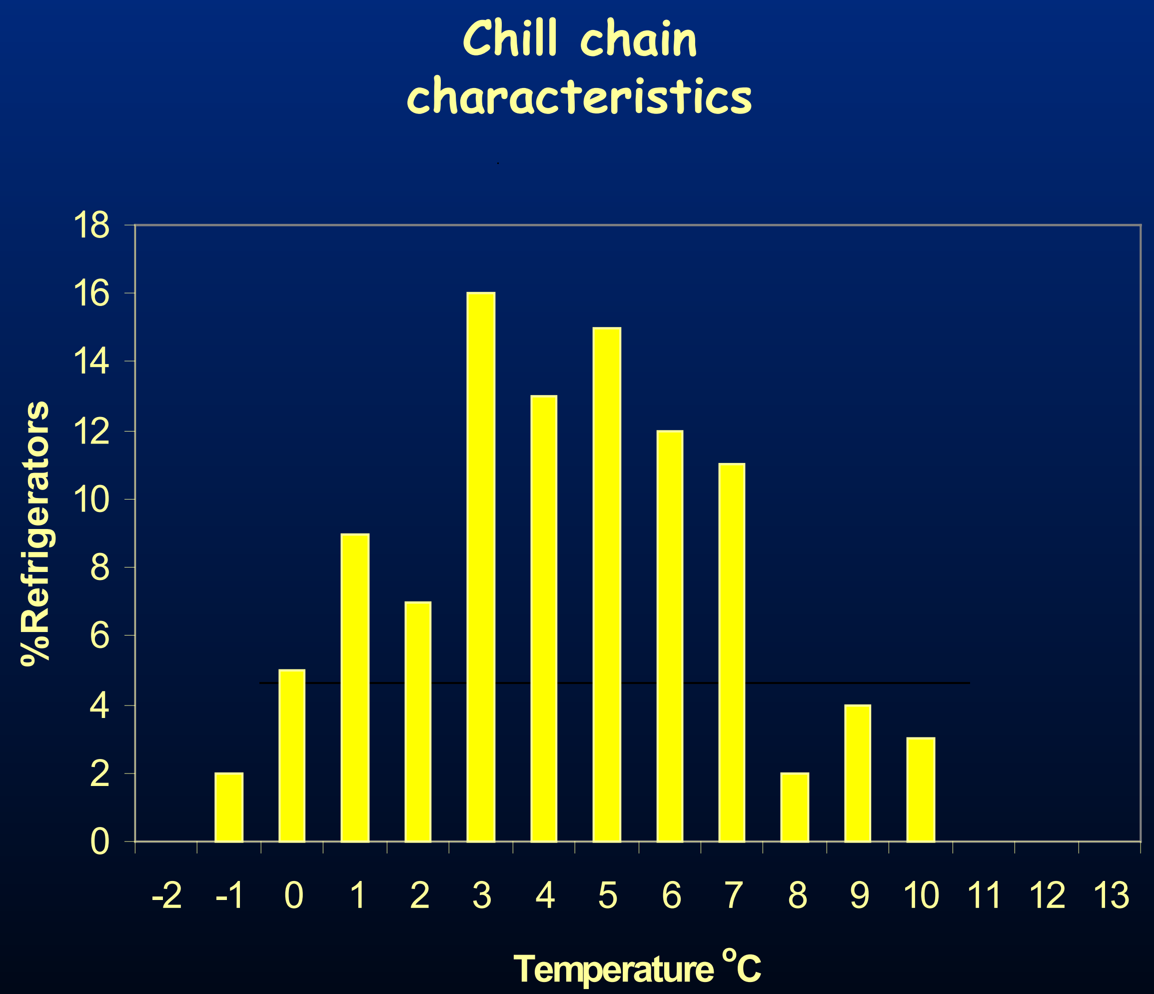
Spoilage level

Monte Carlo Simulation

Self life Assessment and Expiration Date

"Quantitative Spoilage Assessment (QSA)

QSA algorithm



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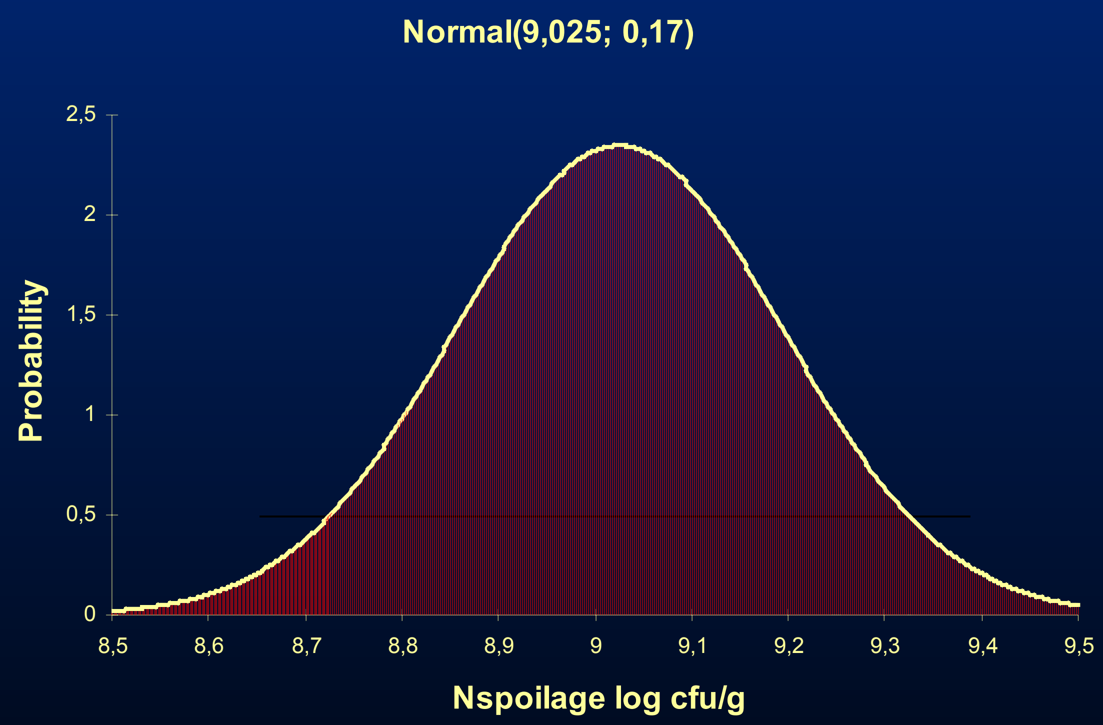
"Quantitative Spoilage Assessment (QSA)

