Meat thermometer usage amongst European and North American consumers: A scoping review

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Abstract

Improper cooking of meat contributes to many foodborne illnesses worldwide. The use of meat thermometers during cooking is recommended by food safety authorities in North America, but not yet in Europe. This scoping review investigated meat thermometer usage trends, consumers' barriers and facilitators, and usage-enhancing interventions, with the aim of informing potential policy changes as necessary towards enhancing meat thermometers usage. The study revealed that Europe is far behind North America in meat thermometer research and consumer use. The study results highlighted the increased compliance among mid-aged and higher socio-economic consumer groups. A considerable percentage of people do not use a meat thermometer, despite owning one and knowing its importance. Barriers to meat thermometer usage among consumers included: cooking habits, non-practicality, and the influence of society and media, whereas responsibility to dependents and enhancing meat quality were strong facilitators. Intervention studies showed that knowledge gain does not necessarily translate to behavior change, unless consumers' barriers and facilitators are addressed; hence behavioral theory-based interventions were most effective. The review concludes with recommendations for food safety authorities, starting with filling the research gap to understand consumers' attitudes and behaviors, followed by implementation and scaling-up of evidence-based interventions, associated with cost-effectiveness studies.

Keywords: proper cooking; foodborne illness; intervention; consumers' attitudes; barriers

1. Introduction

1.1. Foodborne illnesses and outbreaks from undercooked meat

Foodborne illness is a major public health problem, which affected 10% of the world population in 2010, and resulted in almost 420,000 deaths (World Health Organization, 2015). The problem results in about 23 million illnesses in Europe, among which one million cases occur in the UK, resulting in around 500 deaths annually (Food Standards Agency, 2017). About one sixth of Americans, one eighth of Canadians, and one quarter of Australians are affected by foodborne diseases annually (Santacruz, 2016).

Foodborne illnesses are usually linked to improper food-handling practices, such as inadequate cooking, improper storage, and cross-contamination. The top causes of foodborne illnesses in developed countries include *Campylobacter*, *Salmonella*, *norovirus, Listeria* and *Escherichia coli* O157:H7 (*E.coli*). *Salmonella*, *Listeria*, and *E. coli* O157:H7 are mainly found in raw or undercooked meat, including beef, poultry, lamb and pork, while *Campylobacter* is mainly common in poultry products (National Health Services, 2018). Many *Salmonella* and *Campylobacter* outbreaks have been linked to the consumption of undercooked poultry products, whereas consumption of undercooked ground (minced) beef or pork has been associated with many *E. coli* O157:H7 outbreaks (Food Safety Authority of Ireland, 2017a; Moawad et al., 2017; Huusko et al., 2017).

1.2. Proper cooking procedures and current guidelines

Cooking meat to a safe temperature is an important prophylactic measure to eliminate harmful pathogens (Maughan, 2015). The safe cooking temperature depends on meat type. The Food Standards Agency (FSA) (2018), and Food Safety Authority of Ireland (FSAI) (2017b)

recommend cooking meat until the core temperature ≥ 75°C. On the other hand, the New South Wales (NSW) Food Authority (2018), the US Department of Agriculture (USDA)- Food Safety and Inspection Service (FSIS) (2015a), and Government of Canada (2015) have issued charts for safe minimum cooking temperatures for different meat types (Table 1).

Food safety authorities in Europe recommend cooking meat products until the fulfilment of three visual signs, namely; meat is steaming hot, no longer pink, and juices are running clear (Food Standards Agency, 2018, Food Safety Authority of Ireland, 2017a). However, research findings have revealed that these visual cues are not reliable indicators of safety (Bergsma, Fischer, Van Asselt, Zwietering, and De Jong, 2007; Maughan, 2015)

1.3. Meat thermometers

The usage of meat thermometers for identification of the safe cooking temperature has been ranked by food safety experts as of primary importance, compared to other safe food-handling behaviors (Lacroix, Li, and Powell, 2003). Therefore, the food safety authorities in the US, Canada and Australia urge catering and domestic consumers to regularly use meat thermometers for accurate measurement of cooking temperatures (Governement of Canada, 2015; NSW Food Authority, 2018; FSIS, 2015a). There are different commercially available types of meat thermometers, which vary in terms of accuracy, speed, level of technology, insertion method and price (FSIS, 2011). These include digital, dial, and liquid-filled thermometers. Of these types, food safety experts advise consumers to use digital ones, given their accuracy, ease of usage, and instant read provision (Governement of Canada, 2015).

Proper usage of thermometers is essential to ensure accurate measurement of meat temperature. Generally, different food safety authorities recommend the thermometer tip to be inserted in the centre of the thickest part of meat, and waiting until a stable temperature is reached (FSIS,

2011). Core temperature should be measured in several locations, particularly with irregularly shaped cuts of meat. Meat thermometer probes should be properly cleaned before and after each use in order to prevent potential cross-contamination (FSIS, 2011).

The aim of this scoping review of scholarly and grey literature was to map what is known from research about subjects' knowledge, attitudes, and behaviors towards the usage of meat thermometers, to inform recommendations for future research and policy changes as necessary for enhancing meat thermometer usage. To the authors' knowledge, this is the first review focusing on meat thermometers usage across the developed countries. The objectives of this review were (1) to investigate the perceptions and trends in meat thermometers usage among consumers, (2) to analyze the barriers and facilitators to meat thermometers usage, and (3) to explore previously conducted interventions aiming at enhancing meat thermometer usage.

2. Methodology

Given the broad nature of the study topic, a scoping review was conducted in order to categorize existing literature in terms of its nature, features and volume. In contrast, systemic review is designed to collect empirical evidence and answer precisely defined, narrow questions. Both methodologies employ systematic search strategies. The scoping review plan of this study followed the six-stage methodological framework developed by Arksey and O'Malley (2005) as follows:

2.1. Identifying the research question

A broad research question was set to scope the literature: *What is known from literature about the use of meat thermometers to decrease the incidence of foodborne illnesses arising from undercooked meat?*

2.2. Identification of relevant studies

A flexible comprehensive search strategy was developed and implemented to locate any relevant literature. The key concepts were identified in the research question, namely, *meat thermometers, foodborne illnesses* and *undercooked meat*. A total of 25 search terms were operated through two different combinations using Boolean operators 'AND' and 'OR'. The search procedure included various automated and manual search methods to minimize the chance of missing pertinent information.

