EURL Lm
European Union Reference Laboratory for
*Listeria monocytogenes*
http://eurl-listeria.anses.fr

# Report

# Temperatures of the food cold chain at consumer level in Europe

## Version 2 – 08/06/2021

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# 1 CONTEXT

The cold chain is essential for guaranteeing the quality and safety of chilled foods. The final step of the cold chain, storage in domestic refrigerators, is mimicked in challenge tests assessing the growth potential and durability studies for chilled food products.
In recent years, few surveys have been carried out in Europe on the storage temperatures of domestic refrigerators. Gathering available data on this step is important since this storage condition can have a significant impact on the behaviour of *Listeria monocytogenes* (*Lm*) in ready-to-eat (RTE) foods and thus on the microbiological safety of chilled food products.
The European Union Reference Laboratory for *Listeria monocytogenes* (EURL *Lm*) has planned to reconsider the default temperature of the cold chain at consumer level (12°C) set out in Table 3 of the EURL *Lm* Technical Guidance Document for conducting shelf-life studies on *L. monocytogenes* in ready-to-eat foods –Version 3 of 6 June 2014 – Amendment 1 of 21 February 2019.
This work was conducted in 2020 with the collaboration of a working group of volunteering 8 NRLs: Marie POLET (Sciensano, BE-NRL), Jens KIRK ANDERSEN (DTU Food, DK-NRL), Bernadette HICKEY (Department of Agriculture, Food and Marine, IE-NRL), Luigi IANNETTI (IZS Teramo, IT-NRL), Paul IN'T VELD (NWVA, NL Competent Authority and c/o NL-NRL), Gonçalo Nieto ALMEIDA (Iniav, PT-NRL), Linda EVERIS (Campden BRI, c/o UK-NRL), Monica RICÃO CANELHAS (SLV, SE-NRL).
In order to be as realistic as possible, when conducting shelf-life studies, EURL *Lm* reviewed available data in Europe on storage temperatures of domestic refrigerators based on (a) data from national surveys and (b) from scientific literature in the recent years.

The collected data was considered in order to (i) get a better knowledge of refrigerator temperatures at consumer level and (ii) to better assess the shelf-life of RTE food regarding *Listeria monocytogenes.*

## 2 DATA FROM NATIONAL SURVEYS

The EURL *Lm* launched an inquiry in July 2019 to the National Reference Laboratories (NRLs) to know if, over the last ten years, national survey studies were conducted and when possible, to collect data on temperature in domestic refrigerators in each European country.
72.5% of the enquired NRLs replied and among them, 31% have conducted an inquiry in their country. Seven member states conducted an enquiry: Austria (AT), Belgium (BE), Denmark (DK), France (FR), Ireland (IE), Italy (IT) and The Netherlands (NL). Table 1 provide information on the country where the study was conducted, the numbers of refrigerators monitored (size), the targeted population investigated, the sampling method used, the apparatus used for the measurement of the temperature, the duration and frequency of the recording and the area monitored in the fridge or the food used.

Table 1. General information from national surveys

| Index | Country | Year | Scope | Purpose | Size | Target | Sampling | Data reporting | Monitoring | Duration (frequency) | Fridge (with area) or Food |
|---|---|---|---|---|---|---|---|---|---|---|---|
| [A] | **AT** | 2011 | National | Evaluation of food handling behaviours amongst householders in Austria | 353 | Whole population | Random | Interview by phone | TF | ? | Fridge (?) |
| [B] | **BE** | 2004 | National | Enquête de consommation alimentaire Belge 1 – 2004 (Devriese *et al.*, 2004) | 3001 | Whole population | ? | Home investigator | ? | ? | Fridge (?) |
| [C] | **DK** | 2015 | District | Investigate the T°C of elderly people refrigerators | 77 | Elderly people | ? | Health Care workers | DL | 30 min | Fridge (Other) |
| [D] | **FR** | 1999 | National | Study of domestic refrigerator temperature and analysis of factors affecting temperature: a French study (Laguerre *et al.*, 2002) | 118 | Whole population | Representative families | Home investigator | DL | 7 days (2-8 min) | Fridge (T ; M ; B) |
| [E] | **FR** | 2006 | National | The cold chain of chilled products under supervision in France (Derens *et al.*, 2006) | 251 | Whole population covered French territory | Random | Recorder inside food returning by the consumer | DL | mean 4 days | Prepared meat product ; Yoghurt ; Packed meat product |
| [F] | **FR** | 2013 | National | Cold chain of chilled food in France (Derens-Bertheau *et al.*, 2015) | 75 | Whole population from different cities | Random | Recorder inside food returning by the consumer | DL | mean 6 days | Sliced Ham |
| [G] | **FR** | 2014–2015 | National | Estimate of food consumption & nutritional intake of people living in France (Anses, 2017) | 5428 | Whole population | Stratified multi-stage design | Home investigator | T | 30 – 45 min | Fridge (T ; M ; B) |
| [H] | **IE** | 2005 | National | Food safety knowledge of consumers and the microbiological and temperature status of their refrigerators (Kennedy *et al.*, 2005) | 100 | Whole population | Representative sampling | Home investigator | DL | 72h (10min) | Fridge (M) |
| [I] | **IT** | 2019–2020 | National | Network of the Italian Experimental Zooprophylactic Institutes (I.I.Z.Z.S.S.), 2019. Research Project IZS LER 2016/018 RC: National survey of domestic refrigerators temperatures in Italy (preliminary results). Principal Investigator Paolo Daminelli. Research funded by the Italian Ministry of Health | 494 | Whole population | Stratified sampling plan | Home investigator | DL | ? | Fridge (?) |
| [J] | **NL** | 2012 | National | Food waste | 326 | ? | ? | Self-reporting via a questionnaire | T in water | Half a day | Fridge (?) |

*Monitoring: DL, Data Logger; T, thermometer; TF,* Temperature display on the fridge
*Fridge area: T, Top; M, Middle; B, Bottom; Other, Shelf where ready to eat meat products were placed (loggers placed between packages of ready to eat products).*
*?, unknown*

Table 2 summarises for each survey the mean, standard deviation, minimum, maximum and the 75th and 95th percentiles of refrigerator temperatures. Among the ten surveys, eight allowed to obtain 75th and 95th percentiles.

