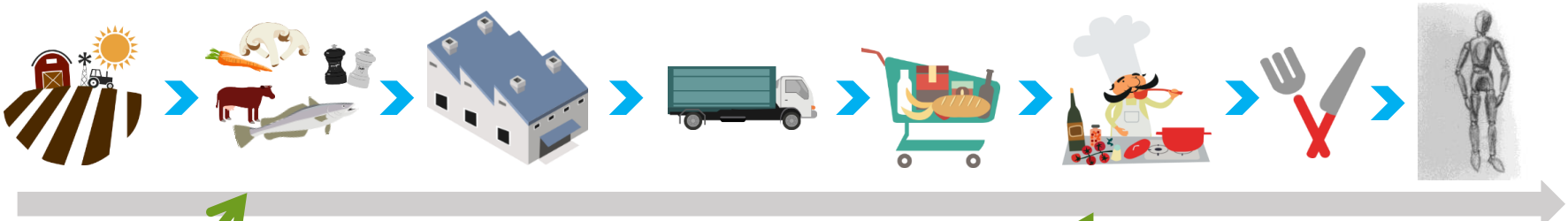
The importance of Predictive Microbiology in Food Safety

Jeanne-Marie Membré

13 June 2017

Food chain production and consumption



Level and frequency of mo in raw materials

Process: Heat treatment

Formulation: pH, water activity

Packagin g

Preservatives

Supply-chain

Shelf-life

Ambient or chilled Storage

Food Safety

Food safety is about **handling, storing and preparing food** to prevent infection and help to make sure that our food keeps enough nutrients for us to have a healthy diet

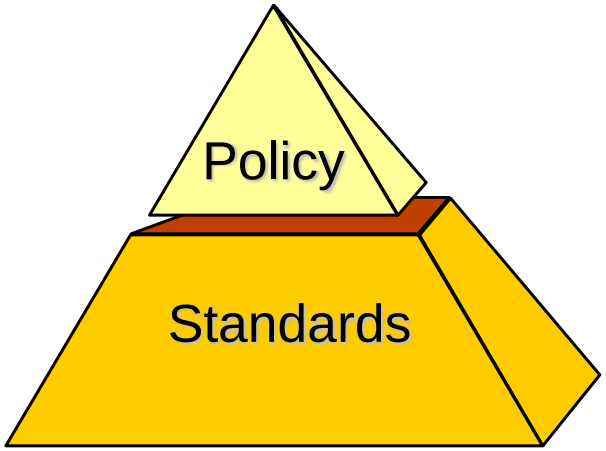
Food and Agriculture organization (FAO)

Food Safety Management System (FSMS) provides a preventative approach to identify, prevent and reduce food-borne hazards.

- This is **to minimize the risk of food poisoning and to make food safe for consumption**.
- A well designed FSMS with appropriate **control measures** can help food establishments comply with food hygiene regulations and ensure that **food prepared for sale is hygienic and safe for consumers.**

Food Safety management

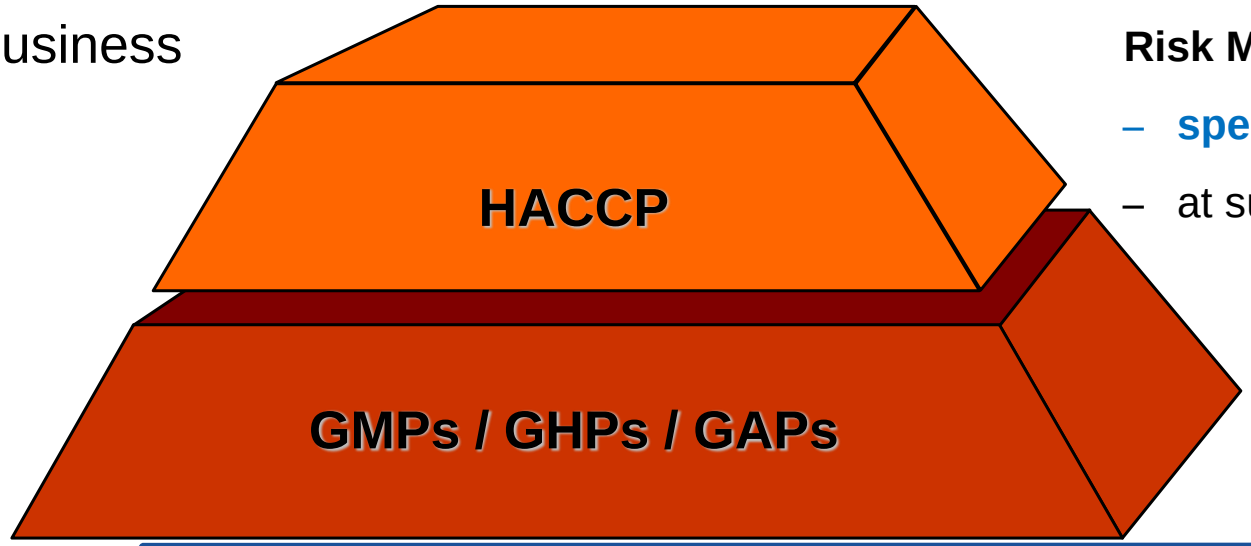
Country level



Risk Management:

- **high level, generic**
- policy bases guidance
- specific standards, criteria

Food business level

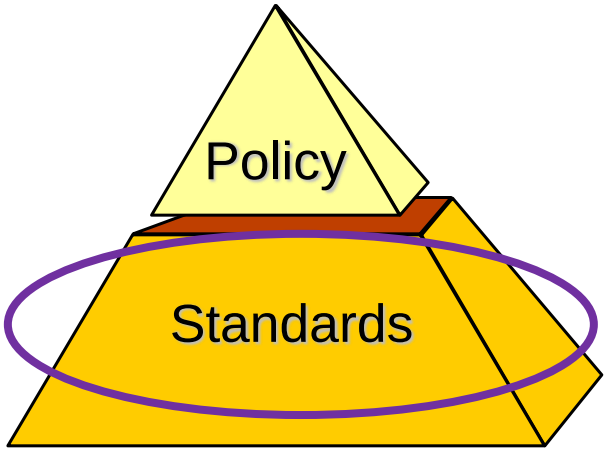


Risk Management:

- **specific**
- at supply-chain level

Food Safety management

Country level



Risk Management:

- high level, generic
- policy bases guidance
- specific standards, criteria

Performance process Standards: Generally recognized processes that have been established by consensus or by regulation, for example:

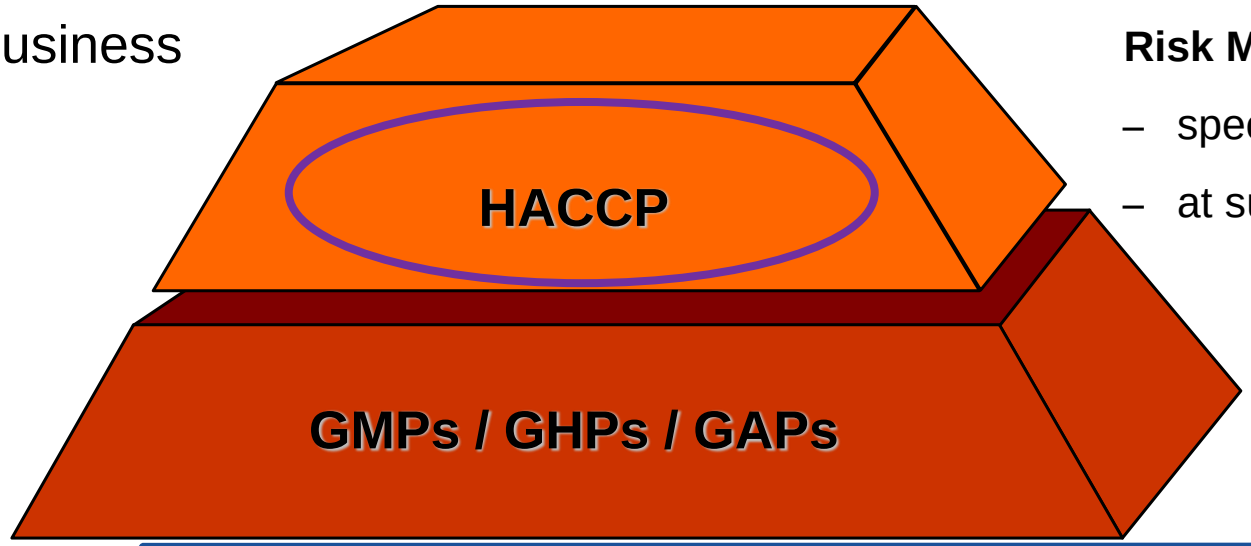
- **Sterilization of ambient stable non acidic food**
  - **3 min at 121.1°C (F_0 3 min) → proteolytic *C. botulinum***

Food Safety management

HACCP consists of seven basic principles, which can be summarized schematically into the three following steps:

- Conduct a hazard analysis.
- **Determine the critical control points (CCPs), e.g. temperature, time, moisture level, water activity, pH… and establish critical limit(s)**
- Develop a HACCP plan form