The automated search was implemented in four databases, namely, Medline, Embase, Scopus and ProQuest, using the selected search terms. The search process had no date limits in order not to exclude any potentially relevant studies. The search strategy also included bibliographies of potential search results, physically examining journals, researching key authors, theses, and technical reports provided by both governmental and non-governmental organizations.

2.3. Study selection

Only English articles were included in the review. Studies were included, if they addressed consumers' meat cooking behaviors, trends of meat thermometer ownership and usage, as well as barriers and facilitators to the usage of meat thermometers. The review also included studies concerned with interventions enhancing meat thermometer usage. The following types of papers were excluded: (1) studies addressing microbiological strains of foodborne pathogens; (2) articles concerned with general food safety practices, and/or proper storage conditions.

Included studies were selected from among the search results in a two-step process, where the titles and abstracts of the search results were first subjected to preliminary screening against the inclusion and exclusion criteria by one author. When there was uncertainty about the eligibility

for inclusion, the records were saved for further assessment by the other authors in order to minimize the possibility of selection bias. The remaining articles were then re-assessed by reviewing their full text, together with the articles identified through bibliographies and manual web search (Fig. 1). The included sources were cited using reference manager software and duplicates were removed (Mendeley Desktop v1.19.3; Mendeley Ltd, UK).

2.4. Charting the data

Data were extracted in standardized forms developed in Microsoft Excel. These included authorship, study title, study objective/aim, study design, study subjects and major findings.

2.5. Collating, summarizing and reporting of results

The analysis phase was divided into several steps in order to classify complex data in a way that provided answers to the research question, as well as link findings to overall research purpose and objectives. Firstly, the data in the extraction form was synthesized descriptively through numerical summary in order to map the different aspects in the literature as outlined in the key question. Secondly, the data were classified into themes. Finally, the implications of results were considered within a broader context to ensure that the results will have practical implications for future research, policy and practice.

2.6. Consultation exercise

The authors considered consultation with *safe*food; a governmental administration of food safety in Ireland (Safefood 2018), through a face-to-face meeting between two authors and *safe*food representative in order to inform and validate the review findings (Tricco et al., 2016). The meeting included presentation of the study aim, objectives, research methodology, and the main themes of the extracted results, followed by mutual discussions and recommendations

from all participants. The outcomes of the consultation exercise were taken into account during further progress of the study.

3. Results

A total of 1009 potential articles were initially retrieved from the searched databases, with an additional 35 sourced from bibliographies and web searches. These were eventually reduced to 75 studies based on the exclusion criteria (Fig. 1). The majority of these studies were conducted in North America (70% in the US and 13% in Canada), while the remainder were conducted in the UK, Ireland, the Netherlands, Austria and Malaysia. The median year of publication was 2009 (range 1991- 2018). The three predominant study designs were statistical survey (40%), combined survey and observation (19%) and uncontrolled before-after study (16%). The data were classified into three major themes: perceptions and trends in the usage of meat thermometers; barriers versus facilitators to meat thermometer usage; and interventions aiming at enhancing meat thermometers usage.

Perceptions and trends in the usage of meat thermometers

This theme included 56 studies, which addressed safe food-handling knowledge and behaviors among consumers, with a special focus on the trends in meat thermometers ownership and usage. The studies were classified according to the country of origin: US (n=38), Canada (n=7), and Europe (n=11).

3.1.1. Perceptions and trends in the US

3.1.1.1. The knowledge-compliance and ownership-usage gaps

Studies revealed low adherence to the usage of meat thermometers, with the presence of a significant ‘knowledge-compliance’ gap (Table 2). Food safety trained store managers were

found to lack essential knowledge about food safety, including the safe temperature of different meat types (Rhynard, 2001; Burch and Sawyer, 1991). Direct observation also highlighted a significant meat thermometer 'ownership-usage' gap (Table 2). In the majority of the studies, participants relied on sensory cues, such as meat color and texture, clarity of juices, poking with a utensil, as well as tasting to check doneness of meat (Koeppl, 1998; Teague and Anderson, 1995). Shapiro, Porticella, Jiang, and Gravani et al. (2011) designed a questionnaire to measure participants' intentions to use a meat thermometer based on the theory of planned behavior (TPB), which proposes that individuals' intention to perform a certain behaviour is an effective predictor of the actual behavior. The study revealed that nearly half of respondents disagreed that they were likely to use one. The transtheoretical model (TTM) suggests that any behavior change process progresses through five stages of change (SOC) namely; precontemplation, contemplation, preparation, action, and maintenance, which can be described as not ready, getting ready, ready, current action, and monitoring, respectively (McCurdy et al., 2006). Based on TTM, Takeuchi, Edlefsen, McCurdy, and Hillers (2006) and McCurdy et al. (2006) designed questionnaires, with the aim assessing consumers' readiness to adopt meat thermometers usage. Both studies reported that the usage of meat thermometer was a new experience for the majority of participants.

Despite these low levels of meat thermometers usage, there are indications of positive shifts over time. Lando and Chen (2012) reported a significant increase in meat thermometers ownership in the US from 49 to 70% over the period (1998-2010). Cody and Hogue (2003) also identified an increase in meat thermometers usage from 22 to 25% over the period (1999-2002).

3.1.1.2. Trends of usage of meat thermometers with different types of meat

Several studies addressed meat thermometer usage with different meat types and found a lower trend of meat thermometer usage with small cuts of meat, compared with large cuts of meat and whole poultry (Table 3). Likewise, studies by Cates, Carter-Young, Durocher, Williams, and Conley (2002b) and Feng, Bruhn, and Marx (2016) revealed that most participants only used meat thermometers with roasts and whole poultry. Despite the low usage with small cuts of meat, Lando and Chen (2012) reported a significant improvement by 20% and 9% in the usage of a meat thermometer with chicken parts and hamburgers respectively, over the period 1998-2010.

3.1.1.3. Meat thermometer usage among different groups of consumers

The trends of meat thermometer ownership and usage varied with age. Meat thermometers usage is generally more common among mid-aged adults (30-59 years), relative to adults of either older or younger ages (Yarrow, 2006; Koeppl, 1998; Lin, 2018; Cates et al., 2009; Cates, Karns, Kosa, and Godwin, 2013). In contrast, Lando and Chen (2012) reported a higher trend of meat thermometers usage for roasts among older adults relative to younger ones. A. L. Anderson, Verrill, and Sahyoun (2011) reported that older adults were significantly more likely to own a meat thermometer than younger adults (73% *vs.* 67%, respectively).

