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Prevalence of *Listeria monocytogenes* in European cheeses: A systematic review and meta-analysis

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20 ABSTRACT

21 Both in Europe and worldwide cheese has caused important outbreaks of listeriosis and can be a
 22 vehicle for transmission of *Listeria monocytogenes* to consumers. A systematic review and meta-
 23 analysis were conducted using scientific literature and European Food Safety Authority (EFSA)
 24 reports to summarize available data on the prevalence of *L. monocytogenes* in different types of
 25 cheeses produced in Europe. Meta-analysis models were used to estimate mean prevalence of the
 26 pathogen and to compare prevalence among types of cheeses (fresh, ripened, veined, smear and
 27 brined) and cheeses produced using, respectively, pasteurized or un-pasteurized milk. Data from a
 28 total of 130,604 samples were analysed. Mean prevalence for presence during 2005-2015 estimated
 29 from scientific literature (2.3% with confidence interval (CI): 1.4-3.8%) was more than three times
 30 higher than results from EFSA reports (0.7%; CI: 0.5-1.1%). The prevalence differed among types
 31 of cheeses including fresh (0.8%; CI: 0.3-1.9%), ripened (2.0%; CI: 0.8-4.9%), veined (2.4%; CI:
 32 0.9-6.3%), smear (5.1%; CI: 1.9-13.1%) and brined (11.8%; CI: 3.5-33.3%). Mean prevalence of *L.*
 33 *monocytogenes* in soft/semi-soft cheeses were not significantly different ($P > 0.05$) for cheeses
 34 produced from pasteurized (0.9%; CI: 0.4-1.9%) or un-pasteurized (1.0%; CI: 0.4-2.2%) milk. For
 35 cheese samples reported by EFSA 0.2% CI: 0.1-0.4% had concentration of *L. monocytogenes* above
 36 the critical European limits of 100 cfu/g. In addition, this systematic review focused on
 37 groups/species of microorganisms suitable as indicator organisms for *L. monocytogenes* in cheeses
 38 to reflect the level of production hygiene or as index organisms to assess the prevalence of *L.*
 39 *monocytogenes* in cheeses. However, no suitable indicator or index organisms were identified. The
 40 performed meta-analyses improved our understanding of *L. monocytogenes* prevalence in different
 41 types of cheeses and provided results that can be useful as input for quantitative microbiological
 42 risk assessment modelling.

43 **Keywords: Occurrence, fresh cheese, soft and semi-soft cheeses, risk assessment**

44 1. Introduction

45 The genus *Listeria* includes more than 20 species that can be divided into three clades
 46 (Weller et al. 2015). Two *Listeria* species belonging to the same clade are generally considered to
 47 be pathogenic, *L. monocytogenes* in humans and *L. ivanovii* in other mammals. Nevertheless, there
 48 have been some reports of *L. seeligeri* and *L. ivanovii* causing illness in humans (Cummins et al.,
 49 1994; Rocourt et al., 1986). The likelihood of *L. monocytogenes* infection leading to listeriosis is
 50 greatest among certain groups; including pregnant woman, neonates, immunocompromised adults
 51 and the elderly (Ryser & Marth, 2007). Within the European Union (EU) there has been a
 52 statistically significant increasing trend of listeriosis over the period 2009-2015. Specifically, the
 53 numbers of confirmed human cases of listeriosis were 1,331 and 2,206 in 2009 and 2015,
 54 respectively (EFSA, 2016). A total of 270 deaths due to listeriosis were reported within nineteen
 55 EU member states. The overall EU notification rate of listeriosis was 0.46 cases per 100.000
 56 population with a case-fatality rate of 17.7% (EFSA, 2016). Seven EU Member States and Norway
 57 provided information from conventional serotyping of *L. monocytogenes* (accounting for 23.3 % of
 58 all confirmed cases). The most common serotypes in 2013 were 1/2a (57.5 %) and 4b (34.3 %),
 59 followed by 1/2b (6.4 %), 1/2c (1.4 %), 3a and 3b (both 0.2 %) (EFSA, 2015).

60 In 2010-2011 an EU baseline survey (EFSA, 2013a) collected data about presence of *L.*
 61 *monocytogenes* and the non-compliance for different ready-to-eat (RTE) food categories at retail.
 62 The proportion of *L. monocytogenes* positive samples at retail was highest in fish products (mainly
 63 smoked fish), followed by soft and semi-soft cheeses and RTE meat products. Specifically, the EU
 64 prevalence of *L. monocytogenes* in cheeses at retail was 0.47 % (CI: 0.29-0.77%) determined as 16
 65 positive samples out of 3393 at the end of shelf-life. For these 2010-2011 samples 0.06% (CI: 0.02-
 66 0.24 %) determined as two samples out of 3393 exceeded the critical concentration of 100 cfu/g

(EFSA, 2013a). In 2015 fifteen samples out of 3039 exceeded the critical concentration of 100 cfu/g (EFSA, 2016).

The first reported outbreak of human listeriosis associated with consumption of cheese occurred in the USA during 1985 (Linnan *et al.*, 1988) and was caused by a fresh cheese. Since then, several outbreaks associated with consumption of cheese have occurred worldwide and fatalities continue to be reported (Table 1). Clearly, it is important to collect information and to analyse data in an attempt to improve our understanding and options to better manage this risk. Meta-analysis is a statistical approach that can be used to analyse, for example, prevalence data (effect size) originating from various sources (primary studies) and in this way provide an overview of effects and variability (Glass, 1976; Sutton, *et al.*, 2001). Lately, meta-analysis has been used to study several food safety issues and the quantitative results obtained can be used as inputs in risk assessment models (Baron *et al.*, 2009).

Fortunately, prevalence and concentrations of *L. monocytogenes* in cheeses and cheese processing environments are low. Therefore, to evaluate its potential presence other index or indicator microorganisms that are easier to determine or quantify can be relevant to analyse. Index organisms can be used to assess likelihood of the presence of a pathogen whereas indicator organisms demonstrate a failure in Good Hygiene Practices (GHP) (Brodsky, 1995; Mossel, 1978). EU Regulation (EC) No 2073/2005 use coagulase-positive staphylococci as index organisms to assess the likelihood of staphylococcal enterotoxins in cheese made from raw or pasteurized milk and *E. coli* is used as an indicator for the level of production hygiene in cheese made from milk that has undergone heat treatment. Furthermore, *Listeria* spp. has been used as index organisms for the likely presence of *L. monocytogenes* in food (FSIS, 2014; Gilbert *et al.*, 2000).

The objective of the present study was to perform a systematic review and a meta-analysis of the prevalence of *L. monocytogenes* in different types of European cheeses and study potential indicator organisms for assessment of production hygiene or index organisms for implementation in the assessment of product safety.

2. Materials and methods

2.1. Literature search and inclusion criteria

A systematic review was performed following the protocol presented by Sargeant et al., 2005. Literature searches were carried out to identify suitable scientific literature using Web of Science (2017) or DTU Findit (2017) databases for papers indexed since 1985 as well as Google searches using English, French, Italian, and Spanish terms for combinations of *Listeria* spp., *L. monocytogenes*, cheese, dairy, prevalence, incidence and occurrence. Electronic searches were carried out to identify reports of the prevalence for *Listeria* spp. in cheese. This included reports by national and international organizations such as World Health Organization (WHO), EFSA and the International Commission for Microbiological Specification in Foods (ICMSF).

For inclusion in the meta-analysis results had to meet three requirements: (i) to come from original studies, (ii) to be obtained by using approved (FDA/FIL-IDF or ISO) microbiological methods for detection of *Listeria* spp. and (iii) originate from cheeses produced in Europe during the period of 2005 to 2015.

2.2. Data and definitions

Cheese-type definitions were necessary in order to categorize studies from scientific literature. Available information allowed for a classification based in maturation characteristics. For

the purpose of this paper, the following definitions apply. Fresh cheeses are curd-style cheeses which do not undergo any ripening (CAC, 2013), for example, queso fresco, cottage cheese, Mozzarella or Ricotta. Ripened cheeses are not ready for consumption shortly after manufacture and maturation is needed for development of specific cheese characteristics (CAC, 2013), for example, Gouda, Edam, Cheddar or Parmesan. Veined cheeses are ripened cheeses in which ripening has been accomplished primarily by the development of the mould *Penicillium roqueforti* throughout the interior and/or on the surface, for example, Roquefort, Gorgonzola, Cabrales, Stilton or Danablu. Smear cheeses are ripened cheeses where the surface is treated with *Penicillium candidum*, *Penicillium camemberti* or *Brevibacterium linens*, for example, Brie, Camembert, Limburger or Taleggio. Brined cheeses are ripened and stored in brine until they are sold or packed, for example, Feta or Ricotta salata (Fox et al., 2000).

Classification of cheese in EFSA reports are based on cheese moisture content. Soft-cheeses have a percentage of moisture, on a fat-free basis, higher than 67 %. Semi-soft cheeses have 62 to 67 % fat-free moisture and are characterized by their firm but elastic feel. Hard cheeses have 49 to 56 % fat-free moisture (CAC, 2013; EFSA, 2013b).