QSA algorithm

Spoilage Level



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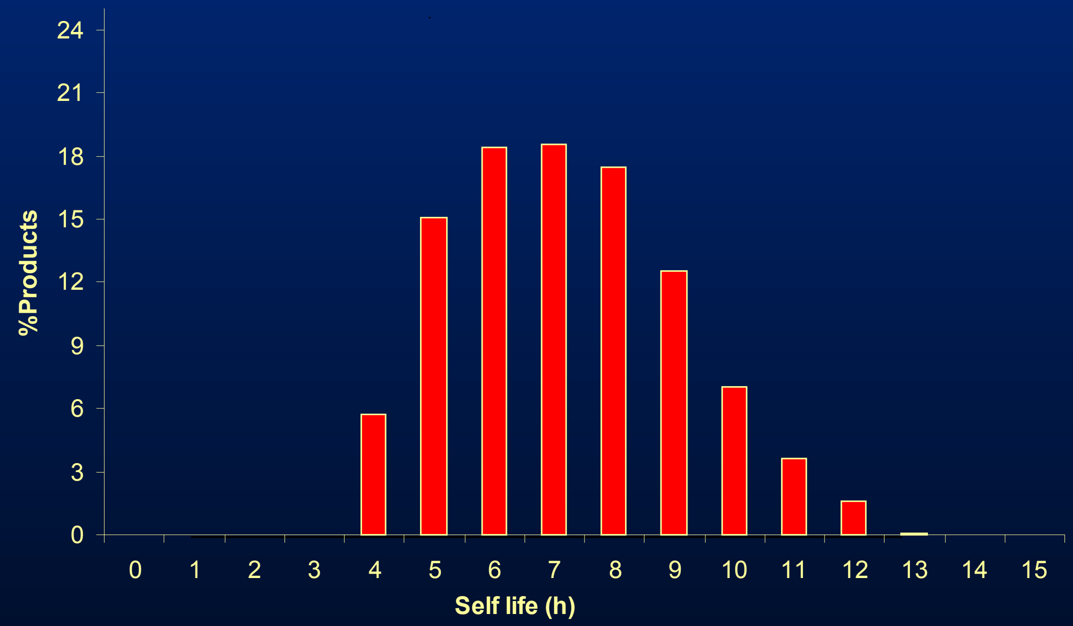
"Quantitative Spoilage Assessment (QSA)

QSA output

Distribution of Shelf life



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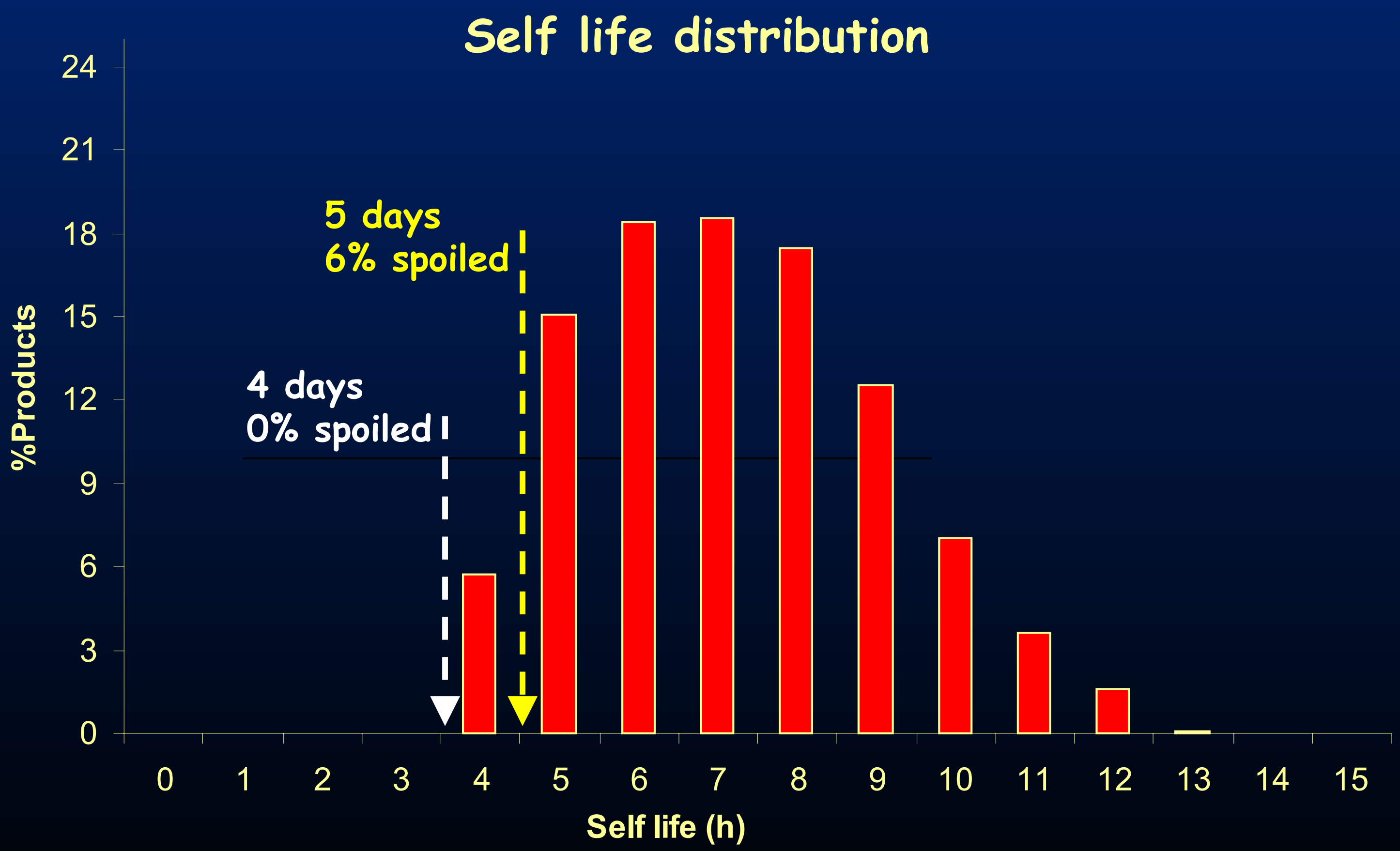
"Quantitative Spoilage Assessment (QSA)

Application of QSA on ground pork

Batch characteristics
SSO initial level: 3.5 log cfu/g
pH=6.0



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"Quantitative Spoilage Assessment (QSA)

Application of QSA on ground pork

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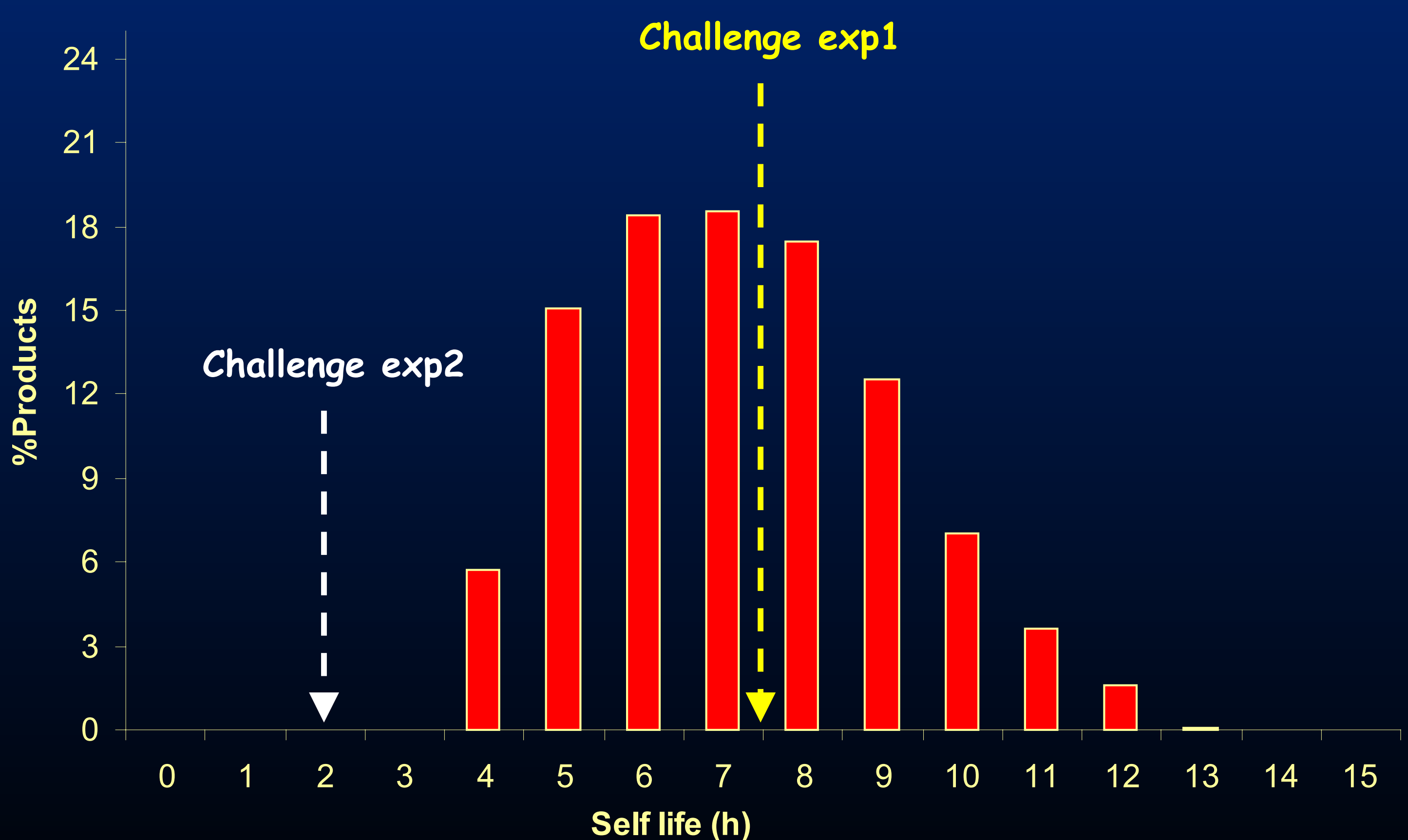