Concerning the effect of gender on safe food-handling knowledge and practices, several reviews and cross-sectional studies showed that women had poor food safety knowledge and were less likely to own and use a meat thermometer relative to men (Scheule, 2004; Patil, Cates, and Morales, 2005; A. L. Anderson et al., 2011; Lando and Chen, 2012). In contrast, Patil, Morales, Cates, Anderson, and Kendall (2004) reported that males were more likely to adopt poor food safety practices than females.

Trends in thermometer ownership may also vary among different ethnic subgroups. In a survey by Henley et al. (2015), the percentage of meat thermometers ownership among Caucasian, African-American, Hispanic and Asian participants were 64%, 56%, 47% and 35%, respectively. A. L. Anderson et al. (2011) reported that non-white participants were less likely to own a meat thermometer relative to white participants (54% *vs.* 76%, respectively), although the former were more knowledgeable about the importance of using one.

Education and socioeconomic status were also found to impact thermometer ownership and usage. A. L. Anderson. et al. (2011) analyzed the 2006 US Food and Drug Administration (FDA) Food Safety Survey, and concluded that more educated people were more likely to own a meat thermometer (79% *vs.* 69%, respectively). In contrast, Shapiro et al. (2011) identified education level as a significant negative predictor of the intention to adopt meat thermometer use. This negative relationship between education level and meat thermometer use was confirmed by Lando and Chen (2012) who reported that those who had a college degree were less likely to use meat thermometers relative to those with a high school certificate, but that meat thermometer ownership was higher among individuals with higher income. In another context, A. L. Anderson et al. (2011) reported that people who lived alone were less likely to own a meat thermometer.

3.1.1.4. Usage of meat thermometers in gatherings/outings

Koeppl (1998) reported that meat thermometers were mostly used over holidays and special occasions, such as Thanksgiving turkey. In contrast, Yavelak et al. (2018) reported that only 33% of the tailgaters in five American universities used meat thermometers.

3.1.1.5. Usage of meat thermometers on TV shows

Lack of meat thermometers usage was reported to be a common behavior among celebrity chefs. A content analysis of 100 US TV shows by Maughan, Chambers, and Godwin (2017) showed that 75% of the shows did not use a meat thermometer or give temperature information for different types of meat. Similar results were reported by Woods (2015) based on 60 TV cooking shows in the US.

3.1.1.6. Trends of correct usage of meat thermometers

Maughan (2015) reported that about 36% of meat thermometer users failed to insert it correctly while cooking poultry products. In contrast, Bruhn (2014) reported that all the participants who used a meat thermometer (34% of total 120 participants) knew where to insert it correctly in chicken, except one participant failed to remove the thermometer from its casing. Dedonder et al. (2009) also reported that two of 41 study participants tried to use the meat thermometer with chicken without removing its casing.

3.1.1.7. Consumers attitude towards different types of thermometers

RTI reports (2002; 2004) showed that some respondents in the focus group couldn't distinguish between thermometer types. Digital-instant read and disposable thermometers were most preferred by participants, due to their convenience, rapid response, easiness to read, and portability while picnicking, yet some didn't trust the accuracy of the latter. However, Kosa and Cates (2004) reported the preference of some participants to dial thermometers, because they don't require batteries.

3.1.2. Perceptions and trends in Canada

3.1.2.1. The knowledge-compliance gap

Nesbitt et al. (2014) published a review of 26 Canadian food safety studies, which inferred that, although food safety knowledge among Canadians is good, meat thermometers usage is limited. This good food safety knowledge *vs.* low meat thermometer usage, or 'knowledge-compliance gap; among Canadian consumers was confirmed by different surveys published during the period 2009-2017, which showed that > 75% of studies participants reported their awareness of proper cooking instructions, the importance of thorough meat cooking, and the risks associated with consumption of undercooked meat, yet < 30% of the participants reported using meat thermometers (Ekos Research Associates Inc., 2010, Murray et al., 2017) (Table 2). Nonetheless, Ekos Research Associates Inc. (2010) reported an exceptionally higher trend of meat thermometer usage among immune-compromised individuals (33%).

3.1.2.2. Trends of usage of meat thermometers with different types of meat

Similar to the US, surveys by Fraser Health and Vancouver Coastal Health (2010), and Murray et al. (2017) reported that higher usage was associated with large cuts of meat, relative to smaller cuts (Table 3).

3.1.2.3. Meat thermometer usage among different groups of consumers

Nesbitt et al. (2009) reported that the urban residents in the Waterloo region were significantly less likely to use meat thermometers than residents in rural areas (12% *vs.* 22%, respectively). Concerning the effect of gender on meat thermometer usage, women reported higher usage of meat thermometers relative to men (32% *vs.* 26%, respectively) (Murray et al., 2017).

3.1.2.4. Usage of meat thermometers on TV shows

Meat thermometers were reported to be rarely used by Canadian TV chefs, which is consistent with the trends in the US. A content analysis of 116 TV cooking shows on Food Network

Canada during 2002-2003, revealed that use of meat thermometers to check meat doneness was only observed eight times, whereas relying on color was three times more frequently (Mathiasen, Chapman, Lacroix, and Powell, 2004).

3.1.3. Perceptions and trends in Europe

Redmond and Griffith (2003), and Wright, Canham, and Masrani (2011) published reviews which concluded that most people in the UK and Ireland know that improper cooking is a risk factor, but generally have low awareness of cooking guidelines, and fail to adopt meat thermometer usage. Different surveys conducted among British and Irish consumers revealed a meat thermometer usage trend of only 2-4%, with the majority of British and Irish consumers using subjective methods to determine doneness (Table 2). Redmond and Griffith (2004) reported that about 45% of Welsh consumers were neutral about the usefulness of meat thermometers. Recent surveys in Ireland showed that food safety is perceived as a risk to health most by those with higher educational attainment, and higher socio-economic status (Safefood, 2012; Corcoran and Porter, 2017). In contrast to the US, Irish women had higher knowledge about food safety compared to men (Safefood, 2012).

Surveys among Dutch consumers by Bergsma et al. (2007) and Fischer et al. (2006) showed that most participants used subjective methods while cooking, and were unlikely to use meat thermometers, despite perceiving adequate cooking as very important.

3.2. Barriers versus facilitators to meat thermometers usage

This theme included 25 studies, which discussed a total of 20 barriers and 14 facilitators to meat thermometers usage. These barriers and facilitators were classified into six descriptive themes according to Young and Waddell (2016).

