# Risk assessment of Salmonella in Danish meatballs produced in the catering sector

**Møller, Cleide Oliveira de Almeida; Nauta, Maarten; Schaffner, Donald W.; Dalgaard, Paw; Christensen, Bjarke Bak; Hansen, Tina Beck**

*Publication date:*
2015

**International Journal of Food Microbiology**

Volume 196, Issue 1, 2015, Pages: 109–125

Contents lists available at ScienceDirect

International Journal of Food Microbiology

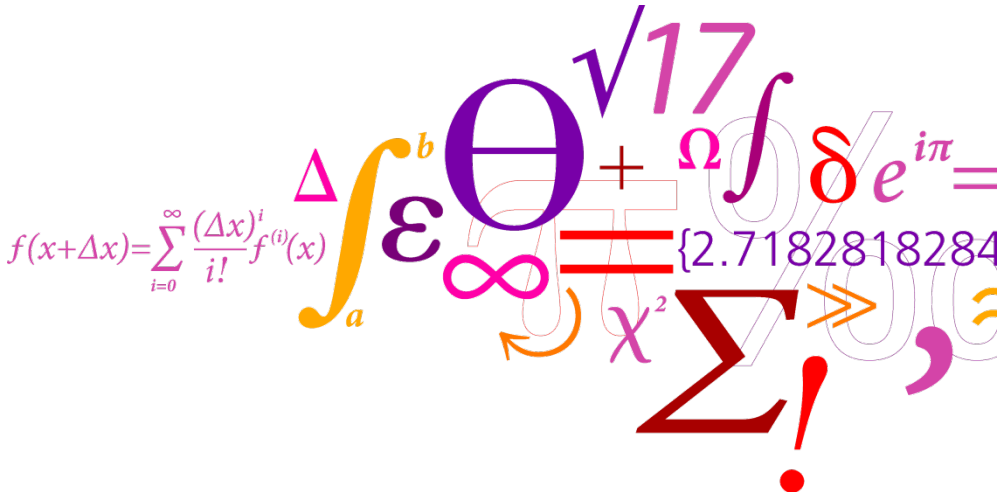
journal homepage: www.elsevier.com/locate/ijfoodmicro

# Risk assessment of *Salmonella* in Danish meatballs produced in the catering sector

Cleide O. de A. Møller [a], Maarten J. Nauta [a], Donald W. Schaffner [b], Paw Dalgaard [c], Bjarke B. Christensen [a,1], Tina B. Hansen [a,*]

[a] National Food Institute, Technical University of Denmark, Mørkhøj Bygade 19, DK-2860 Søborg, Denmark
[b] Department of Food Science, School of Environmental and Biological Science, Rutgers University, 65 Dudley Road, Food Science Building, Room 207, New Brunswick, NJ 08901-8520, USA
[c] National Food Institute, Technical University of Denmark, Søltofts Plads, Bygning 221, DK-2800 Kgs. Lyngby, Denmark

**Correspondence**
Cleide Oliveira de Almeida Møller
E-mail: clemo@food.dtu.dk



DTU Food
National Food Institute

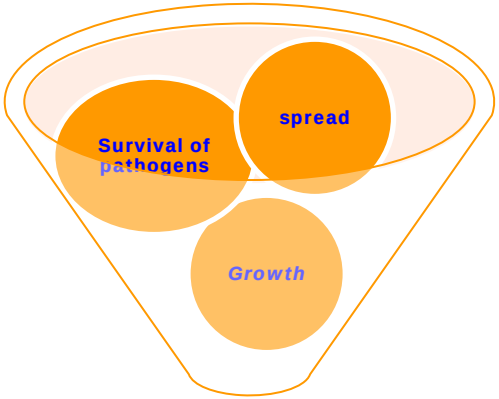
## Outline:

- Introduction
- Objectives of the study
- Summarizing the performed work
- Process to build up the developed model
- Results
- Remarks and future perspectives

# Introduction

- *Salmonella* is a critical pathogen (CDC, 2011; EFSA, 2010).
- Pork still is an important source of salmonellosis (EFSA, 2010; van Hoek *et al*., 2012; Wegener *et al*., 2003).
- Ground meat is frequently associated with outbreaks of salmonellosis (Stock and Stolle, 2001).
- Up to 70% of foodborne illnesses are estimated to be linked to catered food (Filion and Powell, 2011; Hensen et al., 2006; Jones et al., 2004; Lee and Middleton, 2003).
- In Denmark, 61 of 86 reported outbreaks in 2011 were associated with outside-the-home settings (anonymous, 2012).
- To model the distribution of pathogens during the processing operation are of major relevance to risk analysts (Flores, 2006).

# Objectives of the study




**Challenging Food safety** → **Quantitative Microbiological Risk Assessment - QMRA**

risk of salmonelosis by consumption of “frikadeller”, processed by the catering sector

Based on scenario analysis:

- to evaluate existing practices
- challenge the efficiency of different Food Safety Authorities recommendations

**Catering processing**

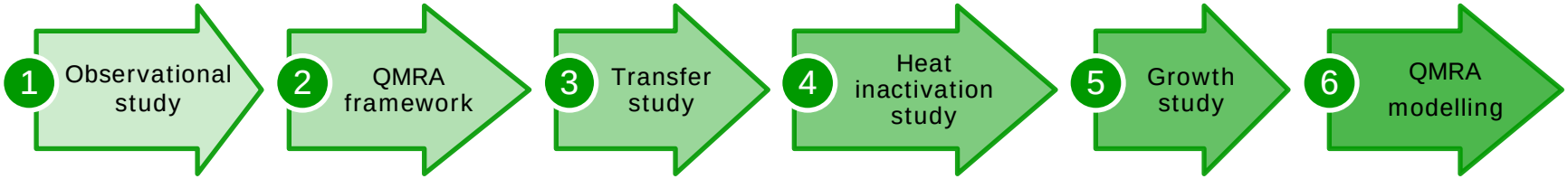
Raw pork

Final meal

*Frikadelle*

# Summarizing the performed work

Experimental work and modelling activities were performed:




Journal of Applied Microbiology

Journal of Applied Microbiology ISSN 1364-5072

ORIGINAL ARTICLE

**Modelling transfer of *Salmonella* Typhimurium DT104 during simulation of grinding of pork**

C.O.A. Møller[1], M.J. Nauta[1], B.B. Christensen[2], P. Dalgaard[3] and T.B. Hansen[1]

1 National Food Institute, Technical University of Denmark, Søborg, Denmark
2 Department of Food Science, Faculty of Life Sciences, University of Copenhagen, Frederiksberg C, Copenhagen, Denmark
3 National Food Institute, Technical University of Denmark, Kgs. Lyngby, Denmark

**Journal of Applied Microbiology**

Volume 112, Issue 1, January 2012, Pages: 90–98

Contents lists available at SciVerse ScienceDirect

Food Microbiology

journal homepage: www.elsevier.com/locate/fm

Effect of natural microbiota on growth of *Salmonella* spp. in fresh pork – A predictive microbiology approach

C.O.A. Møller[a], Y. Ilg[b], S. Aabo[a], B.B. Christensen[a,1], P. Dalgaard[c], T.B. Hansen[a,*]

[a] National Food Institute, Technical University of Denmark, Mørkhøj Bygade 19, DK-2860 Søborg, Denmark
[b] Institute of Animal Science, University of Bonn, Katzenburgweg 7-9, 53115 Bonn, Germany
[c] National Food Institute, Technical University of Denmark, Søltofts Plads, Building 221, DK-2800 Kgs. Lyngby, Denmark

**Food microbiology**

Volume 34, Issue 2, June 2013, pages: 284-295

1 Observational study

# Experimental work

School canteen

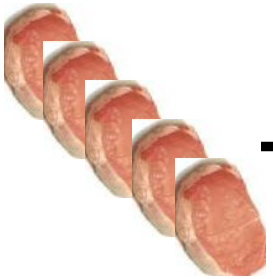
**Object of investigation:**
Danish catering sector

Worksite canteen

- Process flow
- Time and temperature profiles
- Weight of ingredients

- Unit changes during the processing, e.g.:

1 kg meat pieces → 200 g slices → 200 g portions → 5 kg batter → 70-80 g "*frikadelle*" batter


2 QMRA framework

# Risk of salmonellosis from consumption of “frikadeller”

## Modelling activities

**Pathway**

| Processing step | Basic activity | Source/model reference |
|---|---|---|
| Reception | 1. initial contamination | Hansen et al. (2010) |
| Slicing | 2. partitioning | Nauta (2005) |
| Grinding slices into portions | 3. cross contamination | Møller et al. (2012) |
| Mixing of ingredients | 4. mixing | Nauta (2005) |
| Dividing into meatballs | 5. partitioning | Nauta (2005) |
| Heating inactivation in pan | 6. inactivation | this study |
| Holding time | 7. growth | Møller et al. (2013), this study |
| plus | | |
| Heat inactivation in oven | 8. inactivation | this study |
| Serving time plus cold storage until 6° C is reached | 7. growth | Møller et al. (2013), this study |
| Estimation of the risk | 9. dose response | FAO/WHO (2002) |

2 QMRA framework

# Risk of salmonellosis from consumption of ‘frikadeller’

| Processing step | Basic activity | Source/model reference |
|---|---|---|
| Reception | 1. initial contamination | Hansen et al. (2010) |
| Slicing | 2. partitioning | Nauta (2005) |
| Grinding slices into portions | 3. cross contamination | Møller et al. (2012) |
| Mixing of ingredients | 4. mixing | Nauta (2005) |
| Dividing into meatballs | 5. partitioning | Nauta (2005) |
| Heating inactivation in pan | 6. inactivation | this study |
| Holding time | 7. growth | Møller et al. (2013), this study |
| Heat inactivation in oven | 8. inactivation | this study |
| plus | | |
| Serving time plus cold storage until 6° C is reached | 7. growth | Møller et al. (2013), this study |
| Estimation of the risk | 9. dose response | FAO/WHO (2002) |