2.3. Problem statement

To estimate prevalence of *L. monocytogenes* in cheese during the period 2005-2015 (i) from scientific literature data, (ii) from data in EFSA reports, (iii) from scientific literature and data in EFSA reports when combined and (iv) to study groups/species of microorganisms suitable as indicator or index organisms to assess prevalence of *L. monocytogenes* in cheeses.

2.4. Description of data sets for meta-analysis and regression modelling

From each primary study the number of samples positive for *L. monocytogenes* (s) and the total number of samples (n) were extracted. Information about year of survey, country, sample

weight and information on sampling at production site or at retail were also collected from each primary study. Meta-analysis for prevalence of *L. monocytogenes* in cheese as reported in the scientific literature was based on 17 primary studies including a total of 7,221 samples (Table 2), while data from seven EFSA reports with a total of 123,383 samples were included (Table 3 and Table 4). The regression model used to evaluate indicator/index organisms for *L. monocytogenes* in European cheeses was based in 16 primary studies all from the scientific literature and including a total of 3,852 samples (Table 5).

2.5. Meta-analysis

Prevalence ($p_i = s_i/n_i$) data was studied as observed effect size (θ_i) and they were logit transformed in order to restrict values to a range between 0-1 and to stabilize variance (Eq. 1; Viechtbauer, 2010). The parameter measuring effect size (θ_i) is a common metric that permits direct comparison and summation of primary studies (Borenstein et al., 2009).

$$\theta_i = \text{logit } p_i = \ln\left(\frac{p_i}{1-p_i}\right) = \ln\left(\frac{s_i}{n_i-s_i}\right) \quad (1)$$

Models with random-effects were used to calculate prevalence values (mean and 95% CI) of *L. monocytogenes* across primary studies (Eq. 2; Borenstein et al., 2009):

$$T_i = \theta_i + \varepsilon_i = \mu + u_i + \varepsilon_i \quad (2)$$

where T_i is the true effect size for each primary study ($i = 1, 2, \dots$), ε_i is the sampling error and μ is the mean true effect size. u_i represents the true variation in effect sizes being composed of within-study (σ^2) and between-study variance (τ^2).

The between-study variance (τ^2) is estimated from the Q-statistic (DerSimonian & Laird 1986),

$$\hat{\tau}^2 = \begin{cases} \frac{Q - (k - 1)}{\sum w_i - \frac{\sum w_i^2}{\sum w_i}}, & \text{for } Q > (k - 1) \\ 0, & \text{for } Q \leq (k - 1) \end{cases} \quad (3)$$

where Q is calculated by Eq. 4 and 5, k is the number of studies and w_i the weight assigned to each study (Eq.5).

$$Q = \sum w_i (T_i - \mu)^2 \quad (4)$$

$$\mu = \frac{\sum_i w_i T_i}{\sum_i w_i} \quad (5)$$

$$w_i = \frac{1}{\sigma_i^2 + \tau_i^2} \quad (6)$$

A significant value of the Q -statistic indicates a real effect difference between primary studies and suggests the use of a multilevel model (Xabier et al., 2014). The I^2 index was used to measure the extent of between-study variance dividing the difference between the result of the Q -statistic and its degrees of freedom ($k - 1$) by the Q value itself, and then multiply by 100. Higgins & Thompson (2002) proposed a classification of I^2 values with percentages of around 25% ($I^2 = 25$), 50% ($I^2 = 50$) and 75% ($I^2 = 75$) corresponding to low, medium and high between-study variance, respectively. The τ^2 and I^2 indices are related and higher τ^2 values corresponds to higher I^2 index values.

Multilevel meta-analysis including type of cheese and pasteurized or unpasteurized milk were used to account for some of the observed between-study variance in prevalence data.

The multilevel models used were formulated as:

$$T_i = \beta_0 + \beta_1 X_{1i} + \dots + \beta_k X_{ki} + u_i + \varepsilon_i \quad (7)$$

with $(X_1 \text{ to } X_k)$ being study characteristics and β_k the moderator effects.

Meta-analysis modelling was performed by using R version 3.1.3 (R Development Core Team) and the “metafor” package (Viechtbauer, 2010), which provides functions for fitting of random-effects and multilevel models as well as meta-analytical graphs including forest plots.

2.6. Regression modelling

A linear regression model ($y = a + bx$) was used to evaluate the relation between prevalence of *Listeria* spp. (x) and prevalence of *L. monocytogenes* (y). Regression modelling was performed with R and an F-test was used to evaluate if the linear model could be reduced to $y = bx$.

3. Results

3.1. Meta-analysis of prevalence data from scientific literature

The overall prevalence for presence of *L. monocytogenes* in cheese was 2.3% (CI: 1.4-3.8%). Variability in reported prevalence among studies was high (Table 6 and Fig.1) and the between-study variance slightly decrease from $\tau^2 = 1.72$ to 1.12 when cheeses were grouped in categories by the multilevel model. Nevertheless, unexplained variability remained high ($I^2 = 75\%$; p-value < 0.001 in Table 6).

Fresh cheese had the lowest mean prevalence of 0.8% (CI: 0.3-1.9%), followed by ripened cheese 2.0% (CI: 0.8- 4.9%), veined cheese 2.4% (CI: 0.9- 6.3%) and smear cheese 5.1% (CI: 1.9-13.1%). Brined cheese had the highest *L. monocytogenes* prevalence of 11.8% (CI: 3.5-33.3%) (Table 6 and Fig. 1).

3.2. Meta-analysis of prevalence data from EFSA reports

The overall prevalence for presence of *L. monocytogenes* in cheese was 0.7% (CI: 0.5 – 1.1%) with high between-studies variance (Table 7). A multilevel model determined the prevalence of *L. monocytogenes* in hard and soft/semi-soft cheeses produced from un-pasteurized or pasteurized milk. No significant effect of pasteurization ($p > 0.05$) was observed within hard or soft/semi-soft cheeses (Table 7).

A second random-effects meta-analysis was performed to assess non-compliance with the criterion of 100 cfu/g for *L. monocytogenes* in ready-to-eat (RTE) foods. 0.2% (CI: 0.1-0.4) of the cheese samples had more than 100 *L. monocytogenes*/g and high between-study variance was observed (Table 8). Prevalence of *L. monocytogenes* in hard and soft/semi-soft cheese produced with un-pasteurized or pasteurized milk was estimated. Pasteurization of milk had no significant effect ($p > 0.05$) within hard or soft/semi-soft cheeses (Table 8).

3.3. Meta-analysis of combined prevalence data from scientific literature and EFSA reports

The overall prevalence of *L. monocytogenes* in European cheeses was 1.2% (CI: 0.8-1.8%). High between-study variance was observed and a significant difference ($p < 0.001$) was determined between data from the scientific literature and from EFSA reports data (Table 9).

3.4. Evaluation of index organisms for prevalence of *L. monocytogenes* in European cheeses

Of 3852 samples reporting presence of *Listeria* spp., 203 (5.3%) were positive for *L. monocytogenes*, 327 (8.5%) *L. innocua*, 19 (0.5%) *L. grayi*, 188 (4.9%) *L. welshimer*, 18 (0.5%) *L. ivanovii* and 20 (0.5%) *L. seeligeri*. The correlation factor was sufficient to describe the relation between prevalence of *Listeria* spp. (x) and prevalence of *L. monocytogenes* (y) in cheeses ($y = 0.52x$, $r^2 = 0.86$, Fig. 2).

4. Discussion

It is critical to understand and quantified prevalence of *L. monocytogenes* in cheeses since they are an important vehicle for transmission of the pathogen and infection causes the highest fatality case rate among zoonotic diseases (EFSA, 2016).

EU mean prevalence of *L. monocytogenes* in cheese from scientific literature exceeded what was reported by EFSA for the same period. This may result from a focus on problematic cheese products in scientific studies whereas EFSA reports include a larger number of samples from hard cheeses where *L. monocytogenes* can be inactivated and prevalence therefore is lower. The data from scientific studies corresponded to previous studies reporting prevalence between 0 and 4.8% (Esho et al., 2013; Manfreda et al., 2005; Rosengren et al., 2010), but some other studies reported more than 40% prevalence (Loncarevic et al., 1995; Pintado et al., 2005).

Mean prevalence of *L. monocytogenes* in fresh cheese was similar to the overall prevalence obtained from EFSA data. In 1985 consumption of contaminated fresh cheese (queso blanco) was directly linked to more than 142 cases of listeriosis, including 48 deaths (Linnan *et al.*, 1988). From 2009 to 2012 there was an outbreak in Portugal linked to 30 cases of listeriosis, including 11 deaths and related to consumption of fresh cheeses (curded cheese and queijo fresco) (Magalhães *et al.*, 2015). Furthermore, Greco et al., (2014) for example demonstrated how prevalence of *L. monocytogenes* can be high (24.4%) in mozzarella cheese as result of cross-contamination.

