

Kitchen Life 2: Literature Review

Area of research interest: [Research projects](#)

Project status: Completed

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Date published: 21 February 2022

DOI: <https://doi.org/10.46756/sci.fsa.wom249>

Acknowledgements:

The authors thank the Advisory Group Members of the Kitchen Life-2 project (the names are listed below) for their insightful comments on the first draft of the report, Alice Rayner for her guidance throughout the preparation of the report, and Mel Cohen for her help regarding the expert interviews.

Advisory Group Members: Julie Barnett, Baruch Fischhoff, Lynn Frewer, Julie Hill, Alec Kryakides, Susan Michie, Michelle Patel, Anthony Wilson, Hannah Lambie-Mumford and Kerrie Unsworth.

Preface

The aim of the Kitchen Life 2 project is to identify the key behaviours relating to food safety that occur in domestic and business kitchens, as well as the factors that may reduce the likelihood to enact recommended food safety and hygiene behaviours. The outcomes will inform risk assessment and development of hypotheses for behavioural interventions. The goal of this literature review was to ensure that the research design and fieldwork techniques identify existing key behaviours, actors, triggers and barriers in domestic and business kitchens to develop successful behavioural interventions and risk assessment models. Additionally, we have included the impacts of Covid-19 pandemic and national lockdowns on food safety practices in domestic and business kitchens. This addition is important because FSA policy response to the pandemic should address the needs of both consumers and food businesses due to reduced ability to deliver inspection and enforcement activities, business diversification (for example, shifting to online delivery and takeaway), increasing food insecurity, and change in food consumption behaviours (for example, cooking from scratch) (FSA, 2020).

Structure of the literature review

As the bulk of literature exists pre-Covid 19 pandemic, the main review focuses on pre-covid research. Firstly, we take a psychological perspective towards food safety and hygiene, by addressing cognitive and affective influences with respect to individuals' risk perceptions. We also discuss the role of perceived trust in institutions and the supply chain, and how it is related to food safety behaviours. Understanding lay risk perceptions and attitudes is vital to unveil important gaps and inaccuracies in one's food safety knowledge, the sources of these gaps, and how they may impact the enactment of more health-effacing behaviours. Next, we focus on overt kitchen behaviours at households and businesses. These behaviours include cleaning/hygiene, behaviours that may promote cross-contamination, cooking, refrigeration, adherence to use-by dates, and demographic factors that may be especially important for food safety/hygiene

behaviours. Then, we present a summary of key findings, applicable to both domestic and business kitchens. We conclude with a report on the emerging literature regarding kitchen behaviours, and subsequent behavioural change, due to the Covid-19 pandemic.

Methodology

A narrative literature review was carried out, with inspiration taken from systematic reviews with regards to providing structure in acquiring a suitable sample of articles (Rowley and Slack, 2004). For the purpose of the literature review, the following keywords were used as search terms: “Food safety”, “kitchen safety”, “Kitchen behaviour” “food hygiene”, “kitchen hygiene”, “foodborne illness”, and, with additional search terms “risk behaviour”, “risk perceptions,” and “Covid*”. The asterisk search wild card is commonly used in database searches to specify any number of characters beyond a root, allowing for the retrieval of variable endings of a root word. Using the defined keywords, a search was conducted in the database Scopus and Web of Science, two popular, comprehensive literature databases (Guz and Rushchitsky, 2009; Aghaei Chadegani et al., 2013) using the “title, abstract, keywords” function. The date range was set to 2013 to 2021. The search was also refined to peer-reviewed empirical and review articles only, and excluded book chapters, dissertations, etc. Cited reference searches using Google Scholar were conducted on especially relevant articles, in order to identify other empirical and review papers that were not captured by the keyword searches. Further filtering was carried out to assess the suitability of the articles for inclusion in the literature review. For instance, articles that included technical food risk assessments, or highly specialised topics irrelevant to the current enquiry were excluded from the literature review. Additionally, we only retained articles with a sample from the UK, Europe, and North America.

Due to a limited number of relevant research papers published during the Covid-19 pandemic, we supplemented our literature search by conducting in-depth interviews with seven experts working on food safety and related areas, to learn from their work and research-related knowledge and experiences during the pandemic. Two of the expert participants were academics, whereas two others were practitioners working at the FSA. One participant was an academic with an additional post at the FSA, whereas the other one was a practitioner with an additional post at the FSA. All of the participants had extensive experience with Covid-related research and/or practice on food safety behaviours in kitchens. The interview procedure was as follows:

Interview participants gave informed consent prior to inclusion in the study. We conducted the interviews over Zoom and Microsoft Teams. The interviews took 45-60 minutes. As a thank you and appropriate recompense for their time, each participant was informed that they would be provided with an Executive Summary report detailing the findings of the Literature Review.