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"Quantitative Spoilage Assessment (QSA)

QSA as the basis of effective shelf life management systems

Outline

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"Quantitative Spoilage Assessment (QSA)

Application of QSA on ground pork

Batch characteristics

batch 1
pH: 5.6
No: 1.5 log cfu/g

batch 2
pH: 6.0
No: 3.5 log cfu/g

batch 3
pH: 6.4
No: 5.5 log cfu/g

Shelf life based on
Challenge test

3 days

Outline

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"Quantitative Spoilage Assessment (QSA)

Application of QSA on ground pork

Self life distribution

Batch characteristics

batch 1

pH: 5.6

No: 1.5 log cfu/g

batch 2

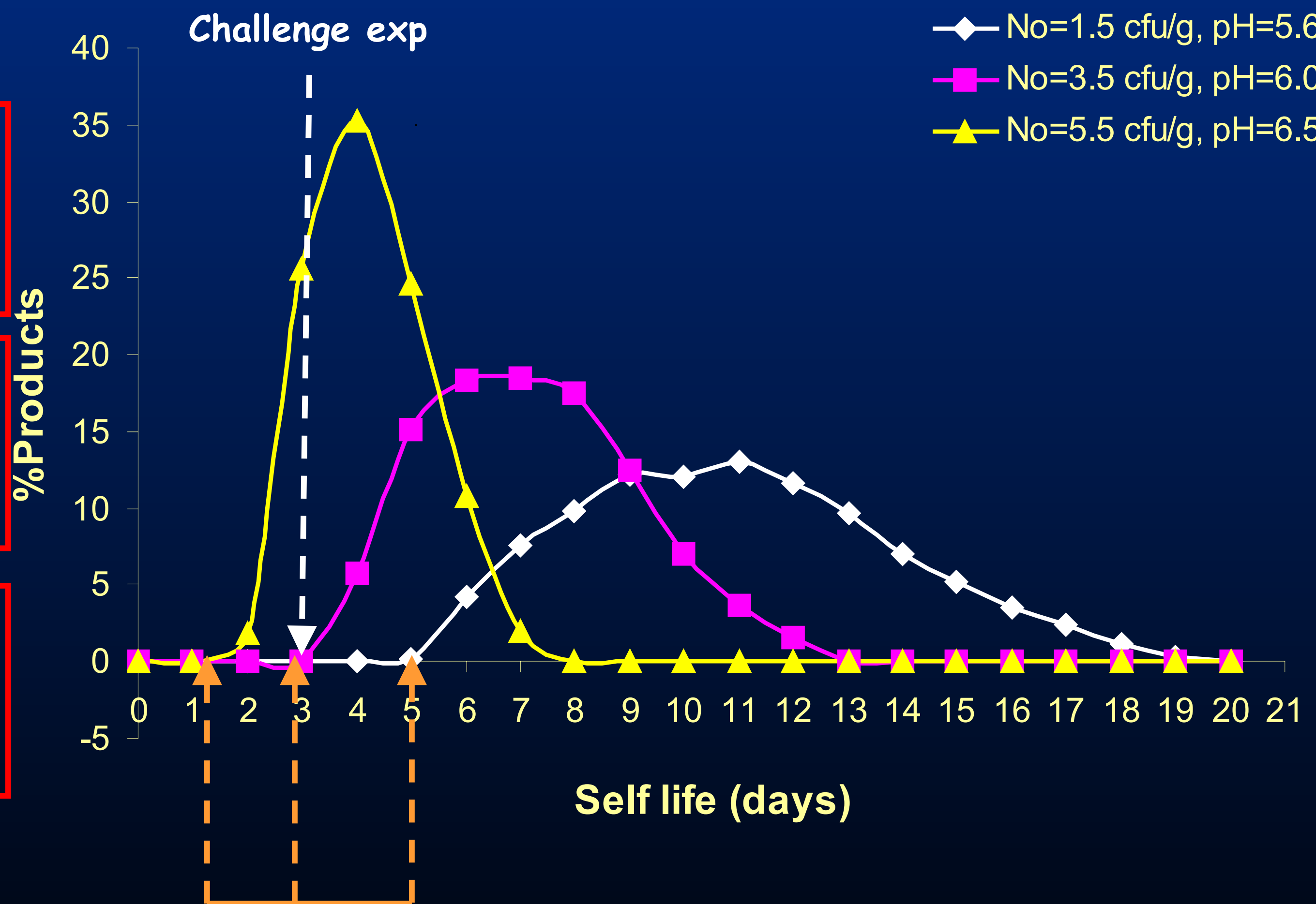
pH: 6.0

No: 3.5 log cfu/g

batch 3

pH: 6.4

No: 5.5 log cfu/g



Shelf life based on QSA

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"Quantitative Spoilage Assessment (QSA)

Application of QSA on ground pork

Batch characteristics	Shelf life based on QSA
batch 1 pH: 5.6 No: 1.5 log cfu/g	2 days
batch 2 pH: 6.0 No: 3.5 log cfu/g	3 days
batch 2 pH: 6.4 No: 5.5 log cfu/g	5 days

"Quantitative Spoilage Assessment (QSA)