The 75th and 95th percentiles of refrigerator temperatures were determined using four different ways (Table 2):

- Calculated from the raw data (when available), using a R script on R software. Only three countries provided us with raw temperature data (DK, FR and IT).
- Provided by a contact person involved in the survey (noted *b,* in Table 2).
- Estimated from a figure available on the survey report (noted *c, in Table 2*).
- Estimated using *"rnorm"* and *"matrix"* functions in R software, when only the mean temperature (expressed with its standard deviation) of *N* measurements were available. The function "*rnorm*" generates a random simulation of temperatures following a normal distribution. The function"*matrix*" repeats the simulation several times (here, 10 000 iterations were performed) in order to determine the most probable 75th and 95th percentiles (noted *d,* in Table 2).

The recommended temperature setting was between 4 to 6°C depending on the country and the mean temperatures observed were between 5.9 to 7.5°C (Table 2).
The 75th and 95th percentiles of refrigerator temperatures were respectively between 7.2 to 9.5°C and between 8.0 to 12.5°C (Table 2). The cumulative distribution curves for refrigerator temperatures from the Danish and French surveys, built with R software, are presented in annex 6.1.

Table 2. Collected data from national surveys and determination of the 75th and 95th percentile of refrigerator temperatures

| Index | Country | Size | Fridge (area) / Food | T° Mean (°C) | SD (°C) | T° min (°C) | T° max (°C) | 75th percentile (°C) | 95th percentile (°C) |
|---|---|---|---|---|---|---|---|---|---|
| [C] | **DK** | 77 | **Fridge (Other)** | **6.1** | **2.1** | **0** | **10.0** | **7.2** | **9.5** |
| [D] | **FR** | 118 | **Fridge (Global)** | **6.6** | **2.2** | **0.9** | **11.4** | **8.2** | **10.2** |
| | | | Fridge (T) | 6.7 | 2.5 | -1.6 | 12.0 | 8.2 | 11.0 |
| | | | Fridge (M) | 6.4 | 2.4 | -0.2 | 10.7 | 7.8 | 10.3 |
| | | | Fridge (B) | 6.5 | 2.7 | -1.0 | 11.6 | 8.4 | 10.7 |
| [E] | **FR** | 251 | **Global food** | **5.9** | **3.0** | **-4.8** | **13.8** | **7.5** | **11.1** |
| | | | Prepared meat product | 5.7 | 3.2 | -4.8 | 13.8 | 7.4 | 11.1 |
| | | | Yoghurt | 6.1 | 2.9 | -2.0 | 12.5 | 7.9 | 11.7 |
| | | | Packed meat product | 6.0 | 2.2 | 1.1 | 10.8 | 7.5 | 9.7 |
| [F] | **FR** | 75 | **Sliced Ham** | **6.3** | **2.2** | **1.1** | **10.7** | **8.1** | **9.9** |
| [G] | **FR** | 3767 | **Fridge (Global)** | **5.9** | **2.9** | **-3.0** | **15.0** | **8.0** | **11.0** |
| | | | Fridge (T) | 6.5 | 3.1 | -3.0 | 15.0 | 9.0 | 12.0 |
| | | | Fridge (M) | 5.6 | 2.8 | -3.0 | 15.0 | 7.0 | 10.0 |
| | | | Fridge (B) | 5.8 | 2.8 | -3.0 | 15.0 | 8.0 | 11.0 |
| [I] | **IT** | 494 | **Fridge (?)** | **7.5** | **3.1** | **-1.2** | **16.4** | **9.5[b]** | **12.5[b]** |
| [J] | **NL** | 326 | **Fridge (?)** | ? | ? | ? | ? | ? | **8.0[c]** |
| [H] | **IE** | 100 | **Fridge (M)** | **5.9[a]** | **2.5[a]** | **-1.7** | **11.8** | **7.6[d]** | **10.0[d]** |
| [A] | **AT** | 353 | Fridge (?) | 7 | 2.5 | 2.0 | 13.0 | ? | ? |
| [B] | **BE** | 3001 | Fridge (?) | 7 | ? | ? | ? | 9.0[b] | ? |

*SD, Standard deviation; ?, not available; [a] data obtain from Roccato et al., 2017; [b] Percentile provided by the contact person; [c] Percentile estimated from a figure; [d] Percentile estimated from R simulation*
*Fridge area: T, Top; M, Middle; B, Bottom; Other, Shelf where ready to eat meat products were placed (loggers placed between packages of ready to eat products).*
*Bold, Data taken into account in the interpretation*

# 3 DATA FROM SCIENTIFIC LITERATURE

A review of the scientific literature on domestic refrigerator temperatures was performed, based on studies published between 2002 and 2020. Seventeen publications were selected and for 10 of them, raw data (8) or 95$^{th}$ percentile (2) of refrigerator temperatures were obtained from the authors or contact persons (index 1 to 10 in Table 3).
These 17 studies were conducted in 11 European countries: Germany (DE), Spain (ES), France (FR), Greece (GR), Italy (IT), Norway (NO), Portugal (PT), Romania (RO), Sweden (SE), Slovenia (SI) and United Kingdom (UK).