2 QMRA framework

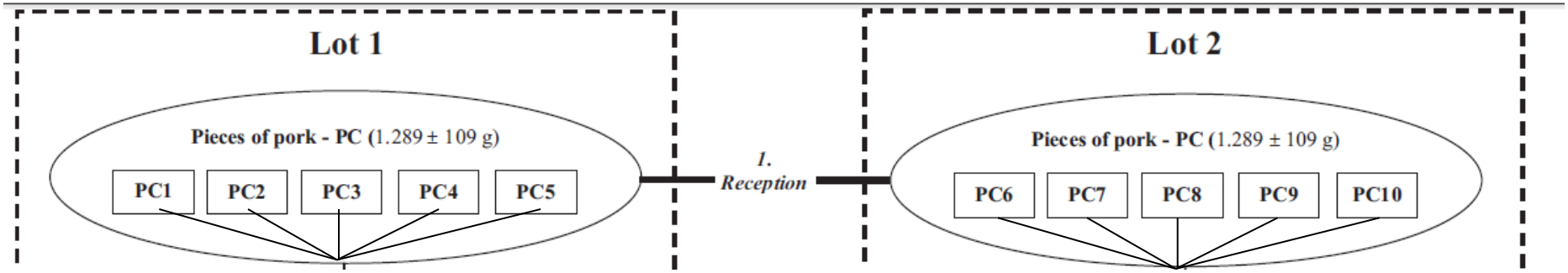
## Risk of salmonellosis from consumption of 'frikadeller'

| Processing step | Basic activity | Source/model reference |
|---|---|---|
| Reception | 1. initial contamination | **Hansen et al. (2010)** |

$R_{prevalence}$ = 4.2% of the samples

- 39 positive samples within the interval 0.04–0.4 CFU/g
- 7 positive samples within the interval 0.4–4 CFU/g
- 5 positive samples within the interval 4–40 CFU/g
- 1 positive sample with more than 40 CFU/g (assumed max. 400 CFU/g)

~Histograma (log(0.04), log(400), {39,7,5,1})

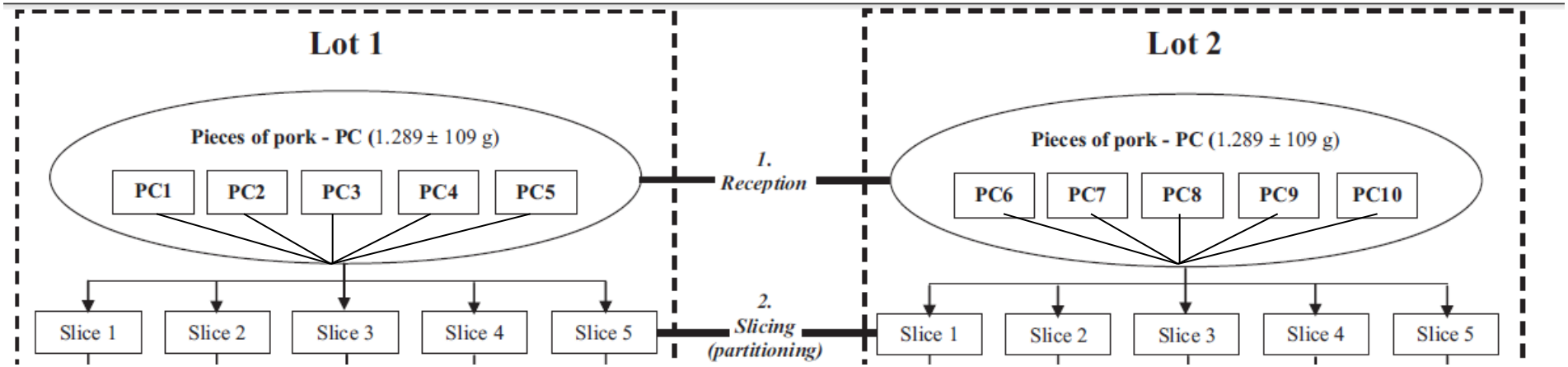


2 QMRA framework

## Risk of salmonellosis from consumption of “frikadeller”

| Processing step | Basic activity | Source/model reference |
|---|---|---|
| Reception | 1. initial contamination | Hansen et al. (2010) |
| Slicing | 2. partitioning | Nauta (2005) |

$S_{conc\ slice} \sim Multinomial(Rconc\ piece, \{1/Sn\ slices\})$

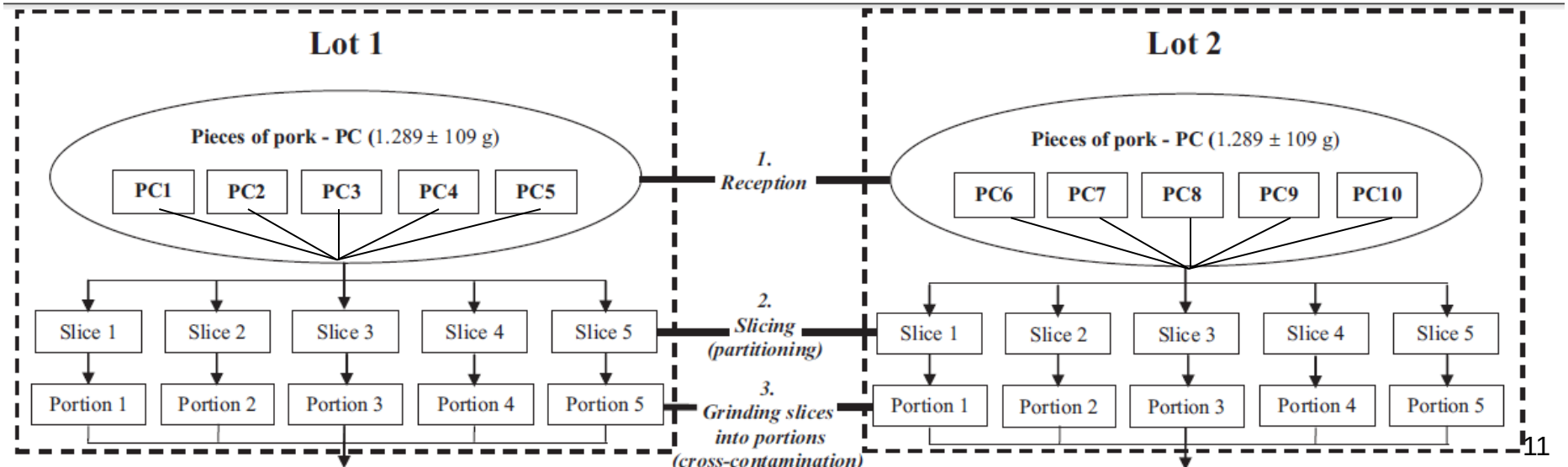


2 QMRA framework

## Risk of salmonellosis from consumption of “frikadeller”

| Processing step | Basic activity | Source/model reference |
|---|---|---|
| Reception | 1. initial contamination | Hansen et al. (2010) |
| Slicing | 2. partitioning | Nauta (2005) |
| Grinding slices into portions | 3. cross contamination | Møller et al. (2012) |

$$M_i = (1-a_1)(1-a_2)(1-c_2)\, S_i + (b_1\, gr_{1,i-1}) + (b_2\, gr_{2,i-1})$$

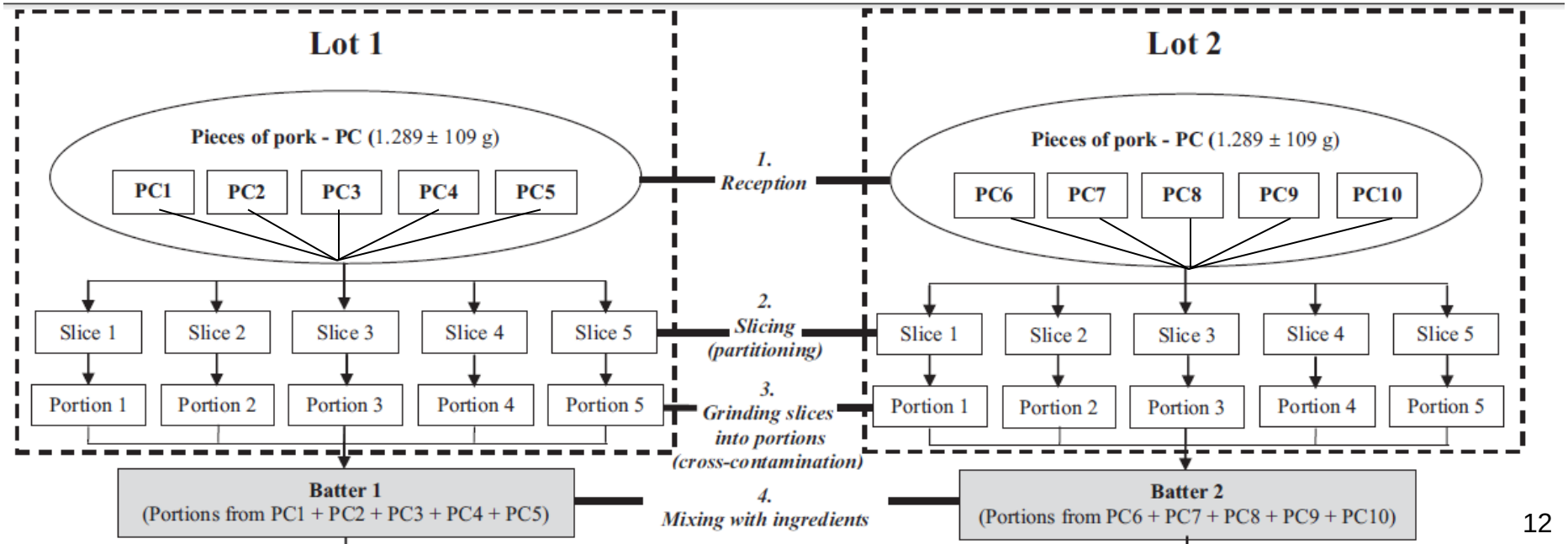


2 QMRA framework

## Risk of salmonellosis from consumption of “frikadeller”

| Processing step | Basic activity | Source/model reference |
|---|---|---|
| Reception | 1. initial contamination | Hansen et al. (2010) |
| Slicing | 2. partitioning | Nauta (2005) |
| Grinding slices into portions | 3. cross contamination | Møller et al. (2012) |
| Mixing of ingredients | 4. mixing | Nauta (2005) |

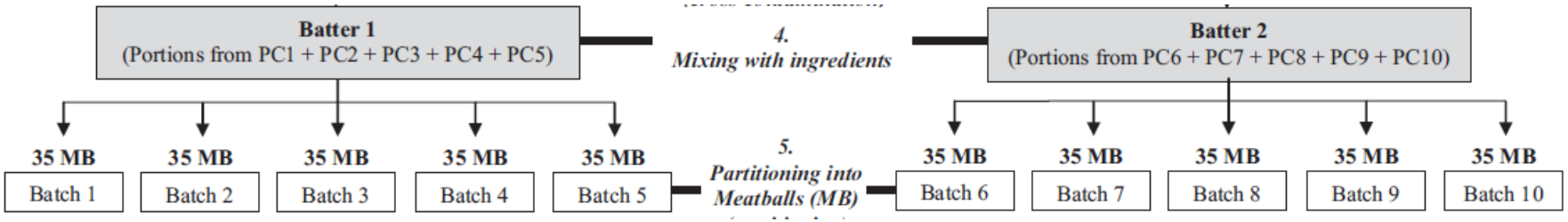
- the meat typically corresponds to 2/3 of the total weight,
- so the total weight is the weight of the meat multiplied by 3/2.



