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ABSTRACT

Listeria monocytogenes responsible for human listeriosis is associated with the highest hospitalization and mortality rates of foodborne pathogens. In recent years, incidence of listeriosis has reported to double in Europe, almost exclusively among older adults (≥60 years). Food safety risk factors associated with increased risk of listeriosis include ‘use by’ date adherence and effective refrigerated storage of foods. Consequently, there is a need to determine older adult consumers’ implementation of such practices. This review aimed to evaluate consumer food safety cognitive and behavioural data relating to risk factors associated with listeriosis in the home. Overall, only 41% of studies assessed consumer cognitive or behavioural data associated with listeriosis; of which 59% assessed safe refrigeration, 54% determined storage length of opened RTE foods and 49% ascertain adherence of ‘use-by’ dates. Majority (83%) of studies utilized survey based data collection methods (questionnaires/interviews), thus resulting in majority of findings based on self-report (74%) and knowledge (44%). Observation (31%) and focus groups (12%) were less commonly used; consequently resulting in a lack of ‘actual behaviors’ and attitudinal data relating to listeriosis risk factors. Only 7% of studies presented older adults food safety data. Although findings suggest older adults may fail to implement the recommended practices thus increasing the risk of listeriosis, this review identifies a need for in-depth research to determine older adults’ food safety attitudes and actual behaviour in conjunction with knowledge and self-report of practices linked to increased risks of listeriosis. Such data combined with review findings would inform targeted food safety education to reduce risks associated with listeriosis in the home.
The key foodborne pathogens responsible for the majority of foodborne illnesses internationally include *Campylobacter*, *Salmonella*, *Escherichia coli* O157 and *Listeria monocytogenes* (43, 110, 118). A comparison of incidence, mortality and hospitalization rates determines that although the incidence of listeriosis is not as extensive as other organisms; however, the severity of illness and the likelihood of a fatal outcome (112) makes listeriosis of significant public health concern (55, 95, 98). *L. monocytogenes* is reported to be responsible for more deaths than *Salmonella* and *E. coli* O157 combined (66), with data suggesting that up to 90% of listeriosis cases are hospitalized (54) and *L. monocytogenes* is associated with the highest mortality rate among foodborne pathogens in the USA (15) and Europe (30) with international mortality rates reported to range from 9% in Germany, 19% in the USA (110) and up to 41% in England and Wales, listeriosis is therefore described as being the foremost foodborne pathogen responsible for mortality (51).

*L. monocytogenes* is an organism widely distributed throughout the environment (30, 109) which is particularly resistant to environmental stress (84, 92). It is the only species of the *Listeria* genus that is pathogenic to humans (108) and is known to be the causative pathogen of listeriosis (59). It can result in two types of human infection; ‘non-invasive listeriosis’, which affects the digestive system which can result in symptoms including diarrhoea (22), and the far more serious ‘invasive listeriosis’ which is associated with common clinical presentations including central nervous system (CNS) infection, sepsis and bacteremia (22, 33).

The majority of reported listeriosis cases are sporadic incidents; outbreaks of listeriosis are reportedly rare occurrences, particularly in the UK (2, 93). However, over the last decade an international increase of listeriosis incidence has been reported (36, 118). For example, in the UK, a substantial increase in listeriosis incidence was reported between 2001 and 2004 (53) with a doubling of bacteremia cases during 2005/2006 compared to 2001 (3); furthermore, recent data has suggested a 23% increase during 2007 in the UK (63). Concurrently, European surveillance data indicated that countries such as Denmark (71), Germany (76), Austria (6), Norway (10), France,
Switzerland, Finland and The Netherlands (56) have all reported considerable increases in listeriosis incidence.

Due to the invasiveness of *L. monocytogenes*, listeriosis fatalities is particularly associated with high-risk populations, such as individuals with compromised immune systems, for instance older adults (aged ≥60 years), pregnant women and new born babies (30). It can cause infection of the CNS (24) and as a result of cell-mediated immunity becoming somewhat impaired during pregnancy, the incidence of perinatal listeriosis, stillbirth or infant death has been reported to occur in over 20% of infections (33, 93). Historical surveillance data (1980s and 1990s) suggests that the majority of listeriosis incidence use to be predominantly associated with pregnant women, however, in more recent years (1993 onwards) international incidence of pregnancy associated infection has reportedly decreased (115). For example, epidemiological data from France indicated that between 1999 and 2005 an 84% decrease in the incidence of pregnancy associated listeriosis was reported (56). It has been suggested that the implementation of targeted consumer education efforts specifically for pregnant women regarding the risks associated with food consumption and listeriosis may have aided the decreased incidence of listeriosis among this consumer group (115, 120).

The relative risk of listeriosis is reported to increase with age (97). Since 2000 incidence of listeriosis among adults aged ≥60 years has increased significantly (36), particularly among adults aged ≥70 years (56), with the median death age from listeriosis in the USA reported to be 71 years (16). Indeed, the recent increased incidence of listeriosis in Germany and Denmark is reported to be predominantly as a result of incidence associated with older adults (71, 76). During the late 1980's, 30% of incidence was associated with adults ≥60 years (107), whereas international data indicates that the majority (58 – 66%) (64, 118) of listeriosis incidence in recent years has predominantly been associated with adults ≥60 years (3). Reports indicate that decreased susceptibility and improvements in detection and notification systems of listeriosis do not explain the reported increased incidence of listeriosis (3).
It is estimated that up to 99% of illnesses associated with *L. monocytogenes* result from foodborne transmission (110). Foods commonly associated with presence of *L. monocytogenes*, which may be contaminated as a result of processing, are often ready-to-eat (RTE), have an extended refrigerated shelf life (68), have the ability to support the growth of the pathogen to high numbers (38) and usually do not require any further processing such as cooking prior to consumption by the consumer (60) which could act as a lethal kill stage. The most common food products contaminated with *L. monocytogenes* include RTE fish and meat products (47, 52, 89) and pre-packed sandwiches containing meat or dairy products and/or salad ingredients (83, 88, 123). Such foods are frequently purchased by consumers, which are subsequently handled and stored in the domestic kitchen. Indeed, market research indicates that almost all UK consumers reportedly used or were familiar with cooked and delicatessen meats (91). Further to this, other RTE foods products such as pâté (62), pasteurised milk (41), pre-packaged sandwiches (83), coleslaw (3), Mexican-style cheeses (19), cantaloupe (81) and butter (85) have been reported as causative sources for listeriosis.