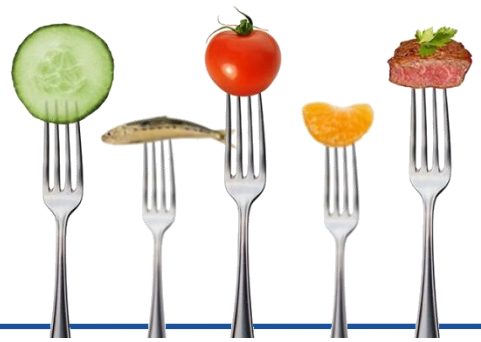
Food business level

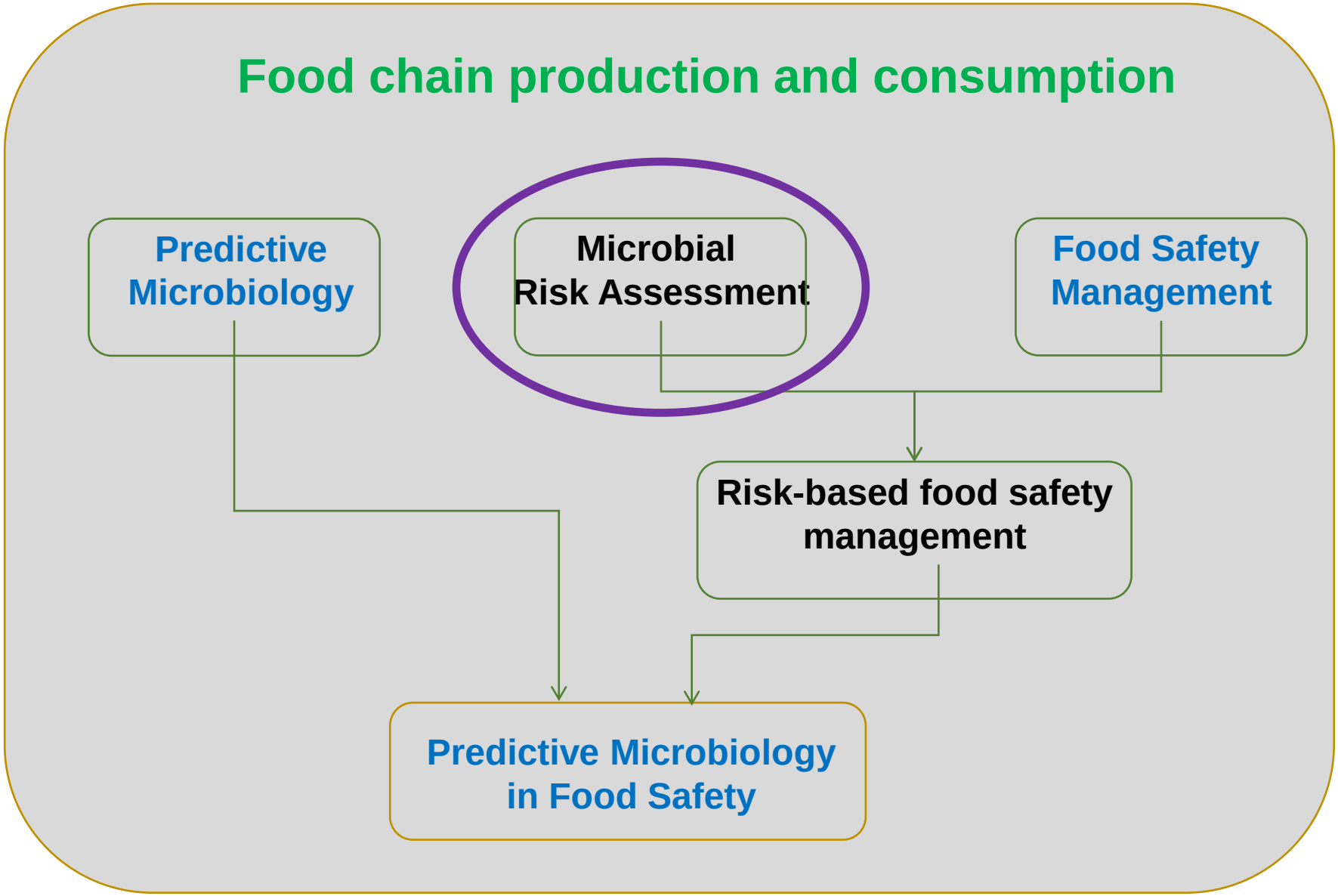


Risk Management:

- specific
- at supply-chain level

Risk assessment and risk-based food safety management

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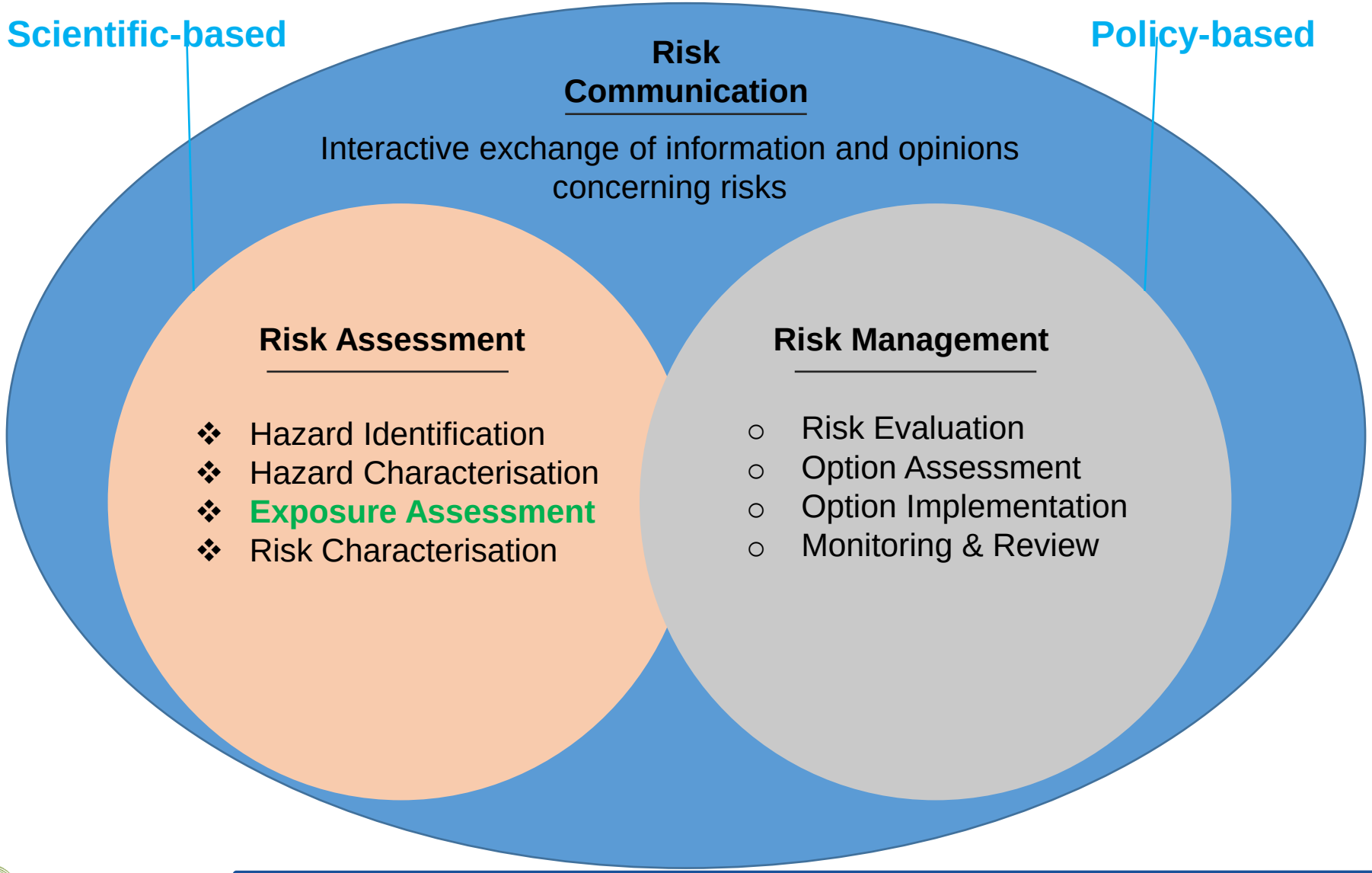
Food Safety Management
Risk-based food safety management
Predictive Microbiology in Food Safety

