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Systematic review of the relative proportion of foodborne disease associated with food preparation or handling practices in the home

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GLOSSARY

Foodborne disease '*A foodborne disease (FBD) can be defined as a disease commonly transmitted through ingested food. FBDs comprise a broad group of illnesses, and may be caused by microbial pathogens, parasites, chemical contaminants and biotoxins'* (WHO, 2015).

Foodborne illness '*any disease of microbial origin caused by, or thought to be caused by, the consumption of food or water. Foodborne illness is synonymous with food poisoning'* (HPSC, 2012).

Food poisoning '*any disease of an infectious or toxic nature caused by or thought to be caused by the consumption of food or water'* (FSA, 2008).

Epidemiology *'the study of the distribution of diseases and determinants of diseases in populations, including all forms of disease that relate to the environment and ways of life'* (Anon, 2017).

Infectious intestinal disease '*any infection of the gastrointestinal tract, regardless of the source'* (HPSC, 2012).

Contamination '*The presence of disease-causing microorganisms or their by-products (e.g. toxins), chemicals and/or foreign bodies, at a level sufficient to present a potential health hazard'* (HPSC, 2012)

Case '*an occurrence of illness as defined by investigators'* (WHO, 2008).

Sporadic *'A case that cannot be linked epidemiologically to other cases of the same illness'* (WHO 2008).

Outbreak '*the occurrence of two or more linked cases of the same illness or the situation where the observed number of cases exceeds the expected'* (HPSC, 2012).

Incidence '*Number of new cases in a specified population in a defined period of time, divided by the population at risk'* (WHO, 2008).

Food hygiene '*all conditions and measures necessary to ensure the safety and suitability for consumption of food at all stages of its growth, distribution and preparation*' (WHO, 2008).

Food safety '*Assurance that food will not cause harm to the consumer when it is prepared and/or eaten'* (WHO, 2008).

LIST OF ABBREVIATIONS

CCP	Critical Control Point
CIEH	Chartered Institute of Environmental Health
EFSA	European Food Safety Authority
FSA	Food Standards Agency
GPP2	Good Publication Practice
HACCP	Hazard Analysis Critical Control Point
IFH	International Food Hygiene
IID	Infectious Intestinal Disease
PICOS	population, intervention, comparator, outcomes
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses
RTD	Round table discussion
SIGN	Scottish Intercollegiate Guidelines Network (Scotland)
WGS	Whole Genome Sequencing
UK	United Kingdom
US	United States of America

SUMMARY

The reduction of foodborne disease has been a FSA priority since its inception in 2000 and foodborne disease incidence is generally considered to be preventable with the application of good personal hygiene and food safety practices. The home is recognised as a point in the food chain where risks of consumers contracting foodborne disease can be minimised through the application of good hygiene practices, however, these practices, for complex reasons are frequently not implemented. The extent of foodborne disease arising in the home compared with other settings is unclear and this study has aimed to estimate the proportion of UK foodborne disease attributable to foods prepared in the home in order to focus further research, interventions and food safety messages proportionally between domestic and other settings.

Academic and grey literature (from 1990, English language and from countries with similar dietary practices to England and Wales) was searched using search terms agreed in an 'expert workshop'. The sourced literature was reviewed systematically against inclusion criteria agreed in the same workshop. Outputs from the systematic review were discussed in a further 'expert workshop' where strengths, weaknesses and data gap analyses were discussed. Theoretical frameworks were developed to summarise the current state of knowledge and where gaps in knowledge exist.

Of the 278 academic articles evaluated (84 incidence studies, 192 behavioural studies and 2 covering both), 71 were included in the review, supplemented with 21 items from the grey literature. Results show a complicated picture for attribution of incidence to setting, with variable results and many caveats around lack of information, inability to confirm organism, investigation of different agents, differing surveillance systems and levels of reporting by setting, and use largely of reported cases. To confirm with any certainty the proportions of foodborne illness deriving from different settings is therefore difficult, although most studies suggest the highest proportion of foodborne illness to derive from commercial food service settings.

The review also investigated domestic hygiene and food preparation practices to identify risk factors linked to illness. The evidence comprised of case reports, case control studies, investigations of refrigerators and domestic hygiene (microbiological testing), and observation studies. Only case reports (which are rare) directly link to episodes of illness; in such cases, behaviours maybe implicated. Case control studies, whilst linked to illness, do not confirm the actual cause, only risk factors. Microbiological investigations of kitchen sites (including refrigerators) identified widespread contamination by pathogens. Hands and chopping boards were most frequently linked to cross-contamination within the kitchen, particularly of surfaces such as knobs and handles. Most domestic refrigerators were operating at above the recommended 5°C. Observation studies highlighted many contraventions in hygiene practice, largely focussing around inadequate hand washing, inadequate sanitation of boards/knives and poor temperature control (storage and cooking). Using findings from the systematic review, the potential links between food activities to the point of consumption have been summarised in a series of generic and pathogen specific theoretical framework diagrams.

To fully understand the extent and causes of food poisoning deriving from the home will require a comprehensive study of cases of foodborne illness (predominately sporadic; outbreaks where relevant), with extensive follow up, including observations to confirm causality in terms of both agents and domestic practices.

EXECUTIVE SUMMARY

This project comprised a full systematic review to establish if data exists to estimate the relative proportion of foodborne disease within the home caused by faults in food preparation or handling, types of foods, pathogens and practices leading to illness. This has been achieved in four stages:

Stage 1: Definition and refinement of the scope and focus of the systematic review and definitions (terms) for use, search terms and inclusion/exclusion criteria.

Stage 2: Expert evaluation of incidence of foodborne disease arising in the home by conducting academic / grey literature search as in agreed scope and search criteria.

Stage 3: Expert evaluation of outcomes of the systematic review; synthesis of outcomes of systematic review according to key research questions.

Stage 4: Development of a theoretical framework to summarise current state of knowledge of incidence, determination of the causes of foodborne illness arising from the home and identification of knowledge gaps.

Key findings: Expert scoping workshop

- Qualitative expert opinions regarding the systematic review scope resulted in an agreed focus on behaviours that the consumer can control and key organisms where poor hygiene in the home (including preparation and temperature control) could result in foods becoming injurious to health.
- A variety of foods to be included in the review were identified and consumer responsibility for food safety/ hygiene was determined as the point where food is taken from the shelf (retail), point of delivery to home (on-line/delivered food) and/or picking up from takeaway.
- Domestic practices included in the scope of the systematic review included hand washing (before/during/after contact with contaminants); cleaning and disinfection; temperature control (chilling and cooking); use of durability indications; indirect transmission; attitude and awareness of food handler; catering for not-for-profit events; place of consumption; background of food handler; washing meat; companion animals.

Key findings: Systematic review

- Overall, >10,000 academic articles and >1400 abstracts relating to foodborne disease in the home between 1990-2016 were identified; evaluation according to inclusion /

exclusion criteria, resulted in a reduced number of articles (n=278) included in the review.

- In total, 192 identified studies were linked to behavioural studies and 84 to incidence of foodborne illness (or similar term).
- A geographic breakdown indicated widespread inclusion of studies from countries with similar dietary patterns to the UK. Some (18%) studies had a global reach, whilst others were country specific or enabled country comparisons. The largest proportions of behavioural studies conducted were in the UK (n=22), Wales (n=14) and USA (n=50).
- Numbers of reported studies indicated a steady increase over the period covered by the review (1990-2016); overall number of studies levelled during 2012-2016 with an increased frequency of incidence studies.

Foodborne illness contribution arising from the domestic setting

- Overall, 19/78 incidence-related academic studies identified met inclusion and evaluation criteria (10 reported on single organisms); no studies specifically sought to differentiate incidence of foodborne illness deriving from different settings.
- Cumulatively, international studies attributing foodborne disease/illness within the home indicated variable incidence rates (12-64%). In the UK, foodborne illness attributed an increased incidence to foodservice settings (44-85%) than the home (12-17%).
- Studies primarily reported *outbreak* incidence, rather than *sporadic cases*, and the latter are believed more likely to occur in the home, therefore, the home as a setting for contracting foodborne illness is likely to be underrepresented.
- Variation in contextual origin of cases, reported incidence (predominantly outbreaks) and different methods of data collection and organism/agent inclusion limited study comparison and the extent to which summarised studies could be used to provide a single body of evidence.
- Foodborne illness can arise from the domestic setting and home food preparation practices are one of a series of control points in the food chain. However, UK surveillance systems are not designed to focus on domestic kitchen practices.
- Cumulatively there was insufficient evidence arising from the literature to confidently attribute the proportion of foodborne illness to setting.

Potential for foodborne disease in the home resulting from failure to implement recommended practices

- Approaches used to link illness and practice included direct follow up of incidents (case reports) and case-control studies (n=15). This was considered to provide a better source of information on risk factors but no direct links to illness were proven.
- Behavioural malpractices identified through all case reports were associated with temperature control (inadequate heating/reheating), storage for long periods at ambient temperatures, or in a refrigerator operating at too high a temperature or a combination of these.
- Poultry and raw / undercooked eggs were frequently identified as risk factors (general studies, *Campylobacter* and *Salmonella*), as was undercooked and barbequed meat (*Campylobacter*). Others in the household (children, adults and pets) with diarrhoea or in nappies were noted for general *Salmonella* and *Campylobacter* outbreaks. Other risk factors included inadequate hand washing and consumption of unpasteurised dairy products.
- Differences in methodological approaches used, and the lack of standard definitions made it difficult to compare studies and draw overall conclusions.