The prevention of foodborne disease including *L. monocytogenes* involves co-operation of all stages of the food chain (37, 67), all of which have responsibilities. Factors such as contamination of *L. monocytogenes* and the safety of foods within the food industry are governed by microbiological criteria (28) and the Food Safety (General Food Hygiene) Regulations (119). Provision of safe food involves careful food handling from farmers, transporters, food processors, importers, restaurants, supermarkets, retailers, institutional food providers, government and ultimately the consumer who has been described as the final line of defense for the safety of foods (105). Post-purchase food safety practices relating to cross-contamination, temperature control and storage are required by consumers to ensure the on-going safety of food products.

Consumer implementation of food safety behaviours specifically relating to time and temperature control of RTE foods have been recommended to reduce the risks associated with listeriosis in the home by the UK FSA and Department of Health (DOH) (34), the European Centre for
Disease Prevention and Control (ECDC) (35) and the USA Centers for Disease Control and Prevention (CDC) (98). These consumer recommendations include:

- Following ‘use-by’ dates on unopened pre-packed RTE food products.
- Avoiding prolonged storage length of leftover, fresh RTE foods and opened pre-packed RTE food products.
- Ensuring safe operating temperatures of domestic refrigerators.

Currently there is a lack of in-depth data detailing consumer behaviour and cognitive influences associated with implementation of these key recommended practices required to reduce the risks associated with listeriosis, particularly regarding adults aged over 60 years. Furthermore, the UK FSA (92), the Advisory Committee on the Microbiological Safety of Food (3) and the U.S. Food and Drug Administration (39) have all recommended that research is required to determine domestic food handling and storage behaviours of consumers ≥60 years to better understand the behavioural risk factors that may be potentially associated with listeriosis.

Therefore, the aim of this study was to systematically review consumer food safety studies and consolidate research findings to determine consumer knowledge, attitudes, self-reported and actual behaviours according to behavioural risk factors reported to be associated with listeriosis. Furthermore, data has been analyzed to specifically determine behavioural risk factors associated with listeriosis that are implemented by older adult consumers (aged ≥60 years).

MATERIALS AND METHODS

A thorough literature review was conducted to obtain consumer food safety data from published articles reports. Online research databases and reference lists were screened using a systematic approach, with the use of keywords relating to the aims of the review paper, to identify research papers that may be suitable for inclusion in the review. Internet searches were completed using electronic databases, including Ingenta Connect, ScienceDirect, EBSCOhost, OvidSP and Emerald Insight.
Studies included for the review assessed consumer knowledge, attitudes, self-reported practices, and/or actual behaviour according to the recommended practices to prevent listeriosis. Such studies were selected according to predefined inclusion/exclusion criteria for suitability for incorporation in the review. Studies included in the review were specific to consumer food safety practices in the domestic kitchen. Studies involving food handlers, such as those within the food industry or care-giving settings were excluded from this review, as such food handlers may have received formal or informal food safety training, which general consumers would not normally receive. Studies included in the review were based on a variety of primary research methods of data collection, such as questionnaires, interviews, focus groups and/or observations. Secondary research papers, such as cumulative reviews and evaluations on aspects of consumer food safety behaviours were not assessed for the purposes of this paper. No publication date limits were applied and no exclusions were implemented with regards to location of publication or sample size.

All identified consumer food safety studies were managed and stored using a reference management software package (EndNote X5, Thomson Reuters 1988 – 2011). Research papers were reviewed and analyzed using a content analysis approach. Findings were summarized according to recommended food safety practices required to reduce the risk of listeriosis by (a) adhering to the ‘use-by’ dates on sealed RTE foods, (b) ensuring the safe operating temperatures of domestic refrigerators, and (c) avoiding the prolonged storage of opened RTE and leftover food, as outlined by the UK DOH and the FSA (34). Consumer food safety study findings relating to the aims of the review were stored and analyzed in a specifically designed Microsoft Office Access 2007 database, with further analysis conducted using Microsoft Office Excel 2007.

RESULTS AND DISCUSSION

Cumulatively, 165 published consumer food safety studies, undertaken over the past 20 years, from 20 different countries, were included for review. The majority of studies were undertaken in the USA (40%) and the UK (21%) (see Table 1); other countries of origin for studies
included the Netherlands (6%), Ireland (5%) and Australia (4%), thus indicating that consumer food safety is of international interest.

Data presented in Table 2 illustrates when consumer food safety studies were published over the last 20 years. The majority (79%) of studies incorporated in this review were conducted over the last decade (2003 – present day); demonstrating that the importance of consumer food safety data has been of increased interest in recent years.