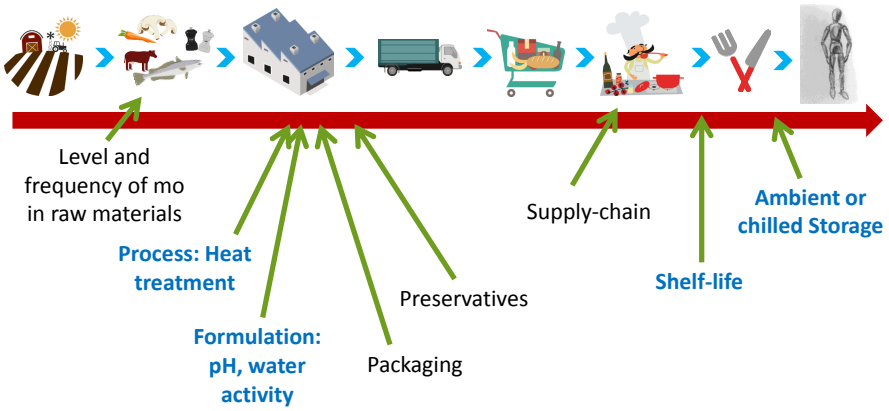
Risk Analysis



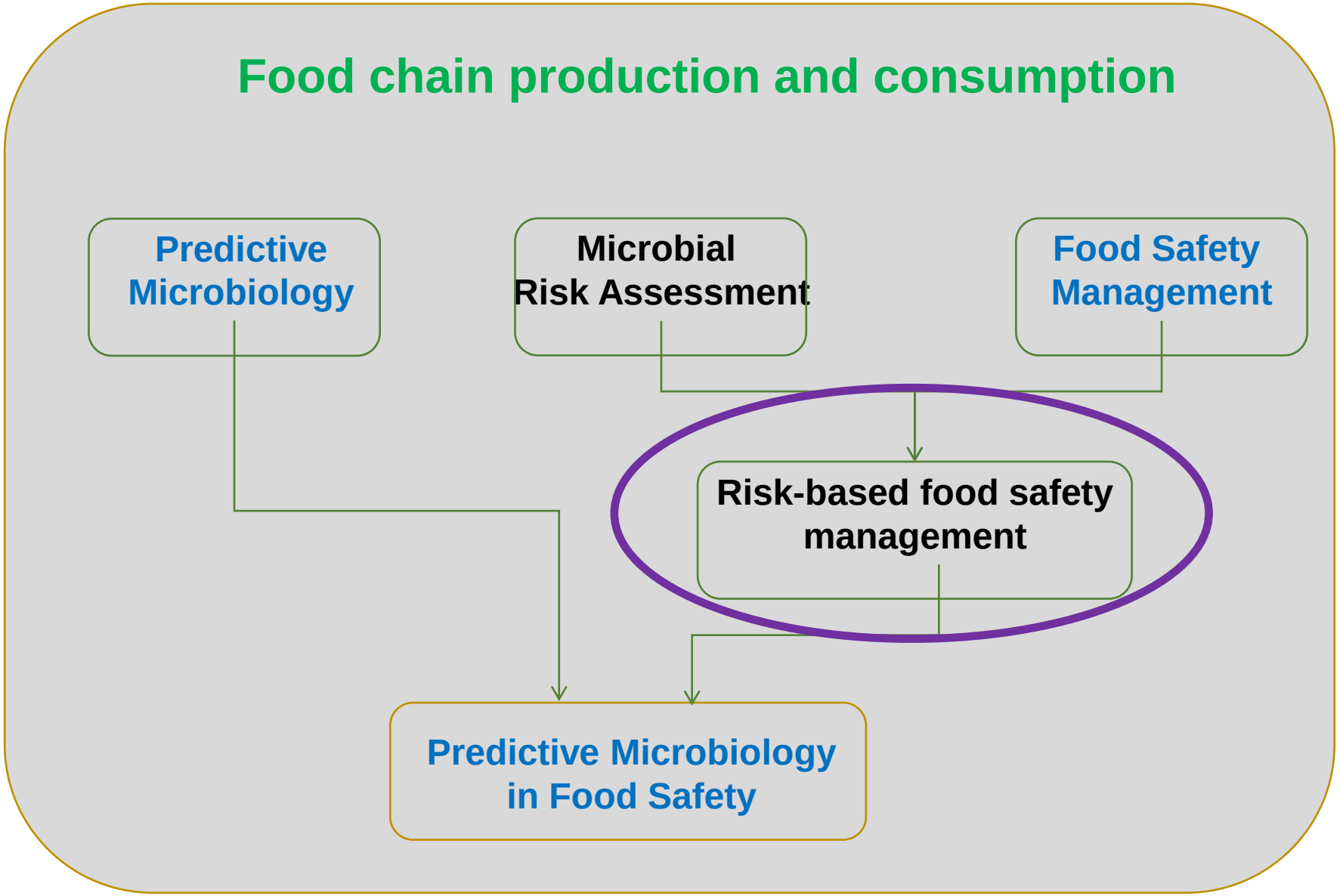
Exposure assessment

Factors to take into account:

- Propagation of microorganisms (hazard) along the food supply-chain (transformation/distribution/consumption)



- Quantity eaten (portion and frequency)
- Number of exposed people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Risk-based food safety management

Public Health Risk Level

RISK ANALYSIS

Decisions?

Risk < ALOP: e.g. no action needed

Risk = ALOP: e.g. no action needed

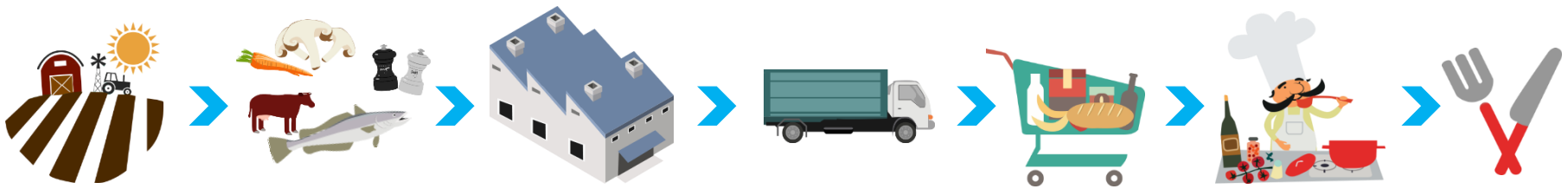
Risk > ALOP: e.g. risk reduction action needed

ALOP[1] or public health goal

FSO[1]

[1]: ALOP, Appropriate Level Of Protection

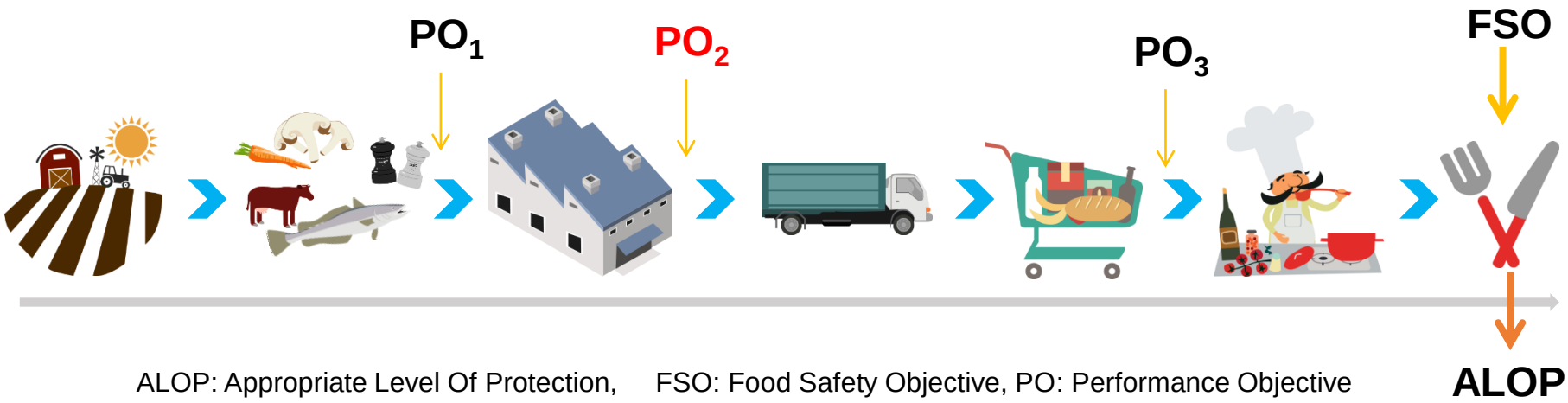
FSO, Food Safety Objective



Risk-based food safety management

- **Food Authority** :
  - Concerned by foodborne pathogens
  - Set **ALOP**
    - e.g.: 0.2 cases of Listeriosis per 100 000 people per year

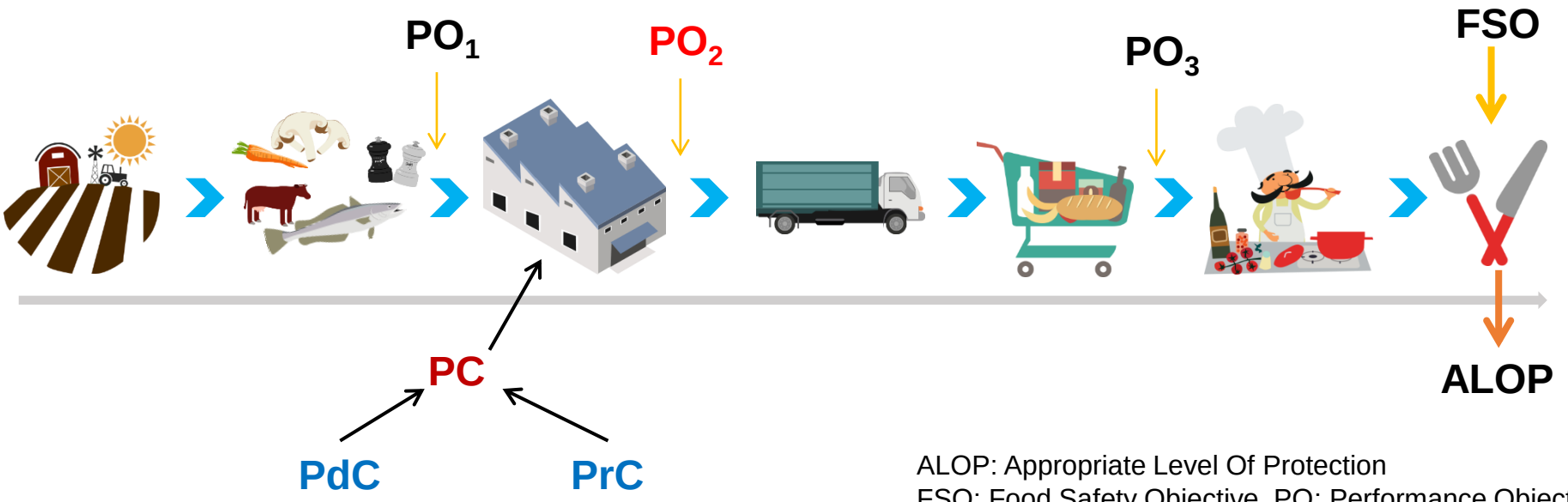
  - To achieve compliance with **ALOP** ➔ Set **FSO** and may set **PO**
    - e.g. FSO as < 100cfu/g of *Listeria* at the point of consumption
    - e.g. PO_2 as < 10cfu/g of *Listeria* at the manufacture release