# Risk of salmonellosis from consumption of “frikadeller”

| Processing step | Basic activity | Source/model reference |
|---|---|---|
| Reception | 1. initial contamination | Hansen et al. (2010) |
| Slicing | 2. partitioning | Nauta (2005) |
| Grinding slices into portions | 3. cross contamination | Møller et al. (2012) |
| Mixing of ingredients | 4. mixing | Nauta (2005) |
| Dividing into meatballs | 5. partitioning | Nauta (2005) |

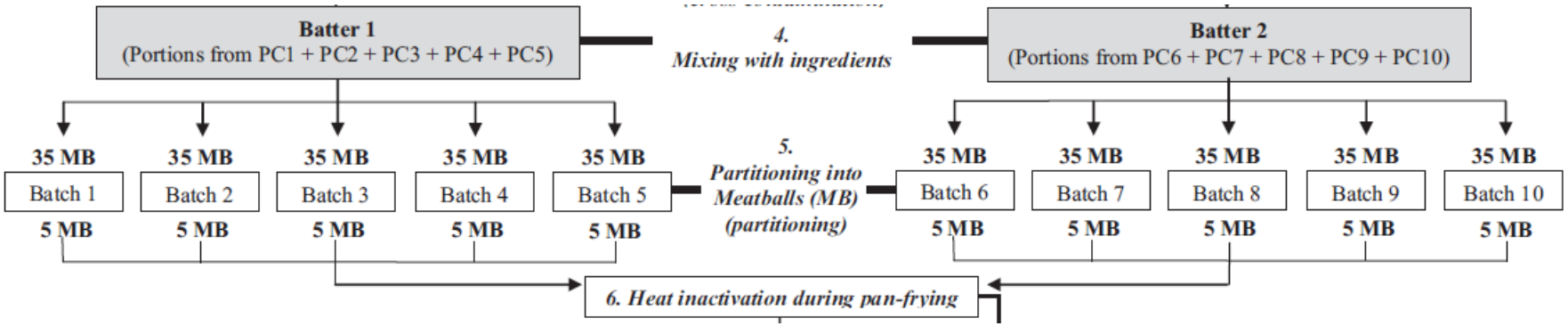
$\sim Multinomial(M_{conc\ batter\ lot}, \{1/P_{weight\ Meatball\ of\ Pn\ MB\ samples}\})$



2 QMRA framework

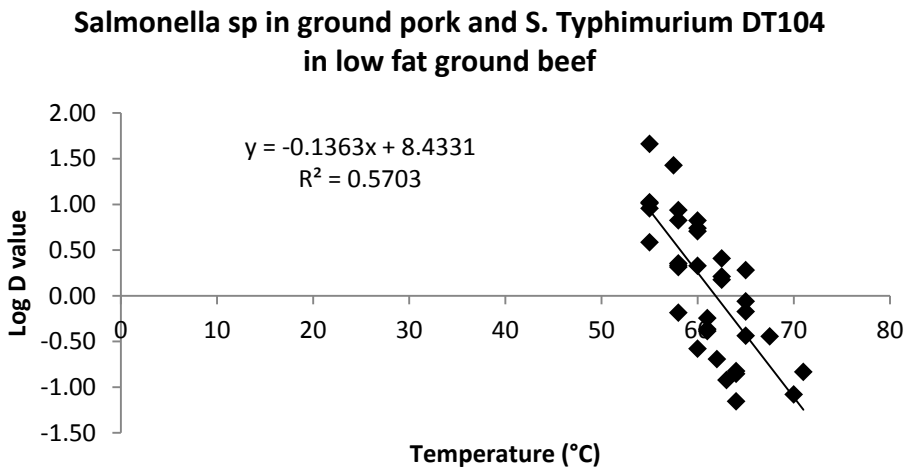
# Risk of salmonellosis from consumption of “frikadeller”

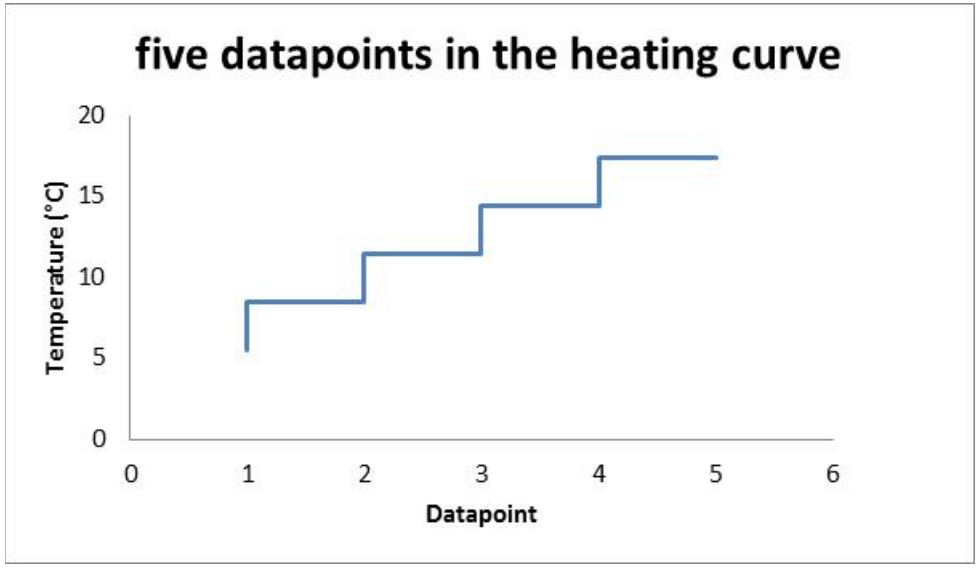
| Processing step | Basic activity | Source/model reference |
|---|---|---|
| Reception | 1. initial contamination | Hansen et al. (2010) |
| Slicing | 2. partitioning | Nauta (2005) |
| Grinding slices into portions | 3. cross contamination | Møller et al. (2012) |
| Mixing of ingredients | 4. mixing | Nauta (2005) |
| Dividing into meatballs | 5. partitioning | Nauta (2005) |
| Heating inactivation in pan | 6. inactivation | this study |



# Heating inactivation in pan

| Literature data | T (°C) | D (min) | log D |
|---|---|---|---|
| MURPHY et al., 2004. | 55 | 45.87 | 1.66 |
| | 57.5 | 26.76 | 1.43 |
| ground pork (40.2% fat) | 60 | 5.07 | 0.71 |
| | 62.5 | 2.56 | 0.41 |
| | 65 | 1.91 | 0.28 |
| | 67.5 | 0.36 | -0.44 |
| | 70 | 0.083 | -1.08 |
| JUNEJA et al., 2001 | 58 | 6.68 | 0.83 |
| | 60 | 6.65 | 0.83 |
| Pork (8.5% fat) | 62.5 | 1.62 | 0.21 |
| | 65 | 0.87 | -0.06 |
| JUNEJA et al., 2001 | 58 | 8.65 | 0.94 |
| | 60 | 5.48 | 0.74 |
| Beef (12.5% fat) | 62.5 | 1.5 | 0.18 |
| | 65 | 0.67 | -0.17 |
| SMITH et al., 2001. | 55 | 9.05 | 0.96 |
| | 58 | 2.26 | 0.35 |
| Low fat ground beef (4.8%) | 61 | 0.57 | -0.24 |
| | 64 | 0.15 | -0.82 |
| SMITH et al., 2001. | 55 | 10.55 | 1.02 |
| | 58 | 2.15 | 0.33 |
| Low fat ground beef (4.8%) | 61 | 0.41 | -0.39 |
| | 64 | 0.07 | -1.15 |
| SMITH et al., 2001. | 55 | 10.27 | 1.01 |
| | 58 | 2.06 | 0.31 |
| Low fat ground beef (4.8%) | 61 | 0.43 | -0.37 |
| | 64 | 0.14 | -0.85 |
| Velasquez et al. (2010) | 55 | 3.846154 | 0.59 |
| | 58 | 0.653595 | -0.18 |
| Ground pork (2.5% fat) | 60 | 0.263158 | -0.58 |
| | 62 | 0.20284 | -0.69 |
| | 63 | 0.119474 | -0.92 |
| JUNEJA et al., 2010 | 60 | 2.12766 | 0.33 |
| Lean ground beef | 65 | 0.364964 | -0.44 |
| | 71 | 0.146628 | -0.83 |



# Heating inactivation in pan

**Appendix B** Observed data used to model heat inactivation of *Salmonella* during pan-frying.

| Observed Batch | Start temperature[a] (°C) | Heating time (min) | End temperature (°C) per measured Meatball (MB) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | MB 1 | MB 2 | MB 3 | MB 4 | MB 5 | MB 6 | MB 7 | MB 8 | MB 9 | MB 10 |
| 2 | 5.1 | 7 | 19.9 | 23.5 | 31.9 | 34.2 | 39.1 | 39.5 | 39.8 | 42.7 | 44.5 | 56.3 |
| 3 | 5.1 | 7 | 18.2 | 18.3 | 20.1 | 20.6 | 27.0 | 28.3 | 29.5 | 41.0 | | |
| 4 | 5.1 | 7 | 23.3 | 32.5 | 34.0 | 35.5 | 37.9 | 42.4 | 47.9 | 52.1 | 54.0 | 59.0 |
| 5 | 5.6 | 10 | 42.1 | 44.3 | 48.6 | 52.2 | 54.3 | 54.6 | | | | |
| 6 | 7.2 | 10 | 37.2 | 46.0 | 49.1 | 50.1 | 62.2 | 66.8 | | | | |
| 7 | 7.2 | 10 | 39.9 | 40.1 | 42.3 | 44.8 | 50 | 51.5 | | | | |
| 8 | 8.4 | 6 | 32.1 | 33.1 | 39.1 | 53.2 | 55.2 | 59 | | | | |
| 9 | 10.2 | 11 | 21.1 | 24.5 | 27.3 | 33.1 | 36.3 | 41.7 | 47 | | | |
| 10 | 10.2 | 5 | 45.1 | | | | | | | | | |

[a] Measured in the batter.