**Food safety behaviours associated with increased risk of listeriosis.** From the 165 consumer food safety studies reviewed, 68 studies (41%) included assessment of the key food safety practices required for reducing the risk of listeriosis in the home, as recommended in the UK (34) and USA (98), the most common practice evaluated related to safe refrigeration temperatures (24%). A smaller number of studies incorporated data detailing storage length of opened RTE or leftover foods (22%); and adherence of ‘use-by’ dates (20%) (see Table 3). This review paper will present the findings of those 68 studies. **Consumer food safety data collection methods.** From the reviewed consumer food safety studies that included data on the practices associated with increased risk of listeriosis (n = 68), the majority (83%) were based on survey methods, few utilized observation methods (29%) and focus groups (12%) were the least applied data collection method in the reviewed studies.

Survey based data collection methods were the most utilized for collation of consumer food safety data, with 47% of studies using interviews and 36% using self-complete questionnaires. A benefit of survey based approaches allows the potential collection of data from a larger sample population size. Data indicates that survey based methods appear to have included the largest number of consumers in the studies reviewed, with questionnaires including the most variable number of respondents (between 50 - 4,343), with the largest number of respondents attained from online questionnaires (see Table 4).
Observation methods of data collection were utilized in 18 of the studies reviewed and included fewer participants that those involved in survey based methods (see Table 4). Nine per-cent of these included recording the operating temperature of domestic refrigerators, which is not a direct observation of consumer behaviour. Direct observation of actual behaviour was predominantly conducted in consumer’s home kitchens (24%) with only 3% including observational studies conducted in model kitchens.

Although consumers’ domestic kitchens provide a familiar environment for the observation of consumer behaviour, variables are not controllable and food preparation sessions are not so easily replicated. Undertaking a behavioural study in a model kitchen enables observation in a controlled laboratory setting (1); variables considered important for food safety can be controlled and enables direct comparison between participants and between repeated food preparation sessions. The method enables a direct interpretation of actual consumer behaviour which is said to be a valuable method that is underutilized (116); direct observation, may be subject to reactivity bias as consumers may change their behaviour as a result of being observed (104).

Although the utilization of model kitchens allows greater control than domestic kitchens, they are artificial environments; consequently, it may be argued that behaviour in such environments may not reflect actual consumer practices. However, the reliability of the technique has been determined, which indicates that behaviours implemented during food preparation in a model kitchen are representative of behaviours implemented in the domestic kitchen (102, 103).

**Focus group data collection.** Focus groups were utilized to collate qualitative consumer food safety data in 12% of reviewed studies. The total sample sizes of the focus groups included in these studies involved between 9 and 85 consumers (see Table 4); with the number of participants included in individual focus groups ranging between 8 and 12 participants. Qualitative data is collected from the utilization of focus groups (90), as a result of the consumers that participate, a
focus group can be dynamic and spontaneous (8), however are fundamentally reliant on the group interaction (23).

**Consumer food safety data measures.** The different data collection methods and types of consumer food safety data obtained are presented in Table 4.

**Self-reported practice.** Assessment of self-reported practices in reviewed consumer food safety studies was predominantly achieved using survey methods (Table 4). Most common self-reported practice, assessed in 46% of the reviewed studies relate to the length of time RTE foods are stored for (see Table 5). Limitations on the utilization of self-reported practices are based on the concept of social desirability bias, which refers to the tendency of research respondents to give a response viewed favorably (14, 57), this can take the form of over-reporting ‘good’ behaviours or under-reporting ‘bad’ behaviours (31). Despite these limitations self-reported consumer food safety data can provide useful information about indirect knowledge of food safety behaviours; however, research indicates considerable discrepancies exist between self-reported practices and actual behaviours (26, 27, 104).

**Attitudes.** Cumulatively, only 12% of the reviewed studies included consumer attitudes towards food safety practices required to reduce the risks associated with listeriosis, which were predominantly determined through the use of interviews (9%)(see Table 4). Consumer attitudes towards adherence of use-by dates were determined in 6% of studies, whereas ensuring safe storage temperatures and avoiding prolonged storage length was assessed in 3% of studies. Given that consumer attitudes are understood to influence behaviour (106), the identification of consumer attitudes towards key listeriosis preventative behaviours is essential to determine the cognitive influence on actual behaviours implemented by consumers during domestic food preparation and storage.
Knowledge. Determination of consumer knowledge of food safety practices required to reduce risks associated with listeriosis was identified in 44% of reviewed consumer food safety studies. Consumer knowledge was predominantly determined through the use of face-to-face interviews (25%) (Table 4). Knowledge of storage temperature was the most commonly assessed food safety practice, reported in 34% (Table 5). Although knowledge is an important cognitive part of a consumers’ approach to food safety, possession of safe food handling knowledge has not been found to correspond with self-reported practice or actual behaviour (96). Research has indicated that consumers found to be knowledgeable of a food safety practice have also been found to have positive intentions and attitudes towards the implementation of food safety practice; however consumer knowledge has not been found to transpose to the appropriate food safety behaviour (25).

Actual behaviour. Evaluation of actual consumer food safety behaviours have been determined in 31% of the consumer food safety studies reviewed. All of such studies were part of general consumer food safety studies, to date, no studies have specifically undertaken an in-depth behavioural analysis of the key behaviours required to reduce the risk of listeriosis. The review has shown that 26% of studies have determined domestic refrigerator operating temperatures (Table 4); however, few studies reported actual behaviour such as observational data of consumers adhering to ‘use-by’ dates (4%) and avoiding prolonged storage of opened RTE and leftover food (6%) (see Table 5). Given observation is the best indicator of what people actually do, there is a need to collect this type of data.