Application of QSA on ground pork

Batch characteristics

pH: 6.0

No: 3.5 log cfu/g

Super market chain

Various Retail stores

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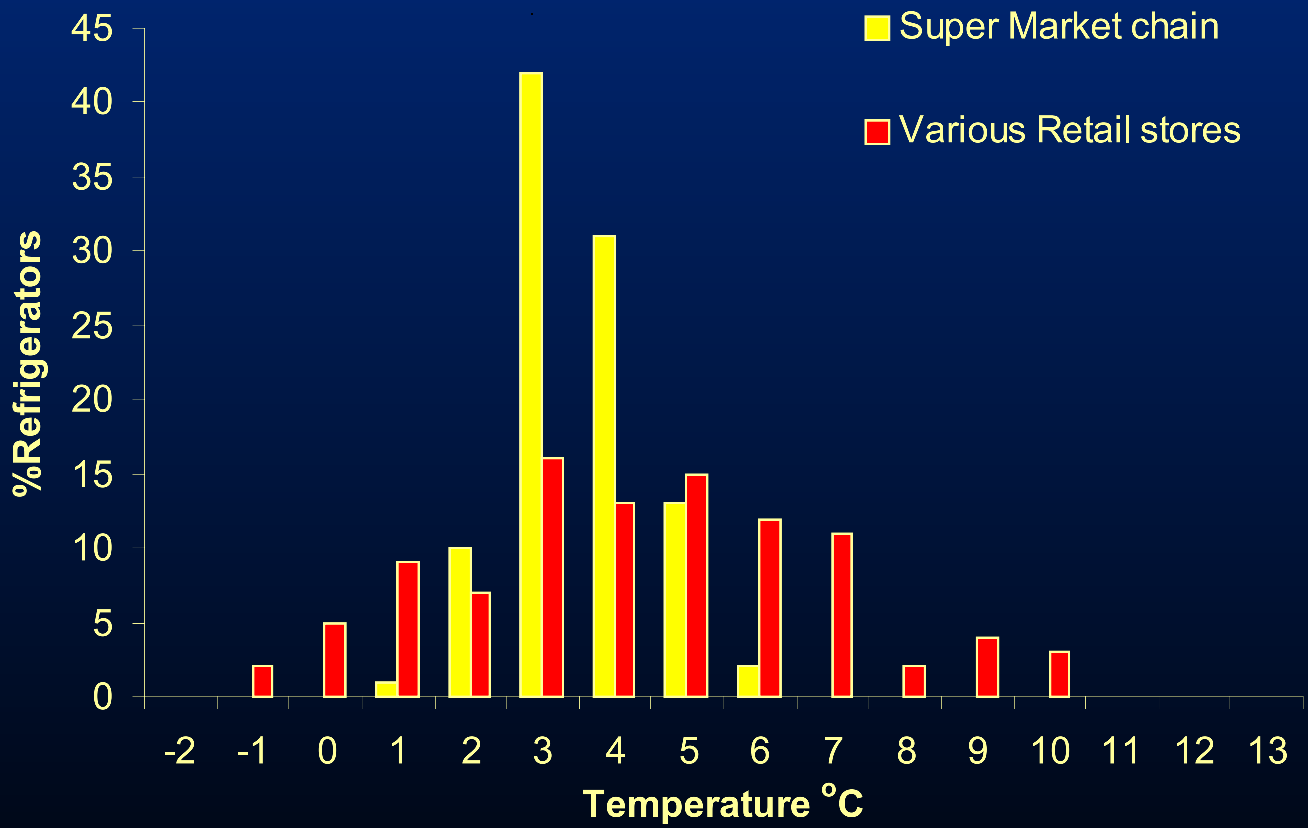
"Quantitative Spoilage Assessment (QSA)

Application of QSA on ground pork

Results from Retail Temperature Survey



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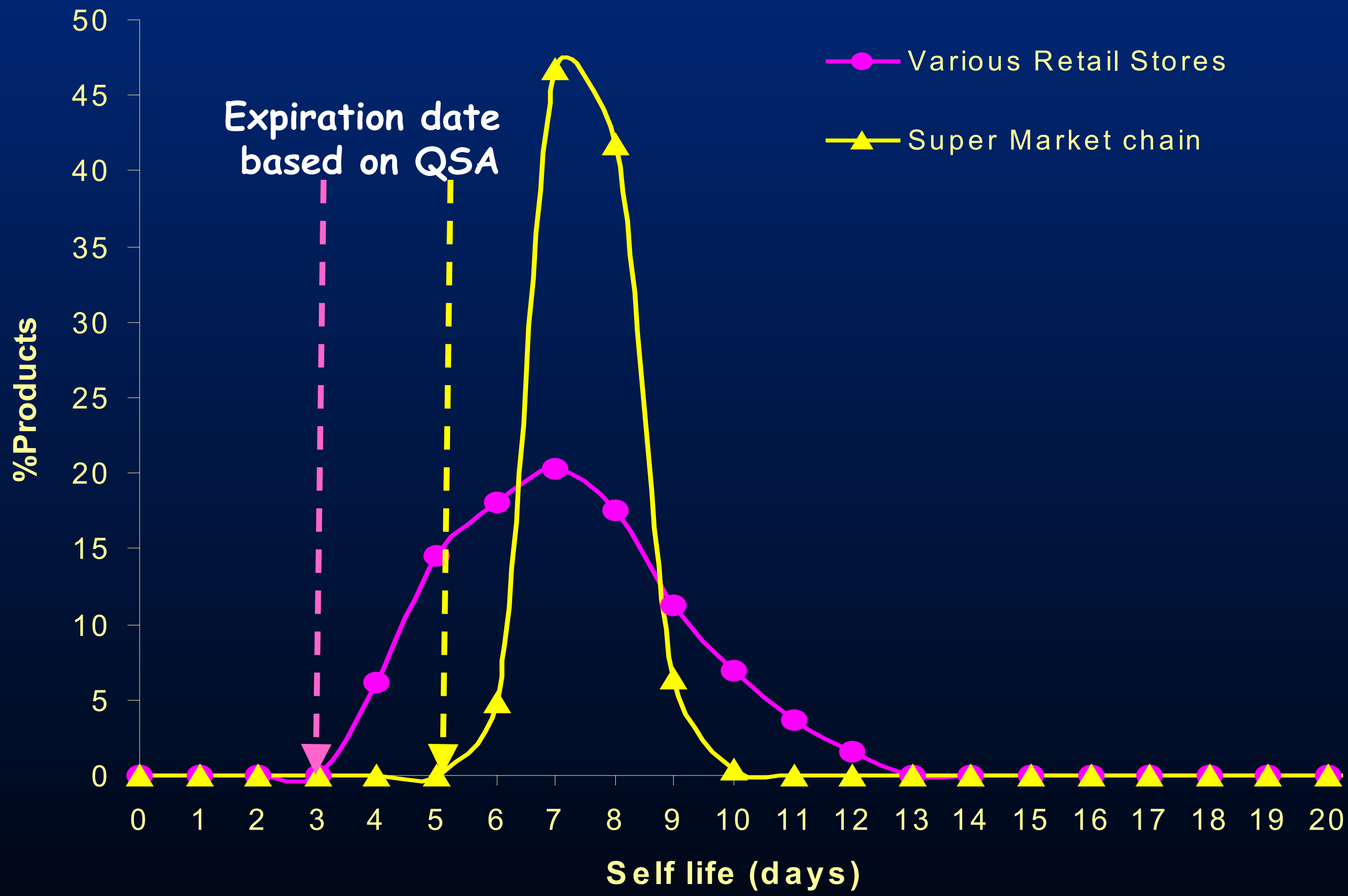
Application of QSA on ground pork



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"Quantitative Spoilage Assessment (QSA)

QSA

Spoilage Characterization ➢SSO identification ➢Determination of Spoilage domain ➢Determination of Spoilage level	**Spoilage Quantification** ➢Model development for SSO ➢Model Validation
Chill Chain Mapping ➢Databases of temperature characteristics of the chill chain	**Self life Assessment** ➢Estimation of self life distribution ➢Establishment of expiration date

➢Estimates the distribution of product self life within the chill chain

➢Allows establishment of expiration date targeted to specific batch units based on their characteristics (initial SSO level, pH, etc)

➢Allows establishment of expiration date targeted to specific chill chains (retail companies)