Practices and behaviours in the home associated with incidence of foodborne disease in the domestic setting.

- Although microbiological assessment of consumers' homes and observation of food handling/storage behaviours provided data indicate the potential for illness, they do not infer causality. Studies involving only self-reports of behaviours (n=37) were not included, as they have no direct link to confirmed practice or illness.
- Studies evidenced the potential for refrigerators to contribute to the risk of foodborne illness indicating storage of foods in refrigerators operating at above 5^{o}C and fridge surfaces harbouring foodborne pathogens.
- Prepared foods, kitchen surfaces and equipment within the home can become contaminated during food preparation.
- Frequently implemented cleaning practices may not be adequate to remove contamination – including washing of chopping boards, enabling microorganism survival/proliferation.
- Wiping cloths are a potential source of contamination, with washing practices often not adequate to remove all organisms, enabling a habitat for microbial multiplication and vector for bacterial cross contamination.
- Studies illustrate the potential of hands to cross contaminate, and for common food cooking regimes to be only marginal in removing pathogens.

- Observation studies highlighted a number of hygiene-related behaviours that increase the risk of foodborne illness and also the multiple uses of kitchen spaces.
- Observed behavioural data was considered to have greater value for the generation of hypotheses about the incidence of foodborne disease in the domestic setting. Self-reported practices data indicated a more optimistic portrayal of practice implementation compared to observed behaviours.

The relative likelihood of a 'specific practice' or 'groups of practices' to cause foodborne illness: expert workshop feedback

- Often several 'practices' could be linked to foodborne disease outbreaks i.e. illness resulted from 'a series of unfortunate events'. However, sporadic cases, believed to be more common in the domestic setting, may result from failure to follow individual recommended practices, rather than a series of events.
- Reviewed studies identified/suggested a range of failures to follow the recommended hygiene practice in the transportation, storing, preparing and handling of food for home consumption. These findings provided a basis for a substantial amount of educational content.
- The 4C's i.e. cooking (proper heat treatment), cooling, cleaning and avoiding cross contamination described the key groups of hygienic practices necessary to reduce the risk of foodborne disease.
- Consumers associated with a greater susceptibility to foodborne disease than the general population include primary immunodeficiency, patients treated with radiation or with immunosuppressive drugs for cancer and diseases of the immune system, those with acquired immune-deficiency syndrome and diabetics, people suffering from liver or kidney disease or with excessive iron in the blood, pregnant women, infants, and the elderly (O'Brien and Lund, 2011). Such consumers require a specific focus in future research to reduce the potential risk of foodborne illness.

Theoretical framework

- Using findings from the systematic review, the potential links between food activities to the point of consumption have been summarised in a series of theoretical framework diagrams.

1.0 BACKGROUND

The reduction of foodborne disease has been a FSA priority since its inception in 2000 with the FSA reiterating consumer protection as its main purpose in the Strategic Plan for 2015-2020 (FSA, 2015). As such, reduction of foodborne illness will remain central to its activities, with the current Foodborne Disease Strategy aiming to reduce the overall burden of foodborne disease in the UK. Although food can become contaminated at many points in the food chain, it is generally considered that the majority of foodborne disease is preventable with the application of good personal hygiene and food safety practices. The home is recognised as a final link in the food chain where risks of consumers contracting foodborne disease can be minimised through the application of good hygiene practices. However, it is also recognised that some consumers do not always apply these practices, despite being aware of them, and the reasons why the kitchen can become a risky place are complex.

Despite studies to estimate the overall prevalence of foodborne disease in the community, the extent of foodborne illness arising in the home compared with other settings remains elusive. The FSA seeks to estimate the proportion of UK foodborne disease attributable to foods prepared in the home in order to help focus further research, interventions and food safety messages proportionally between domestic and other settings.

The FSA and others have attempted to obtain reliable estimates of the incidence of foodborne disease, and its origins. Such work is hampered by the various terminologies and definitions attributed to disease originating from food. Terms include ‘food poisoning’, ‘foodborne illnesses, ‘Infectious Intestinal Disease’ (IID) and ‘gastro-intestinal illness / infection’, all of which encompass different precise meanings, but may be used interchangeably. Similarly, surveillance focuses upon outbreaks and identification of food sources, as opposed to sporadic cases and poor practices that could be improved (Day, 2001). The most comprehensive estimate in the UK derives from the IID2 study (Tam *et al.,* 2012) which includes all infectious intestinal disease, not just those arising from the consumption of food and its extension (FSA, 2014) which focussed upon foodborne disease. In addition, although there is some evidence from these studies of the main sources of illness by food type or pathogen, there is no attempt to identify the proportion of the

incidence arising in different settings. No comparisons between food consumed in the home and food consumed outside of the home in restaurants or from takeaways have been made. Whilst the first IID study (Tam *et al.* 2012) identified caterers as a major source of outbreaks, most foodborne disease arising through errors in food preparation and handling in the home are likely to be sporadic cases. This makes them less likely to be reported and followed up, and, in turn, less likely to appear in surveillance data and official estimates of illness.

The impact of changes in the way that (seemingly) sporadic cases are investigated (or not) over the last 15 years (potentially going back 25 years to the Richmond Committee reports (Department of Health, 1990; 1991)) make it difficult to establish what the true proportion is between illness acquired after eating food prepared in a commercial kitchen, with that acquired through food prepared in a domestic setting. The extent to which sporadic cases are no longer followed up and investigated is likely to be an underlying issue when seeking to establish evidence that the domestic kitchen is a significant locus of infection for foodborne illness. As with all data, however, this is likely to over-represent those pathogens causing more severe/long lasting illnesses. Whilst these are undoubtedly most important in terms of public health, other forms of foodborne disease will also be occurring, e.g. *S. aureus*, and norovirus where the symptoms are less severe, albeit inconvenient, and short-lived.

A review of the FSA's Foodborne Disease Strategy, (Bell, 2006) noted the value of existing surveillance data in assessing the impact of various interventions aimed at reducing pathogen levels in foods. However, an expert workshop reviewing the impact of FSA's Foodborne Disease Strategy noted deficiencies in the UK surveillance systems, albeit these were considered better than in many other countries (Mead, 2007). The workshop also highlighted some key concerns relating to consumers and hygiene in the home, including how to ensure people used the 4Cs, and also enacted what they knew to be correct (reducing optimistic bias), design of domestic refrigerators and training of teachers to enable them to teach food hygiene effectively. It is known that current surveillance data grossly underestimates the incidence of gastroenteritis in the community (Day, 2001; Tam *et al.,* 2012; FSA, 2014) with the extent of food poisoning in the home remaining largely unknown. The increase in the number of sporadic cases of *Campylobacter* has, however,

raised interest in hygiene in the home and domestic food preparation practices (Millman *et al.,* 2014). Byrd-Bredbenner *et al* (2013) noted the home as being the main location of foodborne outbreaks in the US.

A number of studies have reported that consumers perceive their own homes, (and the homes' of friends and family) to be an unexpected location to acquire foodborne disease – a notion associated with the concept of optimistic bias (Weinstein, 1989) and indicating that risks of foodborne disease associated with the home are under-estimated (Redmond, 2002; Redmond and Griffith, 2003a; Prior et al. 2013). In addition, to the failure to associate food safety risks with getting foodborne disease from the home, research has indicated that consumers also perceive a tendency known as the 'illusion of control' whereby more consumers' consider themselves to have more personal control over food safety than 'other people' (Redmond, 2002; Redmond and Griffith, 2004).

Cumulatively, existing data suggests the need when considering historical studies to be clear whether the data establishes clear evidence of an association with food consumed in the home, or merely suggests an association by default, before considering other factors that make it more difficult to establish linkages between foodborne illness and the home such as dietary patterns and habits peculiar to the domestic setting.

1.1 Project aims

The aim of the current project was to carry out a systematic review in order to establish if data exists to allow an estimate of the relative proportion of foodborne disease caused by faults in food preparation or handling within the home, and the types of foods, pathogens and practices leading to illness.

1.2 Project objectives

1. Define the scope and focus of the systematic review and definitions (terms) for use. Refine and define the scope, focus, search terms and inclusion/exclusion criteria for the systematic review.

2. Evaluation of incidences of foodborne disease arising in the home through systematic review. Conduct academic and grey literature search as per agreed scope and search criteria.
3. Evaluation of outcomes of the systematic review; synthesis of outcomes of systematic review as per key research questions
4. Development of a theoretical framework to summarise current state of knowledge of incidence and causes of foodborne illness arising from the home, and to identify knowledge gaps. Summarise the current state of knowledge, where gaps in knowledge exist, and further research required.

1.3 Research questions

The cumulative research question:

- What proportion of UK foodborne disease is caused by faults in transporting, storing, preparing and handling food for consumption within the home?
  [Disease to include toxicants that increase as a result of poor storage practices; to include time food taken from shelf within retail environments, or pick up or receipt of takeaways, or receipt of home deliveries].