Mixed methods. A mixed method approach that includes the use of one or more data collection method such as survey based methods, observation or focus groups. Such studies included multiple measures of data, and this can facilitate a more in-depth analysis of consumer food safety data. However, in addition to a mixed methods approach, different measures can be achieve from using only one method, this is valuable data as it provides information regarding the cognitive influences on the implementation of actual behaviour of consumers. Although the accumulation of
self-report data and observation behavioural data can be utilized to compare what consumers reportedly do and actually do and determine any discrepancies, it can be used to validate self-reports (82).

Although 71% of the reviewed studies combined measures such as knowledge and self-report, only 28% had used combined methods of data collection. The most frequently combined measures were knowledge and self-reported data (25% of studies). The least frequently combined measures were actual behaviour and attitudes (2%); further to this, the inclusion of the three cognitive measures of consumer food safety knowledge, attitudes and self-reported practices were included in 24% of studies, whilst the cumulative comparison of the four measures of knowledge, attitudes, self-reported practice and actual behaviour were incorporated in one study that related to the listeriosis preventative practices; however, this was a small scale pilot study which involved a small sample of consumers. Findings from this study concluded that further in-depth research is required to evaluate older adult consumers’ food safety behaviours in domestic kitchens (65).

Inclusion of food safety behaviours required to reduce risk of listeriosis in the home. Consumer food safety findings from the reviewed studies will be discussed in context of the three key practices associated with the risk of listeriosis

Adherence to ‘use-by’ dates. The shelf life of foods that will support the growth of L. monocytogenes are established to ensure that a limit of 100 cfu/g will not be exceeded at any point between the food products production and consumption (17), ensuring that food products remain safe for consumers (122). Therefore, it is critical that consumers adhere to the ‘use-by’ dates on RTE foods to ensure the safety of the food that they consume.

Nearly half (49%) of the consumer food safety studies reviewed included data on consumer adherence to ‘use-by’ dates. Self-reported data was the most commonly determined cognition with data relating to reported adhesion to following ‘use-by’ dates, included in 32% of the reviewed studies and 16% reported consumer knowledge of following ‘use-by’ dates. Findings indicated a lack
of actual behavioural and attitudinal data related to adherence to ‘use-by’ dates, which was
determined in only 4% and 6% of the studies respectively.

Results in Table 6 illustrate a comparison of consumer knowledge, attitude, self-reported
practices and actual behaviours from reviewed consumer food safety studies relating to consumer
adherence of ‘use-by’ dates. Although 49 – 62% of consumers reported awareness that ‘use-by’
dates were the best indicator of food being safe to eat (50, 99), 71% of consumers indicated
misunderstanding of the terms ‘use-by date’ and ‘best before’ dates (42). Similarly, only 18% of
consumers correctly defined the ‘use-by’ date (77) and further research suggests confusion may exist
among consumers concerning date labeling of food products. Overall findings indicate consumer
knowledge of ‘use-by’ dates is lacking.

Findings indicated that a quarter (25%) of consumers reported not always checking ‘use-by’
dates when purchasing food and reported also to not check before cooking food (69%) (99);
furthermore, 13% of consumers in a US study indicated that ‘use-by’ dates would not always be
adhered to (18). Consumer attitudes towards adherence of ‘use-by’ dates indicated that a large
proportion of consumers (68%) felt that it was ‘very important’ to use food in ‘sell by’ date order
(121), however, only 6% felt that the most important thing that they do to keep food safe is adhere
to the expiry dates on foods (CFIA, 1998). Observations of home refrigerators in US studies indicated
between 41 – 89% of households contained foods beyond the ‘use-by’ dates and a further study
determined 50% of cheese products in consumers’ domestic refrigerators were beyond the best-
before date (117). Some studies indicated that parents were the most frequently reported consumer
group to check expiry dates on food products (49). Although three-quarters of consumers indicated
that it was very important to avoid consumption of foods that have past expiry dates, up to 44% of
consumers in another study reported they would eat food beyond the ‘use-by’ date, in addition
findings indicate that 60% of consumers did not know food eaten beyond the ‘use-by’ date could be
unsafe to eat.
Refrigeration practices of food products in the home. Latest UK food safety requirements for storage of refrigerated foods is ≤5.0°C (34), and USA recommendations state ≤40.0°F (46), domestic refrigerators require consumers to set at appropriate temperatures to keep food at such temperatures or cooler to enable safe storage (39). Listeria spp. in pre-packed salads held at 4°C for 4 days showed a 2-fold increase of microbial counts (111). As L. monocytogenes is a psychrotrophic mesophile it has the ability, albeit slowly, to grow at refrigeration temperatures of 5°C and below (4), the storage temperature of foods associated with listeriosis is a critical variable in controlling the growth rate of L. monocytogenes (68), and therefore the safety of the food product (34). To reduce microbial growth of foodborne pathogenic Listeria spp. there is also a need for consumers to implement safe food handling practices during transportation of RTE food products between purchase and storage in the home. Research has been undertaken that indicates a microbial risk is posed by the transportation of foods particularly in the boot of the car during the summer without a refrigerated environment (75).

Consumer food safety study data relating to the safe storage temperature of RTE foods was the food safety behaviour associated with control of listeriosis most frequently investigated in the reviewed studies and was included in 59% of studies. Findings relating to consumer refrigeration practices of food products in the home were largely determined by assessment of knowledge (34%) and self-reported practices (28%). In addition to this, 26% of reviewed studies reported observed behavioural data. A lack of consumer attitudinal data towards refrigeration practices exists, which was determined in only 3% of the studies reviewed.