The interviews started with a general question asking participants in what ways behaviour in domestic/business kitchens has changed during the pandemic compared to pre-pandemic, based on the work/research they have done and/or been aware of in terms of both published and unpublished work (for example, reports, presentations). This question was followed with probes about behaviour change in relation to cleaning, cooking, cross-contamination, storage, and use-by dates. The interviews were digitally recorded and transcribed to feed into the literature review.

Psychological perspectives on food safety risks: cognitive and affective influences

To build a kitchen food safety culture, one must understand the interplay between cognitive and affective processes in the perception of risk well enough to design effective interventions.

Information utilized in decision making appears to be processed using two different modes of thinking: deliberative and affective/experiential (Chaiken & Trope, 1999; Epstein, 1994; Loewenstein, Weber, Hsee, & Welch, 2001; Reyna & Brainerd, 1991; Sloman, 1996). The two

modes appear to be interdependent but separable (for example, Epstein, 1994; Petty & Wegener, 1999; Zajonc, 1980; see Forgas, 1995 for an alternative classification). Both modes of thinking are important and good choices are facilitated when affective and deliberative modes work in concert and decision-makers think as well as feel their way through judgments and decisions (Damasio, 1994).

In this model, the deliberative mode is conscious, analytical, reason-based, and relatively slow. In order to deliberate accurately in decisions involving numbers, the decision maker must have the ability, motivation, and capacity to process information accurately. In contrast, the experiential mode of thinking is intuitive, automatic, associative, and fast. The experiential mode is based on the production of images and the affect, or emotional feelings, attached to those images. One of the primary functions of affect is to highlight information important enough to warrant further consideration. It also provides both meaning and motivation to choice processes (Damasio, 1994; Osgood, Suci, & Tannenbaum, 1957).

Affect influences whether or not individuals construe a situation as an important problem. Slovic et al. (1982) proposed that a risk needs to be considered in light of two domains: “unknown risks” and “dread risk.” Unknown risks refer to one’s ability to avoid a hazard, whereas dread risk focuses on the emotional impact of a risk, including the severity of a risk’s realized consequences and the immediacy of a risk’s impact. Typically, hazards that are unfamiliar and possess a high degree of dread are typically seen as most dangerous. In contrast, kitchen hygiene and food preparation routines are well-known, habitual, and decision-making often involves applying heuristics (for example, relying on sensory information to assess “doneness” or “safe to eat”; Wills et al., 2013). Because of these automatic, frequent behaviours, individuals may find difficulties in accurately reflecting on kitchen safety behaviours and food hygiene (Kendall et al., 2016; Wills et al. 2011; O’Connell, 2012; Wills, 2012). For example, people may not be aware of how often they wash their hands or why they change their tea towel and these actions may or may not be related to ‘food safety’ when understood from their perspective.

Further, it is important to note that the modern kitchen is not a space exclusively dedicated to food work, which may increase the likelihood of bacterial contamination. For instance, it is a space that includes other activities such as (but not limited to) homework, laundry, household repairs, storage, musical instrument practice, and interacting with household pets (Wills et al., 2013; 2015). Additionally, social encounters with others, both household members and others (for example, carers, cleaners, relatives), often take place in the kitchen (Dickinson et al., 2014; Wills et al., 2015). Further, pet owners, who view their animals as important family members, allow the pets in the kitchen. Many do not see their encounters with animals as pathways to illness, often didn’t wash hands after petting an animal. Moreover, sometimes pet bowls intermingle with surfaces and dishes (Wills et al., 2015).

When asked about food concerns, contamination and food safety and hygiene are often not spontaneously mentioned (FSA, 2018). Indeed, many consumers do not perceive the home kitchen as a risky place with respect to foodborne illness (Byrd-Bredbenner et al., 2013). Engaging in safe food preparation practices may be considered as too difficult or otherwise costly or inconvenient as the risks of public health problems linked to microbial contamination of food are perceived to be low (Bearth et al., 2014; Fischer et al., 2007; Kaptan et al., 2018). If individuals do not perceive food risks as being worthy of attention, then they may not be motivated to either change their current practices or seek out information that would narrow, or correct, any knowledge gaps. Bearth et al (2014) reported that respondents stressed the difficulties of overcoming bad habits during food preparation, such as using the same chopping board for raw poultry and vegetables, because “they have always done it this way.” Similarly, other noted barriers to behavioural change, such as laziness, time pressure, and inconvenience, may be attributed partially to the lack of attention paid to food hygiene risks (Young & Waddell, 2016). Thus, even though risk perceptions are found to correlate with more frequent handwashing and risk-mitigating cross-contamination behaviours (Evans et al., 2020), risk perceptions for food

safety and hygiene risks tend to be low.

Optimistic biases and overconfidence

Since the experiential system processes information in the “here and now”, people may find it difficult to fully comprehend cumulative risk, the concept that the likelihood of harm occurring increases the more the activity is repeated. Put differently, with repeated exposure to a hazard, risk accumulates over time. Thus, recall from past experience may lead individuals astray. Familiarity with a risk can lead to risk normalization (Zwick & Renn, 2002). That is, we become so accustomed to the lack of negative consequences associated with an activity that we come to accept it posing less of a threat.