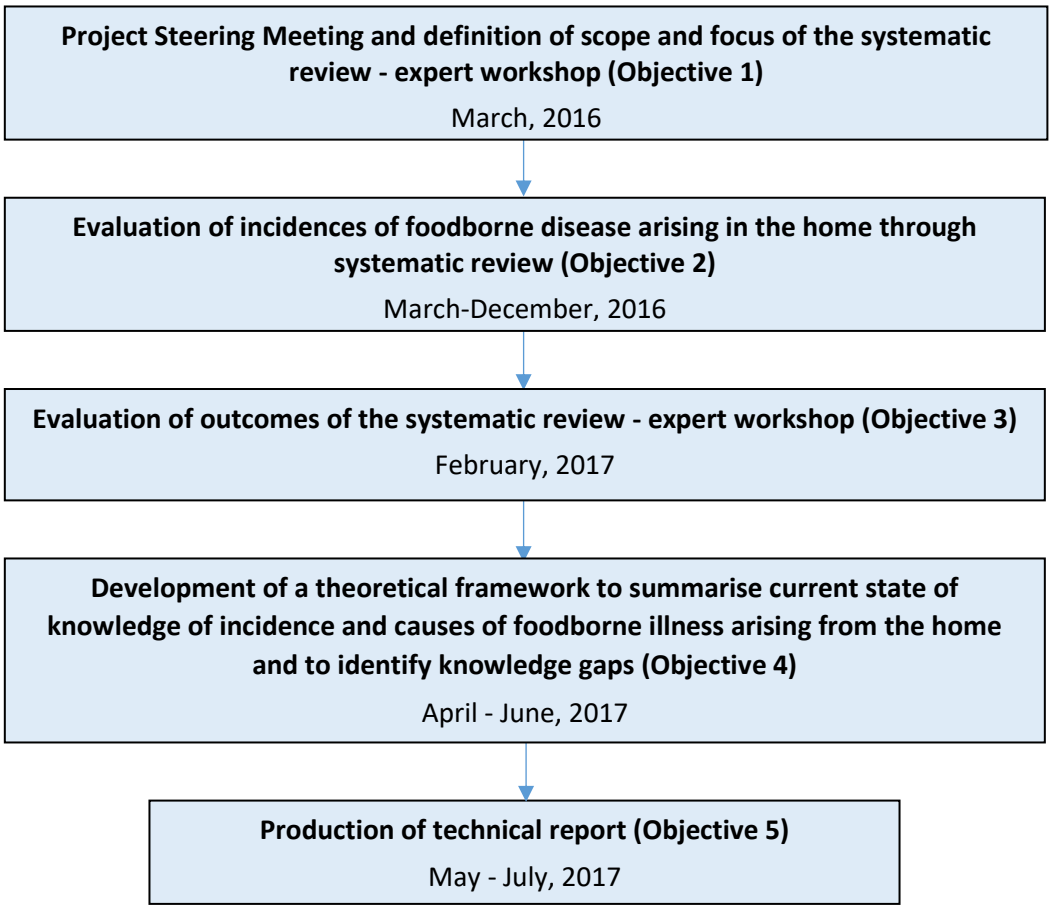
Supplementary (non-impact) questions:

- What leads to foodborne disease in the home – contamination of 'safe' food (making it 'unsafe', possibly as a result of poor in-home practices) and/or inadequate transporting/storing/handling/preparation of 'Unsafe foods'? [where safe food is defined as 'food not injurious to health']
- Is it feasible to determine the proportion of foodborne cases caused by specific pathogens in the home?
- Which pathogens are most likely to lead to foodborne disease through faults in transporting, storing, preparing and handling food for consumption within the home, and in what proportions?
- What are the likely causes of foodborne disease deriving in the home, e.g. contamination of food stuffs in the food chain or malpractices whilst transporting, storing, preparing and handling food within the home?

2.0 EXPERIMENTAL PROCEDURES / METHODS

Research methods adopted for implementation of this study utilised an initial scoping qualitative workshop and generation of expert opinions (section 2.2), a systematic review with predefined inclusion and exclusion criteria (section 2.3) and implementation of a post review workshop to elicit expert opinions regarding review outcomes. Key project stages are outlined in Figure 2.1 and a detailed process flow with responsibilities can be found in Appendix I.

Figure 2.1 Flow diagram indicating study objectives project approaches.



A ‘Steering Group’ of experts (Appendix II) was assembled to provide guidance during the project and was consulted at every stage of the project in accordance with contracted requirements and project deliverables.

2.1 Definition of scope and focus of the systematic review - expert workshop

Prior to implementation of the ‘expert workshop’ a Project Steering Group meeting was held (March, 2016). This meeting involved an overview presentation of the project including aims, objectives and scoping questions. ‘Preliminary questions’ (shown in Figure 2.2) (in addition to details regarding project design, outputs and deliverables) were circulated to members of the Steering Group prior to the meeting and preliminary feedback related to the ‘preliminary questions’ was also presented.

The key objectives of the Scoping Workshop and series of preliminary scoping questions discussed in the workshop, are noted in Figure 2.2. Overall, the workshop helped secure terminology and definitions for key terms and define, confirm and refine review inclusion and exclusion criteria. The workshop was attended by 13 subject matter experts - academics and practitioners, both from the food sector and public health bodies (for list of attendees/expertise see Appendix III). The workshop was conducted as a series of ‘Talking Wall’ exercises against each of the scoping questions detailed below. Further questions were addressed through round-table discussion (RTD). FSA representatives were in attendance as observers, and the research team acted as facilitators, though all were free to express opinion and criticism.

Where the ‘Talking Wall’ was used, participants were asked to identify key criteria that they would wish to see addressed (or not) in respect of the questions in Figure 2.2, and to post these on the ‘Wall’. This approach ensured that all opinions were captured. In this particular setting participants were asked to indicate what should and should not be included, and where doubt existed, what should be qualified by ‘maybe’.

The outcome of the ‘Talking Wall’ was duly summarised by sorting the posted responses into logical groupings, and discussing responses that suggested a difference of opinion, or where there was doubt. In each case, and after discussion, the group sought to arrive at a consensus or established criteria that reflected the outcome of the discussion.

Figure 2.2 Scoping workshop key objectives and preliminary questions.

Scoping workshop key objectives

- Define safe and unsafe food
- Define inclusion and exclusion criteria against the scoping questions
- Locate possible sources of information to inform the systematic review
- Define criteria for the evaluation of the 'academic' and 'grey' literature

Scoping workshop – preliminary questions

- What is the definition of safe and unsafe food? (RTD)
- Should we cover all types of illness derived from consumption of food; which organisms should be considered (e.g. include viruses, parasites, toxins)?
- At what point should we consider the consumer takes responsibility for their food?
- Which foods entering the home should be included (e.g. include/exclude takeaways, 'unusual' foods not widely consumed)?
- Which consumer groups should be considered (e.g. some of the literature refers to individual cases with consumers suffering from specific medical conditions)?
- Which domestic practices should be included?
- To what extent should literature from other countries be included (e.g. which countries would be considered 'developing', or which have dietary norms/practices so different from the UK that their inclusion would be unhelpful)?

Participants were then asked to address the key problems that they felt the researchers might encounter when appealing to existing data and other sources that might serve to inform the study. The research team then explained how they intended to screen and evaluate the quality of the literature so sourced, providing them with an example of one of the evaluation tools – SIGN (Scottish Intercollegiate Guidelines Network)- that could be used to evaluate academic literature and, where appropriate, grey literature. It was agreed that none of the existing tools suited this study and thus a new bespoke tool would be developed.

2.2 Systematic review

The systematic review was conducted to collate empirical evidence meeting pre-determined eligibility criteria, using explicit, systematic methods designed to minimise bias and provide reliable findings (Liberati *et al.,* 2009). The review process followed 'Preferred Reporting Items for systematic reviews and Meta-Analyses' (PRISMA) guidelines, incorporating the twenty-seven items that should be included when reporting a systematic review (Liberati *et al.,* 2009).

2.2.1 PICOS approach and systematic review inclusion and exclusion criteria

The systematic review was guided by PICOS (population, intervention, comparator, outcomes) questions, which helped to refine research questions. This approach has generally been used to define research questions in clinical studies, however, it is considered that the approach had merit for this research, and thus, as far as is possible, the approach was adopted for this study. As noted in section 2.2, the scoping workshop resulted in development of agreed inclusion and exclusion criteria utilised for the review.

Population (P): The population of people focussed upon for this review included all occupants of a household who come into contact with foods to be consumed in the home and consume foods within the home; foods included all foods bought, stored and prepared for consumption in the home, excluding shelf-stable foods. The setting of focus included all points where the occupant(s) of a household has responsibility for the safety of the food – to include transport to home, storage in the home, preparing and handling food in the home through to the point a food is consumed or is deigned unsafe to eat and discarded. Subgroups of the population excluded in the review included those who contract food poisoning as a result of specific medical conditions that predispose them to illness or more severe outcomes.

Intervention (I): Although the study did not involve an intervention, food–related actions included were: hand washing, cleaning and disinfection, temperature control, use of durability indications, indirect transmission of pathogens, background of individuals (demographic/socio-economic), and place of consumption. Intervention studies aimed at improving domestic food safety practices, were included where they

met inclusion criteria, and where baseline measures point to practices that might predispose consumers to foodborne illness.

Comparator (C): In clinical studies, this might include alternative treatments to that being tested. In the current study, there was no real comparator. Some literature made reference to both domestic and professional settings, in which case the information was included, but literature about professional food preparation contexts were not actively sought (as practices can differ markedly from domestic practices, as can the environment and environmental conditions in which the food is prepared).