A comparison of knowledge, attitudes, self-reported practice and actual behavioural data relating to refrigeration temperatures can be found in Table 7. Overall findings have determined positive consumer attitudes towards the need for correct refrigerated temperature storage; however studies have also indicated that large proportions of consumers (up to 93%) did not know what recommended refrigerator operating temperatures were. Furthermore, data shows 41% of American consumers believe that they know the correct temperature for the safe refrigeration of food,
whereas in the UK 35% of consumers claimed to know what temperature their refrigerator should be operating at, however only 18% were correct (42). Self-report data determined that ownership of a refrigerator thermometer was low in countries including Europe and USA. Further to this, 26% of studies presented data on the actual operating temperatures of domestic refrigerators, of which between 9% (29) and 100% (100) were found to be operating above recommended temperatures to ensure food safety. Temperature findings from these studies are not easily comparable due to different sampling methods and recommended safe refrigeration temperatures varying according to country of research. The lack of consumer knowledge regarding the correct operating temperature of the refrigerator and the subsequent inability to assess safe refrigeration practices may allow L. monocytogenes to proliferate in foods stored at unsafe refrigeration temperatures and thus increase the risks associated with listeriosis.

Storage practices of opened RTE and leftover food in the home. The use of modified atmosphere packaging (MAP) increases the shelf life of foods, particularly RTE foods (13, 113). MAP functions by changing the environment that surrounds the food within its packaging with the purpose of extending the shelf life. This is achieved by increasing CO₂ concentration which is reported to inhibit activation of microorganism activity in food, and is particularly antimicrobial when under pressure (69). However, after opening a MAP food product, the antimicrobial properties are removed and research has shown that L. monocytogenes in opened packs of RTE cooked ham can achieve a 2 log increase within 10 days (114). Thus, once consumers open MAP RTE food products it is critical that they avoid prolonged storage to reduce the risk of L. monocytogenes growth in the products. Delicatessen meats purchased by consumers without MAP have also been implicated with listeriosis, therefore it is important that consumer adhere to recommendations of avoiding prolonged storage of RTE foods, a reduction in the storage length of delicatessen meat is predicted to reduce listeriosis risk (40, 68). Although limited, data suggests that the consumption of leftover food has previously been associated with incidence of foodborne disease (61).
Data on the storage length of opened RTE food was included in 54% of the 68 consumer food safety studies included in the review. The majority (46%) of studies included self-reported storage practices of opened RTE and leftover food. Consumer knowledge of storage practices was included in 16% of studies whilst attitude determination and assessment of actual behaviours were evaluated in only 3% and 6% of studies respectively, as a result of the review, it has been identified that there is a lack of data on the actual behaviours of consumers and their attitudes towards the storage practices of opened RTE and leftover foods. This indicates a need for more attitudinal and behavioural research to determine risk perceptions and attitudes towards storage practices as well as actual behavioural data detailing how consumers actually store RTE food products.

Data presented in Table 8 indicates reviewed consumer food safety study findings relating to the storage length of opened RTE and leftover foods. Knowledge data indicates that most consumers are aware of the importance of implementing storage practices to maximize food safety, for example the majority of consumers knew that inadequate storage practices can result in illness as 96% of consumers knew that improper storage of foods represents a ‘health hazard’ (9). Most consumers are aware of the importance of avoiding the storage of RTE foods at room temperature, however data indicates 16 – 33% of consumers may think it is acceptable to store cooked meat at ambient temperature, in addition, larger proportions of consumers reportedly thought that storage of leftover food at room temperature was an acceptable practice. Observation data has shown that a large percentage (up to 58%) of consumers failed to store food according to recommended practices and thus increasing potential microbial growth (125).

Inclusion of older adult consumer data in food safety studies. Given the increased incidence of illness resulting from L. monocytogenes among older adults during the last decade, inclusion of data specific to older adults was analyzed, from the 86 reviewed consumer food safety studies that included data on recommended practices to prevent listeriosis, 6% specifically focused on older adult consumers. Indeed, older adult consumers were more frequently involved in
consumer food safety research than other at-risk consumer groups such as mothers with infants (1%) or consumers with compromised immune systems (1%). Although the majority of studies were based on consumers from the general population, 35% of these included data on adults over the age of 60 and grouped older consumers (≥60 years) for analysis of data. Studies have been further analyzed according to older adult findings.

Older adult consumers’ adherence to ‘use-by’ dates. Data indicates that a smaller proportion of older adults (23%) were reportedly concerned about date labeling on foods (compared with other consumer groups 27% (44)). Although the purpose of ‘use-by’ dates is reportedly understood by older adults, such dates were not always reportedly adhered to (65).

Currently there is a lack of data relating to older adults’ adherence to and understanding of ‘use-by’ dates and further research is required to explore older adults’ knowledge and attitudes towards ‘use-by’ dates. In addition, actual behavioural data regarding older adults’ adherence to ‘use-by’ dates is lacking, there is a need to conduct research which is required to better our understanding and aid development of risk based educational approaches to increase adherence and therefore decrease implementation of behaviours that may increase the potential risk of listeriosis in the home.

Older adult consumers’ refrigeration practices of food products in the home. Findings suggest that knowledge of safe refrigeration temperatures among older adults is lacking, for example 88% of older adults did not know what temperature their refrigerator should operate at (65) and reported ownership of refrigerator thermometers was low, with between 0 – 24% reporting ownership (5, 48, 74, 78) Older adults who were unmarried and lived alone were reported to be less likely to own a refrigerator thermometer and have refrigerators at recommended safe operating temperature (78). Of concern, between 70 - 81% of temperatures recorded from older adult domestic kitchen refrigerators were reported to operate above recommended temperatures (65, 73).
Up to 37% of USA older adults indicated that food may not be consumed immediately after preparation or purchase and adequate refrigeration practices would not be followed (7). Further to this, placing leftover food in the refrigerator immediately was extensively reported by USA older adults. In addition to practices that may influence the storage temperature of RTE foods, studies analyzed in this review also determined that older adults may implement storage practices that may increase risks associated with cross-contamination during storage, such as placing food items wherever there is space in the refrigerator (65). Cumulatively, findings suggest that older adult consumer may implement unsafe storage practices in the domestic kitchen particularly with regards to implementation of adequate refrigeration temperatures, implications of which may increase the growth rate of *L. monocytogenes* in RTE foods thus increasing listeriosis risk.