Fresh cheeses were excluded from the EFSA baseline survey on prevalence of *L. monocytogenes* in certain RTE foods within EU during 2010-2011 (EFSA, 2013a). Interestingly, EFSA (2015) started to differentiate between fresh and soft/semi-soft cheeses but included only 2.1% fresh cheese samples compared to 80.1% hard cheese samples from a total of 13,718 cheese samples. Hard cheese have never been linked to a listeriosis outbreak (Table 1) and as it does not support growth of *L. monocytogenes* (Dalmaso & Jordan, 2014; Wemmenhove et al., 2013; Yousef

& Marth, 1990) the large number of these samples does not correspond to a risk-based sampling approach.

It is important to note that mean prevalence for brined cheese was estimated from only four studies with smaller sample sizes compare with other types of cheese. Consequently, there is a high level of uncertainty and results may be biased by results from a single study (Fig. 1; Table 6). In 2012, Ricotta salata imported from Italy and contaminated with *L. monocytogenes* was involved in a listeriosis outbreak in the USA with 22 hospitalizations and 4 deaths (CDC, 2012). Furthermore, ricotta salata supports growth of *L. monocytogenes* (Coroneo et al., 2016; Spanu et al., 2012) and production of this cheese includes manual processing of the curd and exposure to processing environments that increase the risk of *L. monocytogenes* contamination (Spanu et al., 2013). Our findings suggest that prevalence of *L. monocytogenes* in fresh and brined cheese are not negligible; therefore we encourage EFSA to increase and independently report sampling of fresh and brined cheeses since they have been related with listeriosis outbreaks recurrently (Table 1).

As shown by EFSA reports, contamination of cheese by *L. monocytogenes* is not specific to un-pasteurized milk cheeses since cheeses made from pasteurized milk can be contaminated due to inadequate pasteurization or post-pasteurization contamination (De Buyser et al., 2001; Donnelly, 2001). Our report is the first of our knowledge to analysed EFSA prevalence data of cheeses made from un-pasteurized and pasteurized milk. There was no significant difference in prevalence between cheeses produced with un-pasteurized or pasteurized milk; either for hard or soft/semi-soft cheeses (Table 7 and 8). This may be due to requirements leading to the use of milk of high microbiological quality for the production of un-pasteurized milk cheese and to post-pasteurization contamination of pasteurized milk cheese. Tiwari et al., (2015) compared the risk of soft/semi-soft cheese made from un-pasteurized or pasteurized milk and estimated a higher risk for un-pasteurized milk cheese as a consequence of the higher contamination rate of milk due to the lack of

pasteurization and growth of *L. monocytogenes* in un-pasteurized milk cheese but inactivation in the same pasteurized milk cheese. But this study observed no significant effect of pasteurization in prevalence of *L. monocytogenes* in soft/semi-soft cheese. We provide mean prevalence and distributions for *L. monocytogenes* in soft/semi-soft cheese that can be combined with concentration data of *L. monocytogenes* (cfu/g) for the same period in un-pasteurized and pasteurized milk cheese to perform a quantitative risk assessment of the end product (Crépet et al., 2007) and results from both studies could be compared.

Prevalence and concentration of *L. monocytogenes* in cheeses are low, hence evaluation of potential presence of other index or indicator microorganisms easier to determine or quantify was considered. *Listeria* spp. has been proposed as index organisms for presence of *L. monocytogenes* in RTE foods and as indicator of inadequate hygiene conditions in food production practices and environment (FSAI, 2011; Gilbert et al., 2000; McLauchlin, 1997). These findings were confirmed by the present study and we found prevalence of *L. monocytogenes* corresponded to prevalence of *Listeria* spp. when multiplied by a factor of 0.52. This was further supported by Trmčić et al., (2016) where 273 cheese samples had 12 positive for *Listeria* spp. and five of these positive for *L. monocytogenes*. Silva et al., (2003) also found 33% of *Listeria* spp. positive samples from cheese and dairy processing plants to be *L. monocytogenes* positive. However, Arrese & Arroyo-Izaga (2012) found no *L. monocytogenes* positive amongst 51 cheese samples with five samples positive for other *Listeria* spp. Microbiological methods for detection and quantification of *Listeria* spp. are not more performant than available methods for *L. monocytogenes* (Gasnov et al., 2005). Therefore, we do not consider *Listeria* spp. a useful index- or indicator-organism *L. monocytogenes* despite the relation reported in the present study (Fig. 2).

5. Conclusions

Meta-analysis provided pooled prevalence estimates for *L. monocytogenes* in specific types of cheeses, however, significant between-study variance was observed. Overall prevalence of *L. monocytogenes* in cheese as estimated from scientific literature data was higher than reported by data from EFSA during the same period 2005-2015. Considering prevalence of *L. monocytogenes* in cheeses produced with un-pasteurized or pasteurized milk no significant difference in prevalence was observed. The results obtained provided a broad picture of *L. monocytogenes* prevalence in cheeses and can be used as an important input in quantitative microbial risk assessments. *Listeria* spp. was not a useful index- or indicator-organism for *L. monocytogenes* in cheeses although prevalence of *Listeria* spp. was related to prevalence of *L. monocytogenes*.

Fig. 1. Forest plot of the multilevel model based on scientific literature reporting prevalence of *L. monocytogenes* in different types of cheeses

Fig. 2. Comparison of observed prevalence (%) for *Listeria* spp. and *L. monocytogenes* in European cheeses.

Table 1
Overview of listeriosis outbreaks caused by cheese during the period from 1983 to 2016.

Country	Year	Serotype	No. ^a of cases (fatalities)	Implicated food	References
Switzerland	1983-1987	4b	122(31)	Smear cheese (Vacherin Mont d'Or)	Bula et al., 1995; Bille et al., 2006
USA	1985	4b	142(48)	Fresh cheese (Queso Fresco)	Linnan et al., 1988
Luxembourg	1989	NR ^b	2(0)	Smear cheese (Camembert)	Ries et al., 1990
Denmark	1989-1990	4b	26(6)	Veined or ripened cheese	Jensen et al., 1994
France	1995	4b	37(11)	Smear cheese (Brie de Meaux)	Goulet et al., 1995; Arnold & Coble, 1995
France	1997	4b	14(? ^c)	Smear cheese (Pont l'Evêque)	Ryser & Marth, 2007; Goulet et al., 2013
USA	2000	4b	13(5)	Non-commercial fresh cheese (Queso Fresco)	MacDonald et al., 2005
Sweden	2001	1/2a	≥120(0)	Fresh cheese	Carrique-Mas et al., 2003; Danielsson-Tham et al., 2004
Japan	2001	1/2b	38(0)	Smear cheese	Makino et al., 2005
Canada	2002	4b	47(0)	Soft and semi-soft cheese	Gaulin et al., 2003
Canada	2002	4b	86(0)	Cheese made from pasteurized milk	Pagotto et al., 2006
Switzerland	2005	1/2a	10 (3+2 ^d)	Smear cheese (Soft "Tomme")	Bille et al., 2006
USA	2005	NR ^b	9(?)	Fresh cheese (Queso fresco)	FIOD, 2005
Czech Republic	2006		78(13)	Soft cheese	EFSA, 2007
Germany	2006-2007	4b	189(26)	Acid curd cheese	Koch et al., 2010
Norway	2007	NR ^b	17(3)	Smear cheese (Camembert)	Johnsen et al., 2010
Chile	2008	NR ^b	91(5)	Smear cheese (Brie)	Promed, 2008
Canada	2008	NR ^b	38(5)	Cheeses	Gaulin & Ramsay, 2010
USA	2008	1/2a	8(0)	Fresh cheese (Oaxaca cheese)	Jackson et al., 2011
Austria-Germany-Czech Republic	2009-2010	1/2a	34 (8)	Fresh cheese (Quargel)	Fretz et al., 2010; Rychli et al., 2014
Portugal	2009- 2012	4b	30 (11)	Fresh cheese (Cured cheese and queijo fresco)	Magalhães et al., 2015
USA	2010	NR ^b	5(0)	Fresh cheese (Panela, queso fresco, Requeson)	FIOD, 2010
USA	2010-2015	NR ^b	28(3)	Fresh cheeses	FIOD, 2015b

USA	2011	NR ^b	2(? ^c)	Fresh cheese (Chives cheese)	FIOD, 2011
Austria-Germany	2011-2013	1/2b	7(? ^c)	Fresh cheese	Schmid et al., 2014
Spain	2012	1/2a	2(0)	Fresh cheese (Queso fresco)	De Castro et al., 2012
USA	2012	NR ^b	22(4)	Brined cheese (Ricotta salatta)	CDC, 2012; Coroneo et al., 2016
USA	2013	NR ^b	5(1)	Smear cheese (Les Freres)	FIOD, 2013
Australia	2013	NR ^b	18(? ^c)	Smear cheese	NSW, 2013
USA	2013-2014	NR ^b	4 (1)	Fresh cheese	FIOD, 2014a
USA	2014	NR ^b	7(1)	Fresh cheese	FIOD, 2014b
USA	2015	NR ^b	3(1)	Fresh cheese (Panela, Queso Fresco, Requeson, Cotija)	FIOD, 2015b

^a Number of listeriosis cases

^b Serotype not reported (NR)

^c Fatalities uncertain

^d Septic abortion i.e. fatality

Table 2

Prevalence data (s/n) from the scientific literature.