➢Exploitation of total self life of products

➢Minimization of spoiled products before expiration date

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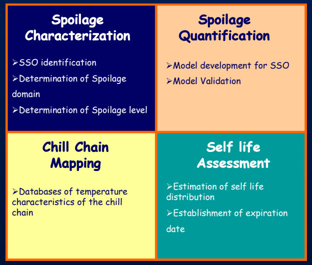
"Quantitative Spoilage Assessment (QSA)

Appropriate level of protection (ALOP)

Microbiological Risk Assessment (MRA)

Food Safety Objectives (FSO)

QSA



- Assure safety
- Improve quality
- Reduce cost due to spoilage and self life losses

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Spoilage modeling vs Risk Assessment

Spoilage modeling vs Risk Assessment

The need of introducing spoilage modeling in Risk Assessment

Spoilage modeling vs Risk Assessment

The need of introducing spoilage modeling in Risk Assessment

- In most Microbial Risk Assessment studies published up till now spoilage is not taken into account.
- As a product approaches the spoilage point the probability to be consumed decreases
- A realistic estimation of safety risk must include the identification of products with acceptable quality at the time of consumption.

Spoilage modeling vs Risk Assessment

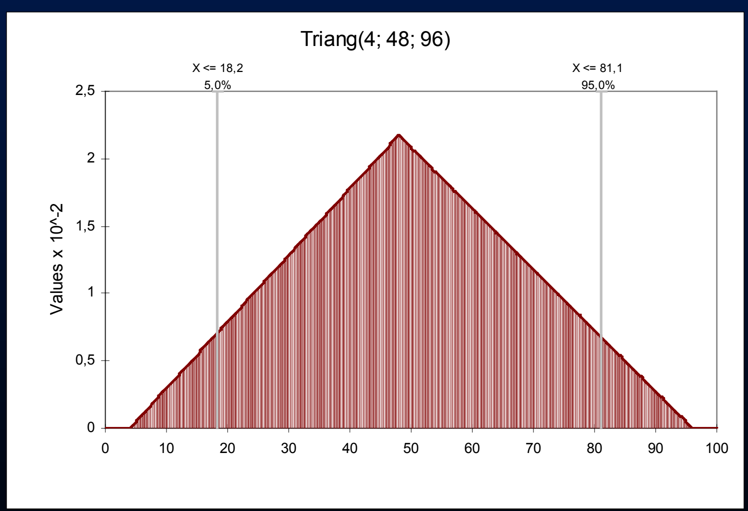
ELSEVIER International Journal of Food Microbiology 41 (1998) 21–44

Quantitative risk assessment for *Escherichia coli* O157:H7 in ground beef hamburgers

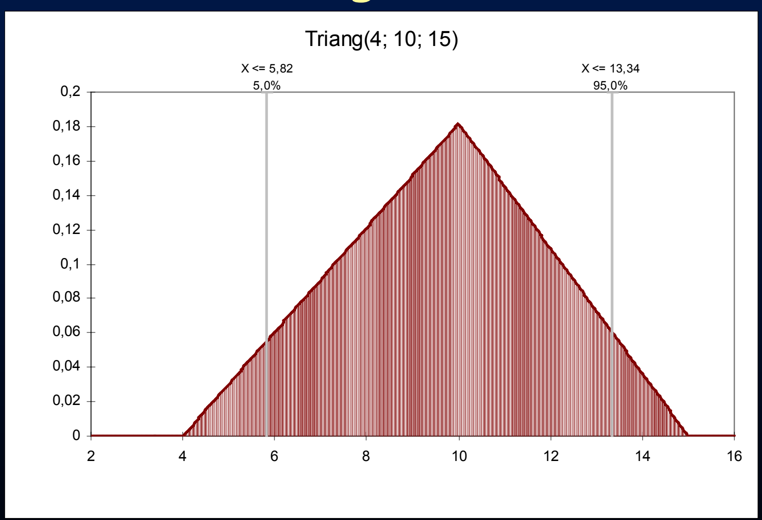
Michael H. Cassin[a], Anna M. Lammerding[b,*], Ewen C.D. Todd[c], William Ross[d], R. Stephen McColl[e]

Retail Storage Scenario

Retail Time Triang(4, 48, 96)



Retail Temperature Triang(4, 10, 15)



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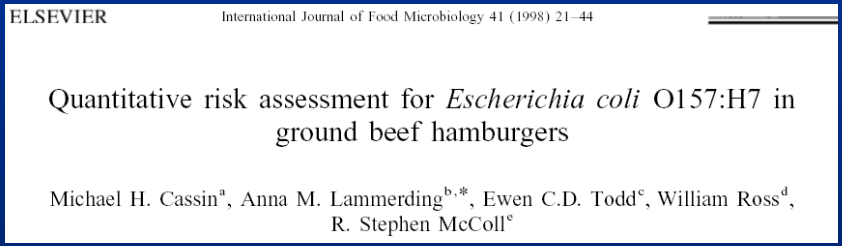
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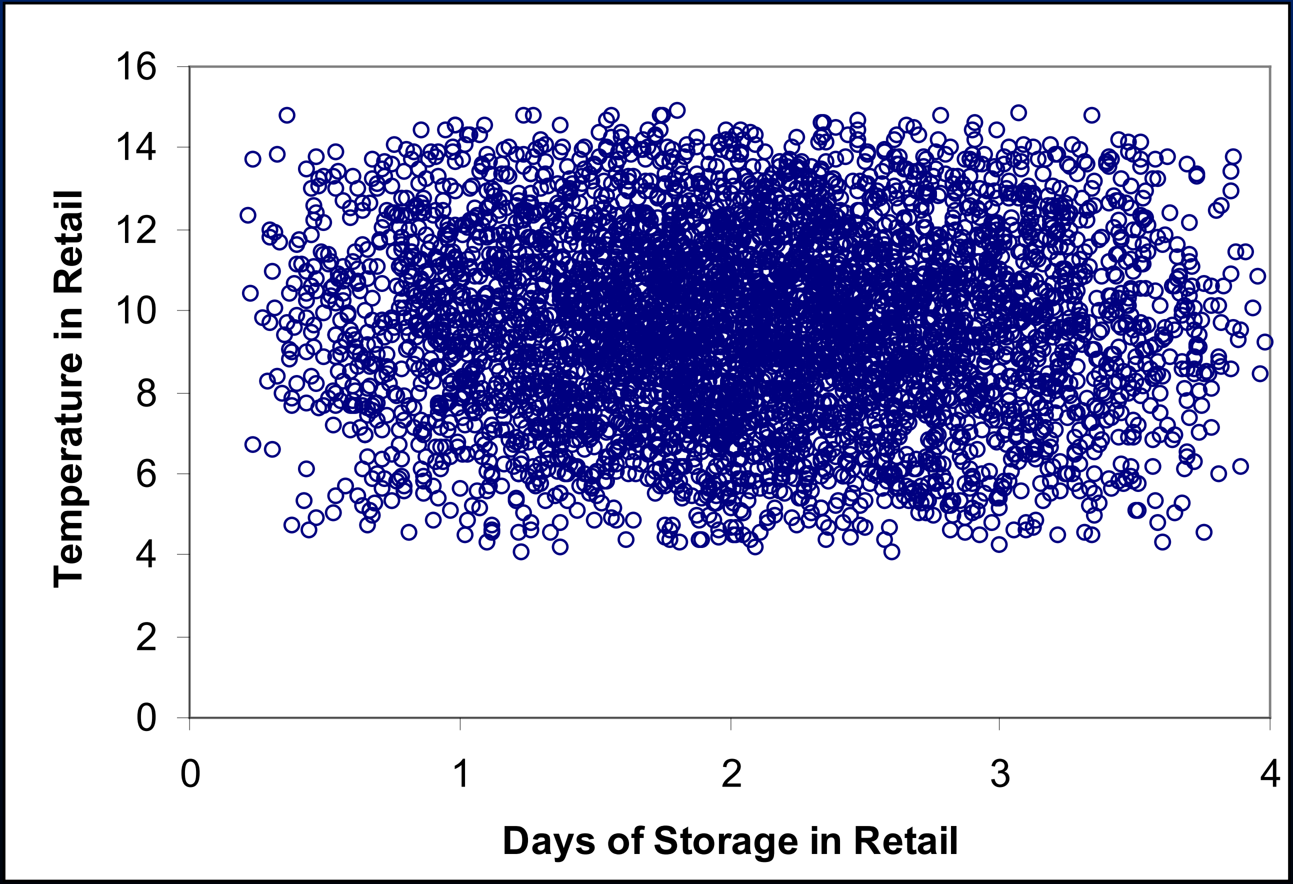