**Older adult consumers’ storage practices of RTE and leftover food in the home.** Analysis of consumer food safety storage practice data according to consumer group showed that the majority (82%) of older adults reported the storage of leftover chilled food in the refrigerator (7), however 78% of older adults have reported that sliced cooked meats would be kept uncovered in the refrigerator (117) and 38% of older adults also reported they would store leftover food on the counter (7). Further to this, 50% of older adults were observed leaving a chicken salad at room temperature for storage prior to consumption in 24 hours after preparation in a model kitchen (101). Studies have found that older adults were unaware of many safe food storage practices (49).

Consequently, the majority of data from reviewed consumer food safety studies has indicated that older adults do implement unsafe food storage and handling practices in the domestic kitchen; this combined with a weakened immune system, situates older adults at an increased risk of foodborne disease including the risk of listeriosis. A lack of detailed analyses specific to the safe food handling and storage practices of older adults in the domestic kitchen to reduce the risks associated with listeriosis has been identified.
CONCLUSIONS

A substantial amount of consumer food safety research has been undertaken over the last 20 years; consequently, there is a wealth of consumer food safety data, however only 41% of the studies reviewed included data on specific consumer food safety practices associated with an increased risk of listeriosis in the domestic kitchen. The majority of such studies were completed in the USA and the UK with the use of single survey based research methods (interviews and questionnaires). Reviewed studies most commonly determined consumer food safety knowledge and self-report data. A lack of actual behavioural research based on observation and collation of attitudinal data towards food safety practices required to reduce the risk of listeriosis in the domestic kitchen has been determined. Furthermore, to date, no studies have linked microbiological isolation of *L. monocytogenes* contamination of the domestic environment with behavioural and cognitive research findings to increase our understanding of older adult consumers’ food safety practices in relation to listeriosis. Such data relating to older adult consumers may be of considerable importance to inform the development of effective and targeted risk communication initiatives to reduce incidence of listeriosis within this consumer group. Key findings of this review have included that:

- Although many consumers from the general population are reported to be aware of ‘use-by’ dates being the best indicator of food safety and many indicating positive attitudes towards the importance of ‘use-by’ dates, self-reported practice and actual behaviour data suggests that consumers frequently fail to adhere to ‘use-by’ dates.

- A positive attitude towards the importance of the operating temperature of the refrigerator did not correspond with consumer knowledge of safe refrigeration temperature, self-reported practices of checking refrigerator temperature or owning a refrigerator thermometer. Furthermore many temperatures recorded in general consumers’ domestic refrigerators exceeded recommended limits.
• Knowledge, attitudinal, self-reported and actual behavioural data on general consumer storage practices of opened RTE and leftover foods suggest that foods associated with *L. monocytogenes* may be subject to prolonged storage, which may increase risk of illness.

• Although discrepancies have been determined between consumer knowledge, attitudes, self-reported and actual behavioural data of practices associated with the increased risk of listeriosis; there is a lack of studies that combine data collection methods to compare consumer behaviour and cognition. Such data would increase our understanding of why potential consumers from the age group have been associated with increased incidence.

• Findings indicate that larger proportions of older adult consumers compared with consumers from the general population may deviate from recommended practices to control listeriosis in the domestic kitchen by failing to adhere to ‘use by’ dates, failing to ensure adequate refrigeration temperatures and prolonging storage of opened RTE food products.

• A lack of data specific to older adult consumers’ risk factors associated with listeriosis has been determined.

As noted above, the key findings from consumer food safety studies have determined that many consumers, including older adults fail to implement safe refrigerated storage practices, fail to adhere to ‘use-by’ dates and subject RTE foods to prolonged storage. Therefore, there is a need for food safety strategies to be targeted to improve these specific behaviours and reduce the risk of listeriosis.

Given the increased incidence of listeriosis, age associated illnesses and weakened immune function of older adults, future strategies are required to focus upon improving specific food safety behaviours of this consumer group. However, further research is needed to undertake in-depth cognitive, behavioural and microbiological analysis of older adult consumers’ preparation and storage practices of RTE food products, there is a need to understand why older adults implement the food safety practices that they do, what their attitudes towards such practices are and what foods they commonly purchase and consume in the context of actual microbiological risk, practical capabilities and social context. Such findings in turn would enable food safety educators to better
understand the risk factors that may potentially contribute to the risks associated with listeriosis among older adults to design and develop targeted risk communication for older adults to reduce incidence of listeriosis.
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1 TABLES
### TABLE 1. Consumer food safety studies country of origin

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of studies included for review ((n = 165)) (%)</th>
<th>Of reviewed studies including data on practices associated with an increased risk of listeriosis ((n = 68)) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>65 (40%)</td>
<td>21 (31%)</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>34 (21%)</td>
<td>15 (22%)</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>9 (6%)</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>Ireland</td>
<td>8 (5%)</td>
<td>5 (7%)</td>
</tr>
<tr>
<td>Australia</td>
<td>6 (4%)</td>
<td>2 (3%)</td>
</tr>
<tr>
<td>Turkey</td>
<td>4 (2%)</td>
<td>2 (3%)</td>
</tr>
<tr>
<td>New Zealand</td>
<td>3 (2%)</td>
<td>3 (4%)</td>
</tr>
<tr>
<td>France</td>
<td>3 (2%)</td>
<td>2 (3%)</td>
</tr>
<tr>
<td>Italy</td>
<td>3 (2%)</td>
<td>2 (3%)</td>
</tr>
<tr>
<td>Portugal</td>
<td>3 (2%)</td>
<td>1 (1%)</td>
</tr>
</tbody>
</table>

Two studies from the following countries were included for review:

- Brazil, India, Malaysia, Malta, Slovenia, Malaysia, Malta, Spain, Turkey.