3.2.1. Confidence and perceived risk

Five US studies revealed that home cooks, particularly those of older age, had confidence in their own experience to cook meat safely with no need to use meat thermometers, and did not believe that foodborne diseases were likely to affect them (Koeppl, 1998; ORC Macro, 2006; Porticella, Shapiro, and Gravani, 2008; Cates et al., 2002b; Shapiro et al., 2011). Responsibility was a strong facilitator among participants of four different studies who reported that they would use a meat thermometer, if messages assured its importance for the safety of their dependent children or elderly (Koeppl, 1998; Cates et al., 2002b; Takeuchi, 2004; McCurdy et al., 2006). Most participants in four focus group studies highlighted the effect of risk motivation, reporting that assuring that meat thermometers usage is the only reliable way to ensure meat safety would be a powerful facilitator (Takeuchi, Hillers, Edwards, Edlefsen, and McCurdy, 2005b; Cates et al., 2002b; McCurdy et al., 2006; ORC Macro, 2006). Similarly, a case study by Starke, Ralston, Brent, Riggins, and Lin (2002) revealed evidence of a positive association between risk motivation and adhering to cooking guidelines. A TTM-based questionnaire study by Takeuchi, Edlefsen, McCurdy, and Hillers (2005a) revealed that responsibility towards dependent children, and risk motivation were the most common facilitators among 89% of participants among all SOCs. A focus group study by Porticella et al. (2008) also revealed that increased perceived susceptibility would motivate consumers to adopt meat thermometer usage.

3.2.2. Knowledge and perception

Participants in several focus group studies reported that their lack of knowledge about the importance of meat thermometers, and the safe temperatures for different meat types was a perceived barrier to adopting meat thermometers usage (Koeppl, 1998; McCurdy et al., 2006;

Cates et al., 2002b; York et al., 2009). Lack of awareness was also inferred by Kosa et al. (2015) as a possible barrier to meat thermometer usage. Nonetheless, Porticella et al. (2008) reported that knowledge alone did not always lead to meat thermometers usage. This is consistent with the previously mentioned significant gap between levels of knowledge about safe cooking behaviors and actual meat thermometer usage. Koeppl (1998) reported that some focus group participants had false perceptions about the benefits and risks of meat thermometers. While some participants were sceptical about whether using a meat thermometer would guarantee meat safety, others believed that using a meat thermometer might cause a false sense of security during cooking. On the other hand, participants in two focus group studies among US adults recommended that including pictures in educational material packages showing that color is not a reliable indicator would be an effective facilitator (McCurdy et al., 2006; ORC Macro, 2006). Takeuchi et al. (2005a) also reported that the message of "appearance and color are not good indicators of meat doneness" was one of the most effective messages in the intervention that was designed to enhance meat thermometers usage.

3.2.3. Habits and heuristics

A focus group study by Koeppl (1998) revealed that many study participants, particularly young adults, were reluctant to change their current habits. A report by the RTI (2002) also mentioned that participants in a focus group study were sceptical about the probability of changing their current cooking habits. Participants recommended that repeating the meat thermometer message could be a potential facilitator (Cates et al., 2002b). Educating children at early ages in school and including thermometer messages in science text books were mentioned by parents in a number of focus group studies (Koeppl, 1998; Cates et al., 2002b; Porticella et al., 2008).

3.2.4. Practical and lifestyle constraints

Participants in nine different focus groups studies in the US considered meat thermometer use as inconvenient and/or impractical, particularly while cooking small cuts of meat, cooking individual portions, or grilling large number of hamburgers. Reported barriers in this context included lack of time, laziness, difficult usage, forgetfulness, and labor intensiveness (Koeppl, 1998; Cates et al., 2002b; Takeuchi et al., 2005a; 2005b; Porticella et al., 2008; Takeuchi, 2004; Kosa, Cates, Godwin, and Chambers, 2017; Phang and Bruhn, 2011; McCurdy et al., 2006). Concerning the barriers at different SOC, Takeuchi et al. (2005a) ranked the difficulty of usage as the main barrier, which was reported by 44% and 33% of the participants in the preparation and action stages, respectively. This barrier is of importance among older consumers, as they were more likely to have to put their glasses on to be able to read the thermometer (Bruhn, 2014). Furthermore, Takeuchi et al. (2005a) reported that lack of time was identified as a barrier by 15% of participants across all SOCs. York et al. (2009) reported unfamiliarity, lack of experience, unavailability or inaccessibility among the main barriers to usage of meat thermometers by restaurant chefs. Other studies also attributed the low usage of meat thermometers among consumers to the same barriers (Kosa et al., 2015; Lando and Chen, 2012; Shapiro et al., 2011; DeDonder et al., 2009; Bergsma et al., 2007; Fischer et al., 2006).

Cost of meat thermometers was controversially considered as barrier. Takeuchi et al. (2005a) reported that 9% of participants across all SOCs identified cost as a potential barrier. A focus group study by Porticella et al. (2008) also identified financial cost as a probable barrier. In contrast, Koeppl (1998) reported that most focus group participants considered thermometer price to be affordable. The cost barrier may be restricted to those with lower incomes, as suggested by both Scheule (2004) and Lando and Chen (2012).

In a TPB-based questionnaire study by Shapiro et al. (2011) developed a TPB-based questionnaire utilizing two constructs; perceived behavioral control and subjective norms.

The former was concerned with person's perception of the extent to which adopting meat thermometers usage is easy or difficult, and was found to be the most significant predictor of the intention to use a meat thermometer. This was followed by subjective norms, which addressed person's recognition and acceptance of expectations of other people to meat thermometers usage. Participants in several studies reported that they would consider meat thermometer usage if practical constraints were removed, such as if thermometers could save time or be placed easily on thin cuts of meat (Takeuchi et al., 2005b; Koeppl, 1998; ORC Macro, 2006). Takeuchi et al. (2005a) noted that 87% of participants demonstrated ease of meat thermometer usage as a strong facilitator, yet most participants cited having a reminder posted in their kitchen as the least powerful facilitator. Other authors suggested that increasing the availability of meat thermometers in the market might be a potential facilitator. (Lando and Chen, 2012; Fischer et al., 2006; McCurdy et al., 2006).