Table 3. Scientific literature collected

| Index | Country | Title | Year | Author |
|---|---|---|---|---|
| [1] | **ES** | Temperature distribution in Spanish domestic refrigerators and its effect on *Listeria monocytogenes* growth in sliced ready-to-eat ham | 2010 | Garrido *et al.*, 2010 |
| [2] | **ES** | Domestic refrigerator temperatures in Spain: Assessment of its impact on the safety and shelf-life of cooked meat products | 2019 | Jofre *et al.*, 2019 |
| [3] | **GR** | Field survey on temperature distribution and hygienic status of domestic refrigerators in Lemnos, Greece | 2019 | Stasinou *et al.*, 2019 |
| [4] | **IT** | Survey conducted in Italy on the consumer refrigeration temperatures and their impact on food safety illustrated with Salmonella. IAFP European Symposium on Food Safety, May 15–17, Marseille | 2013 | Roccato, 2013 |
| [5] | **PT** | Incidence of *Listeria* spp. in domestic refrigerators in Portugal | 2005 | Azevedo *et al.*, 2005 |
| [6] | **PT** | Thermal performance, usage behavior and food waste of domestic refrigerators in a university student community: findings towards cities sustainability | 2017 | Galvão *et al.*, 2017 |
| [7] | **RO ; FR ; NO ; PT ; UK** | Time-temperature profiles and *Listeria monocytogenes* presence in refrigerators from households with vulnerable consumers | 2020 | Dumitraşcu *et al.*, 2020 |
| [8] | **SE** | Home storage temperatures and consumer handling of refrigerated foods in Sweden | 2004 | Marklinder *et al.*, 2004 |
| [9] | **SI** | Temperatures and storage conditions in domestic refrigerators - Slovenian scenario | 2020 | Ovca *et al.*, 2020 |
| [10] | **UK** | Reducing food waste through the chill chain | 2010 | George *et al.*, 2010 |
| [11] | **ES** | Survey of Temperature and Consumption Patterns of Fresh-Cut Leafy Green Salads: Risk Factors for Listeriosis | 2007 | Carrasco *et al.*, 2007 |
| [12] | **DE ; ES ; FR ; UK** | Cold storage in private households: recommendations and consumer real life behaviour | 2002 | Geppert *et al.*, 2010 |
| [13] | **GR** | Modelling the effect of house hold chilled storage condition on the risk distribution of meat product | 2005 | Taoukis *et al.*, 2005 |
| [14] | **GR** | Probabilistic Model for *Listeria monocytogenes* growth during distribution, retail storage, and domestic storage of pasteurized milk | 2010 | Koutsoumanis *et al.*, 2010 |
| [15] | **IT** | The management of the domestic refrigeration: microbiological status and temperature | 2014 | Vegara *et al.*, 2014 |
| [16] | **NO** | Toxin production and growth of pathogens subjected to temperature fluctuations simulating consumer handling of cold cuts | 2014 | Rossvoll *et al.*, 2014 |
| [17] | **UK** | Time-temperature profiling of United Kingdom consumers' domestic refrigerators | 2016 | Evans *et al.*, 2016 |

Table 4, below, provides information on the country where the study was conducted, the number of refrigerators monitored, the targeted population investigated, the sampling method used, the apparatus used for the measurement of the temperature, the duration and frequency of the recording and the area monitored in the fridge or the food tested.

Table 4. General information from scientific literature

| Index | Country | Size | Target | Sampling | Monitoring | Duration (frequency) | Fridge (with area) / Food |
|---|---|---|---|---|---|---|---|
| [1] | **ES** | 33 | Whole population of Pamplona | ? | P | one measure (triplicate) | Fridge (T ; M ; B) Water (T ; M ; B) |
| [2] | **ES** | 106 | Whole population | Random | DL | 24 h (10 min) | Fridge (C ; D) |
| [3] | **GR** | 70 | ? Island of Lemnos | Random | DL | 24 h (15 min) | Fridge (T ; B ; D) |
| [4] | **IT** | 106 | Volunteers population | Random | DL | 6 days (15 min) | Fridge (T ; B ; D) |
| [5] | **PT** | 86 | North of Portugal | Volunteers families | T | ? | Fridge (?) |
| [6] | **PT** | 51 | Student community University of Beira Interior | live alone; with their parents; in conjunction with other students | DL | 8 days (8 min) | Fridge (M) |
| [7] | **RO ; FR ; NO ; PT; UK** | 15/ Country | Specific population, one city per country | elderly, families with infants and/or pregnant women, young single men | DL | 14 days (1 min–1 h) | Fridge (Other) |
| [8] | **SE** | 102 / food | Whole population in Uppsala | Random | DL | 40 min (10 min) | Minced meat; herring; cheese; milk; ham; salmon; RTE salad |
| [9] | **SI** | 50 | ? | linear snowball sampling approach | DL | 7 days (2-8 min) | Fridge (M) |
| [10] | **UK** | 50 | Whole population | Representative fridge type | DL | 4 days (1 min) | Fridge (T ; M ; B) |
| [11] | **ES** | 30 | Whole population in Cordoba | Random in the street | DL | 24h (30 s) | Fridge (?) |
| [12] | **DE ; ES ; FR ; UK** | 100/country | ? | ? | DL | 11 days (1 min) | Fridge (M) |
| [13] | **GR** | 250 | Whole population in Athens metropolitan area | ? | DL | 7 days (?) | Fridge (C) |
| [14] | **GR** | 100 | ? | ? | DL | 24 h (5 min) | Fridge (T ; M ; B ; D) |
| [15] | **IT** | 84 | Whole population Central and North Italy | ? | T | 24 h (?) | Fridge (M) |
| [16] | **NO** | 46 | Specific population from Oslo and Akershus area | Word-of-mouth and snowball effect | DL | 11 days (1 min) | Fridge (?) |
| [17] | **UK** | 43 | Whole population from an urban community in South Wales | Random | P | 136.5 h (1 min) | Fridge (M ; D) |

*Monitoring: DL, Data Logger; T, Digital thermometer; P, Calibrated probe*
*Area: T, Top; M, Middle; B, Bottom; D, Door; C, Core; Other, Storage zone of highly risky foods*
*?, Unknown*

The results of these studies are presented in Table 5. For each study the mean, standard deviation, minimum, maximum, the 75$^{th}$ and 95$^{th}$ percentiles of refrigerator temperatures were determined as previously described (see Part 2). The 75$^{th}$ and 95$^{th}$ percentiles were obtained for 16 out of the 17 studies.

The mean refrigerator temperatures measured in air and in food were respectively between 4.1 to 8.7°C and 5.9 to 8.0°C (Table 5). The average of all these mean temperatures from air (6.35°C) and food (6.73°C) were not statistically different (p-value=0.25, Student test). Therefore, in the following, air and food data were considered together rather than separately.

The 75$^{th}$ and 95$^{th}$ percentiles of refrigerator temperatures were respectively between 5.0 to 10.4°C and 8.0 to 13.9°C (Table 5). Where multiple refrigerator temperature areas were studied, a global value for each percentile was determined by combining, where possible, data from the top, middle and bottom of the refrigerator. Data from the door area were excluded because ready-to-eat foods are rarely stored in this area. These global values, in bold in Table 5, were used for interpretations.