Risk normalization can lead to optimistic biases and overconfidence in one’s abilities to mitigate risks. Millman et al. (2015) not only found that individuals rated the risks of an average person getting food poisoning to be greater than the risks posed to oneself, but also felt that they themselves possessed more knowledge about food risks and perceived greater control over food risks. Individuals may also fail to perceive fully that they or their families are susceptible to food-borne illness, and tend to believe that their risks are lower than others (Byrd-Bredbenner et al., 2013). Optimistic bias (i.e., people do not perceive they are personally vulnerable to a specific food risk) appears to militate against the adoption of safe domestic food hygiene practices associated with the prevention of foodborne illness (Kaptan et al., 2018). This optimism could lead to overconfidence in what could be interpreted as following “common sense” logic to food hygiene (Meah., 2014). Tiozzo et al. (2017) reported a level of high level of self-confidence in one’s ability to determine the “freshness” of goods purchased at the supermarket. No one specifically referred to any dangerous practices that they did at their home. These behaviours have the potential to be reinforced, with the belief that because one has “always done it this way,” there is little reason to change.

Trust

Individuals may believe that food safety rests on the supplier side and with government regulations, rather than personal responsibility. Several studies have suggested that contamination primarily occurs before food reaches their own kitchen (Young & Waddell, 2016). In the most recent FSA Food and You 2 survey (F&Y2 ; FSA, 2021a) reports high confidence in farmers to ensure food is safe to eat (90%), but less for manufacturers, slaughterhouses, and dairies (80 to 82%), and low confidence for take-aways and food delivery services (39 to 51%). Overall, consumers appear to be confident in restaurants’ ability to ensure food is safe (74%). However, this survey also reported that 74% of individuals believed that restaurants should pay more attention to food hygiene. With findings such as these, it is not surprising that the public tends to overwhelmingly support food hygiene grading programs for restaurants (Wong et. al., 2015). Further, 75% reported trusting in the FSA to ensure that food is safe and accurately labelled.

However, trust and confidence have the potential to lead individual consumers to overestimate the ability and authority of the FSA, which may subsequently result in lax adherence to personal food safety practices in their homes. Similarly, if the perception of responsibility for food safety rests on external sources, such as government and industry, rather than on the individual, it may be a barrier to adopting safer kitchen practices. In a meta-analytic review, Nardi et al. (2020) found that greater trust in the government and supply chain was associated with lower food safety risk perceptions. Trust in manufacturing, or lack thereof, may result in behaviours that aim to reduce risks, but may not be effective (Dickinson et al., 2014). Distrust in poultry manufacturing process may indeed be perceived as a barrier to adopting the practice of not washing chicken (Vatral & Quinlan, 2021). In the F&Y2 survey (FSA, 2021a), 74% of respondents believed that they were unlikely to get food poisoning from food prepared in the home kitchen. In contrast, 42%

believed that frequently eating from restaurants puts one at greater risk for foodborne illness. Antonise-Kamp et al. (2018) found that only 33% believed that it was riskier to eat at home than dine out; yet 30% reported unsafe food handling behaviours themselves.

Additionally, there may be a tendency to psychologically tie food-based safety risks to perceptions of “quality.” For instance, Bearth et al. (2014) found that poultry labelled as ‘organic’ were perceived to be safer than conventional or foreign poultry. Maughan et al. (2016) reported that 65% of respondents believed that organic chicken was safer than conventional chicken. Public concern about risks may centre around issues related to chemicals, pesticides, and technological risks (Nardi et al., 2020), rather than microbiological contamination risks (Miles et al., 2004). Additionally, such perceptions may be derived from evaluations of the source of the food (bought closer equals more quality), “freshness”, a lower degree of handling between producer and consumer, and the degree of food processing (Bearth et al., 2014; Tiozzo et al., 2017). With respect to provenance, 58% of respondents in the F&Y2 study (FSA, 2021a) reported that they were ‘very’ or ‘quite sure’ that UK & Ireland produced foods had been prepared to the highest standards. In comparison, only 24% of individuals felt the same levels of surety for foods that were produced abroad.

Knowledge-behaviour gaps

Possessing accurate knowledge about food hygiene and safety, consistent with guidelines set forth by governmental agencies (for example, FSA, US Food and Drug Administration, etc.), has the potential to lead to greater enactment of health-effacing behaviours. For instance, Ali et al. (2014) found that better food risk knowledge was positively correlated with washing hands, which subsequently was associated with a reduced incidence of foodborne illness. However, Tache and Carpenter (2014) report that although people are often well-informed that cross contamination is a major cause of foodborne illness, and of the importance of cooking in its prevention, this knowledge did not necessarily translate into behaviour (see also Young & Waddell, 2016).