= 33 %

**Model approach**

**Temperature profile:**

$$T(t) = T_o + (T_{end} - T_o) / t$$

$$EF_{Tref} = \sum_{start}^{end} 10^{\frac{T(t)-Tref}{z}} \Delta t$$

$$LR_{pan\text{-}frying} = \frac{EF_{Tref}}{D_{Tref}}$$

**Parameter values**

$T_o$ = 5-10° C

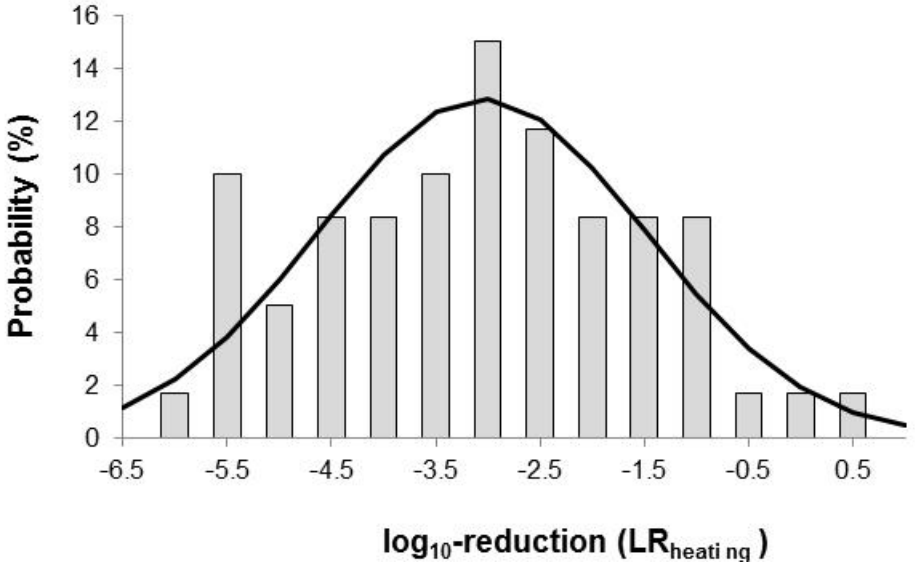
$T_{end}$ = 18-67° C

t = 7-11 min

$T_{ref}$ = 60° C

z = 7.34° C

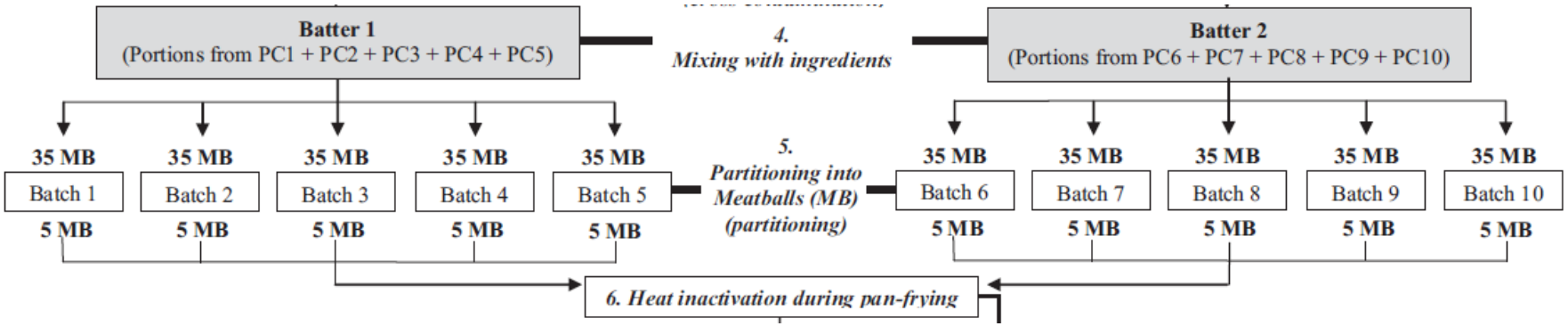
$D_{Tref}$ = 1.8 min



# Risk of salmonellosis from consumption of “frikadeller”

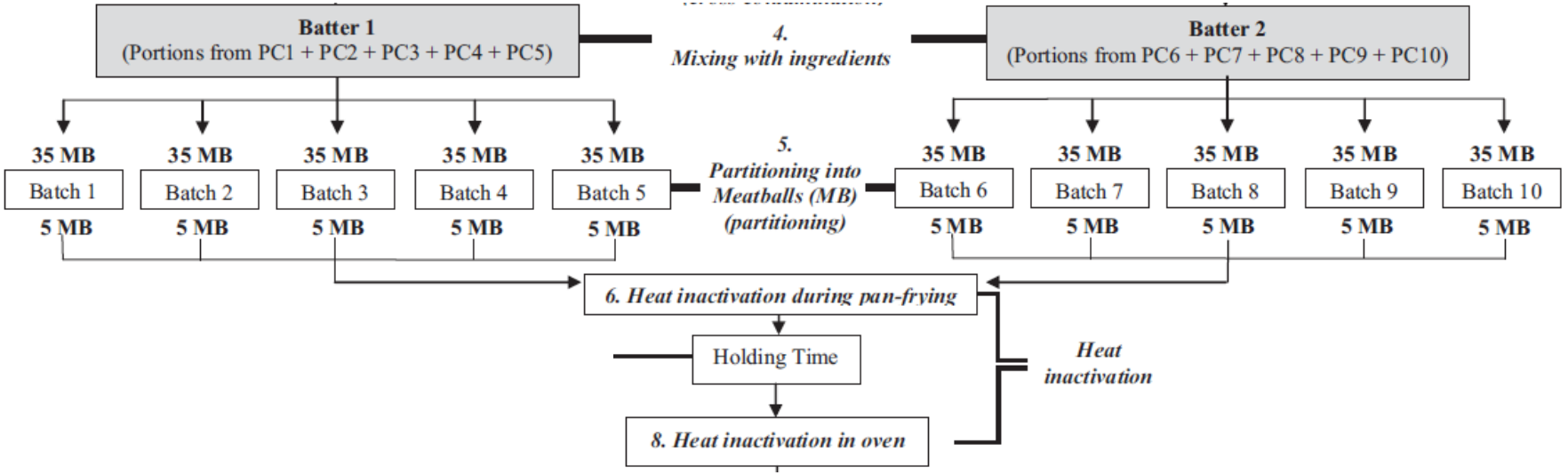
| Processing step | Basic activity | Source/model reference |
|---|---|---|
| Reception | 1. initial contamination | Hansen et al. (2010) |
| Slicing | 2. partitioning | Nauta (2005) |
| Grinding slices into portions | 3. cross contamination | Møller et al. (2012) |
| Mixing of ingredients | 4. mixing | Nauta (2005) |
| Dividing into meatballs | 5. partitioning | Nauta (2005) |
| Heating inactivation in pan | 6. inactivation | this study |

~ Poisson (10^(log10(HP$_{\text{conc crit area}}$) – 10^(HP$_{\text{log log reduction}}$)))

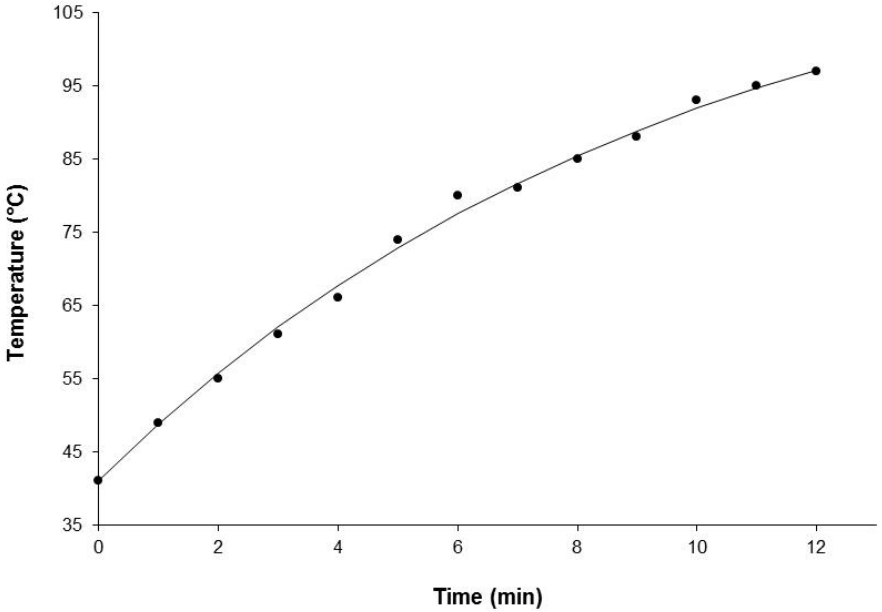


# Risk of salmonellosis from consumption of “frikadeller”

| Processing step | Basic activity | Source/model reference |
|---|---|---|
| Reception | 1. initial contamination | Hansen et al. (2010) |
| Slicing | 2. partitioning | Nauta (2005) |
| Grinding slices into portions | 3. cross contamination | Møller et al. (2012) |
| Mixing of ingredients | 4. mixing | Nauta (2005) |
| Dividing into meatballs | 5. partitioning | Nauta (2005) |
| Heating inactivation in pan | 6. inactivation | this study |
| Holding time | 7. growth | Møller et al. (2013), this study |
| Heat inactivation in oven | 8. inactivation | this study |



# Heating inactivation in oven




Observed (•) and fitted with Newton's Law equation (——) temperature profiles of heating of meatball in oven until an end temperature of 95° C.

| Model approach | Parameter values |
|---|---|
| **Temperature profile:** | $T_a$ = 121°C |
| $T(t) = T_a + (T_o - T_a) \cdot \exp(-k \cdot t)$ | $T_o$ = 25-45°C |
| | k = 6.1 $h^{-1}$ |
| $EF_{Tref} = \Delta t$ | *t* = 4-11 min |
| | $T_{ref}$ = 65-75°C |
| $LR_{oven} = \frac{EF_{Tref}}{D_{Tref}}$ | z = 7.34°C |
| | $D_{Tref}$ = 0.4-0.02 min |