3.2.5. Doneness preference

While some consumers prefer the taste of undercooked meat, others prefer it well-done or even overcooked. Porticella et al. (2008) and Starke et al. (2002) reported that some participants did not use meat thermometers, due to its perceived negative impact on taste. On the other hand, many participants in other studies indicated that they would consider meat thermometer usage, if it enhanced quality of meat besides improving safety (Koeppl, 1998; Starke et al., 2002; Cates et al., 2002b; Maughan, 2015).

3.2.6. Social and societal influences

Koeppl (1998) reported that participants acquired their current cooking behaviors from family members. Takeuchi et al. (2005a) also identified that 81% of their participants who didn't use a meat thermometer don't know anyone who uses one. Many other studies reported the effect

of media as a perceived barrier to meat thermometer usage, such as the lack of meat thermometer usage on TV shows and in magazines (Phang and Bruhn, 2011; Shapiro et al., 2011; Mathiasen et al., 2004; Phang, 2010; Woods, 2015; Maughan, 2015; McCurdy et al., 2006). In the same context, appearance and perceived social costs were cited as perceived barriers to meat thermometers usage by most participants in separate studies (Koeppl, 1998; Porticella et al., 2008). Participants in several focus groups studies reported that directing cooks to use a meat thermometer in recipes, cookbooks, food safety labels, as well as TV cooking shows would be a powerful facilitator (Koeppl, 1998; Porticella et al., 2008; McCurdy et al., 2006; Phang and Bruhn, 2011). Takeuchi et al. (2005a) reported that 87% of participants across all SOC found including temperatures of different meat types with recipes as a strong facilitator. Furthermore, some participants in the focus group studies by both Koeppl (1998) and Porticella et al. (2008) suggested invoking social pressure by conveying the meat thermometer message through celebrities, dieticians, and the government. Participants indicated that they had great concerns with regards to pride in their cooking skills, and that they would use a meat thermometer, if others valued this behavior. In the same studies, participants recommended media stories and in-depth coverage of foodborne illness outbreaks as being powerful motivators for behavioral change.

3.3. Interventions aiming at enhancing meat thermometers usage

This theme included a total of 20 studies utilizing various interventions to improve meat thermometer usage among consumers through increasing knowledge (12 studies) and addressing attitudes (14 studies) towards thermometer usage. The interventions varied between using educational materials, training programs, campaigns, mixed approaches using different intervention types, temporary closure of restaurants in response to poor food safety practices, advising thermometer usage in recipes, as well as positive deviance focus groups, which is a

novel educational intervention where participants discuss their current practices and decide to try adopting the recommended behaviors modelled by people like themselves.

3.3.1. Educational materials

Takeuchi (2004) and Takeuchi et al. (2005a) applied the TTM to evaluate an educational intervention among 2500 randomly selected American consumers, who were distributed among the five different SOCs. Educational material packages comprised a brochure, a video, recipe cards and a refrigerator magnet, but without meat thermometer. The study revealed that the educational materials resulted in a significant increase in thermometer ownership (from 34 to 42%), and usage (from 4 to 16%). The proportion of participants in the precontemplation stage significantly decreased from 80 to 46%, meaning there was a significant increase total proportion of participants who were in the preparation, action or maintenance stages from 12 to 41%. In another study, Takeuchi et al. (2005b) used a similar educational package to assess the impact of each element of the package on enhancing meat thermometers usage. The brochure was the most effective component, which motivated 63% of participants, followed by recipe cards (45%) and the video (38%). The brochure was particularly useful for those in the precontemplation and contemplation stages, whilst participants in the action and maintenance stages found the video most useful.

Edwards, Edlefsen, Hillers, and McCurdy (2005) used a teaching kit including the materials designed by Takeuchi et al. (2005a) to target 326 American high school students, yet additional items were included in the kit (four 50-min teaching lessons, handouts, homework activities, four posters and an instant-read digital thermometer). These were utilized by students through both theoretical and practical classes, allowing students to know about the importance of adopting thermometers usage, besides giving them the chance to use one. The pre- and post-

intervention surveys revealed that the students' mean knowledge score significantly increased by 2.7, with 42% of the students reporting an increase in their confidence in using a meat thermometer. The mean SOC score significantly increased from 2.3 to 2.6, with 30% of the students making progress toward a higher SOC. Later on, McCurdy et al. (2006) published a study with similar findings. The evaluation report of Pathogen Reduction, Hazard Analysis and Critical Control Point System (PR/HACCP) published by the RTI (2002) mentioned using the same educational materials among six groups of parents of young children, among whom, participants of only three groups received meat thermometers. After a one-month intervention, surveys revealed that 63% of participants who received a meat thermometer reported that they began to use one, compared to only 13% of those who did not receive one. Moreover, 50 and 42% of those who received a thermometer used it with chicken pieces and hamburger, respectively, compared to only 22 and 0% of those who did not receive one.

3.3.2. Food safety training

Six studies investigated the effect of food safety training on the knowledge, attitudes and behavioral compliance with safe cooking practices among both catering and domestic consumers. Robert et al. (2008) held a four-hour food safety training covering three food safety practices, including meat thermometer usage for 402 foodservice employees in the US. The post-training assessment showed a significant improvement in knowledge scores related to proper thermometer usage, yet with no significant improvement in adopting meat thermometer usage. Surprisingly, Pilling et al. (2008) reported that food workers in restaurants where training was mandatory for all food handlers had significantly lower knowledge score about food safety compared to those working in restaurants where only managers were knowledgeable about food safety (12.8 *vs.* 14.3 out of 18, respectively). However, there was no significant difference between the two groups in terms of compliance with meat thermometer usage. A four-hour

TPB-based training among food workers in 16 Malaysian school canteens also failed to increase participants' knowledge about using thermometers while cooking (Nik Husain, Wan Muda, Noor Jamil, Nik Hanafi, and Abdul Rahman, 2016). The failure of this intervention may be attributed to its focus on covering the concept without providing a meat thermometer to the canteen workers during the training. In contrast, McIntyre (2011) showed that trained food safety workers in British Columbia used meat thermometers more often than untrained workers. Finch and Daniel (2005) also showed that food safety training of 267 food handlers working at emergency food relief organizations in New York State increased meat thermometers usage among handlers, and significantly improved participants' knowledge. On comparing different types of food safety training, Yeung (2014) showed that both web-based training and workshops for 110 American participants improved their knowledge about the importance of cooking meat to its safe temperature.