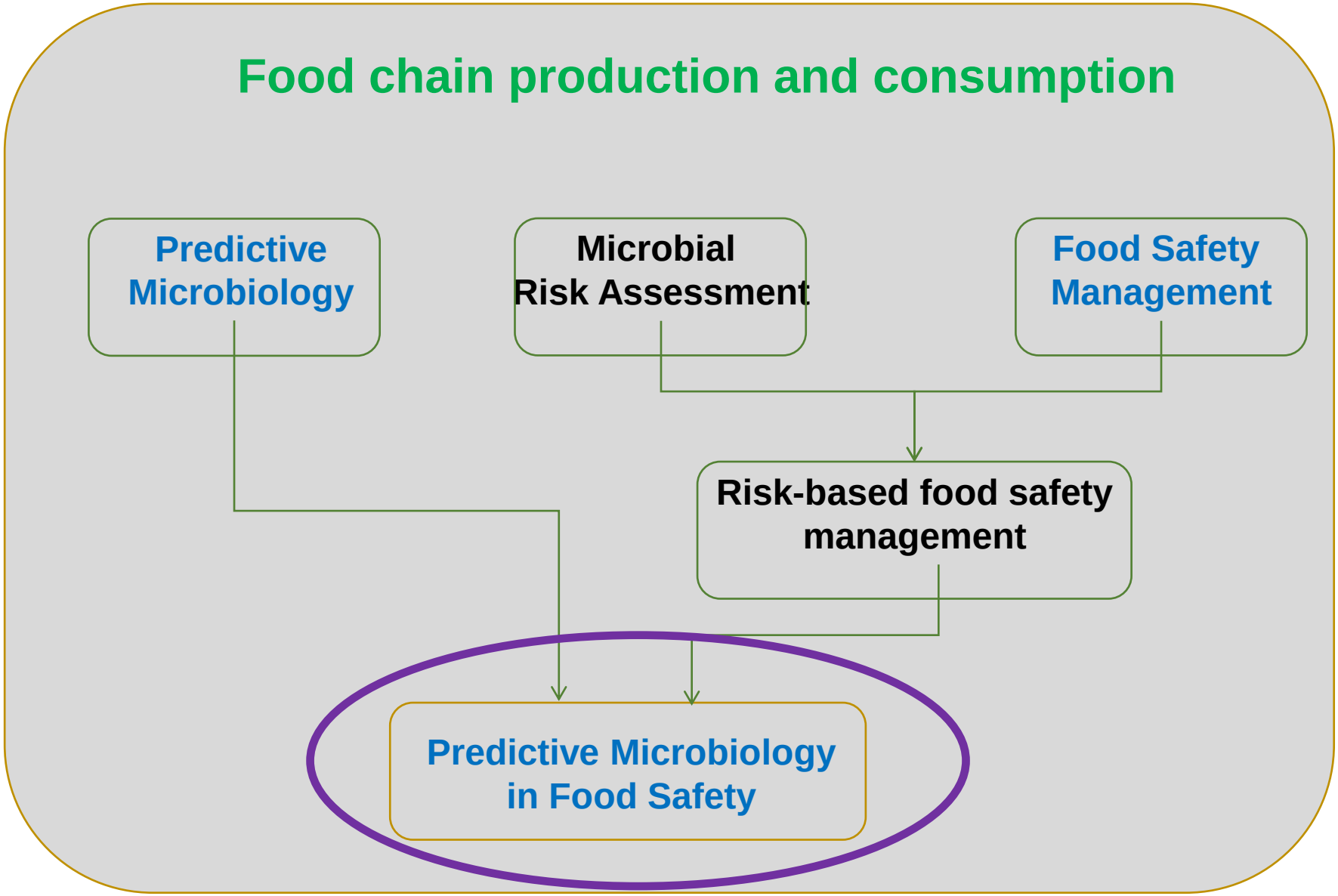
ALOP: Appropriate Level Of Protection, FSO: Food Safety Objective, PO: Performance Objective

Risk-based food safety management

- **Food business operator :**
  - set **Performance Criteria** (PC) to comply with PO/FSO
    - e.g. : PC as < 1 log of growth during food preparation in plant
  - Set **Product criteria** (PdC) and **Process criteria** (PrC) to achieve a PC
    - **PdC**: e.g. pH=5, **PrC:** e.g. T<8°C in manufacturing area



ALOP: Appropriate Level Of Protection
FSO: Food Safety Objective, PO: Performance Objective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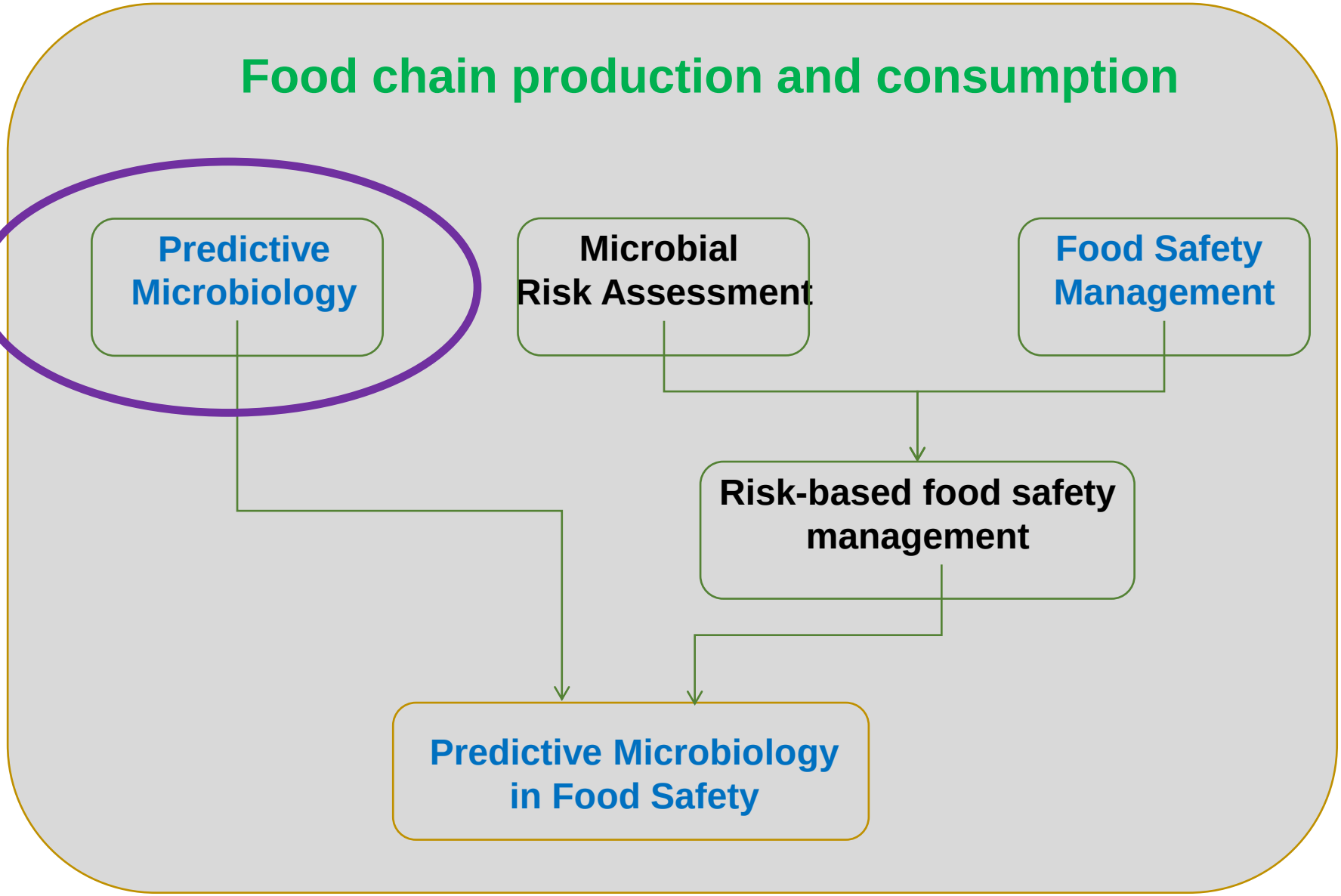
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Predictive Microbiology

Predictive microbiology is a description of the responses of microorganism's to particular environmental conditions such as

- Temperature: storage at cold or ambient conditions, but also heat-treatment (during manufacture process)
- pH and organic acid (for example in dressings), but and more generally preservatives (e.g. nitrite in pork meat)
- water activity (for example in bakery products)

Predictive microbiology utilises mathematical models (built with data from laboratory testing) and computer software to graphically describe these responses

Adapted from Food Safety Authority of Ireland

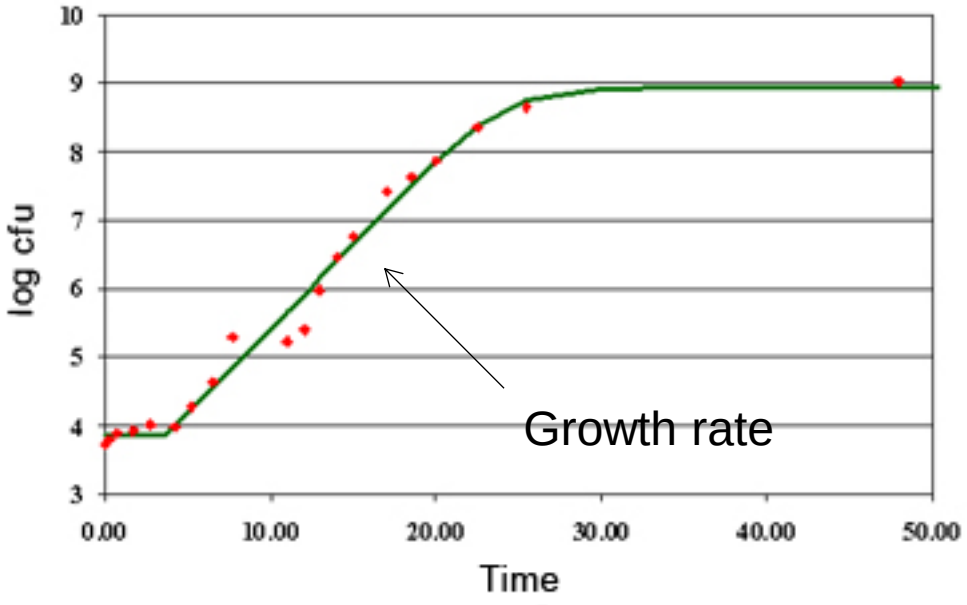
Predictive Microbiology

Three modelling steps

- Primary models: describing the microbial concentration (behaviour: growth, inactivation, survival) as a function of time. Estimate kinetic parameters
- Secondary models: describing kinetic parameters as a function of environmental conditions (e.g. temperature, pH, water activity)
- Tertiary models: integrate primary and secondary models in software tools, with friendly interfaces for use by non-modellers but Food Safety assessors, R&D managers, Quality managers…

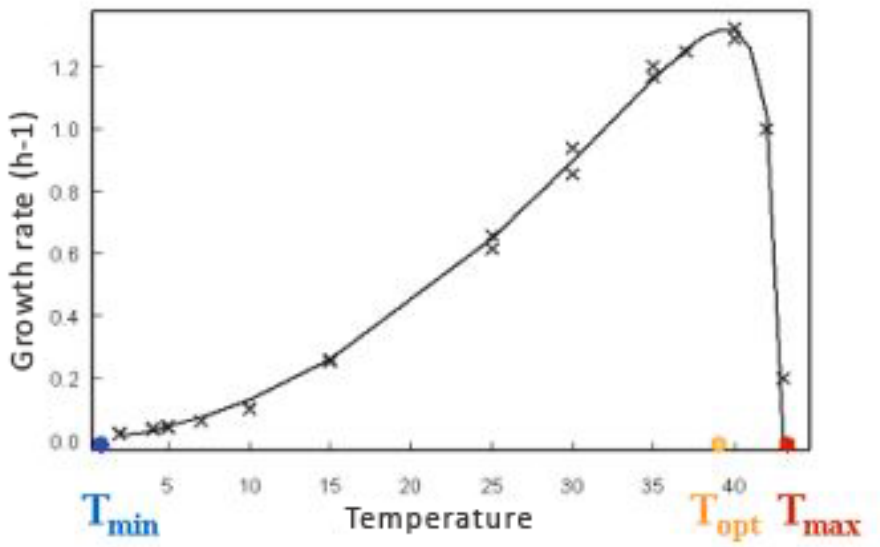
Predictive Microbiology

Primary models: describing the microbial concentration (behaviour: growth, inactivation, survival) as a function of time.