The cumulative distribution curves of the data from the scientific literature built with R software are presented in annex 6.2. Only the 95$^{th}$ percentiles (in bold in Table 5) are presented in annex 6.2.

Table 5. Collected data from scientific literature and determination of the 75th and 95th percentile of refrigerator temperatures

| Index | Country | Size | Fridge (Area) / Food | T° Mean (°C) | SD (°C) | T° min (°C) | T° max (°C) | 75th Percentile (°C) | 95th Percentile (°C) |
|---|---|---|---|---|---|---|---|---|---|
| [1] | **ES** | 33 | **Fridge (Global)** | **8.3** | **2.8** | **3.9** | **14.6** | **9.3** | **13.5** |
| | | | Fridge (T) | 9.4 | 3.7 | 2.2 | 15.0 | 12.2 | 14.5 |
| | | | Fridge (M) | 8.2 | 2.9 | 4.2 | 14.8 | 10.0 | 13.5 |
| | | | Fridge (B) | 7.2 | 3.5 | -1.4 | 14.3 | 9.3 | 12.8 |
| | | | **Food (Global)** | **8.0** | **2.7** | **3.9** | **14.4** | **8.9** | **12.6** |
| | | | Food (T) | 9.1 | 3.1 | 2.2 | 15.0 | 10.7 | 13.6 |
| | | | Food (M) | 7.6 | 2.6 | 3.6 | 14.5 | 9.3 | 12.0 |
| | | | Food (B) | 7.2 | 3.1 | 0.7 | 14.5 | 8.3 | 13.1 |
| [2] | **ES** | 106 | **Fridge (C)** | **5.4** | **2.1** | **0.6** | **12.7** | **6.9**[b] | **9.2**[b] |
| [3] | **GR** | 70 | **Fridge (Global)** | **8.7** | **3.2** | **-0.8** | **17.5** | **10.4** | **13.9** |
| | | | Fridge (T) | 8.7 | 3.3 | -2.1 | 17.1 | 10.7 | 13.2 |
| | | | Fridge (B) | 8.7 | 3.3 | 0.5 | 17.9 | 10.6 | 14.5 |
| [4] | **IT** | 106 | **Fridge (Global)** | **7.2** | **2.5** | **-3.5** | **15.2** | **8.9**[d] | **10.6**[b] |
| | | | Fridge (T) | 6.9 | ? | -3.5 | 13.6 | ? | ? |
| | | | Fridge (B) | 6.6 | ? | -3.0 | 14.8 | ? | ? |
| [5] | **PT** | 86 | **Fridge (?)** | **7.3** | **2.6** | **0.9** | **15.2** | **9.0** | **10.9** |
| [6] | **PT** | 51 | **Fridge (M)** | **5.5** | **2.7** | **-1.77** | **11.9** | **6.9** | **10.5** |
| [7] | **RO** | 14 | **Fridge (Other)** | **5.3** | **2.2** | **1.7** | **9.5** | **6.4** | **8.7** |
| | **FR** | 15 | **Fridge (Other)** | **6.4** | **1.4** | **4.0** | **8.3** | **7.3** | **8.2** |
| | **NO** | 13 | **Fridge (Other)** | **5.4** | **2.1** | **1.2** | **8.8** | **7.0** | **8.3** |
| | **PT** | 15 | **Fridge (Other)** | **5.5** | **1.9** | **3.2** | **9.1** | **6.3** | **8.9** |
| | **UK** | 13 | **Fridge (Other)** | **5.0** | **2.7** | **-0.1** | **9.3** | **6.2** | **8.7** |
| [8] | **SE** | 102/food | **Global food** | **6.9** | **1.8** | **3.0** | **11.4** | **8.1** | **9.8** |
| | | | Minced meat | 6.2 | 2.3 | 0.8 | 11.3 | 7.3 | 10.1 |
| | | | Herring | 6.5 | 2.5 | 0.2 | 12.8 | 7.9 | 10.6 |
| | | | Cheese | 6.8 | 2.0 | 2.4 | 13.6 | 8.1 | 9.9 |
| | | | Milk | 6.9 | 2.2 | 0.6 | 13.2 | 8.4 | 10.4 |
| | | | Ham | 7.2 | 2.4 | 1.1 | 12.3 | 9.1 | 10.4 |
| | | | Salmon | 7.1 | 2.5 | 0.2 | 12.3 | 8.9 | 10.8 |
| | | | RTE salad | 6.9 | 2.8 | 1.8 | 18.2 | 9.1 | 12.1 |
| [9] | **SI** | 50 | **Fridge (M)** | **5.9** | **2.2** | **-0.3** | **10.7** | **7.2** | **9.6** |
| | | | **Food (M)** | **6.0** | **2.2** | **1.0** | **10.7** | **7.5** | **9.6** |
| [10] | **UK** | 50 | **Fridge (Global)** | **6.8** | **3.4** | **-1.6** | **15.5** | **8.8** | **12.1** |
| | | | Fridge (T) | 5.8 | 3.1 | -1.6 | 11.7 | 7.9 | 10.2 |
| | | | Fridge (M) | 5.0 | 2.3 | -1.6 | 10.3 | 6.4 | 8.1 |
| | | | Fridge (B) | 6.7 | 2.7 | 3.0 | 15.5 | 11.7 | 13.4 |
| [11] | **ES** | 30 | **Fridge (?)** | **6.6** | **2.6** | **?** | **?** | **8.3**[d] | **10.8**[d] |
| [12] | **DE** | 100 | Fridge (M) | 6.2 | ? | 0 | 11.0 | 7.0[c] | 10.0[c] |
| | **ES** | 100 | Fridge (M) | 4.1 | ? | 0 | 10.0 | 6.0[c] | 9.0[c] |
| | **FR** | 100 | Fridge (M) | 6.7 | ? | 1.0 | 12.0 | 9.0[c] | 12.0[c] |
| | **UK** | 100 | Fridge (M) | 5.2 | ? | 3.0 | 10.0 | 5.0[c] | 8.0[c] |
| [13] | **GR** | 250 | **Fridge (Global)** | **6.3** | **2.7** | **?** | **?** | **8.1**[d] | **10.7**[d] |
| [14] | **GR** | 100 | **Fridge (T)** | **7.6** | **3.0** | **-1.8** | **14.5** | **9.6**[d] | **12.5**[d] |
| | | | **Fridge (M)** | **6.3** | **2.7** | **-0.7** | **13.0** | **8.1**[d] | **10.7**[d] |
| | | | **Fridge (B)** | **6.7** | **2.3** | **-2.7** | **18.1** | **8.2**[d] | **10.5**[d] |
| [15] | **IT** | 84 | **Fridge (M)** | **8.1** | **?** | **2.5** | **15.9** | **?** | **10.1**[c] |
| [16] | **NO** | 46 | Fridge (?) | 6.2 | ? | 2.9 | 12.0 | ? | ? |
| [17] | **UK** | 43 | **Fridge (Global)** | **5.8** | **1.9** | **1.8** | **11.4** | **7.1**[d] | **8.9**[d] |