Foodborne illnesses in the UK amount to 2.4 million cases/year (FSA, 2020). In the most recent F&Y2 survey (FSA 2021a), around half (47%) of respondents reported that they had experienced food poisoning at some time in their lives, with 16% of adults said they had food poisoning within the last year. It is believed that many who experience food poisoning do not go to the doctor, as many cases are mild. People tend to not attribute flu-like symptoms to food, and only about 10% believe that it was likely that a foodborne illness could occur in the home (Byrd-Bredbenner et al., 2013). For instance, Millman et al. (2015) reported that 26% of their sample reported having had food poisoning in the last five years, yet, but only 20% of those individuals had sought treatment, and fewer received laboratory confirmation.

Both understanding the severity of risks associated with foodborne illness and personal experience with food poisoning may have some effects for improving food hygiene behaviours, but not all. Bearth et al. (2014) found that individuals who perceived greater risk severity with foodborne illness, stated safer behaviours to mitigate cross-contamination. Similarly, Millman et al. (2014) found significant differences between those who have had Campylobacteriosis and those with no known history of food poisoning for using separate chopping boards, using meat by its “use by” date, and following manufacturers’ instructions for cooking. However, microbiological analyses of swab locations (chopping boards, refrigerators, and sink) showed no significant differences between the groups, suggesting that improvements in food hygiene still may be needed.

Often, individuals possess a perfunctory view of risks. They may understand that something is “risky,” but their knowledge is incomplete, leading them to enact risky behaviours. For instance, Wills et al. (2015) noted apparent inconsistencies between knowledge and behaviour (c.f., Nesbitt et al., 2014). For instance, individuals may try to eliminate one risk (suggesting that they acknowledge food-based risks, but fail to enact other risk-reducing behaviours (Dickinson et al.,

2014). Similarly, individuals might possess varying levels of concerns about different food products such as meat and fish vs. fruits and vegetables (Ammann et al., 2019; Sternisa et al., 2018), or may not recognize the presence of a food hazard inside another food product, as the case with consuming raw cookie dough, which contains raw eggs (Byrd-Bredbenner et al., 2013). To illustrate this latter point, Kosa et al. (2015b) found that although 92% of respondents reported not eating raw eggs or foods with undercooked eggs within the last 12 months, 25% reported eating raw homemade cookie dough or cake batter.

In a study of food safety knowledge and behaviours of parents with young children, Meysenberg et al. (2014) found that 76% knew that a child is more likely than an adult to become ill from eating raw or undercooked hamburger and signifies that one cause of foodborne illness is known. However, almost 14% of parents did not know that *E. coli* from undercooked meat can be deadly.

In a sample of older adults, Evans and Redmond (2016a) found that a majority of individuals could name *Salmonella* (62%) as a foodborne illness pathogen, only 20% named *Listeria monocytogenes* or Listeriosis. Subsequently, 55% of this sample were unable to identify any food product associated with *Listeria monocytogenes*. In another study in Ireland, Moreb et al. (2017) reported that 30% of individuals did not know any ways to prevent salmonella. Murray et al. (2017) found that whilst the majority of respondents reported hearing about the risks of foodborne illness associated with chicken (86%) and hamburger (81%), less than 40% reported hearing about the risks associated with soft unpasteurized cheeses, alfalfa sprouts, unpasteurized juice, and frozen chicken nuggets. In a review, Thaivalappil et al. (2020) found that knowledge gaps exist older adults' awareness of *Listeria* (median equals 40%; range equals 33 to 58%; n equals 5 studies).

Individuals also may hold faulty risk knowledge, such as the believe that washing raw poultry to clean it from blood and slime reduces contamination, , but in fact, may spread harmful bacteria like *Campylobacter*. Vatal and Quinlan (2021) reported that some consumers who wash raw poultry did not believe that they cross-contaminate when washing raw poultry because they “do not splash.” Additionally, Feng and Bruhn (2019) reported substantial gaps between acknowledging that using a food thermometer is the best way to tell when meat has been cooked thoroughly; however, when observed, less than 10% of consumers used a thermometer when cooking meat. Individuals also may rely on experiential, but incorrect folk knowledge. Stanovich et al. (2016) refers these erroneous beliefs as “contaminated mindware” that can inhibit rational thought and action. Meah (2014) reported some themes of erroneous reasoning in older adults. Sentiments such as “hygiene was not really present as we know it now, but we didn't get sick so easily...thus, one's immune systems 'got used to' microbiological hazards back then” illustrate this point.

Knowledge gaps and inaccuracies also can be observed in business kitchens. For instance, Brown et al. (2013) asked managers which two pathogens among *Salmonella*, *Campylobacter*, *Staphylococcus aureus*, and *Escherichia coli* were most likely to contaminate their kitchens during raw chicken preparation. Whereas most managers could name *Salmonella* (86.4%), only 15% provided *Campylobacter* as a response. In a study of Turkish business food handlers, only 44% of the food handlers surveyed answered all of the kitchen safety knowledge questions correctly (Ercan & Kiziltan, 2014). In a study of high school kitchens, Illés et al. (2018) found that cleaning and sanitizing (71%) was one of the most deficient areas (both the knowledge about the water temperatures during washing and rinsing were deficient). Further, food handlers in this study demonstrated insufficient attention to the drying of food preparation utensils.