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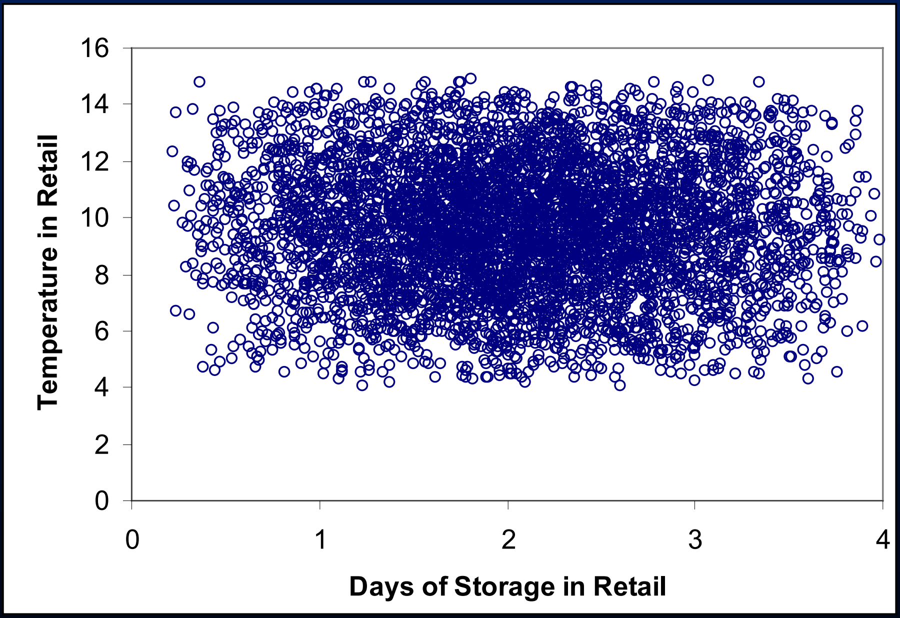

When spoilage is not taken into account Risk is calculated based on all possible time-temperature scenarios

Pitfall !!!

Some products will not be consumed due to spoilage

Outline

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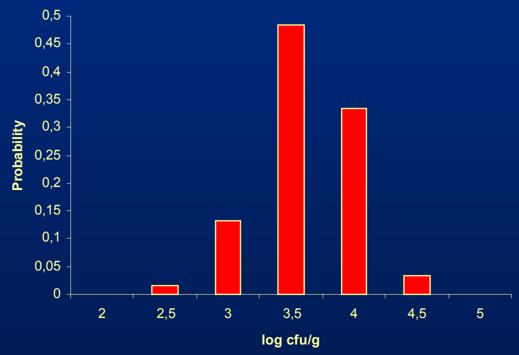
Spoilage modeling vs Risk Assessment

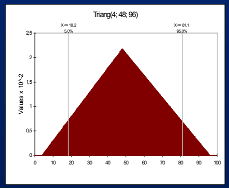
Quantitative Spoilage Assessment

Level of pseudomonads in fresh ground beef

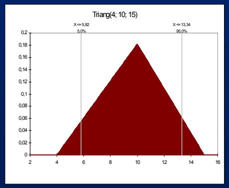


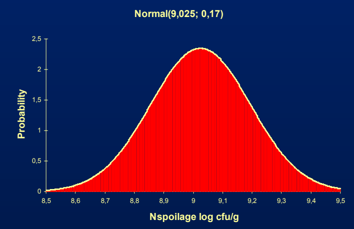
Spoilage model

Time Retail



Temperature Retail

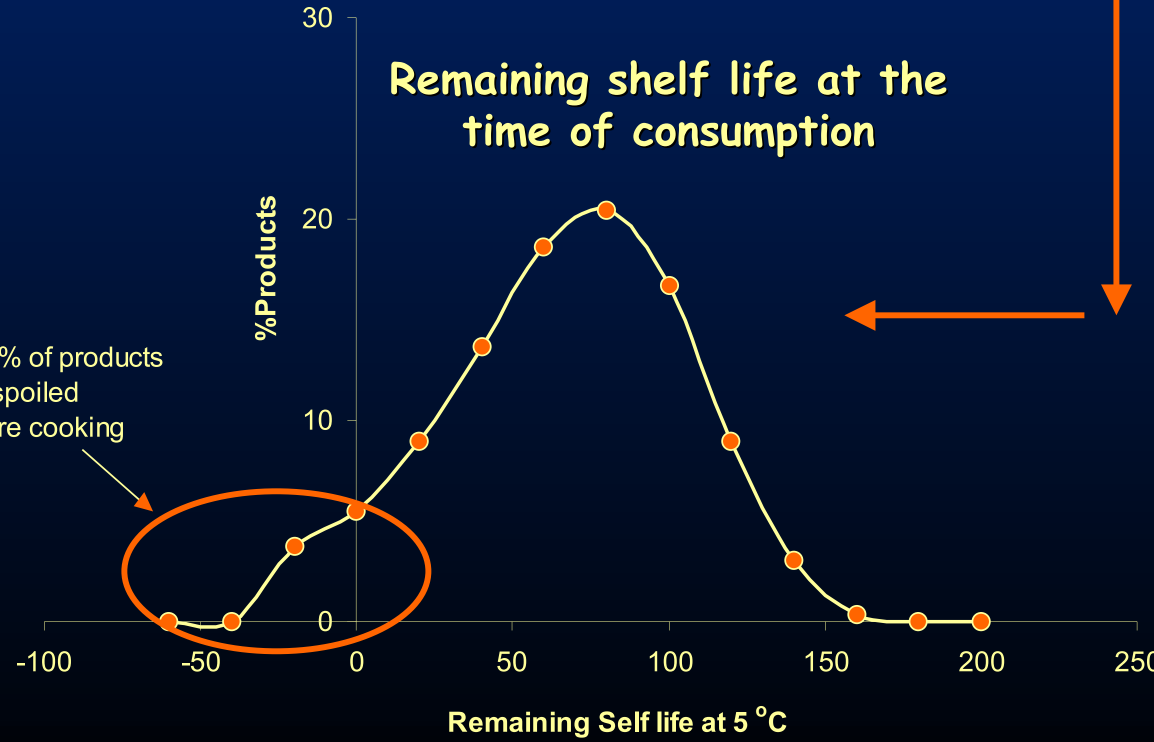




Spoilage Level

Remaining shelf life at the time of consumption

9,26% of products are spoiled before cooking



Outline

Spoilage

Spoilage modeling

Applications

Spoilage modeling vs Risk Assessment

Spoilage modeling vs Risk Assessment

Consumer attitude study

Source: SMAS project

Table 6. Mean values of consumer responses in a scale of 1 to 10.