One study from the following countries were included for review:

- Barbados, Canada, China, Democratic Republic of the Congo, Finland, Jamaica, Slovenia, Sweden.

- Germany, Greece, Jamaica, Japan, South Africa, South Korea, Sweden, Trinidad, multiple European countries.
## TABLE 2. Years consumer food safety studies conducted

<table>
<thead>
<tr>
<th>When consumer food safety study completed</th>
<th>Number of studies included for review ((n = 165)) (%)</th>
<th>Of reviewed studies including data on practices associated with an increased risk of listeriosis ((n = 68)) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993 – 1997</td>
<td>22 (13%)</td>
<td>12 (18%)</td>
</tr>
<tr>
<td>1998 – 2002</td>
<td>41 (25%)</td>
<td>19 (28%)</td>
</tr>
<tr>
<td>2003 – 2007</td>
<td>57 (35%)</td>
<td>22 (32%)</td>
</tr>
<tr>
<td>2008 – present day</td>
<td>45 (27%)</td>
<td>15 (22%)</td>
</tr>
</tbody>
</table>
TABLE 3. *Inclusion of food safety behaviours required to reduce risks of listeriosis in reviewed consumer food safety studies (n = 165)*

<table>
<thead>
<tr>
<th>Recommended food safety practices</th>
<th>Number of studies (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Use-by’ date adherence</td>
<td>33 (20%)</td>
</tr>
<tr>
<td>Storage length of opened RTE foods</td>
<td>37 (22%)</td>
</tr>
<tr>
<td>Safe refrigeration temperature</td>
<td>40 (24%)</td>
</tr>
<tr>
<td><strong>Inclusion of one or more practices associated with increased risk of listeriosis</strong></td>
<td><strong>68 (41%)</strong></td>
</tr>
</tbody>
</table>
TABLE 4. Utilized methods, inclusion of participants, measures of knowledge, attitudes and self-reported practices in reviewed studies (n = 68)

<table>
<thead>
<tr>
<th>Research methods</th>
<th>N</th>
<th>Participants</th>
<th>Knowledge</th>
<th>Attitude</th>
<th>Self-reported practice</th>
<th>Actual behaviour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questionnaires</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postal</td>
<td>5</td>
<td>326 – 1,025</td>
<td>1 (1%)</td>
<td>1 (1%)</td>
<td>5 (7%)</td>
<td>n/a</td>
</tr>
<tr>
<td>Postal</td>
<td>13</td>
<td>50 – 1,340</td>
<td>5 (7%)</td>
<td>1 (1%)</td>
<td>8 (12%)</td>
<td>n/a</td>
</tr>
<tr>
<td>Online</td>
<td>7</td>
<td>258 – 4,343</td>
<td>2 (3%)</td>
<td>0 (0%)</td>
<td>5 (7%)</td>
<td>n/a</td>
</tr>
<tr>
<td>Cumulative</td>
<td>25</td>
<td>n/a</td>
<td>8 (12%)</td>
<td>2 (3%)</td>
<td>18 (26%)</td>
<td>n/a</td>
</tr>
<tr>
<td>Interviews</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Telephone</td>
<td>6</td>
<td>100 – 1,203</td>
<td>3 (4%)</td>
<td>0 (0%)</td>
<td>6 (9%)</td>
<td>n/a</td>
</tr>
<tr>
<td>Face-to-face</td>
<td>26</td>
<td>16 – 3,219</td>
<td>17 (25%)</td>
<td>6 (9%)</td>
<td>23 (34%)</td>
<td>n/a</td>
</tr>
<tr>
<td>Face-to-face</td>
<td>26</td>
<td>16 – 3,219</td>
<td>17 (25%)</td>
<td>6 (9%)</td>
<td>23 (34%)</td>
<td>n/a</td>
</tr>
<tr>
<td>Cumulative</td>
<td>32</td>
<td>n/a</td>
<td>20 (29%)</td>
<td>6 (9%)</td>
<td>29 (43%)</td>
<td>n/a</td>
</tr>
<tr>
<td>Focus groups</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-person, guided group interviews</td>
<td>8</td>
<td>9 – 85</td>
<td>5 (7%)</td>
<td>2 (3%)</td>
<td>7 (10%)</td>
<td>n/a</td>
</tr>
<tr>
<td>Observation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-home</td>
<td>17</td>
<td>16 – 277</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>17 (25%)</td>
</tr>
<tr>
<td>Model kitchen</td>
<td>3</td>
<td>60 – 153</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>3 (4%)</td>
</tr>
<tr>
<td>Temperature recording</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-home</td>
<td>6</td>
<td>9 – 85</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>18 (26%)</td>
</tr>
<tr>
<td>Inclusion of one or more research methods</td>
<td>19</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Cumulative</td>
<td>68</td>
<td>n/a</td>
<td>30 (44%)</td>
<td>8 (12%)</td>
<td>50 (74%)</td>
<td>21 (31%)</td>
</tr>
</tbody>
</table>
TABLE 5. Inclusion of consumer food safety data relating to practices associated with increased risk of listeriosis in reviewed studies (n = 68)