Sources of information about food safety

These knowledge gaps may, in part, be traced back to one's sources of food safety knowledge. According to the F&Y2 survey (FSA, 2021a), the most common sources of information about how to prepare and cook food safely were family and friends (46%), product packaging (36%) and food TV shows and cooking programmes (30%). In general, the proportions of young people aged

between 16 and 24 citing these sources were higher than for other age groups, notably on family and friends (66%), and internet search engines (45%, compared with 28% of respondents in general; see also Maughan et al. 2016). Around a fifth (22%) of respondents said that they do not look for information on how to prepare and cook food safely at home. This was much higher among those aged 75 and over (42%, compared with 26% or less in other age groups). Most have not had a food safety course, as consumer studies and home economic courses have been reduced in schools. However, incidentally, many UK residents support the inclusion of cooking classes in the national curriculum; FSA, 2021a). Professional food handlers may also not take food safety courses. Gruenfeldova et al. (2019) found, in a study of food handlers in Ireland, that 28% of all respondents claimed 'never' to have received food safety training, suggesting insufficient compliance with legislative requirements. Children and young adults have limited experience in preparation and cooking best practices (Byrd-Bredbenner et al., 2013). Lange et al. (2018) found that adolescents most frequently reported obtaining knowledge from the media (i.e. television or the internet). Television programmes fronted by celebrity chefs are popular among younger people who often have a positive impression of the chefs and watched the shows for entertainment. Yet, unsafe food handling was often seen, and poor food handling actions were significantly more common than good, often in relation to not washing hands, fruits and vegetables, or not separating raw food from cooked, which could not be blamed on the lack of time (see also Geppert et al., 2019).

Tiozzo et al (2017) found that people reported also getting their info about food safety from TV and magazines, with some blaming mass media for amplifying food risk issues. Unless a large scale recall of a product, isolated incidents of foodborne illnesses tend not to receive much media attention. As a result, they are not the focus of acute risk communication and information, although the consequences for affected individuals can be as severe as those who were infected during an outbreak. This insight is important because mainstream media and food professionals seldom serve as models for food safety behaviours, and often do not draw attention to them, or in some cases, even ignore.

Kitchen Safety and Hygiene Behaviours

Though the kitchen is an important dynamic space (Wills et al., 2015), it is also one which also presents hygiene-related risks. Azvedo et al. (2014) reported a microbiological analysis in 15 homes, and found 13 isolates of *E. coli*, with surfaces and utensils most heavily contaminated. High counts of *E. coli* (>103 CFU/swab) were detected in toilets, kitchen faucets and counters, knobs, buttons, handles, and on pets. In another study, *Listeria* spp. were isolated from 7% of domestic kitchens under evaluation (Evans & Redmond, 2019).

The FSA (2018) has recommendations for cleaning the kitchen to minimize risk for foodborne illnesses. However, many households do not follow the recommended guidelines. In fact, "cleanliness" may be viewed as a separable construct from hygiene, which may help to explain this gap (Wills et al., 2015). That is, households may adopt an idiographic standard for cleanliness, which represents their household's own standards, and deviates from recommended hygiene standards. (FSA, 2018).

We structure the next section of the literature review into main themes of the food safety and hygiene literature: Cleaning behaviours, cross-contamination, cooking behaviours, chilling and defrosting behaviours, and the adherence to use-by dates.

Cleaning Behaviours

Cleaning is an essential part of personal and kitchen hygiene. Effective cleaning removes bacteria on hands, equipment, and surfaces. This helps to stop harmful bacteria and viruses from spreading onto food. Similarly cleaning fruits and vegetables by washing and/or peeling removes

harmful bacteria from the outside. This section first presents the literature review on cleaning behaviours in domestic kitchens, and then continues with cleaning behaviours in business kitchens.

Domestic kitchens

Hand washing

Individuals typically acknowledge that hand washing is an important behaviour to protect against foodborne illness. Though they may be aware of the proper techniques, or self-report doing so (Meysenburg et al. 2014; Moreb et al., 2017; Nesbitt et al., 2014), people do not follow guidelines consistently, or correctly (Byrd-Bedbrenner et al., 2013). Further, a great deal of variability between self-report and observational studies exists, suggesting that the true rates of these behaviours are over-estimated in self-report studies (Thaivalappil et al., 2020). For instance, Murray et al. (2017) reported that 93% of respondents reported washing their hands with soap and water or using hand sanitizer after handling meat. However, in other studies, many report insufficient, or absence of, hand-washing when storing or preparing foods. In an observational study, Maughan et al. (2016) found that many subjects simply rinsed their hands after touching raw poultry and egg items, or did not wash them at all, choosing instead to simply wipe them on a paper towel. Handwashing after touching eggs was especially low in frequency, as many do not consider egg shells to be a food safety risk (Maughan et al., 2016). Kosa et al (2015b) found that, after cracking eggs, 48.1% of respondents washed their hands with soap and water.