Outcomes (O): The research aimed to establish if it is possible to separate foodborne disease acquired in the home from that contracted elsewhere, and thus establish the proportion of foodborne disease attributable to food-related practices in households. It also sought to establish the pathogens and food-related practices most often implicated. This study intended to identify gaps in knowledge, and further research requirements, including possible interventions to improve domestic food safety practices.

Further inclusion criteria for the literature search involved inclusion of literature from 1990 to 2016 which was published in English, including surveillance systems and methods of detection. Given that major pathogens have changed over time, it was difficult to consolidate data before 1990. Literature from across the developed world was included, with a general rule that it should be sourced from countries with similar dietary patterns to the UK, including USA, Canada, Australia, New Zealand and Europe (for example Holland and Scandinavian countries). In addition, if articles included the following organisms, practices or foods, they were eligible for inclusion in the review:

Agreed organisms, which represented the major pathogenic agents in England and Wales: *Salmonella*, *Campylobacter*, *B. cereus, C. perfringens, S. aureus*, Scombrotoxin, *Cryptosporidium, Shigella, Giardia*, parasites, viruses (norovirus, adenovirus, hepatitis A & E viruses, and rotavirus), *Listeria*, *E. coli* O157, VTEC O157.

Agreed practices, identified in the workshop as important risk factors for foodborne illness if not properly applied: Hand washing, cleaning and disinfection, temperature control, use of durability indications and indirect transmission of pathogens. In

addition, consideration of place of consumption, consumer characteristics and catering for not-for-profit events.

Agreed foods identified in the workshop as having potential to lead to foodborne illness if handled inappropriately: high risk foods - raw or processed, including meat and poultry, and dairy products, ready to eat foods, shellfish, molluscs, oysters. Foods requiring some handling, homemade foods – including preserves; takeaways/doggy bags from restaurants; meals on wheels; foods prepared at school to be consumed at home; food from farmers' markets; fish stalls, and salads and vegetables.

2.2.2 Review searches and database interrogation

The key academic databases interrogated to source academic literature, using the search terms indicated in Appendix IV, were Zetoc and Medline. Zetoc covers all academic disciplines, whereas Medline relates only to articles in designated medical or related journals. Medline was used to supplement those articles identified through Zetoc, cross-referencing to the established database to determine if the search had produced new materials. In addition, where specific journals appeared to offer a useful source of relevant material, content lists were scanned for relevant articles, and reference lists to articles were also used to extend the literature evaluated.

In relation to the grey literature, in addition to the many papers, reports and reviews, members of the Steering Group were canvassed to suggest sources of data and networks that might be explored in order to discover novel material. Subsequently, requests for data were made through the Field Epidemiology Services section at Public Health England, the International Scientific Forum on Home Hygiene (IFH) and the Chartered Institute of Environmental Health (CIEH). In addition, FSA funded project reports were located through the FSA. Further grey literature was identified through the academic literature search, using the references and bibliographies of the published works, the original data arising from surveillance and observational studies were located using 'Google' and the Medline database. Finally, a 'call-out' was released through the FSA's network of relevant practitioners and this led to two unpublished theses being offered up for consideration.

Post identification of articles containing the keywords (title or abstract), article titles were scrutinised to identify their relevance, using the PICOs approach. For articles appearing to meet the inclusion criteria, abstracts were read to further establish their relevance to the study. Where the abstract pointed to the article meeting inclusion criteria, it was obtained and recorded in an Excel database created for this study. Articles were then evaluated to confirm relevance to the study, and also to confirm the quality of the work. This was achieved by developing an evaluation form (based on a combination of the SIGN (2001 – 2014)). Methodology checklists and Graf *et al.*'s (2009) GPP2 checklist for articles and presentations were used to decide if each piece of evidence should or should not be included in the review. Existing tools for evaluation were not deemed suitable, as they tended to be based on randomised control trials (which were not likely to be found as part of this study), and thus, evaluation criteria were too strict, especially for the grey literature. Similarly, an existing tool for the evaluation of case studies was too vague. Thus, a combined tool was developed that did separate studies in terms of the rigour, but also allowed for other literature to be judged.

Literature was judged on its relevance to the study (based on the PICOS questions), the clarity of hypotheses and/or research objectives, the appropriateness of the approach taken (including sampling) and the accuracy and honesty of reporting. This process was completed by two individuals independently. At early stages of this review process, reviewers discussed and agreed how papers that could not easily be classified would be dealt with. Quality of the paper was the major determinant for inclusion in the review, as poor-quality papers were not believed to provide reliable evidence. Similarly, where a full paper could not be sourced (or was not written in English), despite an apparently relevant abstract, it was not included as abstracts alone did not provide enough evidence of the quality of the study.

Tables were created from the database to show the frequency of approach, and studies by year and by country where data were collected. The major groupings were studies of incidence of foodborne illness and studies of food-related behaviours. Based on the evaluation of articles, data were also tabulated to show articles included and excluded from the review.

Thirty-seven studies identified as credible, but based entirely on self-reports of behaviours with no link to incidence of illness, were not included in this review (labelled IQ in database).

This was because there was no confirmation of actual behaviours that might lead to illness. These studies do, however, often include large sample sizes, whereas some other approaches, whilst including links to illness or actual behaviours, are usually based on a much smaller sample sizes, limiting their generalisability. Papers were rejected based on their lack of relevance (e.g. incidence studies that did not ultimately break down to setting; the use of 'domestic' referring to within country rather than within the home; small sample sizes leading to concerns over reliability and validity; location of study, where this had not been evident in the abstract; setting, where articles were ultimately identified as foodservice settings).

Publications where original studies were not being reported, and the level of detail included did not enable evaluation were not included in this systematic review. Review papers were also not used, as they were reporting on other studies. They were, however, used as sources of original studies through scrutiny of the reference lists.

2.3 Expert workshop to discuss outputs of systematic review

An expert workshop was held to discuss the outputs from the systematic review. The aims of the workshop were to establish the strengths and weaknesses of the review; identify gaps in the findings; propose ways in which they might be addressed, such as through further research and agree the current state of knowledge on the research topic. A selected group of experts, with acknowledged insight into surveillance, epidemiology, infection control, consumer views and behaviours, social science and the management of food hygiene, were invited to participate in the workshop (see Appendix V for workshop expert participants n= 14).

All attendees were provided with pre-reading material made up of an Agenda, detailing sessions and questions (Appendix VI); a 'Background briefing' on the research project outlining the research questions, the search methodology and evaluation criteria for inclusion of material in the findings (Appendix VII).

The workshop was held on the 2nd February 2017 and began with a short introduction to the research project given by Darren Holland (FSA). Attendees were split into three groups,

which were changed between sessions, to ensure continuing challenge (which might otherwise have been affected by “group thinking”) and the maximum mix of different areas of expertise. Attendees were asked to consider a range of questions (Appendix IX) that aimed to test the findings of the systematic review. Discussions and question responses were digitally recorded and notes were taken for subsequent analysis.

2.4 Theoretical framework

Based on the outcomes of the systematic review and expert workshop a theoretical framework was developed to summarise the current state of knowledge and where gaps in knowledge exist. This included the sources of foodborne disease arising in the home (vehicles, practices, pathogens) and the frequency with which these are identified in the literature. It included both contamination of ‘safe foods’, inadequate handling and treatment of ‘unsafe foods’ and identification of where the food source is not known. Originally one generic framework was developed, however, additional frameworks were also developed for key pathogens to highlight the differences in factors that might impact food safety.

3.0 RESULTS

3.1 Scoping Workshop

Preliminary qualitative feedback from scoping questions was obtained from members of the steering group and presented during the initial scoping meeting (22nd March, 2016). Cumulative findings outlined in Table 3.1 informed and refined the final review terminologies and inclusion/exclusion criteria structured using the PICOS approach (2.3.1).

Table 3.1 Scoping workshop summarised findings

Scoping question	Agreed comments / inclusion for review
What is the definition of safe and unsafe food?	'Food injurious to health', including food that has become 'unsafe' through the actions of consumers, or that had the potential to cause illness through cross-contamination (e.g. hand-to-mouth) Agreed focus should be on actions over which the consumer has control
Talking Wall	
Should we cover all types of illness derived from consumption of food; which organisms should be considered (e.g. include viruses, parasites, toxins)?	There was agreement on key organisms to include, with these being organisms where poor hygiene practices in the home (including preparation and temperature control), could result in foods becoming injurious to health: *Listeria; Salmonella; Campylobacter;* viruses (norovirus, adenovirus, hepatitis A & E viruses); Toxigenic *C.perfringens;* VTEC; *S. aureus;* Parasites (e.g. tapeworm); Toxigenic *B cereus; S*combrotoxin; *Cryptosporidium; Shigella; Giardia*
At what point should we consider the consumer takes responsibility for their food?	General agreement on the points in the food chain that should provide the starting point for the review: point where food is taken from the shelf (retail outlet); point of delivery to home (on-line/delivered food); picking up from takeaway. All environments where residents were preparing foods for themselves were to be included, even if this was just some of their meals, but not institutions that were fully catered.
Which foods entering the home should be included (e.g. include/exclude takeaways, 'unusual' foods not widely consumed)?	A wide variety of foods that should be included were identified: Takeaways/restaurant doggy bags; Meals on wheels; Foods prepared at school and taken home; Homemade foods, including preserves; Farmers' markets; Foods requiring some handling; RTE foods; Salad and vegetables; High risk foods (raw or processed, including meat /poultry, dairy products).
Which domestic practices should be included?	Domestic practices included: hand washing (before/during/after contact with contaminants); cleaning and disinfection; temperature control (chilling and cooking); use of durability indications; indirect transmission; attitude and awareness of food handler; catering for not-for-profit events; place of consumption (e.g. garden, BBQ); background of food handler (cultural, education…); washing meat; companion animals
Which consumer groups should be considered?	All possible consumers/handlers of food should be included
To what extent should literature from other countries be included?	A general rule was that literature should be sourced from countries with similar dietary patterns to the UK.
What are the key problems with existing data that we should be aware of?	A number of issues were noted including comparability of surveillance systems, the accuracy of data derived from these systems and changes in surveillance practices