Predictive Microbiology

Secondary models: describing kinetic parameters as a function of environmental conditions (e.g. temperature, pH, water activity)

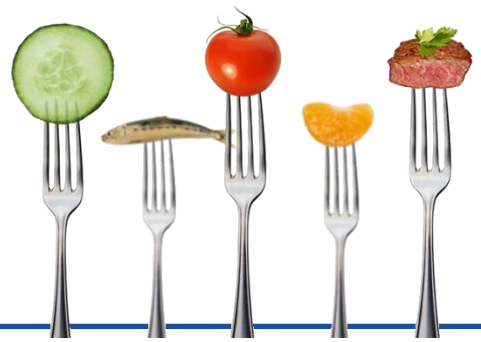


Often 2nd model has a Gamma structure with cardinal values:

$\sqrt{\mu} = \mu_{opt} \times \gamma(a_w) \times \gamma(T) \times \gamma(pH)$

See also K. Koutsoumanis and F Perez talks

Predictive Microbiology in Food Safety



Food Safety

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Food Safety Management System (FSMS) provides a preventative approach to identify, prevent and reduce food-borne hazards.

- This is **to minimize the risk of food poisoning and to make food safe for consumption**.
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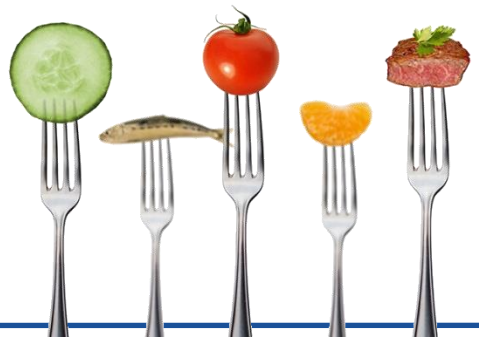
One of the control measures: Shelf-life

Challenge tests aims at **studying the growth potential …** to assess for instance the **product shelf-life as a control measure**.

- It is recommended to estimate the lag time and the maximum growth rate by **fitting a recognized and commonly accepted primary model** used to describe the microbial growth.
- Whenever possible, use strains for which the cardinal values have been determined … **to enable further predictive modelling using the gamma-concept**.
- Assessment of the temperature fluctuations on the microbial growth…. ……use i) available scientific literature data regarding temperature monitoring along the food chain, ii) practical monitoring of storage temperatures in the studied cold chains, and iii) **predictive modelling *(what-if scenarios)***

Norm ISO/DIS 20976-1 (in preparation)

Example of Foie gras



Foie Gras

- Foie gras is a popular and well-known delicacy in French cuisine, belongs to gastronomical heritage (Law n° 2006-11)
- Retorted fatty duck liver
- Ambient stable product
  - Heat-treatment process → Process criteria (PrC)
  - F_0 value (time equivalent at 121.1°C) between 0.5 min to 1 min for 80% of the manufacturers in France
  - (Process Standards for ambient stable products: 3 min)

- **Is it safe to apply a process criteria lower than F_0 3 min?**

Foie Gras

Perform a Microbial Risk Assessment, France, current intake

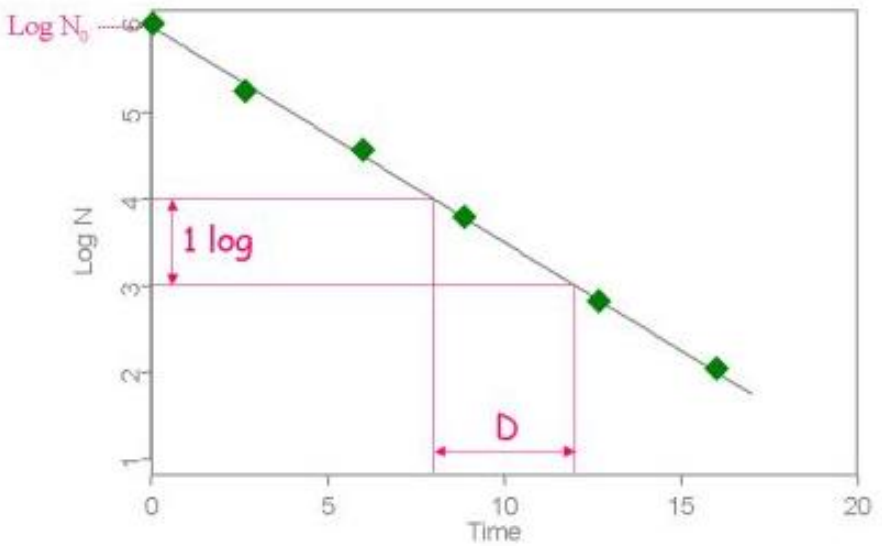
Factors taken into account in the risk assessment

- Level and frequency in “raw” livers
- **Effect of Heat Treatment (HT)**
- Effect of nitrite
- Consumer habit
- Probability illness / dose

Foie Gras

Primary model

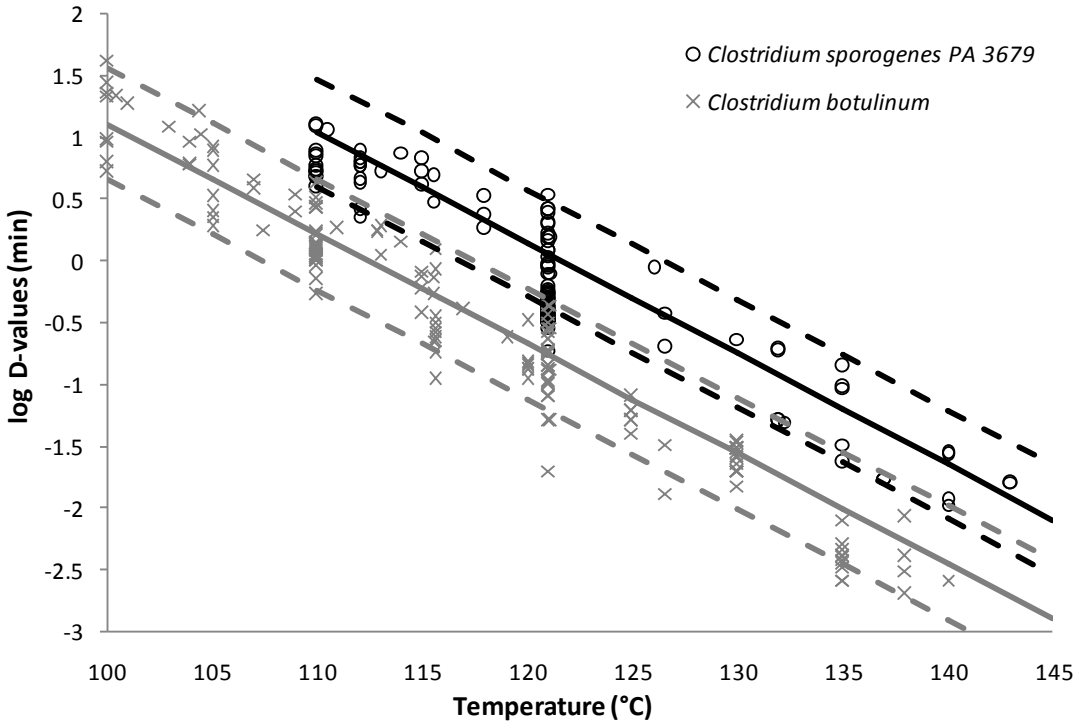
$Log_{10}\ N = log_{10}\ N0 - t/D$



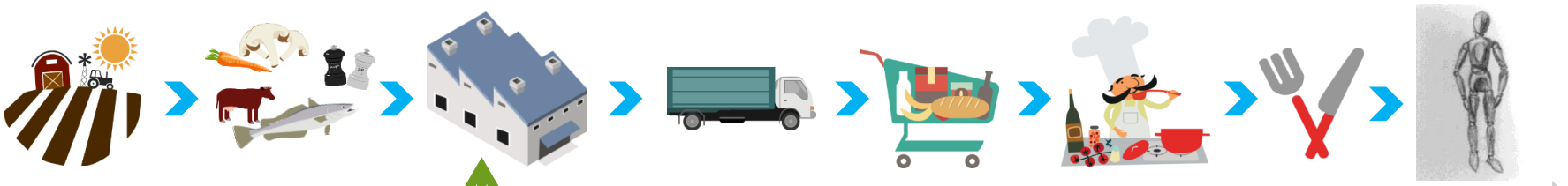
Foie Gras

Secondary model:

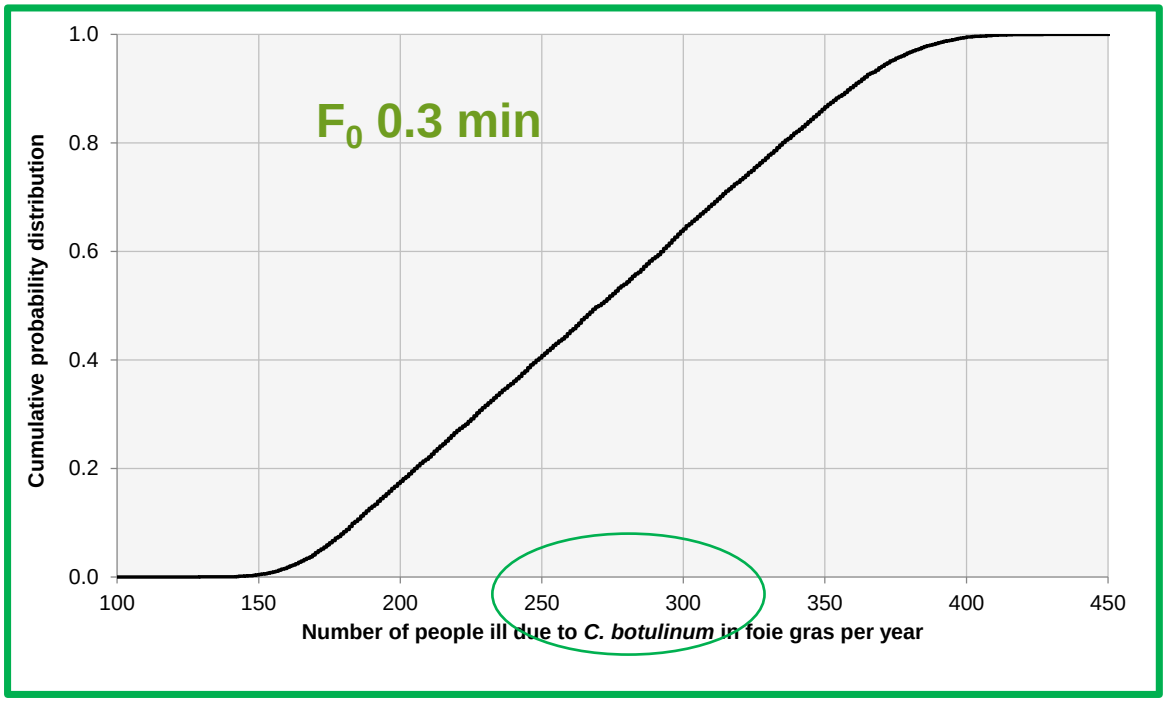
Effet of heat-tretment temperature on inactivation kinetic parameter (D-value)



Foie Gras

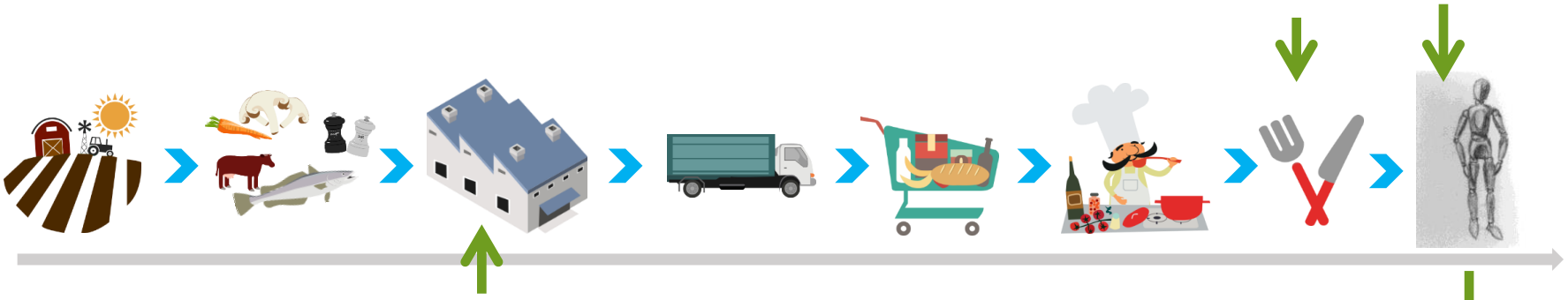


Heat-Treatment

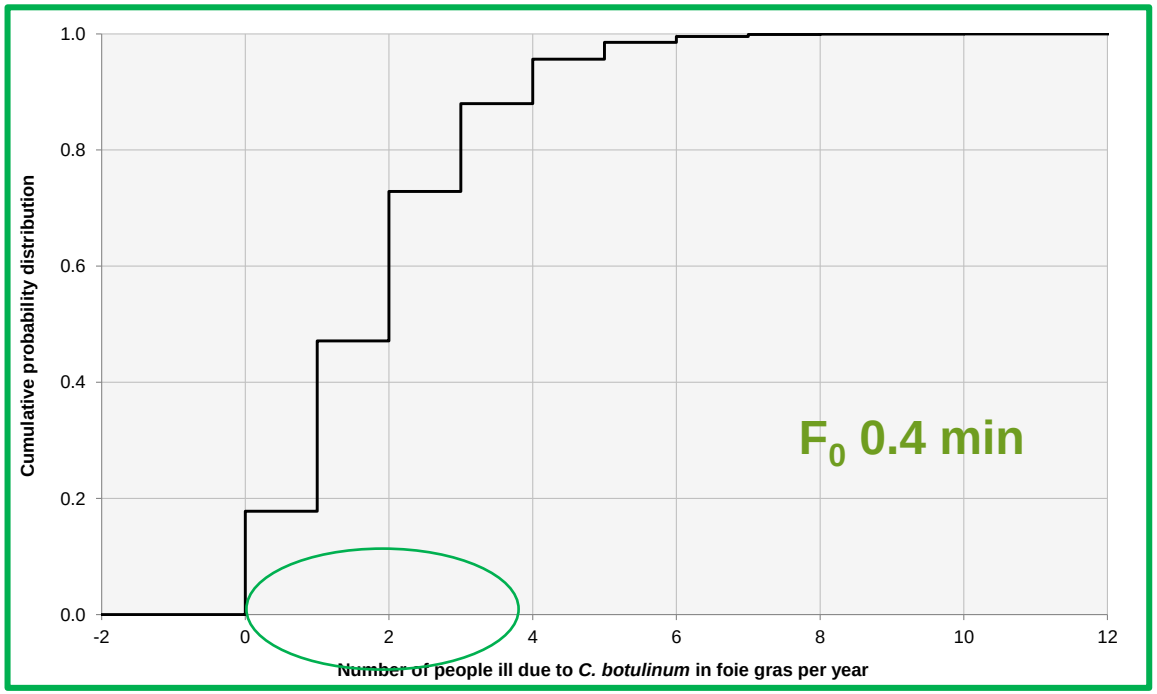


Number of people ill per year

Foie Gras



Heat-Treatment



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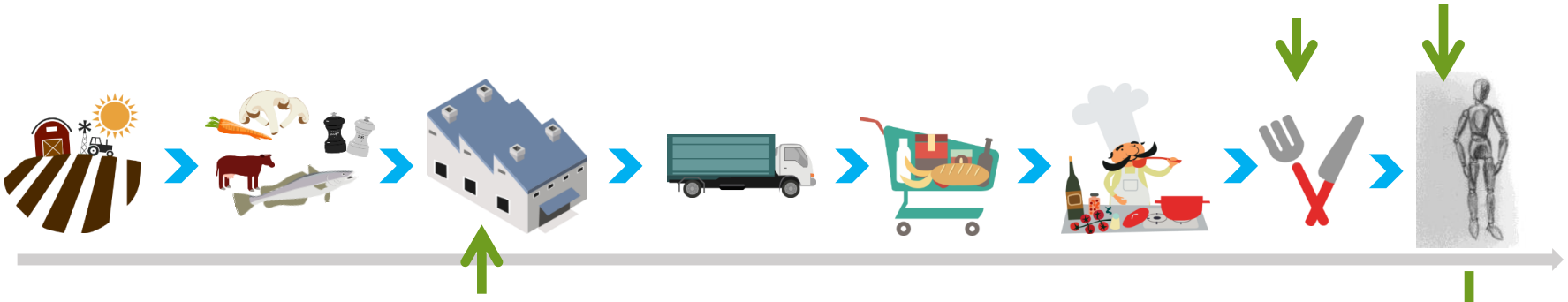
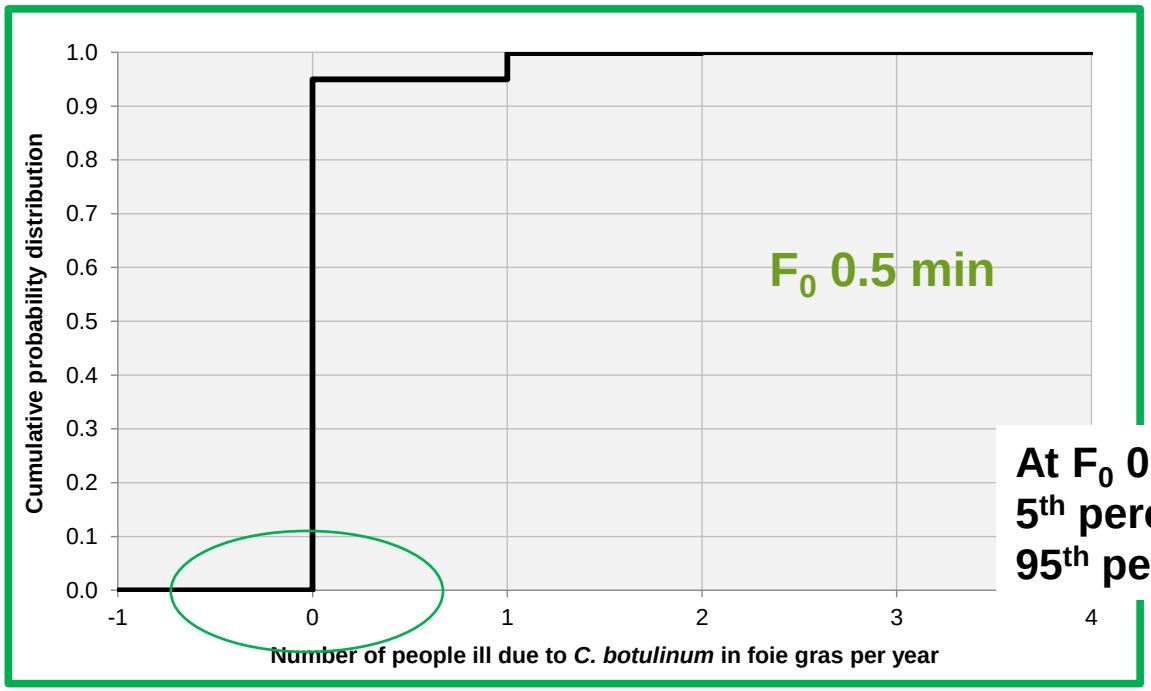