Question	Swe	IE	NL	GR
Knowledge and opinion of fresh packaged meat				
I always find the information I need on a meat package	6.9[a]	8[b]	7.9[b]	7.7[b]
I always look at the use-by (or best before) date label	9.5[a]	9.5[a]	9.7[a]	9.6[a]
I want to able to visually check the visual freshness of the meat	9.5[a]	9.5[a]	9.3[a]	9.2[a]
I always store fresh meat in a fridge	8.7[a]	9.5[a]	8.2[a]	9.2[a]
I often freeze my meat at home	6.5[a]	8.2[b]	6.9[a]	8.0[b]
Fresh meat left out of the refrigerator loses its freshness	9.4[a]	9.3[a]	9.7[a]	9.3[a]
I always smell the meat to assess the freshness before use	6.6[a]	6.2[a]	4.9[b]	8.4[c]
I believe that temperature conditions in the chill chain often deviate from the recommended ones	7.3[a]	7.2[a]	5.4[b]	8.2[c]
I care about the health aspect of fresh meat	9.6[a]	9.3[a]	9.3[a]	9.5[a]

Spoilage modeling vs Risk Assessment

The need of taking into account spoilage in Risk Assessment

↓

Combining data and models for both spoilage and pathogenic bacteria

Spoilage modeling vs Risk Assessment

ELSEVIER International Journal of Food Microbiology 41 (1998) 21–44

Quantitative risk assessment for *Escherichia coli* O157:H7 in ground beef hamburgers

Michael H. Cassin[a], Anna M. Lammerding[b,*], Ewen C.D. Todd[c], William Ross[d], R. Stephen McColl[e]

Contamination of fresh ground beef

E. coli 157:H7

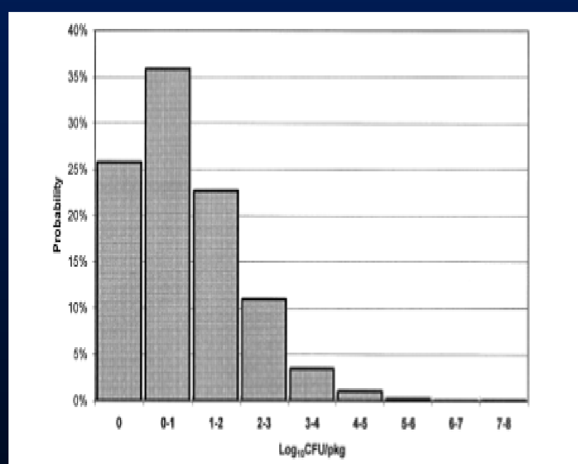
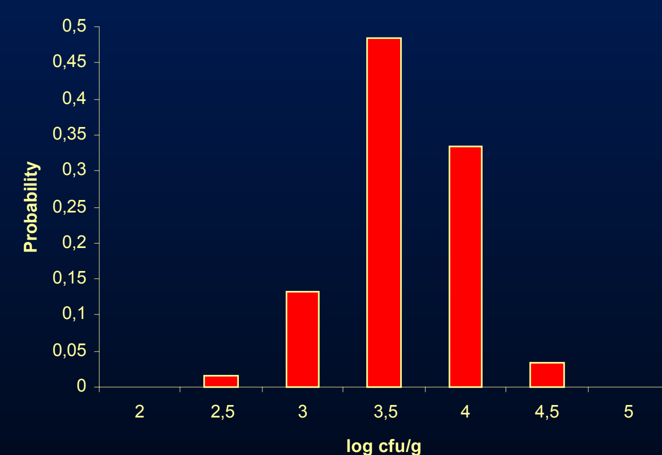


Fig. 3. Predicted total $\log_{10}$ CFU of *E. coli* O157:H7 in a contaminated package of fresh retail ground beef.

SSO (pseudomonads)