During a food storage task in a test kitchen, Masson et al. (2017) found that 0 of 20 participants washed their hands prior to be asked to store food in a refrigerator. The degree to which individuals wash their hands appropriately is also variable. Evans and Redmond (2018) found that a majority (93%) of older adults in their study did not adequately wash their hands on one or more occasion over the course of the study. Further, they found that nearly 2/3 of the sample failed to rub their hands and palms, and clean between their fingers, and nearly half failed to use soap on one or more occasion. Ammann et al. (2019) found that only 53% of participants reported that they always or almost always used soap when washing their hands during cooking. Hand drying is as important as hand washing, as moisture can help to transfer bacteria (Tache & Carpenter, 2014). Sternisa et al (2018) found that more of the respondents reported using paper towels (58.7%) during poultry meat preparation than dishcloths (45.9%), but some reported using both. It should be noted, though, little direct evidence exists regarding the actual frequency of hand-washing/drying, along with the duration for which people do it, and more observational data, for longer periods, are needed.

Washing hands during preparation is also important for reducing cross-contamination. Jevšnik et al. (2013) observed that before and during food preparation, individuals often did not wash hands sufficiently, or at all, when transitioning between tasks. When asked to view video footage of food preparation (of a chicken salad) that included numerous food risk behaviours, Millman et al. (2015) found that 84% of participants were able to identify the actor not washing their hands after handling raw chicken, but only half of the sample identified that the actor touched a radio before washing hands as a risk. Evans and Redmond (2018) noted high rates of touching other surfaces between cooking, without proper decontamination. These areas included frying pan handles, faucets, cupboard, and refrigerator doors.

Dishcloths

Kitchen cloths are often considered as a potential source for cross-contamination, since bacteria tend to persist on them (Mattick et al., 2003; Rusin et al., 1998). Borrusso & Quinlan (2017) conducted a microbiological contamination analysis study in domestic kitchens in a large, urban

US city. Their analyses revealed that dish towels and sponges had the highest levels of coliform bacteria. Contamination was inversely associated with the presence of cleaning materials (soap, paper/cloth towels, and towel in the bathroom). Evans and Redmond (2019) found that dish brushes (in 97% of the kitchens) and dishcloths or sponges (in 93% of the kitchens) were contaminated with microorganisms. The greater the reported turnover of dish brushes, the lower the microbiological contamination levels. The concentration of contamination on hand towels in single-occupant households are significantly greater. Yet, hand towels and sponges are not frequently changed, with only about 50% of people changing them weekly or more (Ammann et al., 2019; 75% from Byrd-Bredbenner et al., 2013). The same dish cloth is often used for various operations (i.e. drying of hands, wiping of working areas, wiping of kitchenware and wiping of vegetables; Jevnsnik, 2013).

Cleaning kitchen appliances, sinks, and work surfaces

Tache and Carpenter (2014) identified several kitchen areas that warrant observation for microbial contamination. They include appliances, work surfaces, and wet areas around sinks, as bacteria can grow in them. Regular cleaning of the refrigerator is recommended, though many clean sporadically, or only when a spill, or mess, occurred. Even then, the cleanup may be incomplete or insufficient (Tache & Carpenter, 2014). Cleaning these appliances may lead to lower contamination levels: Greater self-reported frequency of refrigerator cleaning was correlated with lower levels of microorganisms in two refrigerator storage areas (Evans & Redmond, 2019).

Sink drains are one of the most common areas of contamination, yet it is frequently not cleaned before preparation of food (Jevnsnik, 2013). Evans & Redmond (2019) found the highest bacterial counts were found to be associated with wet sites in the domestic kitchen in addition to hand contact surfaces. Borrusso & Quinlan (2017) found that E.coli contamination was most present in kitchen sinks and dishcloths, compared to other kitchen surfaces. Duthoo et al. (2020) found that the sinks under study had the highest levels of contamination in business kitchen.

Work surfaces are the kitchen areas that are most commonly cleaned. In a telephone survey (Murray et al., 2017), 93% of respondents reported cleaning the preparation surfaces after preparing raw meat or poultry with either, soap and water, disinfectant, or a dishwasher). Additionally, surfaces and other cleaning tasks in the kitchen appeared to be motivated by a desire to improve appearances of the kitchen, rather than making it hygienic or safe (Ammann et al., 2019). Thus, cleaning might be insufficient.