References	Survey year	Number of <i>L. monocytogenes</i> positive (s) /total number of cheese samples (n)				
		Fresh	Ripened	Veined	Smear	Brined
Filiouis et al., 2009	2005-2006		4/20			0/10
Little et al., 2009	2006-2007		2/1240			
O'Brien et al., 2009	2007	0/29	1/104	1/33	14/79	
Di Pinto et al., 2010	2007-2009	2/294				
Pesavento et al., 2010	2008	2/258				
Prencipe et al., 2010	2005-2006	1/437	1/449	21/444	24/802	
Angelidis et al., 2012	2010	0/83		0/38	0/16	
Lambertz et al., 2012	2006-2012			2/465	0/62	
Dambrosio et al., 2013	2009-2010	0/404				
Doménech et al., 2013	2005-2009	0/77				
Parisi et al., 2013	2008-2010	3/70				
Gyurova et al., 2014	2011-2012		0/17	0/7		0/34
Doménech et al., 2015	2006-2012	9/507	3/100			
Schoder et al., 2015	NS ^a		1/15	0/50	1/22	
Spanu et al., 2015	2011-2013		3/50			7/33
Iannetti et al., 2016	2011-2012	0/421	0/106	8/190	11/177	
Coroneo et al., 2016	NS ^a					15/87

Total	17/2,580	15/2,101	32/1,218	50/1,158	24/164

^a Not specified; but assumed within the period 2005-2015.

Table 3

Prevalence data (s/n) from EFSA reports.

Type of cheese		Number of <i>L. monocytogenes</i> positive (s) /total number of cheese samples (n)						
		EFSA, 2006 ^a	EFSA, 2007 ^a	EFSA, 2009 ^a	EFSA, 2010 ^a	EFSA, 2011 ^a	EFSA, 2015 ^a	EFSA, 2016 ^a
		2005 ^b	2006 ^b	2007 ^b	2008 ^b	2009 ^b	2013 ^b	2015 ^b
Hard	Un-pasteurized	0/969	38/718	16/3,242	2/1,606	2/1,001	15/1,618	11/858
	Pasteurized	0/1,367	5/3,284	68/9,449	85/10,877	15/7,246	77/8,288	19/2,384
Soft/ Semi-soft	Un-pasteurized	29/1,505	13/1,959	16/5,943	5/4,203	6/774	155/2,880	10/707
	Pasteurized	25/5,973	22/4,736	853/16,333	70/5,585	41/4,087	49/10,668	67/5,123

^a References

^b Survey year

Table 4

Cheese samples in non-compliance with EU food safety limits for *L. monocytogenes* in RTE foods.

Type of cheeses		Cheese samples (n) with > 100 <i>L. monocytogenes</i> /g /Total number of samples (n)						
		EFSA, 2006 ^a	EFSA, 2007 ^a	EFSA, 2009 ^a	EFSA, 2010 ^a	EFSA, 2011 ^a	EFSA, 2015 ^a	EFSA, 2016 ^a
		2005 ^b	2006 ^b	2007 ^b	2008 ^b	2009 ^b	2013 ^b	2015 ^b
Hard	Un-pasteurized	? ^c	? ^c	2/1,569	0/133	2/940	1/2,854	0/880
	Pasteurized	0/672	7/1,701	14/2,292	3/4,005	1/9,894	10/3,041	0/141
Soft/ Semi-soft	Un-pasteurized	1/1,174	0/64	2/1,008	17/484	0/775	3/2,718	10/809
	Pasteurized	0/3,231	3/1,093	1/2,727	10/3,230	12/4,702	9/1,351	5/1,209

^a References

^b Survey year

^c Not reported

Table 5
European studies reporting the prevalence of *Listeria* species in cheeses.

References	Country	Sample size	Number of samples positive for different <i>Listeria</i> species					
			<i>L. monocytogenes</i>	<i>L. innocua</i>	<i>L. grayi</i>	<i>L. welshimer</i>	<i>L. ivanovii</i>	<i>L. seeligeri</i>
Comi et al., 1990	Italy	1740	65	145	15	185	18	0
Massa et al., 1990	Italy	121	2	2	0	0	0	0
Quagilo et al., 1992	Italy	246	29	42	0	0	0	2
Rota et al., 1992	Spain	58	1	2	0	0	0	0
Pinto & Reali, 1996	Italy	132	7	30	0	2	0	1
Theodoridis et al., 1998	Greece	334	26	8	0	0	0	10
Bottarelli et al., 1999	Italy	100	2	2	0	0	0	0
Rudolf & Scherer, 2000	Germany	50	2	13	0	0	0	0
Rudolf & Scherer, 2001	Austria	274	19	33	0	0	0	4
Vitas et al., 2004	Spain	99	1	6	1	0	0	0
Pintado et al., 2005	Portugal	63	32	23	0	0	0	2
Pesavento et al., 2010	Italy	258	2	6	1	1	0	0
Angelidis et al., 2012	Greece	137	0	1	2	0	0	1
Parisi et al., 2013	Italy	70	3	3	0	0	0	0
Schoder et al., 2015	Europe	87	2	8	0	0	0	0
Spanu et al., 2015	Italy	83	10	3	0	0	0	0
Total		3,852	203	327	19	188	18	20

Table 6

Meta-analysis results for prevalence of *L. monocytogenes* from scientific literature

Meta-analysis type	Prevalence (CI) ^a	τ^2 ^b	$I^2(\%)$ ^c	Q^d
Random-effects	0.023 (0.014-0.038)	1.72	86	197**** (df = 35)
Multilevel		1.12	75	108**** (df = 31)
Fresh cheese	0.008 (0.003-0.019) ^{Af}			
Ripened cheese	0.020 (0.008-0.049) ^{ABf}			
Veined cheese	0.024 (0.009-0.063) ^{Bf}			
Smear cheese	0.051 (0.019-0.131) ^{Bf}			
Brined cheese	0.118 (0.035-0.333) ^{Bf}			

^a 95% confidence interval.

^b Between-study variance.

^c Between-study variance index proposed by Higgins & Thompson (2002).

^d Q-statistic proposed by DerSimonian & Laird (1986).

^e P-value < 0.001.

^f Mean values for classes with the same capital letter do not differ significantly ($p > 0.05$).

Table 7

Meta-analysis results for prevalence of *L. monocytogenes* from EFSA reports

Meta-analysis type	Prevalence (CI) ^a	τ^2 ^b	$I^2(\%)$ ^c	Q^d
Random-effects	0.007 (0.005-0.011)	1.09	98	1712**** (df = 27)
Multilevel		1.17	88	1174**** (df = 24)
Hard and un-pasteurized	0.006 (0.003-0.015) ^f			
Hard and pasteurized	0.012 (0.002-0.010) ^f			
Soft/semi-soft and un-pasteurized	0.009 (0.004-0.019) ^g			
Soft/semi-soft and pasteurized	0.010 (0.004-0.022) ^g			

^a 95% confidence interval.

^b Between-study variance.

^c Between-study variance index proposed by Higgins & Thompson (2002).

^d Q-statistic proposed by DerSimonian & Laird (1986).

^e P-value < 0.001.

^f Mean values within hard cheeses do not differ significantly ($p > 0.05$).

^g Mean values within soft/semi-soft cheeses do not differ significantly ($p > 0.05$).

Table 8

Meta-analysis results assessing non-compliance with the criterion of “> 100 cfu/g” for *L. monocytogenes* in cheeses as reported by EFSA.

Meta-analysis type	Prevalence (CI) ^a	τ^2 ^b	I ² (%) ^c	Q ^d
Random-effects	0.002 (0.001-0.004)	1.22	84	154*** (df = 25)
Multilevel		1.18	82	95*** (df = 22)
Hard and un-pasteurized	0.001(0.000-0.004) ^f			
Hard and pasteurized	0.002 (0.001-0.005) ^f			
Soft/semi-soft and un-pasteurized	0.004 (0.002-0.012) ^g			
Soft/semi-soft and pasteurized	0.002 (0.001-0.006) ^g			

^a 95% confidence interval.

^b Between-study variance.

^c Between-study variance index proposed by Higgins & Thompson (2002).

^d Q-statistic proposed by DerSimonian & Laird (1986).

^e P-value < 0.001.

^f Mean values within hard cheeses do not differ significantly ($p > 0.05$).

^g Mean values within soft/semi-soft cheeses do not differ significantly ($p > 0.05$).

Table 9

Meta-analysis results for prevalence of *L. monocytogenes* from combined data

Meta-analysis type	Prevalence (CI) ^a	τ^2 ^b	I ² (%) ^c	Q ^d
Random-effects	0.012 (0.008-0.018)	1.78	97	1961*** (df = 63)
Multilevel		1.38	97	1909*** (df = 62)
Scientific literature	0.007 (0.004-0.011) ^{Af}			
EFSA reports	0.024 (0.015-0.038) ^{Bf}			

^a 95% confidence interval.