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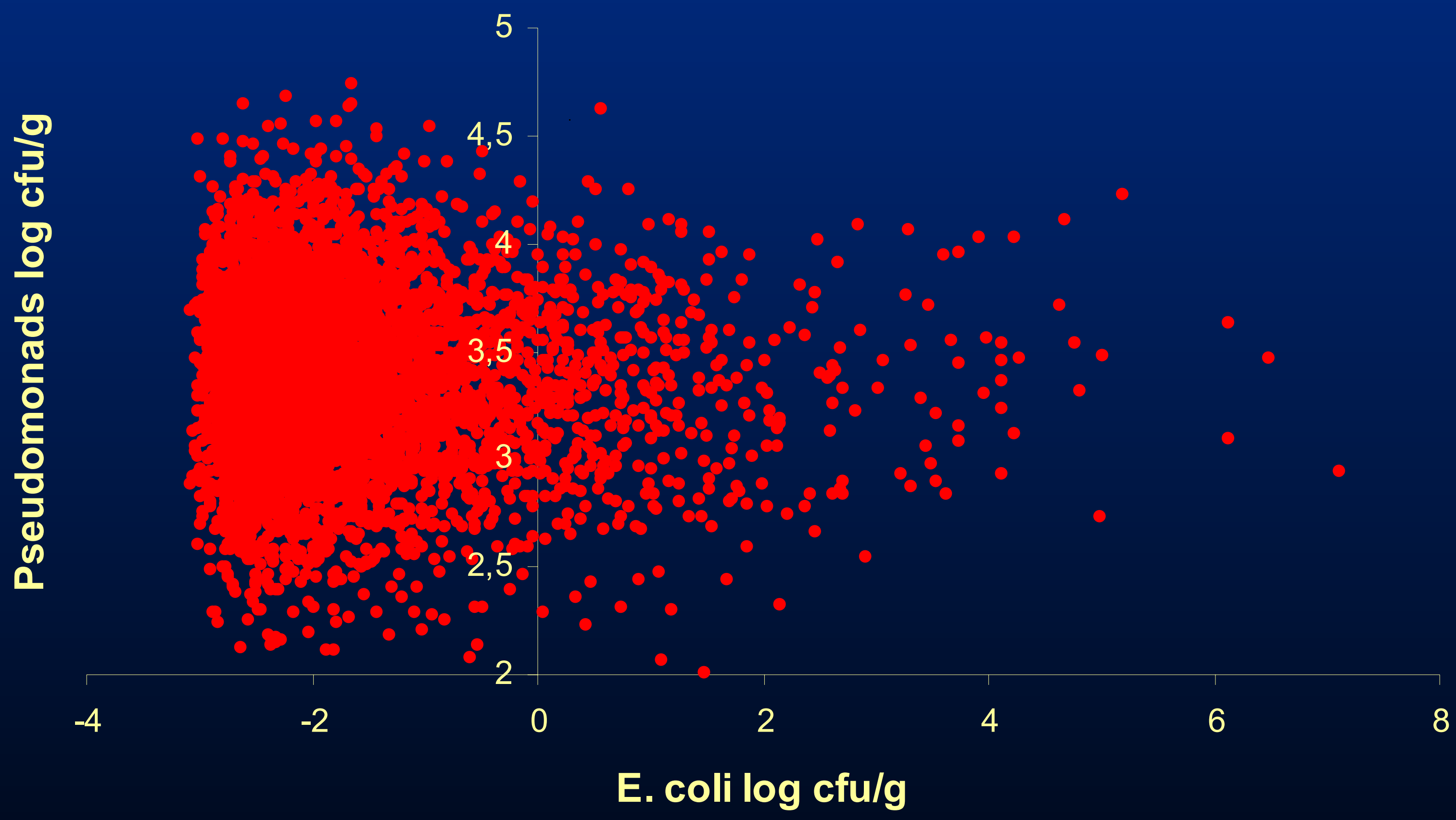
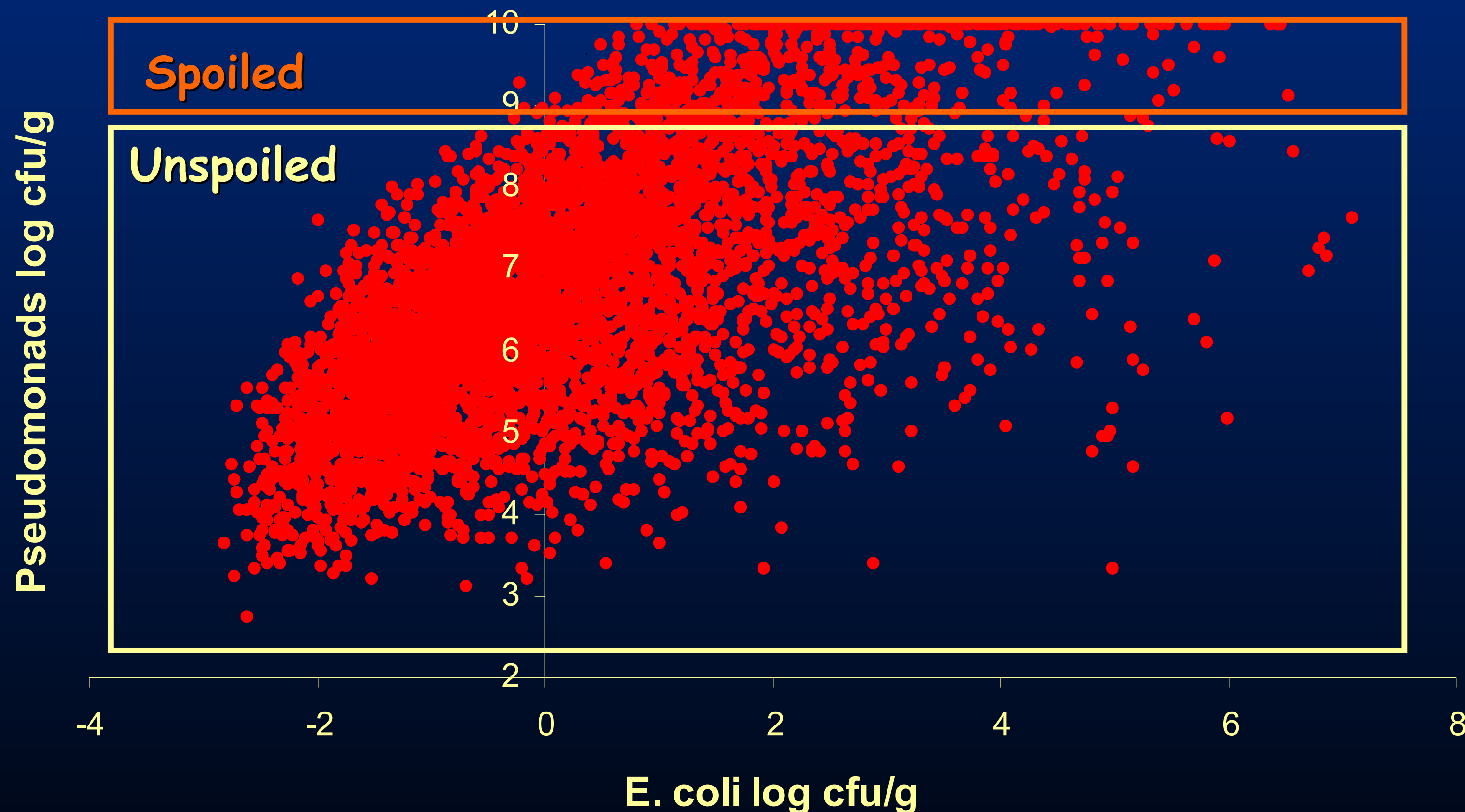


Spoilage modeling vs Risk Assessment

Contamination of ground beef at the time of consumption (before cooking)



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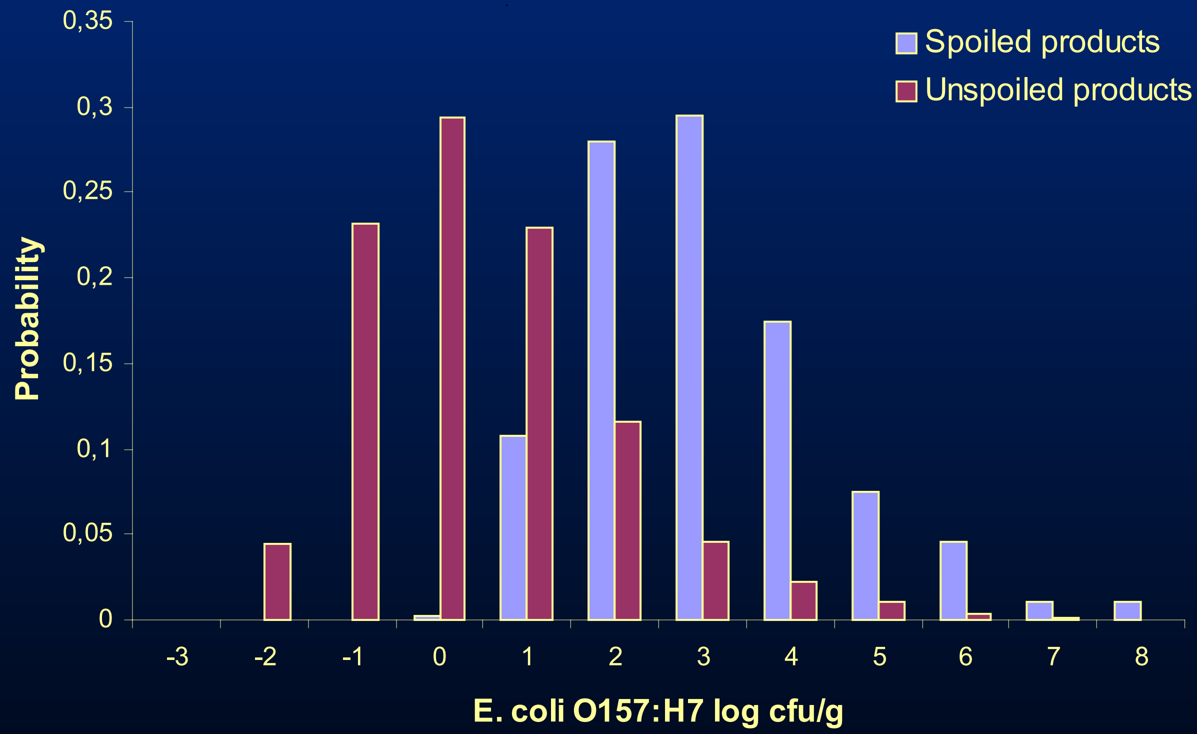
Contamination of ground beef at the time of consumption (before cooking)



Spoilage modeling vs Risk Assessment

The need of taking into account spoilage in Risk Assessment

Ignoring spoilage in risk assessment may lead to significant overestimation of risk

Predicting the shelf life of chilled products

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Aristotle University of Thessaloniki,
Dpt. Of Food Science and Technology

thank you

ευχαριστώ

International Workshop
Quality Management of the Chill Chain
Athens 2005