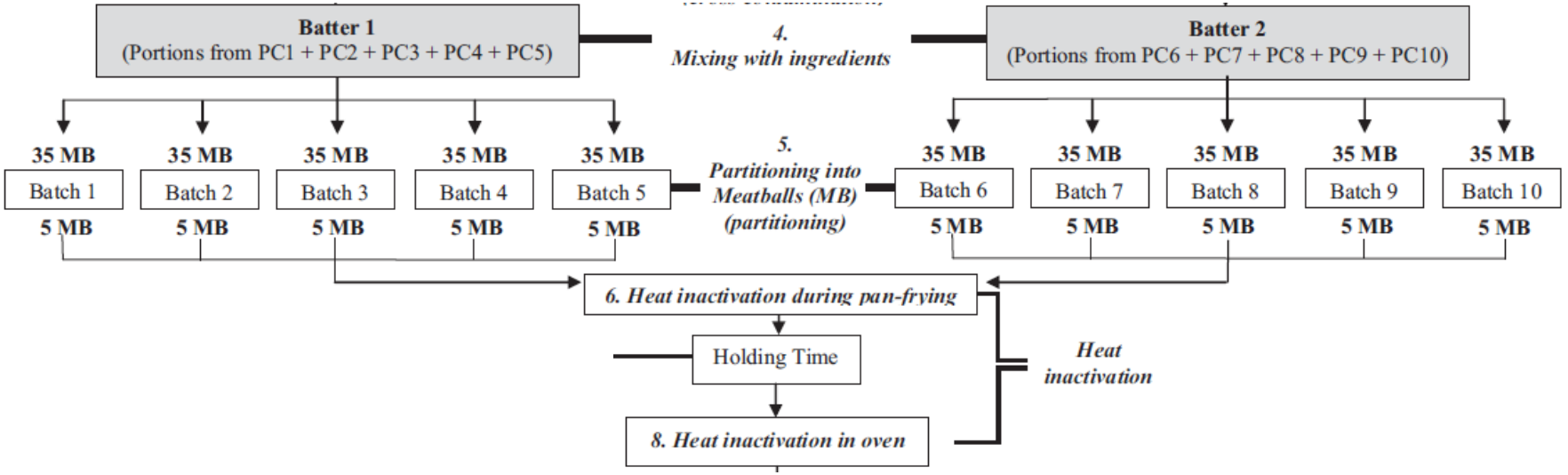
**Data on eight meatballs used to determine the degree of heat inactivation in oven**

| Observed meatball | Start temperature ($T_o$, ° C)[a] | Heating time (t, min)[b] | End temperature (° C)[c] | $T_{ref}$ (° C) | Log ($LR_{oven}$)[d] |
|---|---|---|---|---|---|
| 1 | 25.4 | 11.1 | 89.8 | 95 | 3.74 |
| | | 5.4 | 65.8 | 75 | 0.25 |
| | | 5.2 | 64.6 | 74 | 0.07 |
| | | 5.0 | 63.4 | 73 | -0.10 |
| | | 4.8 | 62.2 | 72 | -0.27 |
| | | 4.6 | 61.0 | 71 | -0.44 |
| | | 4.4 | 59.8 | 70 | -0.61 |
| | | 3.5 | 53.8 | 65 | -1.46 |

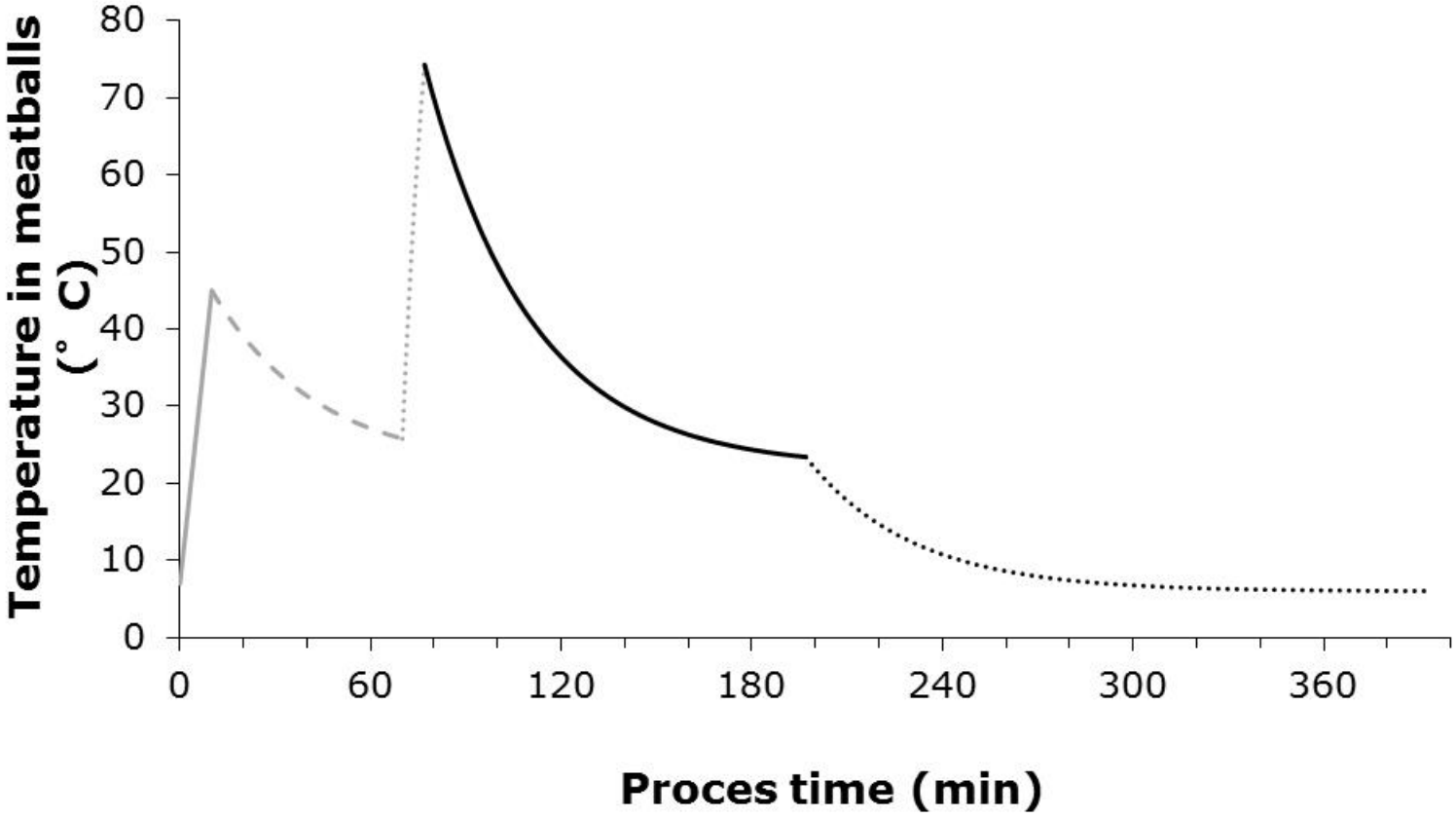
# Risk of salmonellosis from consumption of “frikadeller”

| Processing step | Basic activity | Source/model reference |
|---|---|---|
| Reception | 1. initial contamination | Hansen et al. (2010) |
| Slicing | 2. partitioning | Nauta (2005) |
| Grinding slices into portions | 3. cross contamination | Møller et al. (2012) |
| Mixing of ingredients | 4. mixing | Nauta (2005) |
| Dividing into meatballs | 5. partitioning | Nauta (2005) |
| Heating inactivation in pan | 6. inactivation | this study |
| Holding time | 7. growth | Møller et al. (2013), this study |
| Heat inactivation in oven | 8. inactivation | this study |

~ Normal ($HO_{avg\ log\ log\ red}$, $HO_{st\ dev\ log\ log\ red}$)



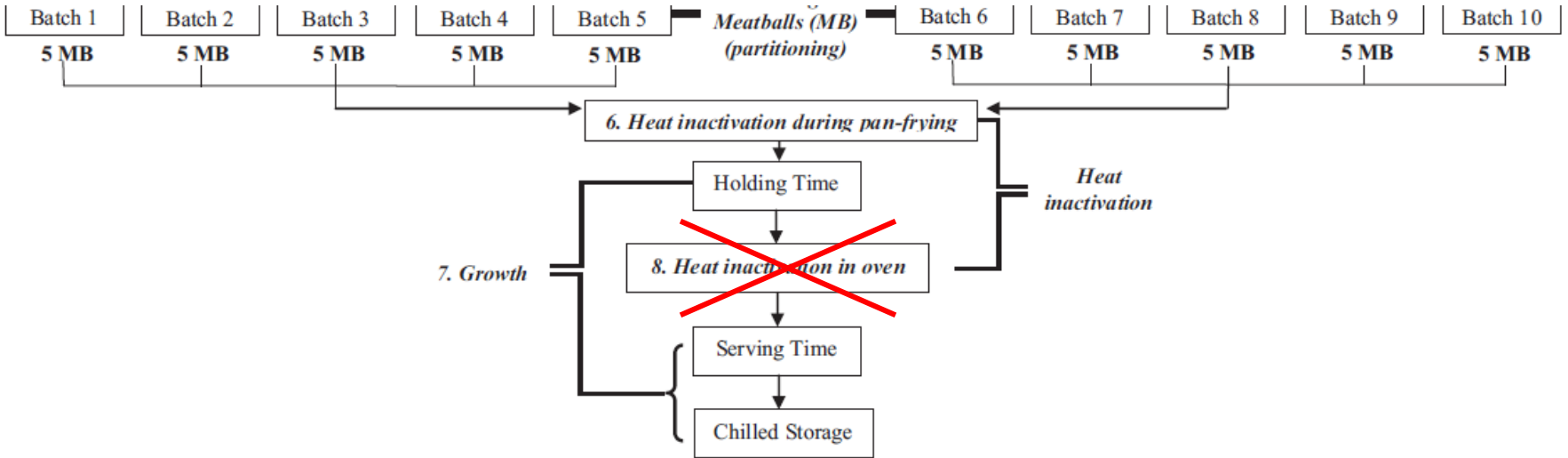
# Example of temperature profile for a meatball during processing at the catering sector



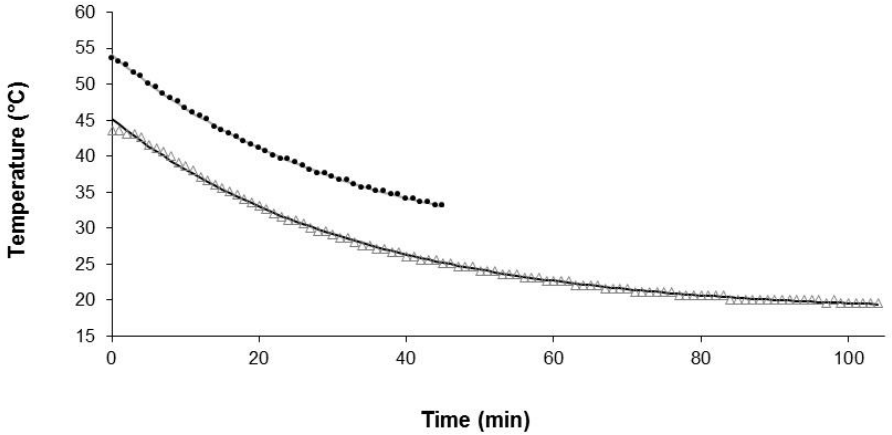

Involving: pan frying (grey full line), holding time (grey dashed line), heating in oven (grey dotted line), serving time (black full line), and chilled storage (black dotted line)

# Risk of salmonellosis from consumption of “frikadeller”

| Processing step | Basic activity | Source/model reference |
|---|---|---|
| Reception | 1. initial contamination | Hansen et al. (2010) |
| Slicing | 2. partitioning | Nauta (2005) |
| Grinding slices into portions | 3. cross contamination | Møller et al. (2012) |
| Mixing of ingredients | 4. mixing | Nauta (2005) |
| Dividing into meatballs | 5. partitioning | Nauta (2005) |
| Heating inactivation in pan | 6. inactivation | this study |
| Holding time | 7. growth | Møller et al. (2013), this study |
| plus | | |
| Heat inactivation in oven | 8. inactivation | this study |
| Serving time plus cold storage until 6° C is reached | 7. growth | Møller et al. (2013), this study |



# Growth during storage




Observed (•, Δ) and fitted (grey line, black line) temperature profiles of the cooling ofmeatballs in kitchens one and two, respectively. Fitting done with Newton's Law resulting in k=1.8 h−1 in both catering units.