Heat-Treatment

Number of people ill per year



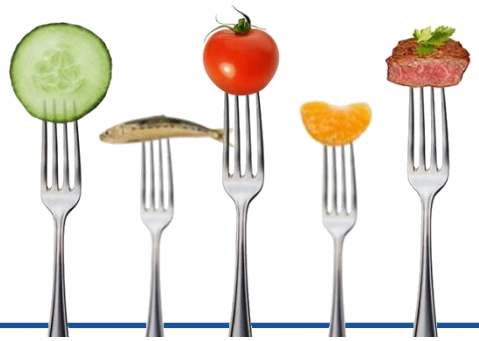
At F_0 0.5 min, 0 case per year
5^{th} percentile: 0
95^{th} percentile: 1

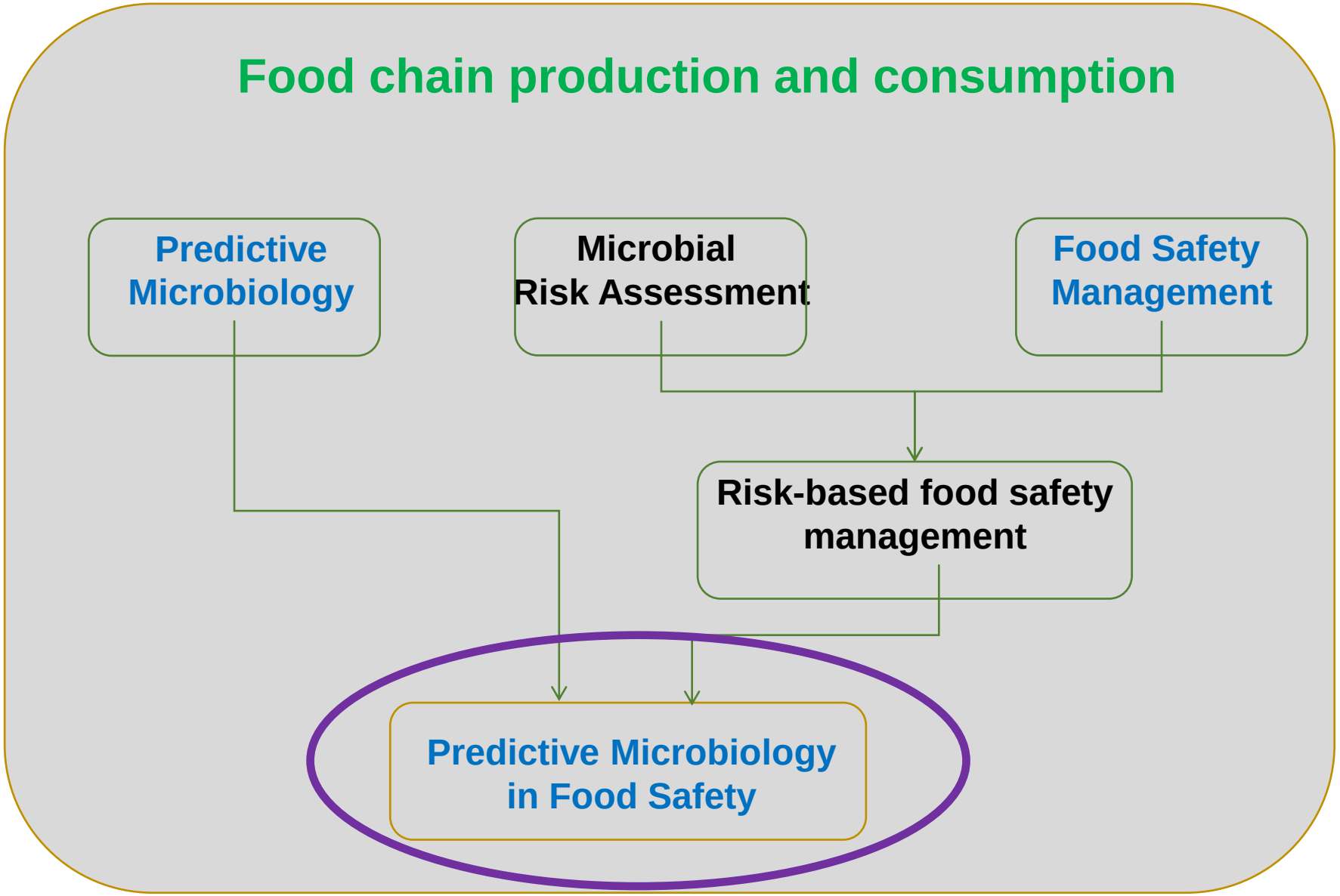
Foie Gras

- **Predictive models implemented in a risk assessment model**
  - A farm to fork to human assessment
- **Foie gras product**
  - **Very low public health risk at F_0 0.5 min**
  - Result in agreement with epidemiological data
- **Power of predictive microbiology**
  - **Enable to challenge Standards as F_0 3 min for ambient stable product**
  - **Enable to optimize/revisit heat-treatment settings of food product**
  - **Enable to design Process criteria**

J.-M. Membré, M. Diao, C. Thorin, G. Cordier, F. Zuber, S. André. 2015. Risk assessment of proteolytic *Clostridium botulinum* in canned foie gras**. International Journal of Food Microbiology**. 210 : 62–72

Conclusion

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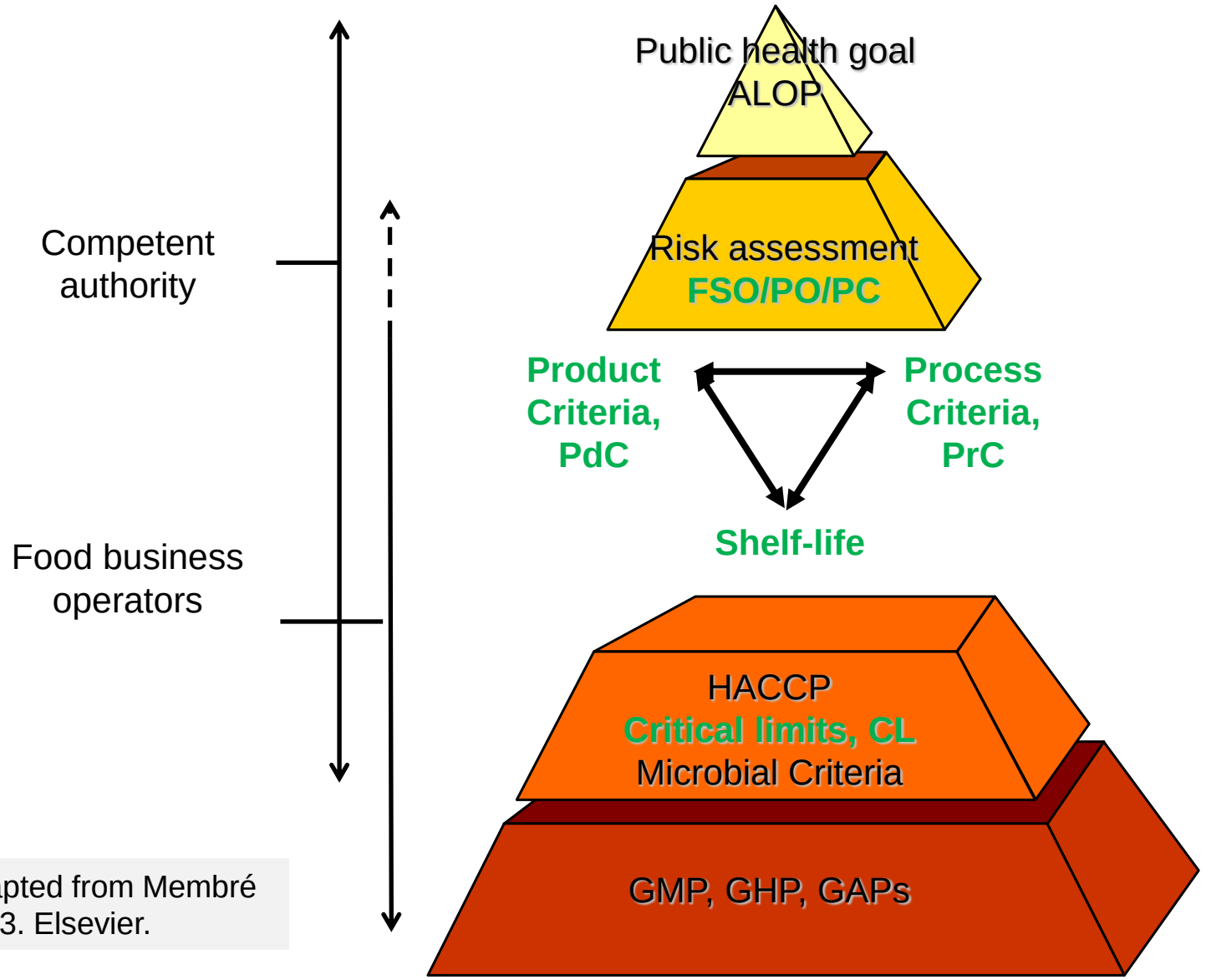
Predictive Microbiology application in Food Safety



Adapted from Membré 2013. Elsevier.

Predictive Microbiology application in Food Safety

- **Shelf-life (SL) determination**
  - → in-silico determination
  - → in addition of challenge-tests: run what-if scenario (ISO Norm)

- **Exposure assessment**
  - → Predictive microbiology is included in exposure assessment
  - → Impact of transformation – distribution on consumer exposure, particularly used in process optimization and storage condition (SL)

- **Risk-based food safety management**
  - → Probability to achieve a PO or an FSO
  - → Set process and product criteria to comply PO and FSO

Talk based on

J.-M. Membré, G. Boué. 2017. **Quantitative microbial risk assessment during food processing**. *In* V. Valdramidis, E. Cummin, J. V Impe (Eds). Quantitative Tools for Sustainable Food and Energy in the food chain. Eurosis Publisher. Chap. 6.

J.-M. Membré. 2016. **Microbiological risk assessments in food industry**. *In* Kotzekidou, P., (Ed.), Food Hygiene and Toxicology in Ready-to-Eat Foods. Elsevier Inc., UK. ISBN: 9780128019160. Chap. 19. Pp.337-349.

Membré, J.-M., Dagnas, S. 2016. **Modeling microbial responses: application to food spoilage**. In: Membré, J.-M., Valdramidis, V., (Eds.), Modeling in food microbiology. From predictive microbiology to exposure assessment. ISTE Press Ltd and Elsevier Ltd, UK. 33-60.