*Fridge area: T, Top ; M, Middle ; B, Bottom ; C, Core ; Other, Storage zone of highly risky foods such as ready-to-eat (RTE) foods.*
*SD, Standard deviation; [a] without lower part (salad crisper); [b] Percentile data provided by the author; [c] Percentile estimated from a figure; [d] Percentile estimated from R simulation; ?, Unknown*
*Bold, Data taken into account in the interpretation*

# 4 SUMMARY OF RESULTS AND CONCLUSION

This report groups together the refrigerator temperatures collected in 14 European countries (Figure 1) from 8 national surveys and 16 scientific publications.

Most of the studies/surveys targeted the whole population of a defined geographic area. Few of them focused on a specific population such as students, elderly, families with infants and/or pregnant women, young single men. The temperature measurements were mainly carried out using data loggers at different places inside the refrigerator, including the top, middle, bottom and the door or inside a food, mainly ready-to-eat foods.

Regarding the results, Table 6 and Figure 2 summarise, for each country, the mean of the operating refrigerator temperatures, the 75$^{th}$ and 95$^{th}$ percentiles (calculated and estimated) presented in bold in Table 2 and Table 5.

It appears that the refrigerators operate in a temperature between 5.3 to 7.6°C, with a mean of 6.2°C (Table 6). It is slightly higher than the recommended temperature (4 - 6°C).
The 75$^{th}$ percentiles are between 6.4 to 9.2°C, with a mean of 7.6°C and the 95$^{th}$ percentiles are between 8.0 to 11.7°C, with a mean of 9.8°C (Table 6).

The working group (WG) composed of eight Member States (BE, DK, IE, IT, NL, PT, SE, UK), gathered in 2018 for the revision of the storage temperature at retail in table 3 of the EURL *Lm* Technical Guidance Document for conducting shelf-life studies on *Listeria monocytogenes* in ready-to-eat foods (version 3, 2014), was also consulted to revise the storage temperature at consumer level. During the meeting of 7$^{th}$ October 2020, the outcomes of the review on temperature of domestic refrigerators were presented and discussed. To be consistent with the percentile defined for the temperature at retail level, the working group decided to also retain the 95$^{th}$ percentile (10°C) instead of the 75$^{th}$ percentile (7.6°C).

Therefore the temperature of 10°C at consumer level, instead of 12°C, was included in the draft version of the EURL *Lm* Technical Guidance Document related to shelf-life studies, to be published in 2021.

In conclusion, based on the actual temperatures recorded in domestic refrigerators in European countries, this study propose to settle a new set point temperature of 10°C which will have to be considered when simulating the storage of RTE foods at consumer level in challenge tests assessing the growth potential or when conducting durability studies.

However, we can point out some limitations of this study report. In some surveys/studies the sampling was not randomly performed, the number of refrigerators investigated was not high enough (lower than 100), the measurement method was not robust (better with data loggers) and finally there was an over-representatively of the southern European countries and an under-representatively of Eastern countries. It would have been preferable to have data from a European survey that covered all European countries and use the same methodology to measure the temperature of domestic refrigerators.


Figure 1. European countries (in orange) where data on temperature of domestic refrigerators (from national surveys and scientific literature) were collected.

Table 6. Summary per country of data from national surveys and scientific literature

| Country | Refrigerators<br>Mean temperature (°C) [a] | 75th percentile (°C) [a] | 95th percentile (°C) [a] |
|---|---|---|---|
| DE | 6.2 | 7.0 | 10.0 |
| DK | 6.1 | 7.2 | 9.5 |
| ES | 6.5 | 7.9 | 11.0 |
| FR | 6.3 | 7.4 | 9.7 |
| GR | 7.1 | 8.9 | 11.7 |
| IE | 5.9 | 7.6 | 10.0 |
| IT | 7.6 | 9.2 | 11.1 |
| NL | ? | ? | 8.0 |
| NO | 5.4 | 7.0 | 8.3 |
| PT | 6.1 | 7.4 | 10.1 |
| RO | 5.3 | 6.4 | 8.7 |
| SE | 6.9 | 8.1 | 9.8 |
| SI | 6.0 | 7.4 | 9.6 |
| UK | 5.7 | 6.8 | 9.2 |
| | | | |
| **Mean** | **6.2** | **7.6** | **9.8** |
| **Median** | **6.1** | **7.4** | **9.8** |
| **Min** | **5.3** | **6.4** | **8.0** |
| **Max** | **7.6** | **9.2** | **11.7** |

*[a], percentile values from studies in Table 2 and Table 5 (in bold); ?, unknown*