## Model approach

**Temperature profile:**

$T(t) = T_a + (T_o - T_a) \cdot \exp(-k \cdot t)$

- $T_a$ = 20-30°C
- $T_o$ = 18.2-66.8°C
- k = 1.8 $h^{-1}$
- $t$ = 0-90 + 120 + 210 min

**Growth model:**

$$\mu_{max} = (b \cdot (T - T_{min}) \cdot (1 - \exp(c \cdot (T - Tmax))))^2$$

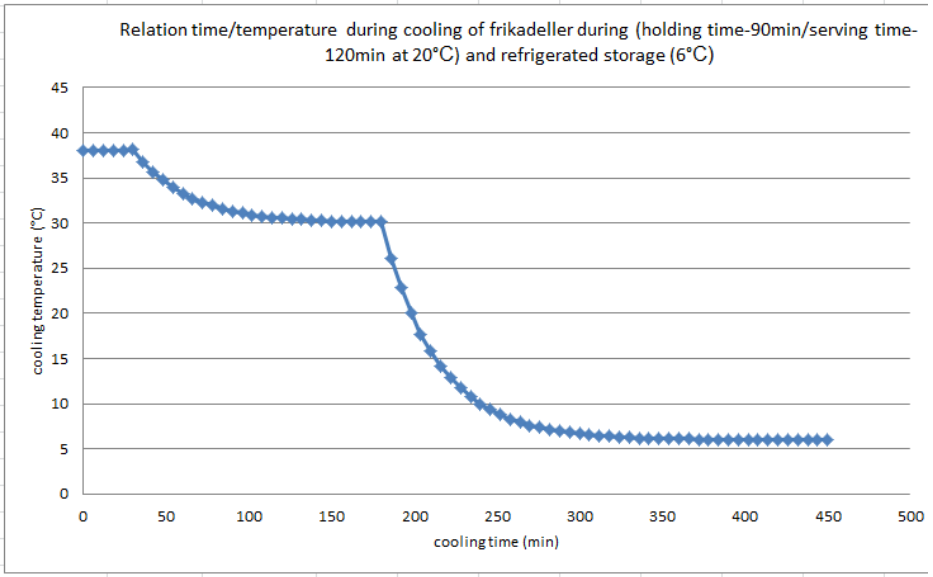
$b$ = (0.04 $h^{-0.5} \cdot C^{-1}$)  $c$ = (0.43 $C^{-1}$)

$T$ is temperature  $T_{min}$ (3.94° C)  $T_{max}$ (48.0° C)

$$Lag\ time = RLT \cdot ln(2) / \mu_{max}$$

where *RLT* is the relative lag time of 3.10

| | cooling (min) | Temperatur | µmax (1/h) | lag (h) | lag (min) | coolingtid minus la | 0=ikke vækst ; 1=vækst |
|---|---|---|---|---|---|---|---|
| 13 | 0 | 38 | 1.61246 | 1.3 | 80 | 80 | 0 |
| 14 | 6 | 38 | 1.61246 | 1.3 | 80 | 74 | 0 |
| 15 | 12 | 38 | 1.61246 | 1.3 | 80 | 68 | 0 |
| 16 | 18 | 38 | 1.61246 | 1.3 | 80 | 62 | 0 |
| 17 | 24 | 38 | 1.61246 | 1.3 | 80 | 56 | 0 |
| 18 | 30 | 38 | 1.62437 | 1.3 | 79 | 49 | 0 |
| 19 | 36 | 37 | 1.50509 | 1.4 | 86 | 50 | 0 |
| 20 | 42 | 36 | 1.40895 | 1.5 | 91 | 49 | 0 |
| 21 | 48 | 35 | 1.33107 | 1.6 | 97 | 49 | 0 |
| 22 | 54 | 34 | 1.26772 | 1.7 | 102 | 48 | 0 |
| 23 | 60 | 33 | 1.21599 | 1.8 | 106 | 46 | 0 |
| 24 | 66 | 33 | 1.17361 | 1.8 | 110 | 44 | 0 |
| 25 | 72 | 32 | 1.13879 | 1.9 | 113 | 41 | 0 |
| 26 | 78 | 32 | 1.11010 | 1.9 | 116 | 38 | 0 |
| 27 | 84 | 32 | 1.08642 | 2.0 | 118 | 34 | 0 |
| 28 | 90 | 31 | 1.06684 | 2.0 | 121 | 31 | 0 |
| 29 | 96 | 31 | 1.05062 | 2.0 | 123 | 27 | 0 |
| 30 | 102 | 31 | 1.03716 | 2.1 | 124 | 22 | 0 |
| 31 | 108 | 31 | 1.02599 | 2.1 | 125 | 17 | 0 |
| 32 | 114 | 31 | 1.01671 | 2.1 | 127 | 13 | 0 |
| 33 | 120 | 31 | 1.00899 | 2.1 | 128 | 8 | 0 |
| 34 | 126 | 30 | 1.00256 | 2.1 | 128 | 2 | 0 |
| 35 | 132 | 30 | 0.99720 | 2.2 | 129 | -3 | 1 |
| 36 | 138 | 30 | 0.99274 | 2.2 | 130 | -8 | 1 |
| 37 | 144 | 30 | 0.98903 | 2.2 | 130 | -14 | 1 |
| 38 | 150 | 30 | 0.98593 | 2.2 | 131 | -19 | 1 |




54 min. growth of Salmonella at 30C

6 min. growth of Salmonella at 26C

# Growth during storage

**Table 4**. Change in log concentration Δlog $C_x$ ($T_o$, RTK, $t_{holding}$) for different start temperatures ($T_o$) observed after pan-frying, for different room temperatures in the kitchen (RTK) and holding times $t_{holding}$ between 0 and 90 min followed by 120 min serving time and cold storage at 6°C.

| RTK – Room Temperature in the Kitchen (°C) | $T_o$ | Δlog $C_x$ ($T_o$, RTK, $t_{holding}$=90 min) | Category[a] | Δlog $C_x$ ($T_o$, RTK, $t_{holding}$=0 min) | Category |
|---|---|---|---|---|---|
| 30 | 18.2 | 0.72 | 2 | 0.00 | 2 |
| | 32.0 | 0.96 | 2 | 0.24 | 2 |
| | 33.0 | 1.00 | 2 | 0.28 | 2 |
| | 40.2 | 1.13 | 2 | 0.41 | 2 |
| | 42.0 | 1.17 | 2 | 0.46 | 2 |
| | 43.0 | 1.18 | 2 | 0.46 | 2 |
| | 44.0 | 1.22 | 2 | 0.50 | 2 |
| | 45.0 | 1.22 | 2 | 0.50 | 2 |
| | 46.0 | 1.23 | 2 | 0.51 | 2 |
| | 47.0 | 1.18 | 2 | 0.46 | 2 |
| | 55.0 | 0.58 | 3[b] | -0.14 | 3 |
| | 56.0 | 0.17 | 3 | -0.33 | 3 |
| | 57.0 | -0.04 | 3 | -0.64 | 3 |
| | 58.0 | -0.26 | 3 | -0.98 | 3 |
| | 59.0 | -0.84 | 3 | -1.57 | 3 |
| | 62.2 | -3.64 | 3 | -4.36 | 3 |
| 25 | 18.2 | 0.19 | 2 | 0.00 | 1 |
| | 32.0 | 0.40 | 2 | 0.00 | 1 |
| | 40.2 | 0.59 | 2 | 0.09 | 2 |
| | 46.0 | 0.64 | 2 | 0.17 | 2 |
| | 52.0 | 0.47 | 3[b] | -0.01 | 3 |
| | 55.0 | 0.14 | 3 | -0.33 | 3 |
| | 57.0 | -0.26 | 3 | -0.74 | 3 |
| | 59.9 | -1.04 | 3 | -1.50 | 3 |
| | 62.2 | -3.40 | 3 | -3.85 | 3 |
| 20 | 18.2 | 0.00 | 1 | 0.00 | 1 |
| | 32.0 | 0.00 | 1 | 0.00 | 1 |
| | 35.5 | 0.02 | 2 | 0.00 | 1 |
| | 40.2 | 0.15 | 2 | 0.00 | 1 |
| | 46.0 | 0.19 | 2 | 0.00 | 1 |
| | 53.0 | -0.01 | 3 | -0.19 | 3[c] |
| | 55.0 | -0.22 | 3 | -0.38 | 3 |
| | 57.0 | -0.58 | 3 | -0.74 | 3 |
| | 59.0 | -1.27 | 3 | -1.44 | 3 |
| | 62.2 | -3.43 | 3 | -3.58 | 3 |

[a] Process determining the result (see section 2.3.1.8). 1: lag phase; 2: growth; 3: inactivation.
[b] Both growth and inactivation can occur within a time temperature profile. The data point is assigned to the category where it gives the best fit to the linear model.
[c] No observations fall in category 2.