3.3.3. Campaigns

Several campaigns have been conducted by food safety authorities in the US to address improper cooking practices among food preparers, utilizing print advertisements and radio public service announcements. In 1997, the Partnership for Food Safety Education in the US (2018) conducted the "Fight BAC!" campaign to convey food safety messages to home cooks including "cook to proper temperature". In order to enhance meat thermometers usage among consumers, the USDA launched the "Thermy" campaign in 2000, followed by "Is it DONE yet?" campaign in 2004. The latter was particularly designed to target parents of young children (FSIS, 2015b; 2016).

Cody and Hogue (2003) examined the impact of the "FightBAC" campaign. Post-campaign surveys indicated that, although a knowledge-compliance gap remained, significantly more

consumers reported using meat thermometers. Kosa and Cates (2004) assessed the effectiveness of the "Is it DONE yet?" campaign, where they reported an increase in participants' knowledge, ownership and frequent usage of meat thermometers.

3.3.4. Mixed approach

The FSIS (1996) published the PR/HACCP final rule with the aim of reducing the risk of foodborne diseases. This was followed by PR/HACCP farm-to-table initiatives, which included education campaigns, promoting farm-to-fork strategies, and training of food handlers (Institute of Medicine and National Research Council (US) Committee 1998). Cates, Kosa, and Carter-Young (2002a) analyzed the US FDA Food Safety Surveys (1998-2001) to assess the effectiveness of PR/HACCP farm-to-table initiatives. Consumers demonstrated increased knowledge, with increase in meat thermometer ownership from 46 to 60% during the period 1998-2001. During the same period, meat thermometer usage increased from 22 to 32% with large cuts of meat, from 6 to 12% with chicken pieces, and from 3 to 6% with hamburgers.

Yavelak et al. (2018) assessed the usefulness of combining positive deviance interventions and educational materials with meat thermometer provision for food handlers working in temporary food settings. Follow-up observation and surveys showed that there was a significant increase in the number of participants using meat thermometers more frequently.

3.3.5. Comparing different types of interventions

Feng et al. (2016) compared the effectiveness of three different intervention types (positive deviance with meat thermometers provision, standard educational materials without meat thermometers, and story-based materials) among 182 US adults. Post-intervention evaluation revealed that the three intervention types significantly increased participants' knowledge about

correct cooking temperatures of different meat types. The active discussions resulted in higher knowledge gain compared to the other intervention types. Participants who were involved in the active discussions reported higher self-efficacy of meat thermometers usage relative to the other interventions.

York et al. (2009) compared the usefulness of two approaches in food service establishments in the US using four different groups of workers receiving either standard food safety training, a TPB-based intervention program, both interventions, or none of them. The participants in the combined training and TPB-based intervention group had better compliance with meat thermometers usage than those in the training and control group. Those who received the combined intervention had significantly higher control over barriers to meat thermometer usage than those in the training and control groups.

3.3.6. Other methods to enhance meat thermometers usage

Maughan (2015) investigated the usefulness of including meat cooking temperatures in different poultry recipes via direct observation. A total of 155 participants were randomly allocated into two groups: with or without food safety instructions. Participants who received recipes with food safety instructions were significantly more likely to use meat thermometers while cooking either chicken pieces (85% *vs.* 30%) or turkey burgers (86% *vs.* 20%). About 58% of those who used meat thermometers among the instructed group were able to insert it correctly in chicken pieces compared to only 16% of the non-instructed group. Similar results were obtained on evaluating proper insertion of thermometer in turkey burgers (76% *vs.* 13% for instructed *vs.* non-instructed groups, respectively). On the other hand, Mandarino (2017) reported that temporary closure of Canadian restaurants with improper food-handling practices

did not improve the employees' practices, and food workers continued to demonstrate low thermometer usage.

3.4. Consultation exercise

The *Safe*food representative supported the study findings, advising that many European consumers lack knowledge about safe food-handling practices, including meat thermometer usage. The *Safe*food representative's input contributed to making sensible recommendations for Europe, and offered helpful guidance for determining next research steps and eventually triggering a process of changing cooking guidelines in Ireland towards recommending meat thermometers usage. This process is expected to be gradual, passing through conducting surveys and focus groups to investigate meat thermometers ownership and usage, and barriers as well as facilitators to meat thermometers usage. Future steps would also include increasing consumers' awareness about the importance of using meat thermometers.

4. Discussion

This scoping review aimed to make recommendations for future research, and to inform necessary policy change of cooking guidelines towards promoting meat thermometers usage. The results of this study highlighted the low or improper usage of meat thermometers among both domestic and catering consumers worldwide. Although surveys in the US and Canada showed relatively high awareness about food safety practices among consumers, with the majority owned a meat thermometer, consumers reported low thermometer usage, revealing both ownership-usage and knowledge-compliance gaps. The usage trends were even lower when observing consumers' cooking practices, indicating possible social desirability bias and response bias (Redmond and Griffith, 2003). Therefore, we believe that the results of direct observation studies are more reliable than the survey results, although the observation process

still sometimes influences the participants' behavior, leading to false reporting of compliance (Redmond and Griffith, 2003; Yavelak et al., 2018). Nonetheless, we identified a notable increase in the ownership and usage of meat thermometers over time in Canada and the US, which may be attributed to the different public health interventions and campaigns conducted by food safety authorities in both countries.

The review produced limited meat thermometer ownership/usage data from Europe, which suggested that meat thermometer usage was not a common food safety practice among European consumers. The reported low usage of meat thermometers in the UK and Ireland may be attributed to the lack of guidelines explicitly recommending their use in both countries (FSA, 2018; FSAI, 2017a).

Direct observation, surveys, and focus groups indicated that meat thermometer usage differs among consumers according to their gender, age, ethnicity, level of education, socio-economic status, environment, and social norms. In spite of some inconsistencies, seniors (60+ years) generally exhibit resistance to adopt behavioral change and young adults (<30 years) exhibit low perceived risk of foodborne illnesses. Practicality is also a major concern for many consumers, where consumers find thermometer use inconvenient with smaller cuts of meat, which justifies the observed gap between thermometer usage with chicken pieces and hamburgers, compared to usage with large cuts of meat and whole poultry. Focusing on cooking time and other visual methods in popular sources such as magazine recipes and TV cooking shows contributed to a general feeling among consumers that using a meat thermometer while cooking contradicts with social norms.