Washing fruits and vegetables

A majority of individuals self-report that they almost, or always, wash raw vegetables before cooking (Ammann et al., 2019; Nesbitt et al., 2014). However, there appears to be variability in the degree to which individuals wash store-bought and “pre-washed” vegetables (Dickinson et al., 2014). When fresh produce is washed, it is often done to remove pesticides/chemicals and external dirt, rather than to reduce microbiological contaminants (Nesbitt et al., 2014). Households that grow their own vegetables were more likely to wash their produce than the produce that they bought (Dickinson, et al., 2014). According the F&Y2survey (FSA, 2021a), 55% of respondents reported that they always washed fruit and vegetables that were going to be eaten raw, while 11% said they never did this.

Food safety and hygiene in business kitchens

Inadequate hygiene and improper food handling are considered to be strong contributing causal factors in cases of restaurant-based, foodborne illnesses (Angelo et al, 2017). Young et al. (2019) also reported several other factors that may impact food risks, including, but not limited to, having

access to handwashing sinks and work policies requiring employees to notify employers when sick.

Handwashing

Jones et al. (2017) estimated that 7.4% of chefs and caterers did not always wash their hands immediately after handling raw fish, meat, or poultry. In an observational study of sushi restaurants in the US, Hedeem (2016) observed bare-hand contact in 17% of restaurants during food preparation, despite 95% of the restaurants having a stated policy against it. In an observational study of a fast food restaurant, Soon (2019) found that hand hygiene activity occurred infrequently before handling exposed ready to eat (RTE) food (21%), and no hand hygiene activity was observed before putting on new gloves, after handling exposed RTE, unsanitary objects, or body parts. Additionally, food handlers who changed into new gloves (21%) did not wash their hands before putting them on. Stefancic and Jevsnik, (2020) also observed inconsistent adherence to hand hygiene standards, often observing business food handlers only rinsing their hands under running water without soap. They also observed inconsistency in the proper use and replacement of aprons amongst handlers. In a sample of institutional kitchen food handlers, Duthoo et al. (2020) found that aprons were replaced less than once per day in 29% of kitchens. Moreover, they observed that hand-washing practices did not eliminate aerobic bacteria risk, as all hand samples yielded countable levels of total aerobic bacteria. Similarly, a slight reduction of aerobic bacteria was observed after cleaning of work surfaces.

Cleaning

In a study of Dutch catering companies, Verhoef et al., (2013) found that catering personnel often lacked access to separate bathrooms, and less than 60% had access to single-use paper towels to dry hands. In 53% kitchens, surfaces were cleaned not more than once per day. Of the cleaned surfaces, the work surfaces had the highest mean total aerobic bacteria counts (TAC). Only a slight reduction in TAC was observed after cleaning. The highest TACs were found in the sink (which had the highest level of contamination), on a used knife, and on a used chopping board, probably because these items are primarily used with raw products (Duthoo et al., 2020). In a study of US restaurants. Brown et al. (2013) found that more than 90% of managers said that their restaurant had a cleaning policy regarding food contact surfaces used to prepare raw chicken. Managers who did not meet recommended guidelines stated that they washed and rinsed surfaces but did not sanitize them (10%), 25% of managers said that disposable gloves were never, rarely, or only sometimes used during the preparation of raw chicken.

Employee illness

Additionally, many kitchen employees have worked whilst ill. Verhoef et al. (2013) reported nearly 50% of food handlers in catering and institutional settings reported ever working when feeling ill, and 20% working in catering companies reported intentions to continue work when experiencing foodborne illness symptoms in the future. In a case study of norovirus in Australia, Maritschnik et al. (2013) reported that food handlers fell ill the day prior, but continued working, cleaning flatware and utensils that were used for a wedding dinner- which subsequently led to the outbreak. Similarly, Jones et al. (2017) estimated that nearly 1/3 of their sample of chefs/caterers reported ever going back to working prior to 48 hours of suffering from diarrhoea or vomiting.

Cross-contamination

Bacterial cross-contamination is most likely to happen when raw food touches or drips onto ready-to-eat food, utensils or surfaces (FSA, 2018). Luber (2009) concluded that cross-contamination events during food preparation presented a greater risk of illness than the risk

associated with undercooking poultry meat. Common routes of exposure to Salmonella include cross-contamination from raw meat to cooked foods either by using the same chopping boards or utensils for different food items without proper washing, or not washing hands between handling raw and cooked meat (Smadi & Sargeant, 2013). Bolton et al. (2014) found bacterial contamination spread readily from poultry to hands, the chopping board, knife handle, knife blade, dishcloth, fridge handle, microwave handle, microwave buttons, press handle, oven handle, plate, tinfoil and the draining board.