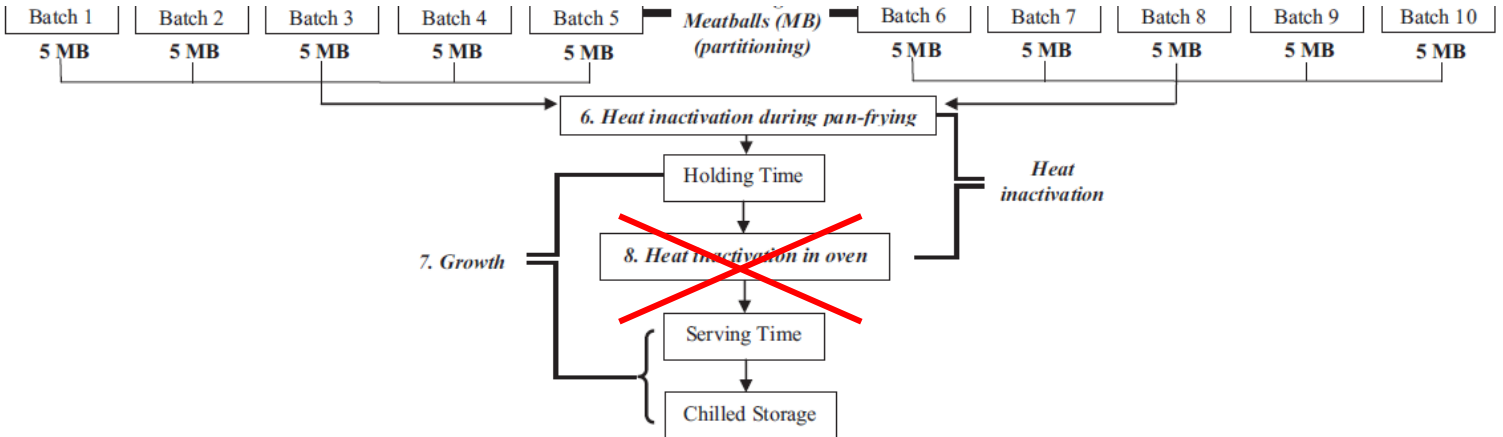
In the QMRA Monte Carlo Normal distribution of $T_o$:

- mean 40.3
- standard deviation 12

# Risk of salmonellosis from consumption of “frikadeller”

| Processing step | Basic activity | Source/model reference |
|---|---|---|
| Reception | 1. initial contamination | Hansen et al. (2010) |
| Slicing | 2. partitioning | Nauta (2005) |
| Grinding slices into portions | 3. cross contamination | Møller et al. (2012) |
| Mixing of ingredients | 4. mixing | Nauta (2005) |
| Dividing into meatballs | 5. partitioning | Nauta (2005) |
| Heating inactivation in pan | 6. inactivation | this study |
| Holding time | 7. growth | Møller et al. (2013), this study |
| plus | | |
| Heat inactivation in oven | 8. inactivation | this study |
| Serving time plus cold storage until 6° C is reached | 7. growth | Møller et al. (2013), this study |

$$= (10\hat{}(\log10(HO_{conc\ after\ inac}) + 10\hat{}(\Delta\log C_x)))$$



2 QMRA framework

## Risk of salmonellosis from consumption of "frikadeller"

| Processing step | Basic activity | Source/model reference |
|---|---|---|
| Reception | 1. initial contamination | Hansen et al. (2010) |
| Slicing | 2. partitioning | Nauta (2005) |
| Grinding slices into portions | 3. cross contamination | Møller et al. (2012) |
| Mixing of ingredients | 4. mixing | Nauta (2005) |
| Dividing into meatballs | 5. partitioning | Nauta (2005) |
| Heating inactivation in pan | 6. inactivation | this study |
| Holding time | 7. growth | Møller et al. (2013), this study |
| plus Heat inactivation in oven | 8. inactivation | this study |
| Serving time plus cold storage until 6° C is reached | 7. growth | Møller et al. (2013), this study |
| Estimation of the risk | 9. dose response | FAO/WHO (2002) |

$$Pill_{dose} \sim 1 - (1 + (C_{conc\ after\ \Delta log\ Cx} / \beta)^{\alpha}$$

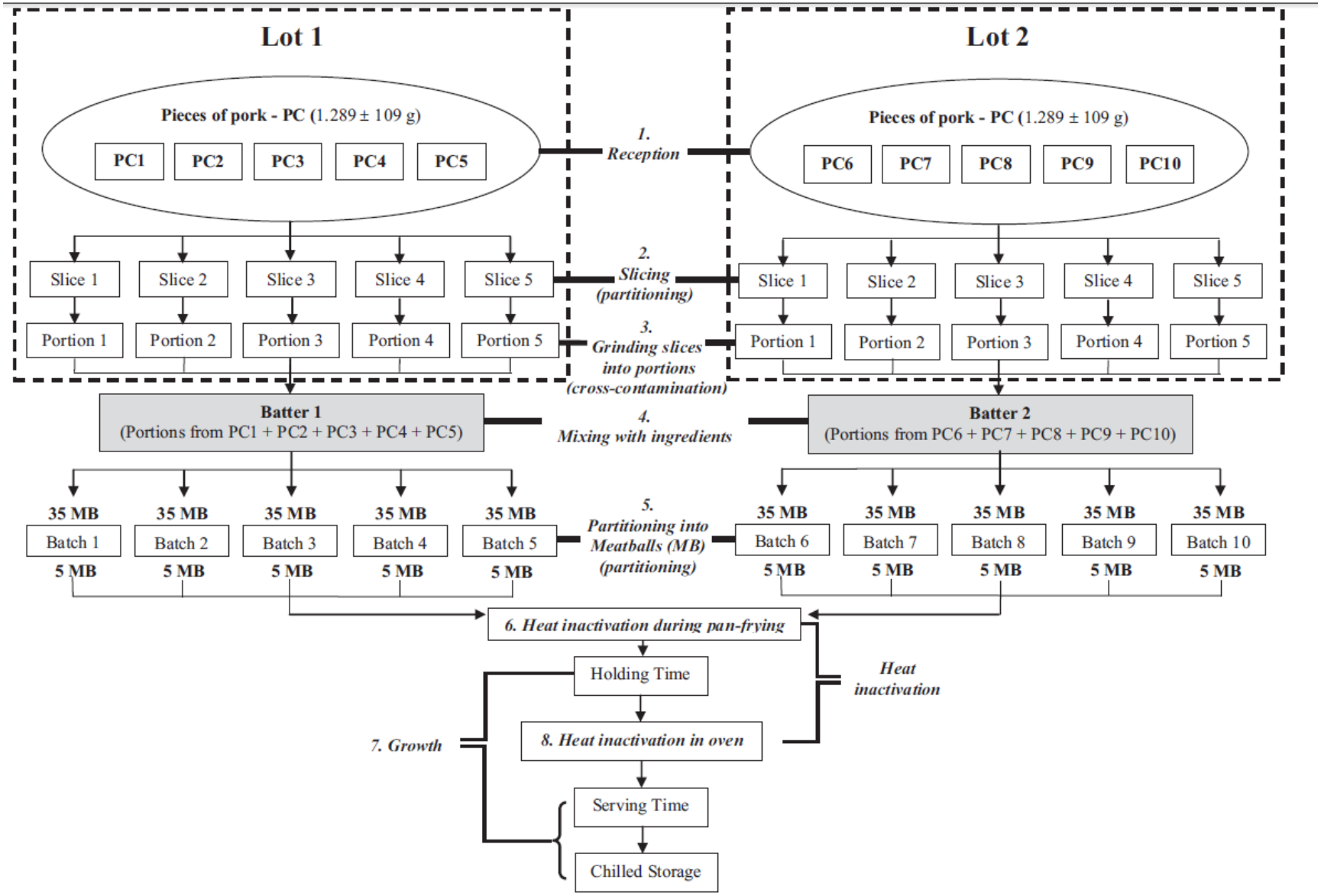
where $C_{conc\ after\ \Delta log\ Cx}$ is the concentration of *Salmonella* spp. in a meatball at the time of serving,

α was -0.1324 and

β equal to 51.45 (FAO/WHO, 2002).

The mean probability of illness from consumption of meatballs was used as the risk estimate

# Risk of salmonellosis from consumption of 'frikadeller'




. 1. Schematic presentation of processing for one lot of Danish meatballs (MB) at a catering unit. Grey boxes indicate the mix of ingredients into two individual batches of batter.

# Baseline model

| Processing step | Parameters |
|---|---|
| Reception | Prevalence = 4.2%<br>Concentration = 91 % 0.04-4 CFU/g<br>9 % → 400 CFU/g |
| Slicing | |
| Grinding slices into portions | |
| Mixing of ingredients | |
| Dividing into meatballs | |
| Heating inactivation in pan | |
| Holding time | |
| plus Heat inactivation in oven | 75° C |
| Serving time plus cold storage until 6° C is reached | RTK = 20° C |
| Estimation of the risk | |

6 QMRA modelling

# Scenario analysis

- Evaluate processing practices
- Test control measures

Scenario **1A – 1G**

Holding time

↓

Heating in oven

core temperature:

**75, 74, 73, 72, 71, 70 and 65° C**

↓

Hot serving

Scenario 2

**Baseline scenario**

RTK = 20° C

Holding time

↓

Hot serving

Scenario **3A – 3C**

Holding time

↓

Hot serving

↓

Cold storage

**R**oom **T**emp in the **K**itchen

(**RTK** = **20, 25 and 30° C**)

↓

Cold serving

6 QMRA modelling

# Scenario analysis

**Challenge 1:**

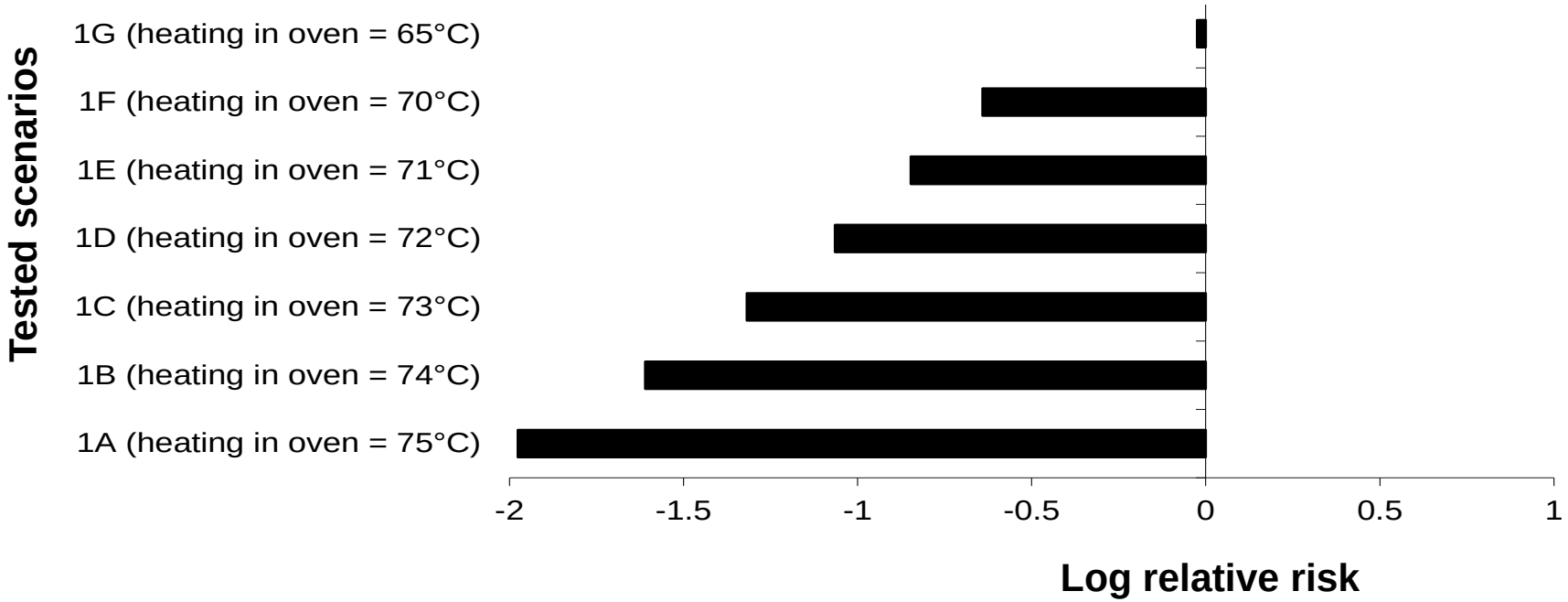
Are the recommendations of Food Safety Authorities good enough?