Comparison of the effectiveness of different interventions developed in the US for enhancing meat thermometers usage revealed that the interventions based on behavior change theories were most effective. Educational materials and campaigns designed to address the perceived

barriers and facilitators to meat thermometers usage were effective in terms of enhancing usage among different types of consumers (e.g. adults, students, and foodservice employees). Active discussions with consumers were likely to improve consumers' attitudes and intentions, as well as induce behavioral change, particularly if combined with supportive educational materials. Conveying the thermometer usage message through recipes was also found to be effective in terms of behavioral change. In contrast, food safety training seems to be effective only in terms of improving foodservice workers' knowledge, but it had a little impact on their behaviors. These findings confirm that knowledge gain is not necessarily translated to adopting the recommended behaviors, and that addressing the perceived barriers and facilitators through evidence-based interventions is crucial to induce behavioral change among consumers (Patil et al., 2005).

We identified the presence of obvious gaps in research in Australia and continental Europe, and, to a lower extent, in the UK and Ireland, with regards to investigating meat thermometer ownership and usage, as well as barriers to and facilitators of using meat thermometers among consumers. Although many studies in both the US and Canada investigated the effects of different interventions on enhancing meat thermometers usage, the Canadian interventions relied on addressing barriers and facilitators extracted from other US studies, as a result of the lack of studies investigating consumers' perceptions in the Canadian community.

5. Study limitations

While a comprehensive approach was adopted for scoping of various sources in order to address the research question in a robust way, some limitations still exist. A potential limitation is that only English articles were reviewed and included, due to financial constraints for translation. This posed a possibility of missing potential articles from non-English speaking countries. The limited literature available from Europe also posed a limitation of not reflecting

the cultural and ethnic difference among European consumers. As a result of being a relatively under-researched area with a limited number of sources, the authors did not assess the evidence quality in order to include a broader range of evidence from both scientific and grey literature, avoid missing any potentially important documents, and to identify gaps in research to develop recommendations for future research.

6. Recommendations and conclusions

Based on the results of this scoping review, we recommend the following steps to enhance meat thermometers use among consumers in order to improve population health worldwide:

1. Conduct surveys and direct observation studies to investigate ownership and usage of meat thermometers (e.g. considering differences by gender, socioeconomic status, age, ethnicity, and in domestic and catering environments) utilizing well-validated TTM and/or TPB-based questionnaires.
2. Conduct qualitative research among consumers, utilizing appropriate behavioral theories, such as TTM and/or TPB as conceptual framework, in order to understand perceptions, attitudes, barriers and facilitators to meat thermometers usage in specific populations and population sub-groups.
3. Based on evidence from 1 and 2 above, design evidence-based interventions to promote meat thermometer usage, with testing in feasibility studies before wider exposure, and evaluate such interventions using validated questionnaires conducted pre- and post-intervention.
4. Scale up the interventions showing the most significant improvements in inducing behavior change.
5. Track incidence rates of foodborne illnesses in specific areas where interventions are being implemented.

6. Conduct cost-effectiveness studies evaluating the costs involved in promoting meat thermometer usage *vs.* anticipated decrease in the economic burden of foodborne illnesses.

We also recommend the following actions to be adopted by food safety authorities to promote thermometer usage among both domestic and catering consumers:

1. Establish of partnerships with food safety authorities in the US to benefit from the four decades of US experience in conducting campaigns promoting of meat thermometer usage.
2. Ensure the availability of affordable types of meat thermometers in both urban and rural areas.
3. Encourage media (e.g. T.V cooking shows, recipes and magazines) to model and normalize meat thermometers usage and convey the thermometer message in recipes.
4. Urge food manufacturers to print the safe minimum cooking temperatures and thermometer advice on raw meat package labels.
5. Urge industrial and commercial settings to promote meat thermometer use in different ways, such as offering discount coupons for meat thermometers users, tracing domestic usage of meat thermometers through mobile applications, providing disposable thermometers with raw meat packaging...etc.
6. Conduct regular inspections in food service establishments to ensure adherence to the recommended cooking guidelines, including meat thermometers usage.
7. Include meat thermometers usage in the rating criteria of restaurants, and urge restaurants to declare to the public that they are using meat thermometers.
8. Encourage schools to focus on meat thermometers use in students cooking activities.

In conclusion, this review revealed low meat thermometer usage in the developed countries, particularly in Europe. Lack of knowledge does not appear to be the main barrier to meat

thermometers usage. Instead, the low usage may be attributed to consumers' negative perceptions and attitudes. Educational interventions addressing both consumers' knowledge and attitudes were more effective in changing consumers' behaviors, compared to those concerned only with addressing knowledge. Therefore, food safety authorities worldwide should focus on investigating consumers' beliefs and attitudes towards meat thermometers usage, in order to design effective tailored interventions.

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Tables captions:

Table 1. Safe minimum cooking temperatures for different meat types recommended by USDA- FSIS (2015a), Government of Canada (2015), and NSW Food Authority (2018)

Table 2. Summary of the findings of direct observation studies and surveys concerned with trends of thermometers ownership and usage

Table 3. Summary of trends in meat thermometers usage with different meat types

Figures captions:

Fig. 1. Flow diagram of the included studies

1 Table 1. Safe minimum cooking temperatures for different meat types recommended by

2 USDA- FSIS (2015a), Government of Canada (2015), and NSW Food Authority (2018)

Meat type	Safe minimum cooking temperature (ºC)		
	US	Canada	NSW
Beef, Veal, and Lamb	62.8	63	63
Pork	62.8	71	63
Ground/minced meat	71.1	71	71
Whole poultry	73.9	82	74
Ground/Pieces of poultry	73.9	74	74
Fish	62.8	70	63

3

1 Table 2. Summary of the findings of direct observation studies and surveys concerned with trends of thermometers ownership and usage

Type of study	Participants	Country	Type of cooked food	Direct observation		Survey			% relying only on sensory cues (observation or survey)	Reference
				Cooking setting	% usage of meat thermometer	% ownership of meat thermometer	% knowledge of minimum safe cooking temperature	% usage of thermometers		
Direct observation + survey	Phone-recruited adults	US	Beef, chicken, or fish	Participant's home	5% voluntarily	30%	30%	N/A	89%	(J. B. Anderson, Shuster, Hansen, Levy & Volk, 2004)
Direct observation + survey	Adults recruited via advertisement	US	Burger	Participant's home	4% voluntarily	53%	35%	N/A	75%	(Phang and Bruhn, 2011)
Direct observation + survey	Adults recruited at shopping centres	US	Chicken	Participant's home	< 5% voluntarily	48%	53%	N/A	95%	(Bruhn, 2014)
Web-based survey	Online randomly selected adults	US	Burger	N/A	N/A	16%	N/A	19% of participants	59%	(Lin, 2018)
Direct observation + survey	Adults recruited by fliers, friends and family members	US	Poultry	Participant's home	5% voluntarily	43%	50%	25% of participants	95%	(Mazengia, Fisk, Liao, Huang, and Meschke, 2015)