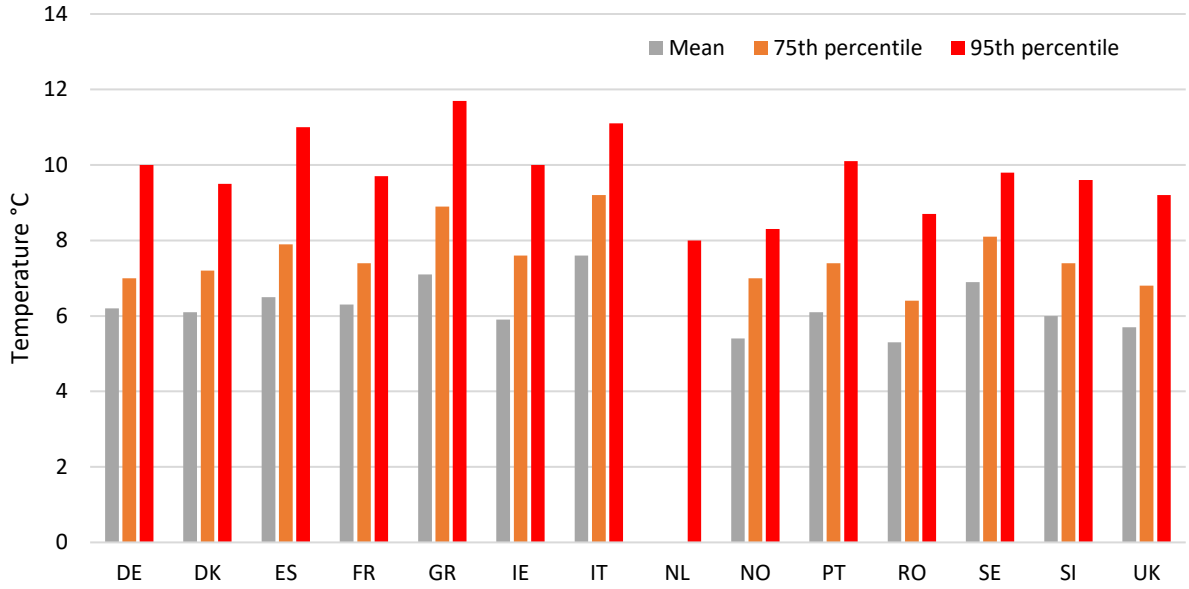


Figure 2. Histogram of the mean of the operating refrigerator temperatures (grey), the mean of the 75$^{th}$ (orange) and of the 95$^{th}$ (red) percentiles, per country, in Europe

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# 6 ANNEXES

## 6.1 CUMULATIVE DISTRIBUTION CURVES OF DATA COLLECTED FROM NATIONAL SURVEYS

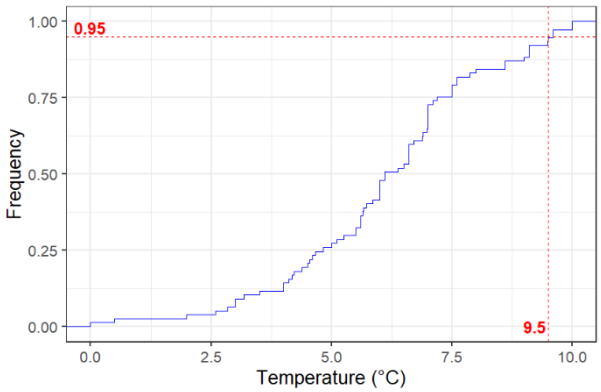


Figure 3. Cumulative distribution curve from the Danish survey [C] (95th percentile show in red)

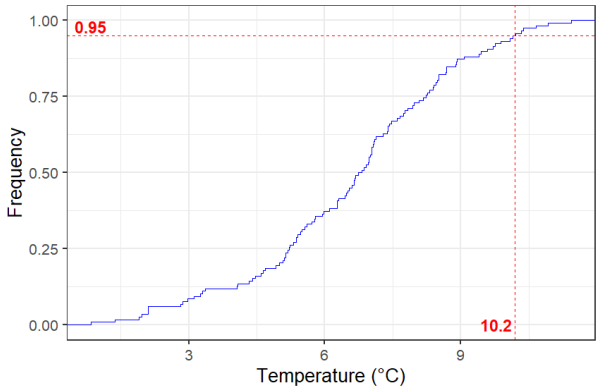


Figure 4. Cumulative distribution curve from Laguerre *et al.*, 2002 [D] (95th percentile show in red)

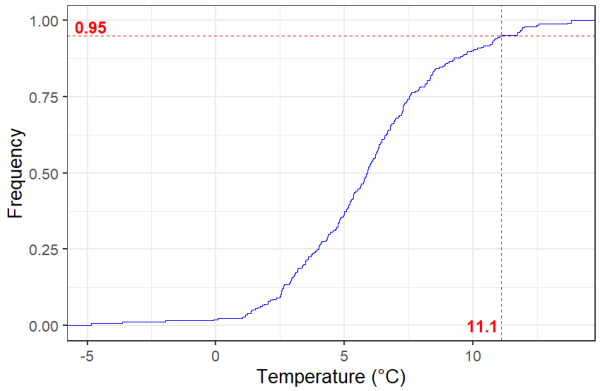


Figure 5. Cumulative distribution curve from Derens *et al.*, 2006 [E] (95th percentile show in red)

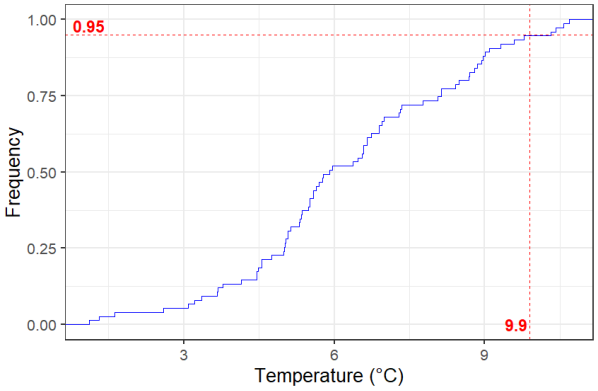


Figure 6. Cumulative distribution curve from Derens *et al.*, 2015 [F] (95th percentile show in red)