**Core temperature of "frikadeller" in oven**

| 1A | 1B | 1C | 1D | 1E | 1F | 1G |
|---|---|---|---|---|---|---|
| 75° C | 74° C | 73° C | 72° C | 71° C | 70° C | 65° C |

**Baseline scenario: no oven, RTK = 20° C**

(1 case in 10,000 servings)



6 QMRA modelling

# Scenario analysis

**Challenge 2:**

Is it safe to consume cold “frikadeller”?

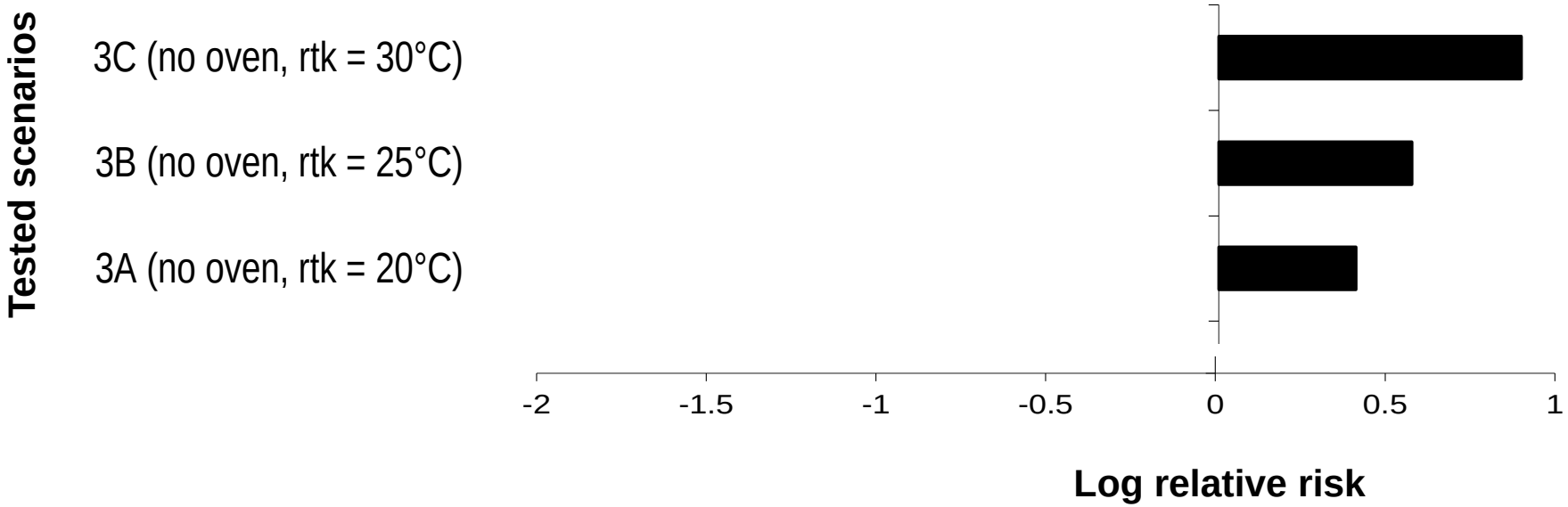
Holding time (0 to 90 min)
+
Serving time (120 min)
+
Refrigerated storage (210 min)

**Room Temperature in the Kitchen (RTK)**

| 3A | 3B | 3C |
|---|---|---|
| 20° C | 25° C | 30° C |

**Baseline scenario: no oven, RTK = 20° C**

(1 case in 10,000 servings)



6 QMRA modelling

# Scenario analysis

**Challenge 3:**

How many people would became ill with salmonellosis in Denmark per year?

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **serving times/year =** | **24** | | Danish population (2013) = | 5600000 | | 20% of Danish population = | 1120000 | |
| | | | | | | | | |
| 1A (heating in oven = 75°C) | 1B (heating in oven = 74°C) | 1C (heating in oven = 73°C) | 1D (heating in oven = 72°C) | 1E (heating in oven = 71°C) | 1F (heating in oven = 70°C) | 1G (heating in oven = 65°C) | 2 (no oven nor storage) | 3C (no oven, rtk = 30°C) |
| 0.000005 | 0.000012 | 0.000027 | 0.000044 | 0.000081 | 0.000122 | 0.000541 | 0.001217 | 0.003332 |
| | | | | | | | | |
| | | | | | | 5.41E-04 | 1.22E-03 | 3.33E-03 |
| | | | | | | | | |
| 137 | 332 | 717 | 1186 | 2168 | 3291 | 14556 | 32706 | 89562 |

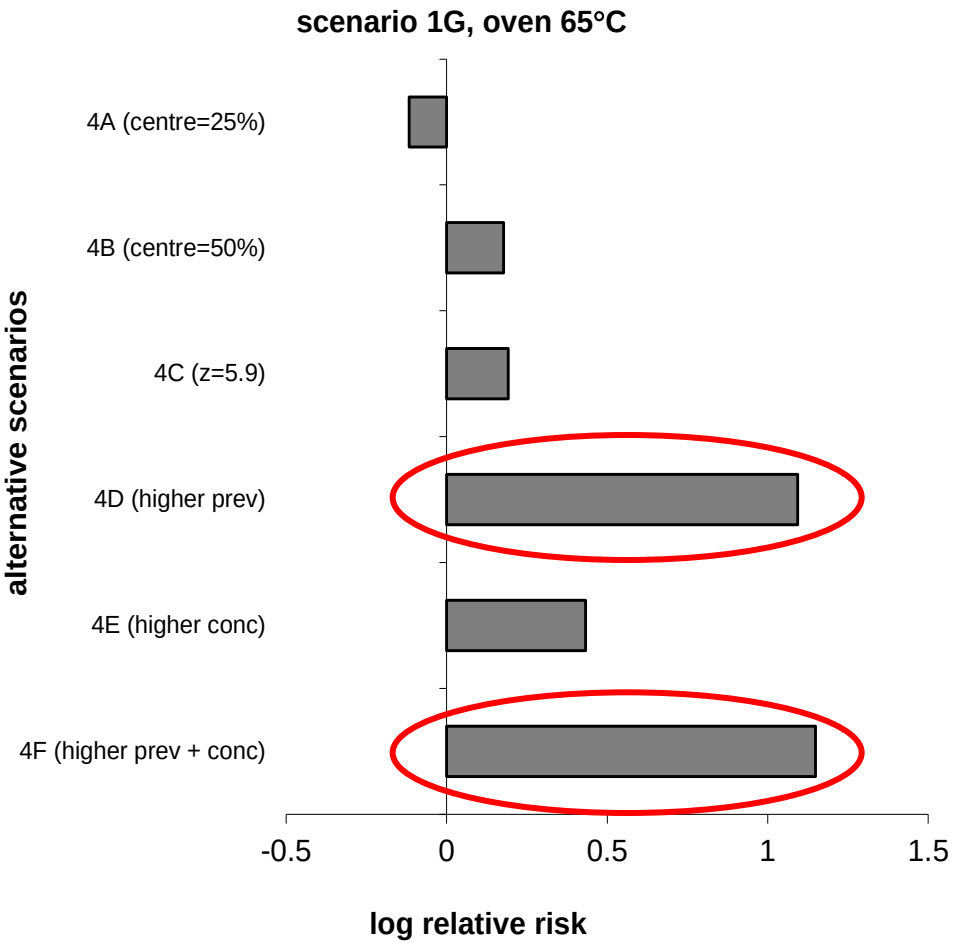
6 QMRA modelling

# Sensitivity analysis

| Investigated aspect | Baseline model | Sensitivity analysis | Alternative scenario |
|---|---|---|---|
| ✓ Fraction of "frikadelle" with Survival of *Salmonella* |  = 33 % | = 25 % | 4A |
| | | = 50 % | 4B |
| ✓ Heating inactivation according to meat matrix | z-value = 7.34 | z-value = 5.90 | 4C |
| ✓ Prevalence of *Salmonella* in pork | 4.2 % | 20.0 % | 4D |
| ✓ Concentration of *Salmonella* in pork | 91 % 0.04-4 CFU/g<br>9 % → 400 CFU/g | 88 % 0.04-4 CFU/g<br>*12 % 40-400 CFU/g* | 4E |
| ✓ ↑ prevalence and ↑ concentration | | | 4F |

6 QMRA modelling

# Sensitivity analysis




↑ **impact on the risk estimates**

Combination of

↑ prevalence and ↑ concentration

# Remarks and future perspectives

**Risk assessment of *Salmonella* spp. in Danish meatballs produced at the catering sector**

Cleide O. de A. Møller[1], Maarten J. Nauta[1], Donald W. Schaffner[2], Paw Dalgaard[3], Bjarke B. Christensen[1,4], Tina B. Hansen[1]

- ✓ The model flexible structure allows scenario analysis
- ✓ Core temperatures > 70° C inactivate *Salmonella*
- ✓ *No growth of Salmonella if:*
  - *RTK = < 20° C*
  - *For 3.5 h until refrigeration*
  - *Refrigerated storage = < 6° C*

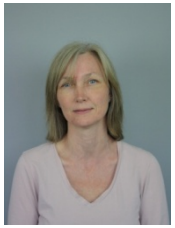
## To be investigated

- ✓ Heat inactivation :
  - Specific heating profile
  - "Frikadelle" batter
- ✓ Growth
  - Heat injured *Salmonella* cells
- ✓ Improvement of the previously developed models (transfer and growth)

# Acknowledgements

✓ This research project was financed by the Technical University of Denmark through the FoodDTU programme

✓ Constructive advice and critical comments were given by:


Tina Beck Hansen


Maarten Nauta


Donald W. Schaffner


Paw Dalgaard


Bjarke Bak Christensen


✓ Skillful technical assistance was provided by colleagues from the Division of Food Microbiology at the National Food Institute.