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Type of study	Participants	Country	Type of cooked food	Direct observation		Survey			% relying only on sensory cues (observation or survey)	Reference
				Cooking setting	% usage of meat thermometer	% ownership of meat thermometer	% knowledge of minimum safe cooking temperature	% usage of thermometers		
Direct observation + survey	Adolescents and parents of youth basketball teams	US	Breaded chicken	Student food preparation kitchen in the university	12% (instructed on package)	73%	43%	20% of participants	37%	(DeDonder et al., 2009; 2012)
Web-based survey	Adult grocery shoppers	US	Poultry	N/A	N/A	62%	N/A	26-73%* of owners	N/A	(Kosa, Cates, Bradley, Chambers, and Godwin, 2015)
Survey	Seniors and parents of young children	US	Beef, pork, burger	N/A	N/A	42%	N/A	5-24%* of participants	N/A	(Cates and Anderson, 1999)
Survey	Students of East Carolina University	US	Burger and fish	N/A	N/A	23%	N/A	< 67% of owners	N/A	(McArthur, Holbert, and Forsythe III, 2007)
Direct observation + survey	Graduates of nutrition education program	US	Burger and chicken	Community kitchens	16% voluntarily	N/A	N/A	N/A	N/A	(Kendall et al., 2004)

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Type of study	Participants	Country	Type of cooked food	Direct observation		Survey			% relying only on sensory cues (observation or survey)	Reference
				Cooking setting	% usage of meat thermometer	% ownership of meat thermometer	% knowledge of minimum safe cooking temperature	% usage of thermometers		
Direct observation + survey	Sample of consumers distributed among 2-3 states	US	Chicken breast and turkey patties	Home style kitchens	22-37% depending on type of food	63%	N/A	20-30% depending on type of food	6-22% depending on type of food	(Maughan, 2015)
Phone survey	Randomly phone-recruited adults of different ethnicities	US	Poultry	N/A	N/A	35-64% depending on ethnicity	20%	N/A	53%	(Henley, Stein, and Quinlan, 2015)
Survey	Students in 3 universities in 3 states from food and non-food related majors	US	General	N/A	N/A	N/A	N/A	6% of participants	91%	(Unklesbay, Sneed, and Toma, 1998)
Direct observation	Young adults – college students	US	Chicken	Food preparation laboratory	3% voluntarily	N/A	N/A	N/A	97%	(Byrd-Bredbenner, Maurer, Cottone, Clancy, and Wheatley, 2007)

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Type of study	Participants	Country	Type of cooked food	Direct observation		Survey			% relying only on sensory cues (observation or survey)	Reference
				Cooking setting	% usage of meat thermometer	% ownership of meat thermometer	% knowledge of minimum safe cooking temperature	% usage of thermometers		
Survey	Phone-recruited adults in Waterloo region	Canada	Burger, chicken or fish	N/A	N/A	N/A	N/A	14% of participants	64%	(Nesbitt et al., 2009)
Survey	Phone-recruited adults (including high-risk groups)	Canada	Pork, poultry and ground meat	N/A	N/A	N/A	61-63%*	29% of participants	75%	(Ekos Research Associates Inc., 2010)
Survey	Phone-recruited adults from all Canadian provinces	Canada	Pork, poultry and fish	N/A	N/A	N/A	53%	29% of participants	65%	(Murray et al., 2017)
Survey	Undergraduate University students	Canada	Meat and chicken	N/A	N/A	N/A	N/A	21% of participants	N/A	(Courtney, 2017)
Survey	Phone-recruited residents in Vancouver area	Canada	Burger and chicken breasts	N/A	N/A	N/A	N/A	14-18%* of participants	N/A	(Fraser Health and Vancouver Coastal Health, 2010)

1

Type of study	Participants	Country	Type of cooked food	Direct observation		Survey			% relying only on sensory cues (observation or survey)	Reference
				Cooking setting	% usage of meat thermometer	% ownership of meat thermometer	% knowledge of minimum safe cooking temperature	% usage of thermometers		
Survey	Consumers interviewed in central London and Bexleyheath	UK	Meat and fish	N/A	N/A	N/A	N/A	4% of participants	91%	(Bates, Hovard, Sal, and Eaton, 2017)
Survey	Randomly selected households	Ireland	Meat and poultry	N/A	N/A	N/A	N/A	2% of participants	80%	(Kennedy et al., 2005)
Survey	Phone-recruited adults	Ireland	Beef	N/A	N/A	N/A	N/A	3% of participants	83%	(Mahon, Cowan, Henchion, and Fanning, 2006)
Direct observation + survey	Recruited by advertisement	Austria	Chicken	Participants' home	3%	N/A	N/A	N/A	78%	(Hoelzl et al., 2013)
Survey	Nationally selected adult participants	Netherlands	Meat and chicken	N/A	N/A	N/A	N/A	11% of participants	N/A	(Fischer, Frewer, and Nauta, 2006)

1 * Different percentages depending on type of food

Table 3. Summary of trends in meat thermometers usage with different meat types

Meat type	Percentage of usage	Reference
Whole poultry	24%	(Cates and Anderson, 1999)
Whole chicken	33 - 57%	(Kosa et al., 2015; Murray et al., 2017)
Whole turkey	42 - 73%	(Kosa et al., 2015; Murray et al., 2017)
Roasts	21 - 38%	(Cates and Anderson, 1999; FDA, 2016; Murray et al., 2017)
Chicken parts	18 - 37%	(Maughan, 2015; FDA, 2016; Fraser Health and Vancouver Coastal Health, 2010)
Turkey patties	22%	(Maughan, 2015)
Ground poultry	23%	(Kosa et al., 2015)
Hamburger, ground meat	5 - 14%	(Cates and Anderson, 1999; FDA, 2016; Fraser Health and Vancouver Coastal Health, 2010; Murray et al., 2017)
Fish	3.5%	(Murray et al., 2017)

1 Fig. 1. Flow diagram of the included studies