^b Between-study variance.

^c Between-study variance index proposed by Higgins & Thompson (2002).

^d Q-statistic proposed by DerSimonian & Laird (1986).

^e P-value < 0.001.

^f Mean values for classes with different capital letters differed significantly ($p < 0.001$).

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References

- Angelidis, A. S., Georgiadou, S. S., Zafeiropoulou, V., Velonakis, E. N., Papageorgiou, D. K., & Vatopoulos, A. (2012). A survey of soft cheeses in Greek retail outlets highlights a low prevalence of *Listeria* spp. *Dairy Science and Technology*, 92(2), 189–201.
- Arnold, G. J., & Coble, J. (1995). Incidence of *Listeria* species in foods in NSW. *Food Australia*, 47(2), 71–75.
- Arrese, E., & Arroyo-Izaga, M. (2012). Prevalence of *Listeria monocytogenes* in Idiazabal cheese. *Nutricion Hospitalaria*, 27(6), 2139–2141.
- Barron, U. G., Soumpases, I., Butler, F., Prendergast, D., Duggan, S., Duffy, G. (2009). Estimation of Prevalence of Salmonella on Pig Carcasses and Pork Joints, Using a Quantitative Risk Assessment Model Aided by Meta-Analysis. *Journal of Food Protection*, 72(2), 274–285.
- Bille, J., Blanc, D. S., Schmid, H., Boubaker, K., Baumgartner, A., Siegrist, H. H., Tritten, M.L., Liernhard, R., Berner, D., Anderau, R., Treboux, M., Ducommun, J.M., Malinverni, R., Genné, D., Erard, P., & Waespi, U. (2006). Outbreak of human listeriosis associated with Tomme cheese in Northwest Switzerland, 2005. *Eurosurveillance*, 11(6), 91–93.
- Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2009). *Introduction to meta-analysis* (1st ed.). Chichester: Wiley.
- Bottarelli, A., Bonardi, S., & Bentley, S. (1999). Presence of *Listeria* spp. in short-ripened cheeses. *Annali Della Facoltà Di Medicina Veterinaria*, 29, 293–296.
- Brodsky, M. H. (1995). The benefits and limitations of using index and indicator microorganisms in verifying food safety. Presented at the FSIS meeting on the "Role of microbiology testing in verifying food safety", May 1-2, 1995, Philadelphia, PA.
- Büla, C. J., Bille, J., & Glauser, M. P. (1995). An epidemic of food-borne listeriosis in western Switzerland: description of 57 cases involving adults. *Clinical Infectious Diseases*, 20(1), 66–72.
- CAC (2013). Codex General Standard for Cheese. CODEX STAN 283-1978
www.fao.org/input/download/standards/175/CXS_283e.pdf Accessed 13.05.16
- Carrique-Mas, J. J., Hökeberg, I., Andersson, Y., Arneborn, M., Tham, W., Danielsson-Tham, M. L., Osterman, B., Leffler, M., Steen, M., Eriksson, E., Hedin, G., & Giesecke, J. (2003). Febrile gastroenteritis after eating on-farm manufactured fresh cheese--an outbreak of listeriosis? *Epidemiology and Infection*, 130(1), 79–86.
- CDC (2012). Centers for Disease Control and Prevention. Multistate outbreak of listeriosis linked to

imported Frescolina Marte brand ricotta salata. <https://www.cdc.gov/listeria/outbreaks/cheese-09-12/> Accessed 23.03.17.

Cochran, W. G. (1954). The combination of estimates from different experiments. *Biometrics*, 10(1), 101–129.

Comi, G., Cantoni, C., Valenti, M., & Civilini, M. (1990). *Listeria* species in Italian cheeses. *Microbiologie Aliments Nutrition*, 8, 377–382.

Condoleo, R., Mezher, Z., Marozzi, S., Guzzon, A., Fischetti, R., Senese, M., Sette, S., & Bucchini, L. (2016). Risk assessment of human listeriosis from semisoft cheeses made from raw sheep's milk in Lazio and Tuscany (Italy). *Risk Analysis*. <http://doi.org/10.1111/risa.12649>

Coroneo, V., Carraro, V., Aissani, N., Sanna, A., Ruggeri, A., Succa, S., Meloni, B., Pinna, A., & Sanna, C. (2016). Detection of Virulence Genes and Growth potential in *Listeria monocytogenes* strains isolated from Ricotta salata cheese. *Journal of Food Science*, 81(1), M114–M120.

Crepet, A., Albert, I., Dervin, C., & Carlin, F. (2007). Estimation of microbial contamination of food from prevalence and concentration data: Application to *Listeria monocytogenes* in fresh vegetables. *Applied and Environmental Microbiology*, 73(1), 250–258.

Cummins, A. J., Fielding, A. K., & McLauchlin, J. (1994). *Listeria ivanovii* infection in a patient with AIDS. *Journal of Infection*, 28(1), 89–91.

Dalmasso, M., & Jordan, K. (2014). Absence of growth of *Listeria monocytogenes* in naturally contaminated Cheddar cheese. *Journal of Dairy Research*, 81(1), 46–53.

Dambrosio, A., Quaglia, N. C., Saracino, M., Malcangi, M., Montagna, C., Quinto, M., Lorusso, V., & Normanno, G. (2013). Microbiological quality of Burrata cheese produced in Puglia Region: Southern Italy. *Journal of Food Protection*, 76(11), 1981–1984.

Danielsson-Tham, M.-L., Eriksson, E., Helmersson, S., Leffler, M., Ludtke, L., Steen, M., Sørgerd, S., & Tham, W. (2004). Causes behind a human cheese-borne outbreak of gastrointestinal listeriosis. *Foodborne Pathogens and Disease*, 1(3), 153–159.

De Buyser, M.-L., Dufour, B., Maire, M., & Lafarge, V. (2001). Implication of milk and milk products in food-borne diseases in France and in different industrialised countries. *International Journal of Food Microbiology*, 67(1–2), 1–17.

de Castro, V., Escudero, J. M., Rodriguez, J. L., Muniozguren, N., Uribarri, J., Saez, D., & Vazquez, J. (2012). Listeriosis outbreak caused by Latin-style fresh cheese, Bizkaia, Spain, August 2012. *Eurosurveillance*, 17(42), 3–5.

- DerSimonian, R., & Laird, N. (1986). Meta-analysis in clinical trials. *Controlled Clinical Trials*, 7(3), 177–188.
- Di Pinto, A., Novelleo, L., Montemurro, F., Bonerba, E., & Tantillo, G. (2010). Occurrence of *Listeria monocytogenes* in ready-to-eat foods from supermarkets in Southern Italy. *New Microbiologica*, 33(3), 249–252.
- Doménech, E., Amorós, J. A., & Escriche, I. (2013). Effectiveness of prerequisites and the HACCP plan in the control of microbial contamination in ice cream and cheese companies. *Foodborne Pathogens and Disease*, 10(3), 222–8.
- Doménech, E., Jimenez -Belenguer, A., Amoros, J. A., Ferrus, M. A., & Escriche, I. (2015). Prevalence and antimicrobial resistance of *Listeria monocytogenes* and *Salmonella* strains isolated in ready-to-eat foods in Eastern Spain. *Food Control*, 47, 120–125.
- Donnelly, C. W. (2001). Factors associated with hygienic control and quality of cheeses prepared from raw milk: a review. *Bulletin of the International Dairy Federation*, 369, 16–27.
- DTU Findit. Technical University of Denmark digital library (2017). <https://findit.dtu.dk/> Accessed 05.04.17.
- EFSA. (2006). The community summary report on trends and sources of zoonoses, zoonotic agents, antimicrobial resistance and foodborne outbreaks in the European Union in 2006. *EFSA Journal*, 94, 1–288.
- EFSA. (2007). The Community Summary Report on Trends and Sources of Zoonoses, Zoonotic Agents, Antimicrobial resistance and Foodborne outbreaks in the European Union in 2006. *EFSA Journal*, 130, 1–352.
- EFSA. (2009). Trends and sources of zoonoses and zoonotic agents in the European Union in 2007. *EFSA Journal*, 223, 1–320.
- EFSA. (2010). Trends and sources of zoonoses and zoonotic agents and food-borne outbreaks in the European Union in 2008. *EFSA Journal*, 8(1), 1–368.
- EFSA. (2011). The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2009. *EFSA Journal*, 9(3), 1–378.
- EFSA. (2013a). Analysis of the baseline survey on the prevalence of *Listeria monocytogenes* in certain ready-to-eat foods in the EU, 2010-2011 Part A: *Listeria monocytogenes* prevalence estimates. *EFSA Journal*, 11(6), 3241.
- EFSA. (2013b). The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2011. *EFSA Journal*, 11(4), 1–250.