3.2 Systematic review and expert workshop consultation

Overall, >10,000 academic articles and >1400 abstracts were identified using specified search terms from the initial searches of the literature (1990-2016). Following a review of this data, a reduced number of articles (n=278) were included in the systematic review database. The database was created in Microsoft Excel (2010) and included eleven fields to record article/abstract details and inclusion/Post review, a selected group of 15 experts with acknowledged insight into surveillance, epidemiology, infection control, consumer views and behaviours, social science and management of food hygiene participated in the workshop and provided insight and opinion regarding review outputs.

3.2.1 Profile of reviewed studies

In total, 192 identified studies were linked to behavioural studies and 84 to incidence of foodborne illness (or similar term). Some of these had a global reach (these were often reviews where papers were derived from across the world), whilst others were either country specific or were comparisons between a small number of countries. For a geographic breakdown of reviewed studies see Appendix VIII where the countries listed relate to the source of the sample, not the origin of the authors (although these were often the same). A finding of note is the number of behavioural studies conducted in the UK (n=22), Wales (n=14) and USA (n=50).

Regarding publication date, numbers of reported studies indicated a steady increase over the period covered by the review, levelling in the last 5-year period (2012-2016) (see Appendix IX). In this latter period, the balance of studies changed, with the number of incidence studies showing a large rise, whilst the number of behavioural studies decreased compared to the previous year's high. Within the 5-year blocks, there were peaks of activity in 2001, 2008 and 2014/15.

In terms of the reported types of study / research methods utilised for data collection (Appendix X), the most frequently occurring approaches were case control studies (n=24), literature reviews (n=42), use of surveillance data for incidence studies (n=56) and use of surveys for behavioural studies (n=62). Following evaluation of the academic papers, 19/78 (26%) incidence studies were included in the systematic review and 51/188 (71%)

behavioural studies (Appendix XI). Few studies had a primary purpose that matched the aims of this systematic reviews.

The following sections discuss literature (academic and grey) included in the systematic review, taking each research question in turn and combining findings with expert feedback regarding review outputs. Summary tables including relevant literature and expert workshop findings are presented in Appendices XII-XX. As far as possible, reviewed studies with a similar purpose are discussed together (e.g. those covering the 'same' illness or organism), although the methods employed to generate data differ between studies, making direct comparison problematic.

3.2.2 Foodborne illness contribution arising from the domestic setting

Research Question: What proportion of UK foodborne disease is caused by faults in transporting, storing, preparing and handling food for consumption within the home?

Of the 78 incidence-related academic studies identified, 19 met inclusion and evaluation criteria, although ten reported on single organisms. None of these studies was explicitly designed to differentiate incidence of foodborne illness deriving from different settings, these results being reported as part of a larger study. Settings included are only the home and foodservice settings, thus percentages of incidences do not total one hundred. The remaining sources vary (where reported), and include institutional settings, airlines, hospitals, retail settings and workplaces. Eleven studies attempted to determine proportions of outbreaks arising from different settings. The grey literature offered some insights, including one major study conducted by WHO (2000). In addition, there were a series of studies conducted by EFSA (2011, 2014, 2015).

Results from studies of the contextual origin of outbreaks are summarised in Appendix XIII, ordered with the UK/England and Wales listed first, followed by the rest of Europe and finally North America and Australia. Data indicates how widely estimates of the proportions of foodborne disease originating in different settings vary, reflecting the form and agents of illness investigated, and different methods of data collection. For instance, some studies

included toxic as well as microbiological agents, and sometimes waterborne infections were included in estimates of foodborne illness. Where poisonous mushrooms were identified as a source of food poisoning, all outbreaks derived from the home setting. Consumption of such foods reflected local dietary custom which was a further variable complicating comparisons. The variation in these factors not only makes it difficult to make direct comparisons between studies, but also limits the extent to which the collection of studies can be used to provide a single body of evidence. Studies, primarily, also report outbreak incidence, rather than sporadic cases, and there is a suggestion that the latter are more likely to occur in the home (Scott, 2003). Thus, the home as a setting for contracting foodborne illness is likely to be underrepresented, further exacerbated as outbreaks are more likely to be followed up.

Most studies do show the home to be a setting for foodborne illness, although the proportion varies widely. The proportion of illness deriving from the home varied between 12-64% and from commercial foodservice from 13–85% (Eves *et al.,* 2017). Data collected within the UK or England and Wales are consistent in attributing more outbreaks to foodservice settings (44-85%) than the home (12-17%) (Eves *et al.,* 2017), but there is recognition that the extent of follow up for commercial premises is likely to be greater, which may skew results. EFSA (2011, 2014, 2015) reported consistent results for foodborne illness arising from the home (between 36-39%), and foodservice establishments (22-26%) (Eves *et al.,* 2017).

3.2.2.1 Expert workshop feedback

Expert responses in this component of the review workshop are summarised in Appendix XX. All attendees agreed that the findings demonstrated that foodborne illness can arise from the domestic setting and it was accepted that food preparation practices in the home are one of a series of control points along the food chain. However, it was recognised that the UK surveillance system(s) were not designed to focus on domestic kitchen practice and findings indicated agreement that there was insufficient evidence arising from the literature to confidently attribute the proportion of foodborne illness to setting. It was not possible to

suggest a measure of the contribution of foodborne illness arising from the domestic setting, although it was clear this setting contributed to the overall disease burden.

3.2.3 Proportion of foodborne disease cases in the home caused by specific pathogens

Research Question: Is it feasible to determine the proportion of foodborne cases caused by specific pathogens?

Research Question: Which pathogens are most likely to lead to foodborne disease through faults in transporting, storing, preparing and handling food for consumption within the home, and in what proportions?

Thirteen studies either broke down the biological source of foodborne illness, or studied specific organisms, most focusing on *Salmonella*. Three studies investigated a range of organisms.

As with more general evaluations of overall incidences of foodborne illness, these studies were not specifically focussed on determination of the relative proportions of illness derived from different settings. The results of studies looking at specific organisms differed widely – both within and between different organisms. Once again, issues with the accuracy of the data include the level to which setting had been followed up, under reporting, recall bias and differing methods of data collection or surveillance systems, making comparisons or consolidation of evidence difficult. In addition, there were small numbers of incidents relating to individual organisms in the case of more general studies. Further issues with the data for individual organisms included that only some organisms are reportable and others not, thus the level of under reporting is likely to vary by organism. Similarly, the severity of the illness varies by organism, with more severe illness more likely to be reported and followed up than mild, self-limiting illnesses (e.g. *S. aureus* or *C. perfringens*).

A number of studies focussed on *S. enteritidis* at a time when there was a high incidence of contamination of eggs in particular, with a number of studies clustered in the late 1990's and early 2000s. It is notable that issues surrounding this organism are now largely resolved

through preventative practices in primary production, and thus evidence from studies investigating this organism is now largely redundant.

3.2.3.1 Expert workshop feedback

Expert responses in this component of the review workshop are summarised in Appendix XXI. Reviewed information from studies was mainly derived from outbreaks, particularly *Salmonella*, with a notable absence of studies indicating *Campylobacter* outbreaks. It was agreed that the data collated from this review was not sufficiently reliable to draw conclusions about the proportion of foodborne disease cases caused by specific pathogens.

3.2.4 Potential for foodborne disease in the home resulting from failure to implement recommended practices

Research Question: What leads to foodborne disease in the home – contamination of 'safe' food (making it 'unsafe', possibly as a result of home practices) and/or transporting /storing /handling /preparation of 'Unsafe foods'? [where safe food is defined as 'food not injurious to health']

Although a number of approaches have been employed to understand domestic practices leading to foodborne disease, most are not based on actual cases of illness, rather self-reports of domestic practices, or investigations in the home to establish potential risks. Two approaches do link illness and practice: direct follow up of incidents (case reports), although rarely reported, and case-control studies.

3.2.4.1 Case reports

Case reports are rare in the academic literature, and generally linked to fatal cases. A review of findings summarising identified case reports is found in Appendix XV. A key issue identified through all case reports is temperature control, either inadequate heating or

reheating, or storage for long periods at ambient temperatures, or in a refrigerator operating at too high a temperature or a combination of these. There is also some question over why someone would think it appropriate to consume perishable food stored at room temperature for five days. The extent to which these behaviours can be generalised as key or causative risk factors for foodborne illness is limited by the reporting of individual cases. A large body of such case reports might allow conclusions to be drawn, but these do not appear to exist in any number, with reported cases covering the 'unusual'.