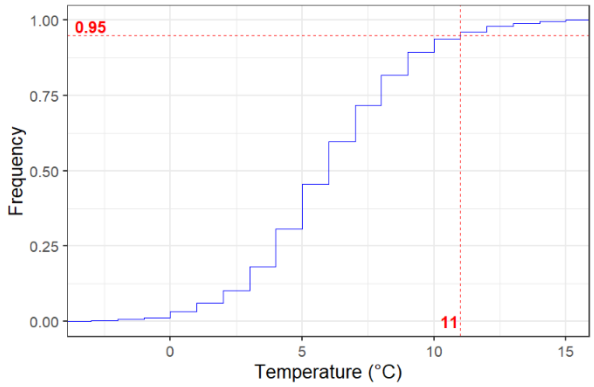


Figure 7. Cumulative distribution curve from the French survey [G] (95th percentile show in red)

## 6.2 CUMULATIVE DISTRIBUTION CURVES OF DATA COLLECTED FROM SCIENTIFIC LITERATURE

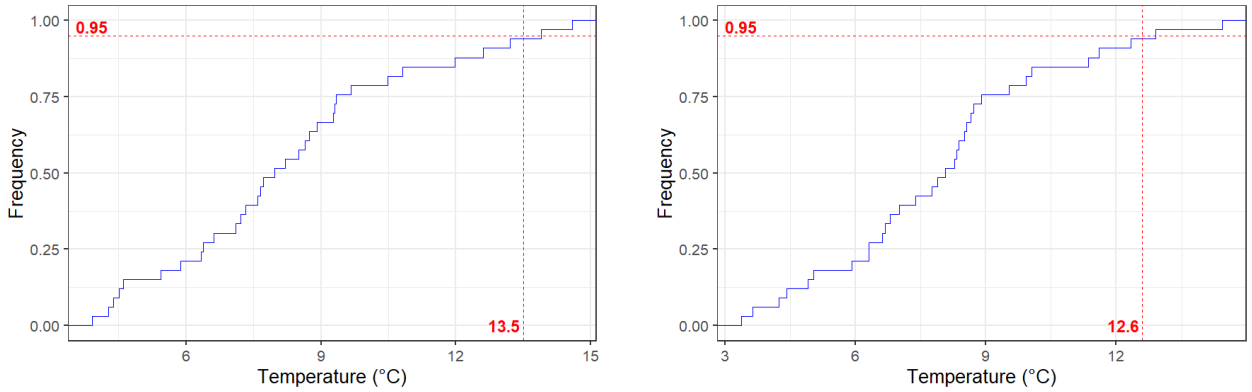


Figure 8. Cumulative distribution curve from Garrido *et al.*, 2010 [1] in air (on the left) and inside food (on the right) (95th percentile show in red)

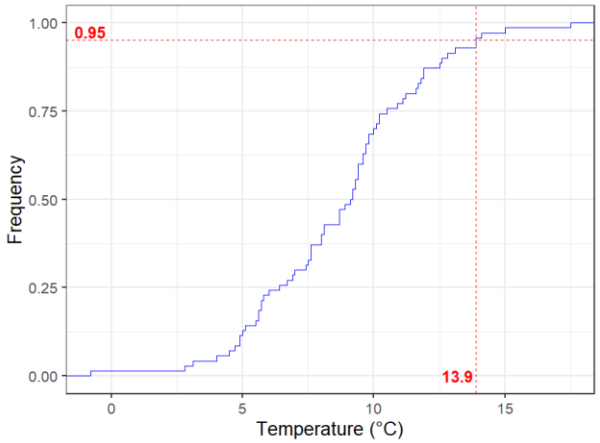


Figure 9. Cumulative distribution curve from Stasinou *et al.*, 2019 [3] (95th percentile show in red)

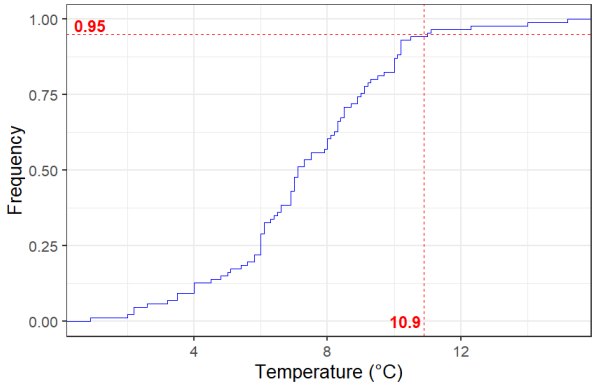


Figure 10. Cumulative distribution curve from Azevedo *et al.*, 2005 [5] (95th percentile show in red)

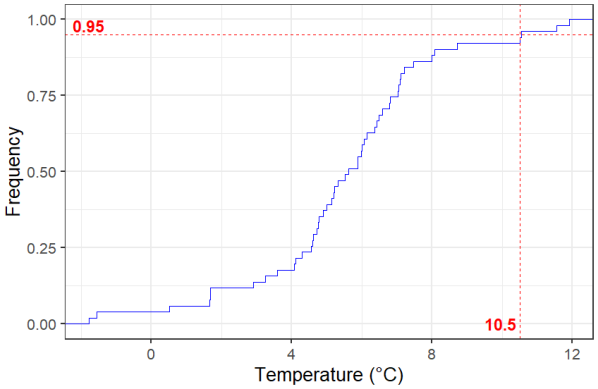


Figure 11. Cumulative distribution curve from Galvão *et al.*, 2017 [6] (95th percentile show in red)