- EFSA. (2015). The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2013. *EFSA Journal*, 13(1), 3991.
- EFSA. (2016). The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2015. *EFSA Journal*, 14(14), 4634.
- Esho, F. K., Enkhtuya, B., Kusumoto, A., & Kawamoto, K. (2013). Microbial Assessment and Prevalence of Foodborne Pathogens in Natural Cheeses in Japan. *BioMed Research International*, 2013:20580, 1–6. <http://doi.org/10.1155/2013/205801>
- EU Regulation (EC) N0. 2073/2005. Commission Regulation (EC) N0. 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. *Official Journal of the European Communities*, 338(2073), 1–26.
- FDA. (2015). Joint FDA / Health Canada quantitative assessment of the risk of listeriosis from soft-ripened cheese consumption in the United States and Canada: Report. <https://www.fda.gov/downloads/Food/FoodScienceResearch/RiskSafetyAssessment/UCM429419.pdf> Accessed 10.03.16.
- Filiosis, G., Johansson, A., Frey, J., & Perreten, V. (2009). Prevalence, genetic diversity and antimicrobial susceptibility of *Listeria monocytogenes* isolated from open-air food markets in Greece. *Food Control*, 20(3), 314–317.
- Finazzi, G., Daminelli, P., Serraino, A., Pizzamiglio, V., Riu, R., Giacometti, F., Bertasi, B., Losio, M.N., & Boni, P. (2011). Behaviour of *Listeria monocytogenes* in packaged water buffalo mozzarella cheese. *Letters in Applied Microbiology*, 53(3), 364–370.
- FIOD (2005). Raw, unpasteurized, queso fresco 2005. <http://www.outbreakdatabase.com/details/raw-unpasteurized-queso-fresco-2005/?organism=Listeria+monocytogenes&vehicle=cheese> Accessed 29.05.16
- FIOD. (2010). Queseria Bendita Fresh Cheese 2010. <http://www.outbreakdatabase.com/details/queseria-bendita-fresh-cheese-2010/?organism=Listeria+monocytogenes&vehicle=cheese> Accessed 29.05.16
- FIOD. (2011). Green Cedar Dairy - Harb, Inc. Natural Ackawi and Chives Cheese 2011. <http://www.outbreakdatabase.com/details/green-cedar-dairy-harb-inc.-natural-ackawi-and-chives-cheese-2011/?organism=Listeria+monocytogenes&vehicle=cheese> Accessed 29.05.16.
- FIOD. (2013). Les Freres Cheese Listeriosis Outbreak, June 2013. <http://www.outbreakdatabase.com/details/les-freres-cheese-listeriosis-outbreak-june-2013/?organism=Listeria+monocytogenes&vehicle=cheese> Accessed 29.05.16

- 578 FIOD. (2014a). 2013-2014 Listeria linked to Oasis Brands Cheese.
 579 [http://www.outbreakdatabase.com/details/2013-2014-listeria-linked-to-oasis-brands-](http://www.outbreakdatabase.com/details/2013-2014-listeria-linked-to-oasis-brands-cheese/?organism=Listeria+monocytogenes&vehicle=cheese)
 580 [cheese/?organism=Listeria+monocytogenes&vehicle=cheese](http://www.outbreakdatabase.com/details/2013-2014-listeria-linked-to-oasis-brands-cheese/?organism=Listeria+monocytogenes&vehicle=cheese) Accessed 29.05.16.
- 581 FIOD. (2014b). 2014 Outbreak of Listeriosis Linked to Soft Cheese Produced by Roos Foods.
 582 [http://www.outbreakdatabase.com/details/2014-outbreak-of-listeriosis-linked-to-soft-cheese-](http://www.outbreakdatabase.com/details/2014-outbreak-of-listeriosis-linked-to-soft-cheese-produced-by-roos-foods/?organism=Listeria+monocytogenes&vehicle=cheese)
 583 [produced-by-roos-foods/?organism=Listeria+monocytogenes&vehicle=cheese](http://www.outbreakdatabase.com/details/2014-outbreak-of-listeriosis-linked-to-soft-cheese-produced-by-roos-foods/?organism=Listeria+monocytogenes&vehicle=cheese) Accessed
 584 29.05.16
- 585 FIOD. (2015a). 2015 Listeria Outbreak Linked to Queseria Bendita Latin-style cheese, Washington
 586 State. [http://www.outbreakdatabase.com/details/2015-listeria-outbreak-linked-to-queseria-](http://www.outbreakdatabase.com/details/2015-listeria-outbreak-linked-to-queseria-bendita-latin-style-cheese-washington-state/?organism=Listeria+monocytogenes&vehicle=cheese)
 587 [bendita-latin-style-cheese-washington-](http://www.outbreakdatabase.com/details/2015-listeria-outbreak-linked-to-queseria-bendita-latin-style-cheese-washington-state/?organism=Listeria+monocytogenes&vehicle=cheese)
 588 [state/?organism=Listeria+monocytogenes&vehicle=cheese](http://www.outbreakdatabase.com/details/2015-listeria-outbreak-linked-to-queseria-bendita-latin-style-cheese-washington-state/?organism=Listeria+monocytogenes&vehicle=cheese) Accessed 29.05.16
- 589 FIOD. (2015b). Listeriosis linked to soft cheese produced by Karoun Dairies, Inc., 2010 to 2015.
 590 [http://www.outbreakdatabase.com/details/listeriosis-linked-to-soft-cheese-produced-by-](http://www.outbreakdatabase.com/details/listeriosis-linked-to-soft-cheese-produced-by-karoun-dairies-inc.-2010-to-2015/?organism=Listeria+monocytogenes&vehicle=cheese)
 591 [karoun-dairies-inc.-2010-to-2015/?organism=Listeria+monocytogenes&vehicle=cheese](http://www.outbreakdatabase.com/details/listeriosis-linked-to-soft-cheese-produced-by-karoun-dairies-inc.-2010-to-2015/?organism=Listeria+monocytogenes&vehicle=cheese)
 592 Accessed 29.05.16
- 593 Fox, P.F., Guinee, T.P., Cogan, T.M., & McSweeney, P.L.H. (2000). Fundamentals of cheese
 594 science. (1st ed.). Maryland: Aspen, (Chapter 17).
- 595 Fretz, R., Pichler, J., Sagel, U., Much, P., Ruppitsch, W., Pietzka, A. T., Stöger, A., Huhulescu, S.,
 596 Hueberger, S., Appl, G., Werber, D., Stark, K., Prager, R., Flieger, A., Karpísková, R., Pfaff,
 597 G., & Allerberger, F. (2010). Update: Multinational listeriosis outbreak due to “quargel”, a
 598 sour milk curd cheese, caused by two different *L. monocytogenes* serotype 1/2a strains, 2009-
 599 2010. *Eurosurveillance*, 15(16), 2–3.
- 600 FSAI. (2011). Establishing baseline data on the presence of *Listeria monocytogenes* on cooked meat
 601 slicers in retail and catering.
 602 [https://www.fsai.ie/establishingbaselinedataonthepresenceoflisteriamonocytogenesoncookedm](https://www.fsai.ie/establishingbaselinedataonthepresenceoflisteriamonocytogenesoncookedmeatslicersinretailandcateringpremises.html)
 603 [eatslicersinretailandcateringpremises.html](https://www.fsai.ie/establishingbaselinedataonthepresenceoflisteriamonocytogenesoncookedmeatslicersinretailandcateringpremises.html) Accessed 10.05.17
- 604 FSIS. (2014). FSIS Compliance Guideline: Controlling *Listeria monocytogenes* in post-lethality
 605 exposed ready-to-eat meat and poultry products.
 606 [https://www.fsis.usda.gov/wps/wcm/connect/d3373299-50e6-47d6-a577-](https://www.fsis.usda.gov/wps/wcm/connect/d3373299-50e6-47d6-a577-e74a1e549fde/Controlling-Lm-RTE-Guideline.pdf?MOD=AJPERES)
 607 [e74a1e549fde/Controlling-Lm-RTE-Guideline.pdf?MOD=AJPERES](https://www.fsis.usda.gov/wps/wcm/connect/d3373299-50e6-47d6-a577-e74a1e549fde/Controlling-Lm-RTE-Guideline.pdf?MOD=AJPERES) Accessed 25.04.16.
- 608 Gasanov, U., Hughes, D., & Hansbro, P. M. (2005). Methods for the isolation and identification of
 609 *Listeria* spp. and *Listeria monocytogenes*: a review. *Fems Microbiology Reviews*, 29(5), 851–

875.

Gaulin, C. (2003). First documented outbreak of *Listeria monocytogenes* in Quebec, 2002. *Canada Communicable Disease Report = Relevé Des Maladies Transmissibles Au Canada*, 29(21), 181–186.

Gaulin, C., & Ramsay, D. (2010). Le lien suivant vous amènera à un autre site Web Rapport d'investigation et d'intervention à la suite de l'éclosion d'infections à *Listeria monocytogenes* pulsovar 93 liée à la consommation de fromages québécois, 2008.

<https://www.mapaq.gouv.qc.ca/fr/Publications/Rapporteclosionlisteriose.pdf> Accessed 08.06.16.