3.2.4.2 Case-control studies

Case-control studies aim to determine behavioural (or socio-demographic or underlying condition) differences between those who contract illness and those who do not. Most controls were matched on the basis of age, gender and region of residence. Differences in behaviours between groups, however, point only to possible risks, causality is not proven. In addition, sample sizes are often small, and thus the generalisability of the data to populations (either within country or beyond) is limited and cannot be assured. A total of 15 case-control studies that explored foodborne illness met the inclusion criteria. Some looked at gastroenteritis in general, whilst most investigated specific organisms. Such studies are summarised in Appendix XV.

Poultry and raw or undercooked eggs were frequently identified as risk factors (general studies, *Campylobacter* and *Salmonella*), as was undercooked and barbequed meat (*Campylobacter*). Others in the household (children, adults and pets) with diarrhoea or in nappies was noted for general outbreaks, *Salmonella* and *Campylobacter*. Other risk factors included inadequate hand washing and consumption of unpasteurised dairy products. Case-control studies suffer from many of the more general problems associated with identifying causative agents, recalling activities and use of different methodologies. In addition, they can only point to behaviours that are more prevalent amongst cases than controls as potential risk factors, and are constrained by the questioning used. In addition, studies report conflicting results.

3.2.4.3 Expert workshop feedback

Expert responses in this component of the review workshop are summarised in Appendix XXII. Several concerns were raised about the differences in approach and the lack of standard definitions used in papers. This made it difficult to draw overall conclusions, about the potential to increase the risk of foodborne disease through certain practices in the home. Attendees recognised the greater levels of certainty in conclusions drawn from reviewed case reports, because of the study type i.e. case reports link cause(s) to effects.

There was consensus that apart from the paper by Ryan *et al.,* (1996) (an older study) which considered a number of outbreaks involving home catered events, there was no indication of the relative risk of foodborne disease arising from failures to follow recommended good hygiene practice.

Information provided in the reviewed case control studies was a better source of information on risk factors but no direct links to illness were proven. The focus of the papers appeared to be on identifying the foods involved in the outbreaks, it was not clear what specific hypotheses were being tested in relation to handling faults in the domestic setting.

3.2.5 Risk factors attributed to practices and behaviours in the home associated with incidence of foodborne disease in the domestic setting.

Research question: What are the likely causes of foodborne disease deriving in the home, e.g. contamination of food stuffs in the food chain or practices when transporting, storing, preparing and handling food within the home?

Studies evaluating peoples' homes, or actual practices through observation showed the potential for illness, but cannot be used to infer causality. Approaches included microbiological investigations of homes, kitchens and domestic appliances, observational studies of in-home behaviours and surveys or interviews asking about knowledge and behaviour. Studies involving only self-reports of behaviours (n=37) have not been included, as they have no direct link to confirmed practice or illness.

A number of studies have investigated microbiological loads of kitchen sites. Whilst these are not directly related to illness, they do represent the actual situation within homes. Some studies looked at a variety of sites, whilst others focussed on particular risk areas, such as refrigerators. Although appropriate for the type of study, sample sizes are relatively small, and often localised, limiting the extent to which results can be generalised.

3.2.5.1 Domestic refrigerator studies

A summary of reviewed studies relating to domestic refrigerators is found in Appendix XVI. A key result in refrigerator studies is the high proportion of refrigerators operating above 5°C, and that, where investigated, fridges were found to harbour a number of pathogens. Issues around transport of food were highlighted, with extended times needed to return foods to acceptable storage temperatures. Most studies, however, rely on relatively small samples that cannot be generalised to the wider population. They do, however, point to the potential of refrigerators to contribute to the risk of contracting foodborne illness.

3.2.5.2 Microbiological investigations of kitchen sites.

Review findings indicating microbiological investigations of kitchen sites are found in Appendix XVII. Studies suggest that this might lead to conclusions that domestic practices contribute to the risk of contracting foodborne illness, but the small sample sizes limit the extent to which such a generalisation can be made. Studies also show that frequently used cleaning practices may not be adequate to remove contamination – including washing of chopping boards, and that organisms may survive and proliferate on some surfaces. Wiping cloths were also found to be a potential source of contamination, with, again, washing practices often not removing all organisms, and organisms multiplying readily on these. Importantly, studies illustrate the potential of hands to cross contaminate, and for common food cooking regimes to be only marginal in removing pathogens. Also of note is the number of studies identifying contamination of knobs and handles in the kitchen. Although, studies do show that domestic sites may be contaminated, and that cross contamination can occur, including to non-food related sites, sample sizes in such studies are small, limiting their generalisability. In addition, these studies only highlight potential problems, and not that such practices lead to foodborne illness.

3.2.5.3 Observation studies

Sixteen studies observing food-related practices met the inclusion criteria, all were from the academic literature (see Appendix XVII). Studies have highlighted a number of hygiene-related behaviours that might increase the risk of foodborne illness (Appendix XIX), and also the multiple uses of kitchen spaces. Common issues arose around inadequate hand washing practices, and use of contaminated surfaces and utensils. Temperature control issues, whether in storage or during cooking were evident, as were inappropriate storage practices in terms of how foods, particularly ready to eat foods, were stored (e.g. under raw meat). These issues become exacerbated where consumers exceed recommended storage times. Some studies had both observed consumers and sought self-reports of behaviour. In these cases, results arising from the two approaches were not consistent, with self-reports being more optimistic in the application of appropriate behaviours compared to observed behaviours. This highlights the value of observation of behaviours, rather than simply seeking self-reports, which may be influenced by, for instance, recall problems and social desirability bias, albeit that some may alter behaviour as a result of being observed.

3.2.5.4 Expert workshop feedback

Expert responses in this component of the review workshop are summarised in Appendix XXIII. The studies indicating fridge contamination / temperature, microbiological investigations in the home/realistic settings and observation studies provide some useful information on practices in the domestic kitchen. They report considerable failure to follow good hygienic practice with mention of poor hand washing, cross-contamination and some disregard for date labelling. They do not however provide sufficient evidence to prove that foodborne illness will occur because of poor hygienic practices in the home. Nevertheless, they do provide information that will assist in the generation of hypotheses about the incidence of foodborne disease in the domestic setting, which could be tested in future studies. A quantitative risk assessment framework might help in estimating the likely relative importance of a range of issues.

3.2.6 Assessment of the relative likelihood of a 'specific practice' or 'groups of practices' to cause foodborne illness: expert workshop feedback

Expert responses in this component of the review workshop are summarised in Appendix XXIV. There was a general view that often several '*practices*' could be linked to foodborne disease outbreaks i.e. illness resulted from '*a series of unfortunate events'*. However, it was also considered that, sporadic cases of foodborne disease (believed to be more commonly associated with the domestic setting) may result from failure to follow individual recommended practices, rather than a series of events. It was indicated that there is literature on '*necessary, sufficient and component causes'* that might be a useful framework for consideration.

It was also agreed that several variables would impact on the outcome/significance of specific practices including type of food, type of pathogen, dose and consumer vulnerability. As such when seeking to assess the significance of specific practices these factors need to be considered.

Despite caveats/recommendations, at a macro level all expert attendees agreed that the 4 Cs i.e. cooking (proper heat treatment), chilling, cleaning and avoiding cross-contamination (FSA, 2006) described the key groups of hygienic practices necessary to reduce the risk of foodborne disease. It was reiterated that vulnerable groups must be particularly considered.

3.2.7 Proportion of UK foodborne disease caused by faults in transporting, storing, preparing and handling food for consumption within the home: expert workshop feedback

Research question: Considering the findings of the systematic review to what extent can the overall research question - What proportion of UK foodborne disease is caused by faults in transporting, storing, preparing and handling food for consumption within the home? - be answered? If there is insufficient evidence to properly address the main research question, what additional information is available that could assist i.e. other references and sources? And/or: What additional research or actions would be required to properly address the main question?

Whilst workshop discussions raised many caveats about pooling the epidemiological evidence to gain a better view on the proportion of illness arising from the home setting; it was noted that several papers in the systematic review suggest a range of between 10-17% (Eves *et al.* 2017). There was considerable discussion between the expert attendees as to whether this range was realistic. Attendees raised several concerns about determination of a reliable range: sporadic cases are not routinely identified or investigated (and there is a belief that many domestic cases will be sporadic), thus, it is likely that numbers are under estimated but the true extent of this is not known.

The papers included in the systematic review identify and/or suggest a range of failures to follow recommended hygiene practice in the transportation, storing, preparation and handling of food for home consumption. These findings provide a basis for a substantial amount of educational content. They do not however assist greatly in determining the proportion of foodborne disease arising from the home setting.

It was suggested that only a small number of outbreaks in the home would be reported to public health systems and so those recorded were likely to be an underrepresentation of the true position. To get a better estimate of extent of incidence, the mapping of "outbreaks" to burden would require multiplication by cases per outbreak. It would be worth doing this systematically across the dataset where possible. Beyond this further information of value might be generated by the production of semi-quantitative risk assessments, on a pathogen by pathogen basis, from outbreak data.

To properly address the research question, further studies with a clear focus on foodborne illness arising from the home would be required to permit a reasonable estimation of the disease burden from this setting. Any such studies would need to include identification and consideration of sporadic cases linked to domestic food preparation/consumption. The starting point should be descriptive studies to test hypotheses (which might be generated from the findings of the systematic review) and subsequent case control studies, perhaps focused on individual pathogens.