<table>
<thead>
<tr>
<th>Inclusion of recommended practices</th>
<th>Self-reported practices</th>
<th>Attitudes</th>
<th>Knowledge</th>
<th>Actual behaviour</th>
<th>Total inclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Use-by’ date adherence</td>
<td>22 (32%)</td>
<td>4 (6%)</td>
<td>11 (16%)</td>
<td>3 (4%)</td>
<td>33 (49%)</td>
</tr>
<tr>
<td>Storage of opened RTE foods</td>
<td>31 (46%)</td>
<td>2 (3%)</td>
<td>11 (16%)</td>
<td>4 (6%)</td>
<td>37 (54%)</td>
</tr>
<tr>
<td>Safe refrigeration temperature</td>
<td>19 (28%)</td>
<td>2 (3%)</td>
<td>23 (34%)</td>
<td>18 (26%)*</td>
<td>40 (59%)</td>
</tr>
<tr>
<td>Inclusion of one or more practices associated with increased risk of listeriosis</td>
<td>50 (74%)</td>
<td>8 (12%)</td>
<td>30 (44%)</td>
<td>21 (31%)</td>
<td></td>
</tr>
</tbody>
</table>

*Recorded temperatures obtained from domestic refrigerators in consumer homes not observation of actual behaviour
TABLE 6. Consumer knowledge, attitudes, self-reported practices and actual behaviour relating to use-by dates in reviewed studies (n = 68)

<table>
<thead>
<tr>
<th>Knowledge</th>
<th>Attitudes</th>
<th>Self-reported practices</th>
<th>Actual behaviour</th>
</tr>
</thead>
<tbody>
<tr>
<td>49% - 62% of UK consumers were aware that the ‘use-by’ date was the best indicator that food is safe to eat (50, 99).</td>
<td>23 – 27% of UK consumers were concerned about the date labels on foods (44).</td>
<td>54% - 75% reported to always look for or check the ‘use-by’ dates or date of durability when shopping for food (48, 72, 99).</td>
<td>41% of households in the USA had products present that had expired ‘use-by’ dates (29).</td>
</tr>
<tr>
<td>40% knew that food beyond the ‘use-by’ date could be unsafe to eat and should be thrown away (42).</td>
<td>6% of Canadian consumers believed that the most important thing they did to keep food safe from “germs” is to watch the expiry dates on foods (21).</td>
<td>13% reported that a product after its ‘use-by’ date would be ignored and use the product if it smelt unspoiled (18).</td>
<td></td>
</tr>
<tr>
<td>73 - 75% considered it was very important to avoid the consumption of foods that have expired dates (121).</td>
<td></td>
<td>18 - 40% reported to never eat food beyond its expiry date (58, 86).</td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 7. Consumer knowledge, attitudes, self-reported practices and actual behaviour relating to refrigeration in reviewed studies (n = 68)

<table>
<thead>
<tr>
<th>Knowledge</th>
<th>Attitudes</th>
<th>Self-reported practices</th>
<th>Actual behaviour</th>
</tr>
</thead>
<tbody>
<tr>
<td>68% Australian consumers (70), 44% Slovenian consumers (72), did not know</td>
<td>58 - 72% felt that it was very important to take perishable foods home quickly</td>
<td>No consumers in Malta (48); 23% Irish consumers (74); 11 - 24% of USA consumers (5, 79), reportedly own/ have a thermometer in their refrigerator.</td>
<td>70 - 81% older adults refrigerators operated at temperatures in excess of recommended guidelines (65, 73).</td>
</tr>
<tr>
<td>recommended refrigeration temperatures.</td>
<td>after purchase (121).</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>34% feel that the most important thing that they do to keep food safe from</td>
<td>65% consumers in Trinidad (12); 71% UK consumers (124); 75% Australian consumers (70), reportedly do not or have never checked/ measure the operating temperature of their refrigerator.</td>
<td>In the USA 47% (32); Wales 56% (126); Ireland 59% (74); 60% New Zealand (94); the Netherlands 66% (117) and in Portugal 71% (11) of refrigerators operated at temperatures exceeding recommended guidelines.</td>
</tr>
<tr>
<td></td>
<td>“germs” is refrigerate foods promptly (21).</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>51% reported to refrigerate seafood immediately on arrival at home (12).</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 8. Consumer knowledge, attitudes, self-reported practices and actual behaviour relating to storage RTE and leftover food in reviewed studies (n =68)

<table>
<thead>
<tr>
<th>Knowledge</th>
<th>Attitudes</th>
<th>Self-reported practices</th>
<th>Actual behaviour</th>
</tr>
</thead>
<tbody>
<tr>
<td>96% were aware that the improper storage of food may represented a health hazard (9).</td>
<td>No data available.</td>
<td>40 - 69% reported to always/usually follow manufacturer’s instructions for storage of food products (45, 99).</td>
<td>28% of consumers stored fermented meat products without packaging (11).</td>
</tr>
<tr>
<td>73% knew leftover food should be allowed to cool at room temperature for less than two hours prior to refrigeration (49)</td>
<td></td>
<td>70% reported that they never put food in the refrigerator while the food was still warm or hot (80).</td>
<td>58% kept left over food for later consumption at room temperature for longer than 90 minutes (125).</td>
</tr>
<tr>
<td>54% were aware that left over food should be allowed to cool to room temperature before storing in the refrigerator (87).</td>
<td></td>
<td>13% reported that they put leftover food with meat/poultry in the refrigerator immediately (20).</td>
<td></td>
</tr>
</tbody>
</table>