J.M. Membré. 2013. **HAZARD APPRAISAL (HACCP) | Establishment of performance criteria** (MS 155) In Encyclopedia of Food Microbiology, 2nd Edition. Elsevier

J.-M. Membré. 2012. **Setting of thermal processes in a context of food safety objectives (FSOs) and related concepts**. *In* V. Valdramidis and J. F.M. Van Impe (Eds). Progress on Quantitative Approaches of Thermal Food Processing. Series “Advances in Food Microbiology and Food Safety”. ISBN: 978-1-62100-842-2. Chapter 12, pp 295-324. Nova Science Publishers

Thanks for your attention !

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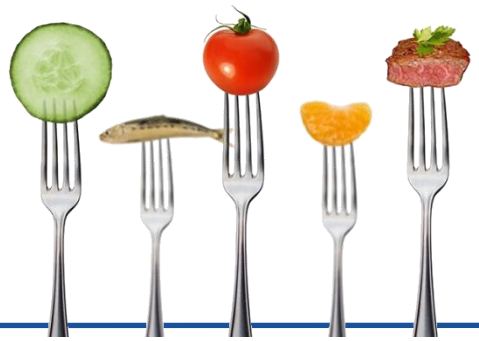
http://www6.angers-nantes.inra.fr/secalim

Example of bakery products



Brioche-type Product

- Best-by-date around 21 days
- Water activity (a_w) around 0.86
- No preservative
- Slightly acidic (pH ca 5.2)

- In-factory mould contamination: possible

- Key formulation factor: **a_w**
  → Combination of **a_w** and shelf-life to avoid spoilage?

Predictive models for SL determination

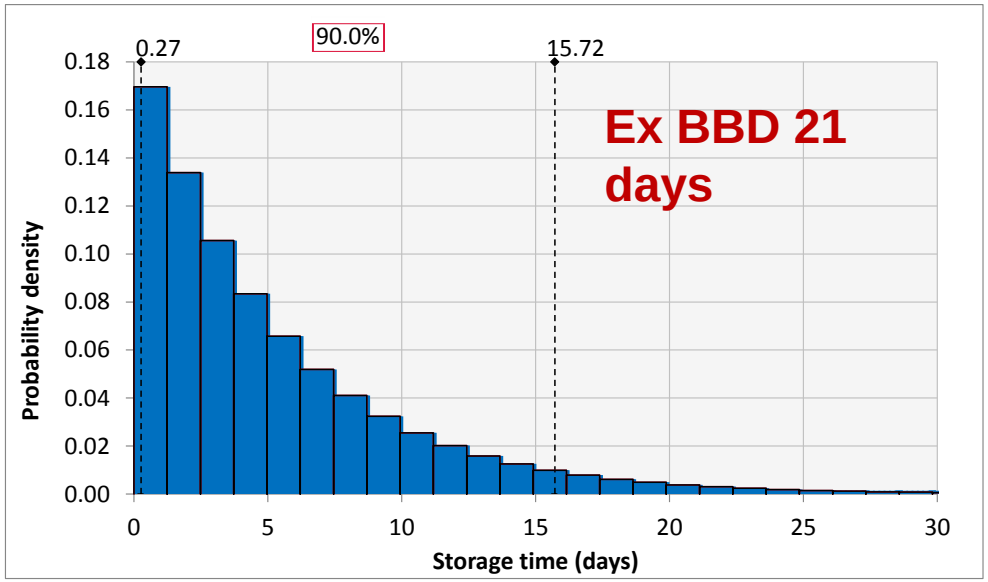
- **Time** (primary model):
  - the storage time varies with consumer's habits.

- Formulation and environmental factor (secondary models):
  - the **formulation**, and particularly **a_w**, does not vary (for a given product), it has limited acceptable changes, related to technological feasibility, legislation, regional requirements, consumer's preference, etc.
  - the storage **temperature** varies with region & season

Shelf-life

Best before date (BBD) and Shelf-life (= storage time):

- Storage time varies with consumer's habits (BBD is fixed)
- A general rule for modelling ha been recently suggested: Time = Exp(Best-Before-Date / 4)

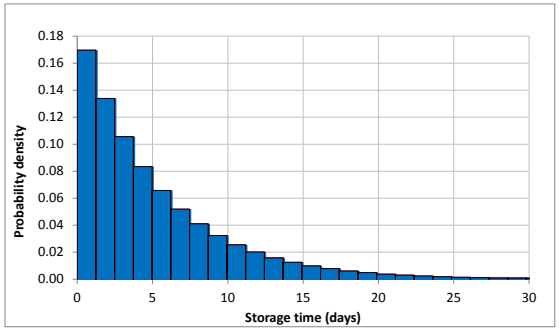


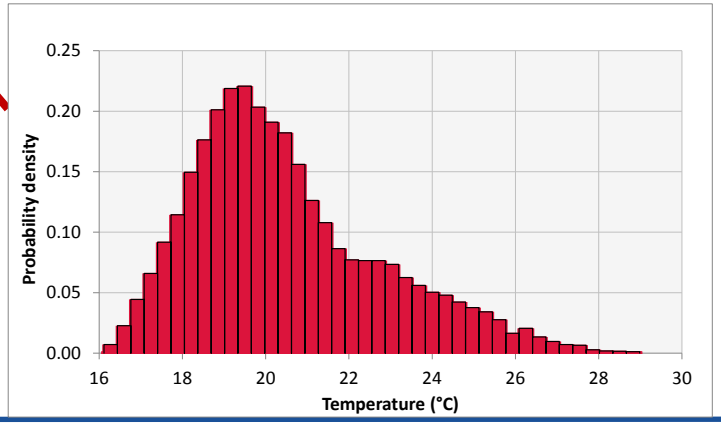
Roccato et al. 2017. **International Food Research** 96, 171-181.

Probability of spoilage

- Spoilage: proba to achieve visible growth before shelf – life
- Spoilage rate = $\Pr(\mathrm{Ind}_{\lambda} \leq \text{Storage time})$ **BBD**: 7, 14…. 35 days

$$\sqrt{1/\mathrm{Ind}_{mean}} = \sqrt{1/\lambda_{opt}} \times \gamma(a_w) \times \gamma(T)$$



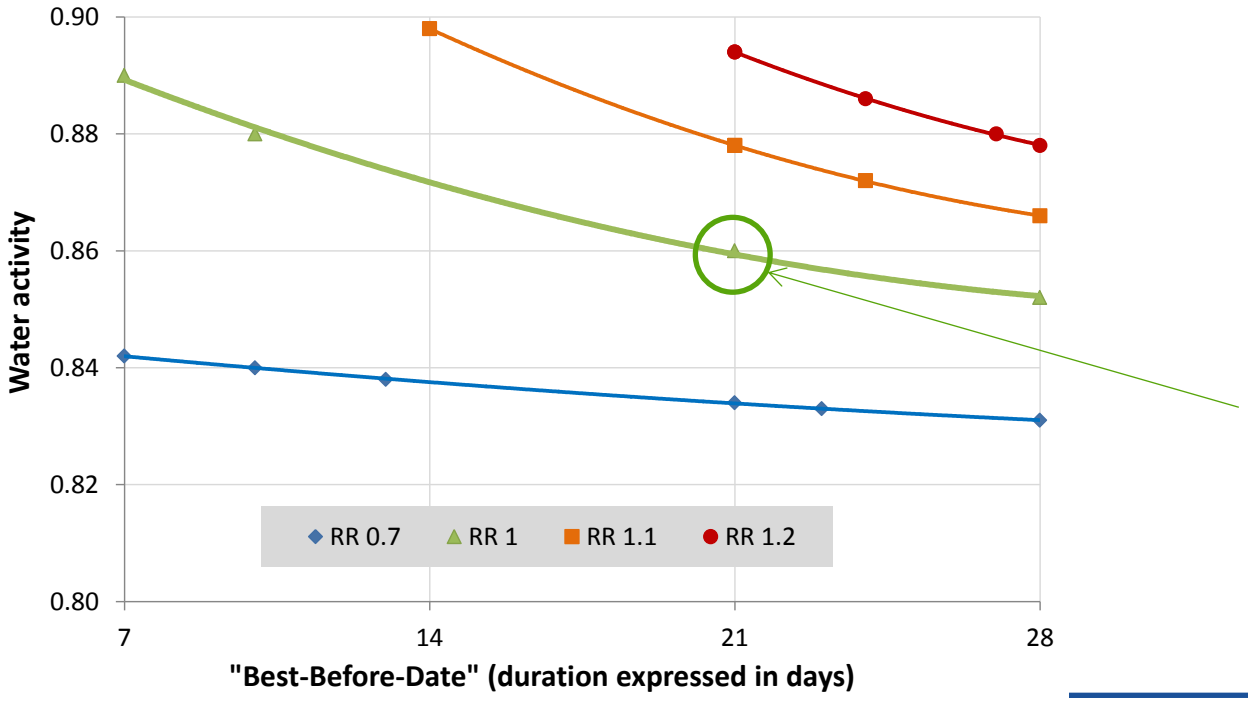


A_w: 0.85; 0.86; 0.87….. 0.90

Brioche-type Product

Combinations of **a_w** and **BBD** having same spoilage rate

- Iso-risk curve, expressed in Relative Risk (RR)
- RR=1 for current BBD and formulation



Brioche-type Product

- **Predictive modelling for shelf-life determination**
  - Individual spore growth (germination + mycelium growth) as initially low number of spore on product (post-process contamination)
- **Secondary model → aw and temperature effect on lag**
  - Gamma structure
  - Probabilistic inputs: Storage temperature
- **Shelf-life set as small probability of growth before consumption**
  - Pr(lag ≤Storage time)
  - Probabilistic inputs: Storage time
- **Power of predictive microbiology**
  - **Build combinations of aw and SL giving same probability**

  → Highly valuable in **formulation and shelf-life design** (what-if scenarios)

Dagnas, S., Gougouli, M., Onno, B., Koutsoumanis, K.P., Membré, J.-M., 2017. Quantifying the effect of water activity and storage temperature on single spore lag times of three moulds isolated from spoiled bakery products. Int. J. Food Microbiol. 240, 75-84.