Gianfranceschi, M. V., Rodriguez-Lazaro, D., Hernandez, M., González-García, P., Comin, D., Gattuso, A., Delibato, E., Sonnessa, M., Pasquali, F., Prencipe, V., Sreter-Lancz, Z., Saiz-Abajo, M.J., Pérez-De-Juan, J., Butrón, J., Kozačinski, L., Tomic, D.H., Zdolec, N., Johannessen, G.S., Jakočiune, D., Olsen, J.E., De Santis, P., Lovari, S., Bertasi, B., Pavoni, E., Paiusco, A., De Cesare, A., Manfreda, G., & De Medici, D. (2014). European validation of a real-time PCR-based method for detection of *Listeria monocytogenes* in soft cheese. *International Journal of Food Microbiology*, 184, 128–133.

Gilbert, R. J., de Louvois, J., Donovan, T., Little, C., Nye, K., Ribeiro, C. D., Richards, J., Roberts, D., & Bolton, F. J. (2000). Guidelines for the microbiological quality of some ready-to-eat foods sampled at the point of sale. PHLS Advisory Committee for Food and Dairy Products. *Communicable Disease and Public Health*, 3(3), 163–167.

Glass, G. V. (1976). Primary, secondary, and meta-analysis of research. *Educational Researcher*, 5(10), 3–8.

Greco, S., Tolli, R., Bossù, T., Flores Rodas, E. M., Di Giamberardino, F., Di Sirio, A., Vita, S., De Angelis, V., Bilei, S., Sonnessa, M., Gattuso, A., & Lanni, L. (2014). Case of contamination by *Listeria monocytogenes* in mozzarella cheese. *Italian Journal of Food Safety*, 3(1), 51-53.

Goulet, V., Jacquet, C., Vaillant, V., Rebière, I., Mouret, E., Lorente, C., Maillot, E., Stäiner, F., & Rocourt, J. (1995). Listeriosis from consumption of raw-milk cheese. *The Lancet*, 345(8964), 1581–1582.

Goulet, V., King, L. A., Vaillant, V., & de Valk, H. (2013). What is the incubation period for listeriosis? *BMC Infectious Diseases*, 13, 11. doi:10.1186/1471-2334-13-11.

Gyurova, E., Krumova-Vulcheva, G., Daskalov, H., & Gogov, Y. (2014). Prevalence of *Listeria monocytogenes* in ready-to-eat foods in Bulgaria. *Journal of Hygienic Engineering and*

- Design, 7, 112–118. UDC 579.67:579.869.1.
- Higgins, J. P. T., & Thompson, S. G. (2002). Quantifying heterogeneity in a meta-analysis. *Statistics in Medicine*, 21(11), 1539–1558.
- Iannetti, L., Acciari, V. A., Antoci, S., Addante, N., Bardasi, L., Bilei, S., Calistri, P., Cito, F., Cogoni, P., D'Aurelio, R., Decastelli, L., Iannetti, S., Iannito, G., Marino, A.M.F., Muliari, R., Neri, D., Perilli, M., Pomilio, F., Prencipe, V.A., Proroga, Y., Santarelli, G.A., Sericola, M., Torresi, M., & Migliorati, G. (2016). *Listeria monocytogenes* in ready-to-eat foods in Italy: Prevalence of contamination at retail and characterisation of strains from meat products and cheese. *Food Control*, 68, 55–61.
- Jackson, K. A., Biggerstaff, M., Tobin-D'Angelo, M., Sweat, D., Klos, R., Nosari, J., Garrison, O., Boothe, E., Saathoff-Huber, L., Hainstock, L., & Fagan, R. P. (2011). Multistate outbreak of *Listeria monocytogenes* associated with Mexican-style cheese made from pasteurized milk among pregnant, Hispanic women. *Journal of Food Protection*, 74(6), 949–953.
- Jensen, A., Frederiksen, W., & Gerner-Smidt, P. (1994). Risk Factors for Listeriosis in Denmark, 1989–1990. *Scandinavian Journal of Infectious Diseases*, 26(2), 171–178.
- Johnsen, B. O., Langaas, E., Torfoss, D., Strøm, E. H., & Nordøy, I. (2010). A large outbreak of *Listeria monocytogenes* infection with short incubation period in a tertiary care hospital. *Journal of Infection*, 61(6), 465–470.
- Koch, J., Dworak, R., Prager, R., Becker, B., Brockmann, S., Wicke, A., Wichmann-Schauer, H., Hof, H., Werber, D., & Stark, K. (2010). Large listeriosis outbreak linked to cheese made from pasteurized milk, Germany, 2006-2007. *Foodborne Pathogens and Disease*, 7(12), 1581–1584.
- Lambertz, S. T., Nilsson, C., Brådenmark, a, Sylvén, S., Johansson, a, Jansson, L.-M., & Lindblad, M. (2012). Prevalence and level of *Listeria monocytogenes* in ready-to-eat foods in Sweden 2010. *International Journal of Food Microbiology*, 160(1), 24–31.
- Linnan, M. J., Mascola, L., Lou, X. D., Goulet, V., May, S., Salminen, C., Hird, D.W., Yonekura, M.L., Hayes, P., Weaver, R., Audurier, A., Plikaytis, B.D., Fannin, S.L., Kleks, A., & Broome, C. V. (1988). Epidemic listeriosis associated with Mexican-style cheese. *New England Journal of Medicine*, 319(13), 823–828.
- Little, C. L., Sagoo, S. K., Gillespie, I. A., & Grant, K. (2009). Prevalence and level of *Listeria monocytogenes* and other *Listeria* species in selected retail ready-to-eat foods in the United Kingdom. *Journal of Food Protection*, 72(9), 1869–1877.

- 674 Loncarevic, S., Danielsson-Tham, M. L., & Tham, W. (1995). Occurrence of *Listeria*
 675 monocytogenes in soft and semi-soft cheeses in retail outlets in Sweden. *International Journal*
 676 *of Food Microbiology*, 26(2), 245–250.
- 677 MacDonald, P.D., Whitwam, R.E., Boggs, J.D., MacCormack, J.N., Anderson, K.L., Reardon, J.W.,
 678 Saah, J.R., Graves, L.M., Hunter, S.B., & Sobel, J. (2005). Outbreak of listeriosis among
 679 Mexican immigrants as a result of consumption of illicitly produced Mexican-style cheese.
 680 *Clinical Infectious Diseases*, 40(5), 677–682.
- 681 Magalhães, R., Almeida, G., Ferreira, V., Santos, I., Silva, J., Mendes, M. M., Pita, J., Mariano, G.,
 682 Mancio, I., Sousa, M.M., Farber, J., Pagotto, F., & Teixeira, P. (2015). Cheese-related
 683 listeriosis outbreak, Portugal, March 2009 to February 2012. *Eurosurveillance*, 20(17), 1–6.
- 684 Makino, S. I., Kawamoto, K., Takeshi, K., Okada, Y., Yamasaki, M., Yamamoto, S., & Igimi, S.
 685 (2005). An outbreak of food-borne listeriosis due to cheese in Japan, during 2001.
 686 *International Journal of Food Microbiology*, 104(2), 189–196.
- 687 Massa, S., Cesaroni, D., Poda, G., & Trovatelli, L. D. (1990). The incidence of *Listeria* spp . in soft
 688 cheeses , butter and raw milk in the province of Bologna. *Journal of Applied Bacteriology*,
 689 68(2), 153–156.
- 690 McLauchlin, J. (1997). The identification of *Listeria* species. *International Journal of Food*
 691 *Microbiology*, 38(1), 77–81.
- 692 Mossel, D. A. . (1978). Index and indicator organisms - a current assessment of their usefulness and
 693 significance. *Food Technology in Australia*, 30, 212–219.
- 694 NSW. (2013). Further Cases of *Listeria* Identified.
 695 http://www.health.nsw.gov.au/news/Pages/20130118_01.aspx Accessed 15.06.16.
- 696 O'Brien, M., Hunt, K., McSweeney, S., & Jordan, K. (2009). Occurrence of foodborne pathogens in
 697 Irish farmhouse cheese. *Food Microbiology*, 26(8), 910–914.
- 698 OXOID. (2016). *Listeria* Precis. http://www.oxoid.com/pdf/uk/27363_Listeria_Precis.pdf
 699 Accessed 20.05.16.
- 700 Pagotto, F., Ng, L.-K., Clark, C., & Farber, J. (2006). Canadian listeriosis reference service.
 701 *Foodborne Pathogens and Disease*, 3(1), 132–137.
- 702 Parisi, A., Latorre, L., Fraccalvieri, R., Miccolupo, A., Normanno, G., Caruso, M., & Santagada, G.
 703 (2013). Occurrence of *Listeria* spp. in dairy plants in Southern Italy and molecular subtyping
 704 of isolates using AFLP. *Food Control*, 29(1), 91–97.
- 705 Pesavento, G., Ducci, B., Nieri, D., Comodo, N., & Lo Nostro, A. (2010). Prevalence and antibiotic