Some concerns were expressed about the ability to design descriptive studies to test hypotheses and it was suggested that further work would be required to test the practicability of such an approach.

It was suggested that information on sporadic cases might be obtained through some form of on-line reporting about patients suffering from gastro-intestinal illness who visited a GP. Investigation into a variety of means of reporting, including the use of social media was recommended.

Expert attendees identified that conducting case control studies might also be problematic as the case may not have been involved in the (suspect) food preparation. Consequently, studies might need to extend to food preparation practices within the household. Such studies would also need to be pathogen specific as questions would have to be fitted to the different vehicles of infection associated with the pathogen being studied. It was also noted that the track record of such studies was not good and as such future studies might benefit from the inclusion of social scientists to collaborate on the design and the need to actually identify where illness originated.

3.3 Theoretical framework

Using findings from the systematic review, the potential links between food activities to the point of consumption have been summarised in a series of theoretical framework diagrams. The generic theoretical framework can be found in Figure 3.1. Pathogen specific theoretical frameworks (*Campylobacter, Salmonella, Listeria, Staphylococcus* and norovirus) can be found in Appendix XXV.

Figure 3.1 Generic theoretical framework for potential influences in the home leading to foodborne disease, based on systematic review and expert workshops (2016).

Food related activities to point of consumption	Action identified in systematic review as possibly linked to hazard	Hazard	Potentially leading to food borne disease as a result of consumption of:	Key
Purchase [a]		Contaminated	Ready to eat food; eaten immediately	→ Literature points to a possible link, but not a proven causal link → Definite link; extended time will increase risk of hazard occurring, represented by heavier line [a] contamination could be exacerbated through prolonged transport out of chill [b] including exceeding use by dates [c] Contamination may also be through dirty cloths [d] infected other relates to another individual in the home with symptoms of food borne disease Highlighted text indicates key hazardous practices
Storage	Inadequate chilling/ extended storage time [b]	Bacterial growth	Ready to eat food or prepared, uncooked, food after further storage	
Preparation	Infected other [d] Inadequate handwashing Inadequate cleaning, including reuse equipment [c]	Contamination/cross contamination	Prepared food, no cooking	
	Pets in household	Contamination/cross contamination		
Cooking	Inadequate cooking – temp/time/both	Survival of pathogens	Cooked food eaten immediately	
Storage after cooking/ service	Inadequate chilling/ Extended storage time [b]	Bacterial growth	Cooked food stored for later use – without reheating	
Reheat/hot holding	Inadequate heating – time/temp/both	Survival of pathogens	Cooked food stored for later use – with reheating	
Serve	Infected other [d] Inadequate handwashing Inadequate cleaning, including reuse equipment [c]	Contamination/cross contamination	Hot or cold food, could be ready to eat, may be subsequently stored for later use	
	Pets in household	Contamination/cross contamination		
	Inadequate chilling/ Extended storage time [b]	Bacterial growth		

4.0 DISCUSSION

4.1 Systematic review: discussion

The review of the literature, whether academic or grey, has identified that the home is a potential setting for contracting foodborne illness. However, it has indicated widely varying estimates of the proportions of foodborne illness arising both from the home and from commercial foodservice settings. For studies within the United Kingdom (including studies of England and Wales), the home has been implicated in between 12-17% of outbreaks (one study did not state a proportion from the home), and food service between 44-85% of outbreaks (Eves *et al.,* 2017). Results for other geographic areas are again variable: for countries within the EU, the home has been implicated in 12-64% of outbreaks, and commercial foodservice settings in 21-85% of outbreaks; in North America (USA and Canada) the home was implicated in 7-46% of outbreaks and commercial foodservice outlets in 40 to 66% of outbreaks (Eves *et al.,* 2017). Of note are data reported by EFSA over three years (2011, 2014, 2015), which are fairly consistent; 36-39% of outbreaks attributed to the home setting, 22-26% to foodservice settings foodservice (Eves *et al.,* 2017).

Differences in attributions of setting reflect a number of factors within studies that can influence results, and particularly the ability to compare between studies (or to treat studies en bloc as evidence). These include different surveillance systems and different agents of illness included, (e.g. bacterial, viral, parasites, poisonous mushrooms and pesticides), sometimes reflecting local dietary practices (high incidence of illness deriving from the home in Italy and Poland were largely linked to the consumption of poisonous mushrooms). In addition, different studies explored different variants of gastrointestinal illness (food poisoning, infectious intestinal disease, foodborne disease, foodborne infection and intoxication, gastrointestinal illness and foodborne illness).

None of the studies had been designed to specifically investigate the setting where foodborne illness originated. Most studies were based on reported, but not always, confirmed cases. However, not all forms of foodborne illness are reportable, and sometimes reporting is not mandatory. In particular, milder forms of foodborne illness are neither reportable nor likely to present to a doctor, and thus are almost certainly underreported and underrepresented.

People are more likely to report more serious illnesses, or those believed to derive from commercial foodservice settings, thus estimates of attribution to food service settings are likely to be exaggerated, and to the home underestimated. Whilst this assertion has been made previously, information collected as a result of this review can neither confirm nor refute it. Adding to the difficulties of ascribing firm estimates of incidence is that the vehicle of infection is often not identified. This may be because of poor recall or lack of information, or failing to identify the organism responsible for illness. Hence, many incidents are unexplained. In addition, many cases are not followed up, or not followed up in a timely fashion, adding to problems of recall bias and difficulties in confirming the source of illness (both food source and organism). Follow up (or lack of) is a particular problem for sporadic cases, with larger outbreaks more likely to be followed up and setting/source identified.

A number of studies investigated multiple agents of illness, and some specific organisms. In terms of *Salmonella*, some studies suggest more cases arising from the home, whilst others suggest more originate in foodservice outlets, although, overall, more studies report higher proportions of salmonellosis originating in foodservice settings. This may, in part, be related to the particular *Salmonella* serovar studied. The most common serovar studied was *S.* Enteritidis, which now is largely controlled through interventions in primary production, but was previously problematic in the foodservice sector owing to the use of raw eggs in a number of popular dishes. Norovirus was also more often linked to food service settings, as was *C. perfringens*, consistent with an organism usually linked to slow cooling of large batches of food. The only very clear attribution to the home was illness following consumption of poisonous mushrooms, but this was unique to countries with a habit of foraging for wild mushrooms (Italy and Poland in this case). These data suffered many of the same concerns discussed above, with agents of illness or setting often not reported or confirmed, recall bias, underreporting, especially for organisms causing mild illnesses, and lack of information. In addition, the extent of follow up differed by organism (probably linked to severity of illness or size of outbreak), when trying to pinpoint cases associated with individual organisms the number of cases could be very small making it difficult to draw conclusions, some studies focussed on specific foodstuffs, rather than all outbreaks attached to an organism, and in a number of studies data were not available for both the home and foodservice settings. An additional problem, if data are to be compared across time, is improved identification of some

organisms and the emergence of new pathogens or new pathogenic strains. As such, it is not possible, with confidence, to attribute percentages of outbreaks linked with particular organisms to setting, or to suggest which organisms are responsible for most foodborne illness arising in the home.

To derive data to allow accurate attribution of illness to setting or organism would require identification of all incidences of foodborne illness, mild and more severe, confirmatory microbiology and prompt follow up to confirm agent of illness and setting. This would be a study akin to the IID studies, but with timely and more detailed follow up, allowing confirmation of source and setting. Significant challenges occur when determining such data, largely due to its collation being based upon patient/consumer recollection of practices and food consumption and cumulative difficulties associated with infection source determination based on a retrospective analysis of events.

Few studies have made a direct link between illness and behaviours leading to illness. Those that have attempted to do this tend to be the unusual cases, for instance a pathogen normally associated with mild illness leading to fatalities. These case reports, where illness has been more rigorously followed up, all point to inappropriate temperature control as the key reason that illness arose, including prolonged storage at ambient temperatures, prolonged storage in a refrigerator operating at high temperature, and not heating/reheating the food to temperatures high enough to destroy pathogens. This is not withstanding that the food was at some point contaminated. Only one case report confirmed the source of the pathogen (in this case a reptile). In most case reports there was not enough detail to fully confirm the behaviours leading to illness, either because insufficient data were presented or because only anecdotal reports were cited. It must be remembered, however, that the causality sought in these reports is more often the organism leading to illness, rather than the vehicle or setting of infection. A further issue with case reports is their reliance on single incidents, thus a large number would be needed to draw firm conclusions about the generalizability of behaviours leading to illness, and these do not appear to exist.

All other studies highlight risk factors for illness, but do not prove causality. In addition, sample sizes are generally small, limiting the generalizability of the data. Case-control studies seek behaviours that differ between those with and without illness, but cannot confirm which of the identified risk factors (if any) lead to illness. Risk factors for gastroenteritis were

consumption of beef, handling raw poultry, contact with animals or nappies and incontinence pads, eating at a restaurant and keeping food at ambient temperature. Risks associated with salmonellosis included eating raw/undercooked eggs, handling raw and eating ready-to-eat chicken, poor hand hygiene, and reptiles, or contact with nappies and incontinence pads or someone with diarrhoea in the home. Risks for campylobacteriosis included eating barbequed meat or poultry, consumption of unpasteurised milk or undercooked poultry, poor hand hygiene and less thorough cleaning. There were, however, some contradictory results, e.g. whether occupational exposure to raw milk was a risk or protective factor. Experiencing food poisoning made people perceive themselves to be more vulnerable to food poisoning, although we do not know how long this perception is sustained for. As above, a variety of factors limit the value of these studies. For the cases, the same issues previously discussed again restrict the reliability of the data. Additional issues include studies on restricted groups, questioning that did not probe deeply into practices, for instance asking about consumption of a food, but not how it was prepared, stored, cooked, and the extent to which controls matched cases in characteristics beyond age, gender and place of residence.