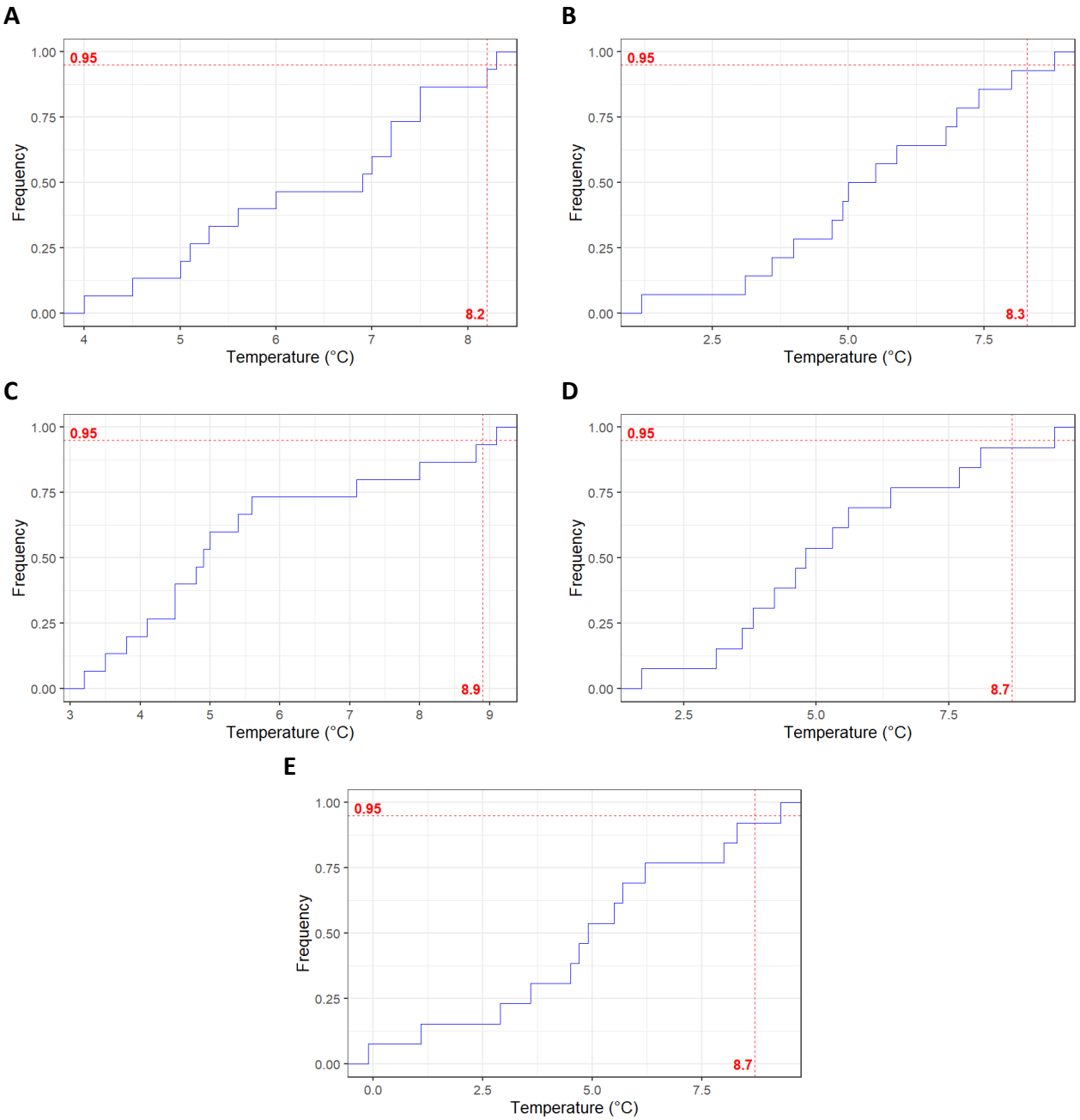


Figure 12. Cumulative distribution curve from Dumitrascu *et al.*, 2020 [7] for each country: France (A), Norway (B), Portugal (C), Romania (D) and United Kingdom (E) (95th percentile show in red)

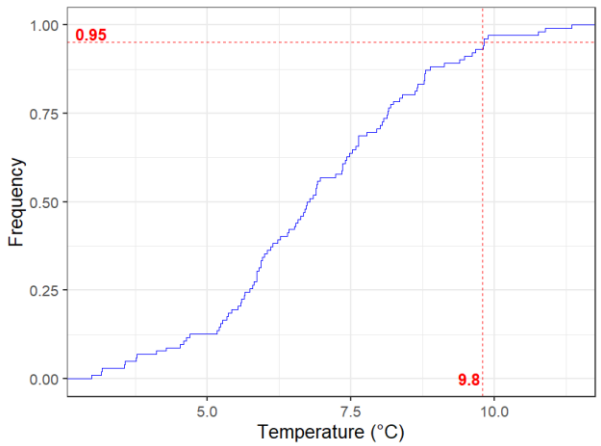


Figure 13. Cumulative distribution curve from Marklinder et al., 2004 [8] (95th percentile show in red)

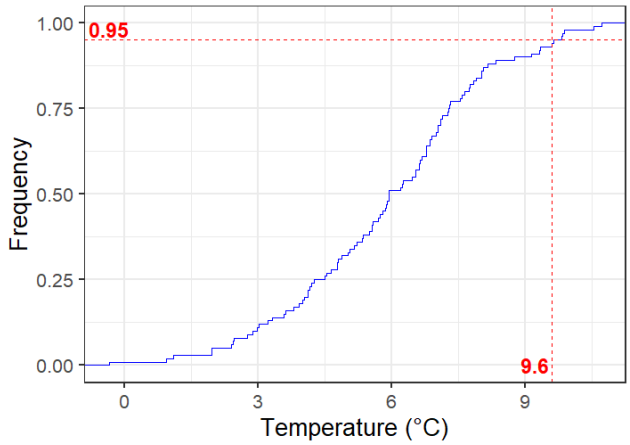


Figure 14. Cumulative distribution curve from Ovca et al., 2020 [9] (95th percentile show in red)

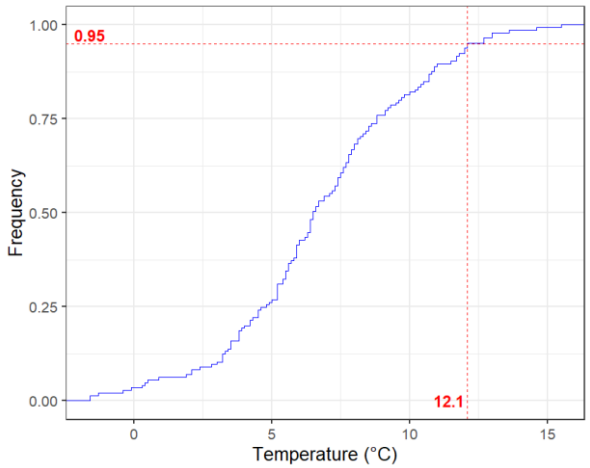


Figure 15. Cumulative distribution curve from Georges *et al.*, 2010 [10] (95th percentile show in red)