- 706 susceptibility of *Listeria* spp. isolated from raw meat and retail foods. *Food Control*, 21(5),
707 708–713.
- 708 Pintado, C. M. B. ., Oliveira, A., Pampulha, M. E., & Ferreira, M. A. S. (2005). Prevalence and
709 characterization of *Listeria monocytogenes* isolated from soft cheese. *Food Microbiology*,
710 22(1), 79–85.
- 711 Pinto, B., & Reali, D. (1996). Prevalence of *Listeria monocytogenes* and other listerias in Italian-
712 made soft cheeses. *International Journal of Hygiene and Environmental Medicine*, 199(1), 1–
713 98.
- 714 Prencipe, V., Migliorati, G., Matteucci, O., Calistri, P., & Giannatale, E. Di. (2010). Valutazione
715 della qualità igienico sanitaria di alcuni tipi di formaggi prelevati in fase di vendita al dettaglio.
716 *Veterinaria Italiana*, 46(2), 221–231.
- 717 ProMed. (2008). Listeriosis, fatal - Chile: (Santiago), cheese suspected, request for information.
718 <http://www.promedmail.org/post/20081128.3754> Accessed 10.06.16.
- 719 Quaglio, G., Casolari, C., Menziani, G., & Fabio, A. (1992). Indagine sulla presenza di *Listeria*
720 *monocytogenes* in campioni di latte e derivati. *L'Igiene Moderna*, 97, 565–579.
- 721 Ries, F. (1990). Camembert, *Listeria* and the immunocompromised patient. *Bulletin De La Societe*
722 *Des Sciences Medicales Du Grand-Duche De Luxembourg*, 127(1), 41-43.
- 723 Rocourt, J., Hof, H., Schrettenbrunner, A., Malinverni, R., & Bille, J. (1986). Acute purulent
724 *Listeria seelingeri meningitis* in an immunocompetent adult. *Schweizerische Medizinische*
725 *Wochenschrift*, 116(8), 248-251.
- 726 Rodriguez-Lazaro, D., Gonzalez-García, P., Gattuso, A., Gianfranceschi, M. V., & Hernandez, M.
727 (2014). Reducing time in the analysis of *Listeria monocytogenes* in meat, dairy and vegetable
728 products. *International Journal of Food Microbiology*, 184, 98–105.
- 729 Rosengren, Å., Fabricius, A., Guss, B., Sylvén, S., & Lindqvist, R. (2010). Occurrence of
730 foodborne pathogens and characterization of *Staphylococcus aureus* in cheese produced on
731 farm-dairies. *International Journal of Food Microbiology*, 144(2), 263–269.
- 732 Rota, C., Yangüela, J., Blanco, D., Carramiñana, J. J., & Herrera, A. (1992). Aislamiento e
733 identificación de microorganismos del G. *Listeria* en quesos frescos, quesos curados y quesos
734 fundidos. *Alimentaria*, 236, 59–62.
- 735 Rudolf, M., & Scherer, S. (2000). Incidence of *Listeria* and *Listeria monocytogenes* in acid curd
736 cheese. *Archiv Für Lebensmittelhygiene*, 51, 81–128.
- 737 Rudolf, M., & Scherer, S. (2001). High incidence of *Listeria monocytogenes* in European red smear

- cheese. *International Journal of Food Microbiology*, 63(1–2), 91–98.
- Rychli, K., Müller, A., Zaiser, A., Schoder, D., Allerberger, F., Wagner, M., & Schmitz-Esser, S. (2014). Genome sequencing of *Listeria monocytogenes* “Quargel” listeriosis outbreak strains reveals two different strains with distinct in vitro virulence potential. *PLoS ONE*, 9(2), 1–11.
- Ryser, E. T., & Marth, E. H. (2007). Foodborne Listeriosis. In *Listeria, listeriosis, and food safety*. (3th ed.). Boca Raton: CRC Press, (Chapter 10).
- Sanaa, M., Coroller, L., & Cerf, O. (2004). Risk assessment of listeriosis linked to the consumption of two soft cheeses made from raw milk: Camembert of Normandy and Brie of Meaux. *Risk Analysis*, 24(2), 389–399.
- Sargeant, J. M., Amezcua, M., Rajic, A., & Waddell, L. (2005). A guide to conducting systematic reviews in agri-food public health. <http://www.angelfire.com/co4/civph/english.pdf> Accessed 22.10.15.
- Schmid, D., Allerberger, F., Huhulescu, S., Pietzka, A., Amar, C., Kleta, S., Prager, R., Preußel, K., Aichinger, E., & Mellmann, A. (2014). Whole genome sequencing as a tool to investigate a cluster of seven cases of listeriosis in Austria and Germany, 2011–2013. *Clinical Microbiology and Infection*, 20(5), 431–436.
- Schoder, D., Strauß, A., Szakmary-Brändle, K., & Wagner, M. (2015). How safe is European Internet cheese? A purchase and microbiological investigation. *Food Control*, 54, 225–230.
- Silva, I. M. M., Almeida, R. C. C., Alves, M. A. O., & Almeida, P. F. (2003). Occurrence of *Listeria* spp. in critical control points and the environment of Minas Frescal cheese processing. *International Journal of Food Microbiology*, 81(3), 241–248.
- Spanu, C., Scarano, C., Spanu, V., Penna, C., Viridis, S., & De Santis, E. P. L. (2012). *Listeria monocytogenes* growth potential in Ricotta salata cheese. *International Dairy Journal*, 24(2), 120–122.
- Spanu, C., Spanu, V., Pala, C., Viridis, S., Scarano, C., & De Santis, E. P. L. (2013). Evaluation of a post-lethality treatment against *Listeria monocytogenes* on Ricotta salata cheese. *Food Control*, 30(1), 200–205.
- Spanu, C., Scarano, C., Ibba, M., Spanu, V., & De Santis, E. P. L. (2015). Occurrence and traceability of *Listeria monocytogenes* strains isolated from sheep’s milk cheese-making plants environment. *Food Control*, 47, 318–325.
- Sutton, A. J. (2001). An illustrated guide to the methods of meta-analysis. *Journal of Evaluation in Clinical Practice*, 7(2), 135–148.

- Theodoridis, A., Abraham, A., Sarimvei, A., Panoulis, C., Karaioannoglou, P. Genigeorgis, C., & A., M. (1998). Prevalence and significance of *Listeria monocytogenes* in Greek whey cheeses . A comparison between the years 1990 and 1996. *MILCHWISSENSCHAFT*, 53(3), 147–149.
- Tiwari, U., Cummins, E., Valero, A., Walsh, D., Dalmasso, M., Jordan, K., & Duffy, G. (2015). Farm to fork quantitative risk assessment of *Listeria monocytogenes* contamination in raw and pasteurized milk cheese in Ireland. *Risk Analysis*, 35(6), 1140–1153.
- Trmčić, A., Chauhan, K., Kent, D. J., Ralyea, R. D., Martin, N. H., Boor, K. J., & Wiedmann, M. (2016). Coliform detection in cheese is associated with specific cheese characteristics, but no association was found with pathogen detection. *Journal of Dairy Science*, 99(8), 6105–6120.
- Viechtbauer, W. (2010). Conducting meta-analyses in R with the metafor. *Journal of Statistical Software*, 36(3), 1-48.
- Vitas, A. I., Aguado, V., & Garcia-Jalon, I. (2004). Occurrence of *Listeria monocytogenes* in fresh and processed foods in Navarra (Spain). *International Journal of Food Microbiology*, 90(3), 349–356.
- Web of Science.Thomson reuters (2017). <https://webofknowledge.com/> Accessed 05.04.17.
- Weller, D., Andrus, A., Wiedmann, M., & den Bakker, H. C. (2015). *Listeria booriae* sp. nov. and *Listeria newyorkensis* sp. nov., from food processing environments in the USA. *International Journal of Systematic and Evolutionary Microbiology*, 65(Pt 1), 286–292.
- Wemmenhove, E., Stampelou, I., van Hooijdonk, A. C. M., Zwietering, M. H., & Wells-Bennik, M. H. J. (2013). Fate of *Listeria monocytogenes* in Gouda microcheese: No growth, and substantial inactivation after extended ripening times. *International Dairy Journal*, 32(2), 192–198.
- Xavier, C., Gonzales-Barron, U., Paula, V., Estevinho, L., & Cadavez, V. (2014). Meta-analysis of the incidence of foodborne pathogens in Portuguese meats and their products. *Food Research International*, 55, 311–323.
- Yousef, A. E., & Marth, E. H. (1990). Fate of *Listeria monocytogenes* During the Manufacture and Ripening of Parmesan Cheese. *Journal of Dairy Science*, 73(12), 3351–3356.

Highlights:

- Overview of listeriosis outbreaks caused by cheese 1983-2016
- Overall prevalence of *L. monocytogenes* in European cheese 2005 - 2015
- Prevalence of *L. monocytogenes* in different types of cheese
- No indicator or index organism identified for *L. monocytogenes* in cheese