Two types of study evidence potential sources of cross contamination and behaviours that may increase the risk of foodborne illness arising in the home, microbiological studies of domestic sites and observation studies. Studies of domestic sites, e.g. refrigerators, boards and utensils, give an indication of which of these harbours most pathogens, and therefore may pose the greatest risk. Observation studies, report behaviours that might increase the risk of foodborne illness. Neither, however, proves cause as these studies were not linked to illness, and again sample sizes and limited geographical spread in data collection, mean results cannot be generalised.

Key findings from studies of refrigerators are the large proportion of domestic appliances operating above 5°C, with some operating at temperature well above this. Refrigerators were also found to harbour pathogens suggesting inadequate fridge management. Studies of kitchen sites, including studies where artificially inoculated food was prepared with utensils, showed how areas of the kitchen (and food) could become contaminated as a result of food preparation practices. Key areas becoming contaminated by pathogens or indicator organisms included taps, knobs and handles touched with contaminated hands as a result of no, or

inadequate washing. Dish cloths were also identified as a potential source of contamination, and commonly used decontamination practices did not eliminate harboured pathogens.

The majority of observation studies did not seek to confirm that observed practice lead to contamination. Studies identified how food and risks to food safety were not unique to the kitchen area, and how areas where foods were prepared were also used for non-food related activities, which highlights the many potential routes of contamination. A key behaviour that may increase the risk of foodborne illness was inadequate hand washing practice, whether this was not washing the hands at all, not using soap or not washing hands for the recommended 20 seconds. Inadequate hand washing practice was observed in people failing to wash their hands appropriately prior to food preparation and/or during food preparation (after touching faces, blowing nose, handling raw meat). A similar pattern was seen in the use of chopping boards. Other key issues that may increase the risk of foodborne illness were inadequate storage practice, whether related to positioning of raw and cooked foods in the refrigerator or storing high risk foods at ambient temperature, and inadequate cooking practices such as not preheating the oven or using unreliable methods to check if foods were adequately cooked. Foods were also stored beyond use by dates, with consumers using their own judgement as to whether food was still safe to eat. Where both self-reports of behaviour were also collected, these tended to contradict observed behaviours, the former being more optimistic in correct application of appropriate hygiene-related behaviours. This highlights the value of observing behaviour in real or realistic settings to understand what it is that consumers do that has the potential to increase their risk of contracting foodborne illness, although altering behaviour owing to being observed remains a limitation.

4.2 Discussion: expert workshop

All expert attendees believed that the workshop had highlighted the complexities of identifying setting and causation in relation to foodborne disease through published papers. They agreed that the work had produced useful information that would be of considerable value in seeking answers to the research questions.

There was no easy answer to the main research question although it was clear that poor hygienic practices in the domestic setting will contribute to the foodborne disease burden.

The studies included in the systematic review varied considerably in approach, focus, study basis, definitions, surveillance systems, country norms, behaviours and context; all of which meant that it was extremely problematic to combine them to reach properly evidence based conclusions about the UK situation.

The papers assessed were generally based on outbreak data, which expert attendees believed presented only a partial picture of foodborne illness arising from the home. A mechanism to generate data on sporadic cases would add value to any future studies, but this would require a specific approach as surveillance systems are generally focused on outbreaks.

The systematic review has however produced valuable information that could be used to generate hypotheses for future, properly focused research. Any further research, to properly answer the question, would need to be in 2 parts i.e. firstly a descriptive study to test hypotheses and secondly subsequent case control studies, probably focused on individual pathogens.

In finalising the systematic review, it was identified that use of appropriate language would be important. The language used should recognise that domestic practices may be habitual and not intentional.

4.3 Methodological challenges and limitations

Given the sanctity of the home, and the difficulty of securing access even in the most extreme circumstances, much of the current discussion/literature regarding domestic kitchen hygiene behaviour and its links to foodborne illness is anecdotal. However, there is evidence to be drawn from experimental research in which people are observed performing food handling tasks in naturalistic settings. These will be explored through the published literature.

One of the challenges will be to find literature that distinguishes foodborne illness cases arising in the home from those contracted from food consumed outside of the home. The cases that are normally investigated are associated with outbreaks, where the origin of the problem is, perhaps, more easily pinpointed through common factors amongst cases. Outbreaks originating in commercial settings are also more likely to be reported because they are investigated, and thus are represented in official statistics. It is probable that many sporadic cases resulting from poor practice in the home will be amongst the proportion of

cases that do not cause the patient to consult their GP and so result in no purposeful investigation (Day, 2001). However, such cases may also be part of wider outbreaks where the origin of the problem is not the home.

A number of limitations in the studies determination of incidence of foodborne disease, including under reporting, lack of information and recall bias, and few outbreaks/cases having confirmatory microbiology, large proportions of outbreaks/cases with no path of infection identified, and not all types of illness being reportable. Thus, how accurately the studies represent the true situation is questionable.

A key limitation of case studies identified is that these usually relate to single cases, and thus the generalisability of reported behaviours that might have led to foodborne illness is questionable. In addition, the attributed cause is based on recall of cases and/or those they live with, and thus may be inaccurate.

With regards to microbiological investigations of the kitchen, studies do show that domestic sites may be contaminated and that cross contamination can occur, including to non-food related sites, however, sample sizes in such studies are small which, limits the generalizability.

Studies evaluating peoples' homes, or actual practices through observation show the potential for illness, but cannot be used to infer causality. In many cases, sample sizes are also relatively small, limiting the generalisability of the outcomes.

When considering observation studies in this systematic review, it is noted that sample sizes are small, which whilst not uncommon for such in-depth approaches, does limit their generalisability. A common limitation of observations is social desirability bias, whereby those observed match their behaviour to that which they think is expected. Careful study design, including observing over longer periods, can minimise this effect. In addition, the effect of such biases can be minimised and reliability of data determined using reliability, repeatability and reproducibility analyses (Redmond, 2002; Redmond *et al.* 2000).

5.0 CONCLUSIONS

Results show a complicated picture for attribution of foodborne incidence to the domestic setting, with variable results and many caveats around lack of information, inability to confirm organism, investigation of different agents, differing surveillance systems and levels of reporting by setting, and the use largely of reported cases. To confirm with any certainty the proportions of foodborne illness deriving from different settings is therefore difficult, although most studies suggest the highest proportion of foodborne illness to derive from commercial food service settings.

Risk factors for contracting foodborne illness included inadequate temperature control in both storage (often prolonged) and cooking/reheating, handling raw meat/poultry, consumption of under cooked meat/poultry/eggs, consumption of barbequed meat/poultry, consumption of unpasteurised dairy products, inappropriate hygiene-related behaviours, contact with animals or nappies and incontinence pads, inadequate hand washing leading to contamination of many sites, and inadequate sanitation of boards/knives. However, only temperature control was linked directly to actual cases of illness, and the number of such reported cases was very small.

To fully understand the extent and causes of food poisoning deriving from the home will require a comprehensive study of foodborne illness, with timely and extensive follow up to enable attribution of illness to the home setting and identification of vehicles and practices that increase the risk of contracting foodborne illness.

FURTHER RESEARCH

- Further research, focused on the domestic setting and including identification and investigation of sporadic cases would be required to properly estimate the proportion of foodborne illness arising from the home. Such research might include prevalence surveys e.g. following up all reported *Salmonella* cases in a defined population. A framework to categorise cases as domestic or non-domestic would be required to produce reproducible data. Alternatively, research projects using social scientists, epidemiologists and modelers might assist in developing an estimate.
- To determine and quantify microbiological risks and actual behavioural risk factors implemented by persons who have experienced foodborne disease it is suggested that further research is undertaken in a model kitchen environment. The limitations of this approach have been previously reported (Redmond and Griffith, 2003b), however, UK studies (Redmond, 2002; Redmond et al. 2000) have undertaken behavioural reliability, repeatability and reproducibility studies and concluded that specific food safety behaviours of relevance maybe habitual and thus reliability ascertained in a model domestic environment. Linking microbiological contamination from prepared foods and food and hand contact surfaces in a model kitchen enables ascertainment of actual risk based data.
- Currently there is no framework nor resources to collate microbiological, behavioural or data indicating cognitive influences from persons who have foodborne disease in the UK. Further research is needed to pilot and ascertain the feasibility and reliability of collation of this information from individuals who have experienced incidence of foodborne disease. It is suggested that a generic, online, self-complete questionnaire is designed and distributed to cases.
- In future research into domestic hygiene, it is suggested that there should be consideration of a range of factors that could influence behaviours such as socio-economic differences and demographics. The 'Food and You' studies may well help in the selection of relevant factors.
- The wider use of Whole Genome Sequencing (WGS) might allow identification of more domestic origin outbreaks. However, to provide useful information about the importance

of specific good hygiene practices, WGS work would need to be supported by field epidemiology investigations.

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