Washing poultry/eggs

Many households erroneously wash raw poultry, which increases risk of spread of Campylobacter in the kitchen. The F&Y2 survey (FSA, 2021a) reported that 35% of respondents washed raw chicken at least occasionally. The most common reasons for this practice were to clean the meat (e.g. to remove slime, juices, or blood; 53%), or for food safety reasons (e.g. to remove or kill bacteria; 30%). An earlier USA study reported that 68.7% of participants washed raw poultry before cooking (Kosa et al., 2015a). These numbers may be higher within certain ethnic groups, such as black and Asian households (FSA, 2021a; 2021c). Related, Kosa et al (2015b) found that 13.2% of respondents reported rinsing or washing eggs before cooking them. The F&Y2 survey (FSA, 2021a) reported that older respondents (>75 years) more often reported that they wash chicken (at least occasionally) than other age groups (see also Millman et al., 2014, 2015). This is also consistent with prior research conducted by Evans and Redmond (2018), which found that 90% of older adults in their study did not adequately decontaminate their hands immediately after handling raw chicken, and 24% failed to attempt a hand decontamination practice after handling raw chicken. Nearly half (48%) failed to attempt a hand decontamination practice after handling the raw chicken packaging. This study also reported that microbiological contamination of the refrigerator door handle was significantly higher when raw chicken was observed to be washed than after sessions in which raw chicken was not washed. The erroneous practice of washing chicken appeared to persist in business kitchens as well as domestic kitchens: In one study, 42% of US restaurant managers reported that raw chicken was often or always washed or rinsed before preparation (Brown et al. 2013).

Chopping Boards and Utensils

Chopping boards and utensils are considered to be major sources of cross-contamination. In one study on hygienic practices in business kitchens, the highest microbial load was identified on the used knives and chopping boards (Duthoo et al. 2020). Beyond thoroughly cleaning a chopping board between tasks, it is recommended to use different chopping boards for raw and cooked food (FSA, 2018). In an observational sample of older adults, Jevsnik (2013) observed only one knife and chopping board were used during food preparation, although was cleaned (warm water, cleaning agent, drying with dish cloth) between different work operations. However, FSA recommends using different utensils, plates and chopping boards for raw and cooked food (FSA, 2018). Millman et al (2015) found that only half of respondents identified the use of utensils covered in raw marinade to cut cooked chicken as a hazard. In a study of Canadian domestic food handlers, Murray et al. (2017) reported that about 2 out of 3 individuals reported using separate chopping boards for raw meat and other foods. Ammann et al. (2019) found that 50% of consumers reported that they did not use or rarely used a designated chopping board for the preparation of raw meat (see Sterns et al. 2018 & Kosa et al., 2015b, for greater reported rates). If only one chopping board is used, it frequently is not properly decontaminated, in terms of washing and drying – still remaining contaminated (Evans & Redmond, 2018). Thus, even though many may acknowledge that properly washing chopping boards and utensils are important using self-report, they may not be done as frequently in practice, or to a sufficient degree.

Moreover, Brown et al. (2013) found that, for US restaurant managers that did not meet recommended guidelines, 40% reported designating certain chopping boards for raw meat only

(including chicken) “sometimes” or less frequently. Similar practices occurred with ground beef. In a sample of 247 US restaurants that served ground beef, Bogard et al. (2013) reported that in approximately 1/3 of these restaurants, utensils were used between food preparation tasks without washing or gloved hands (without changing gloves between handling times) for food preparation tasks involving raw ground beef and RTE foods. In 42% of restaurants, the same utensils or gloved hands were used on both raw and cooked ground beef. Duthoo et al. (2020) found that in 56% of institutional kitchens, there was no separation between meat and vegetable preparation. Moreover, in 37% of kitchens, there was no separation between contamination activities (for example, no clear spatial separation for preparation of hot meals, sandwiches, and salads).

Personal electronic devices (PED)

PEDs such as mobile phones travel with the user across numerous locations throughout the day, raising potential for contamination (for example, toilets, hospitals, offices, etc.). Bhoonderowa et al. (2014) found that 92% of phones that were analysed demonstrated bacterial contamination. Lando et al. (2018) investigated the impacts of personal electronic devices (PED; for example, phones, tablets, laptops, etc.) in the kitchen. About half of all food preparers used a PED while preparing food, despite an acknowledgement that these devices are dirty. Yet, many reported that they did not wash their hands after use when preparing food. However, consumers were more likely to wash their hands before touching their phone after handling raw meats, or “sticky” foods. Some participants acknowledged attempts to diffuse risk, such as operating the device with a pinky finger or limit the times in which they touched the phone during cooking. However, this may be done as an attempt to keep the phone surface clean, rather than to prevent cross-contamination per se. Stefancic and Jevsnik (2020) found that professional food handlers were not aware of the potential for cross-contamination when using a mobile phone. There is a dearth of literature that addresses the impacts of PED usage in the kitchen, and thus, more research is needed to understand fully how this technology use interacts with food safety behaviours. For instance, beyond contamination concerns, PED usage could also create greater distraction which may relate to more automatic behaviours that may increase contamination risk.

Reusable grocery bags

One potential source of contamination that is often overlooked is the use of reusable grocery bags. Reusable grocery bags have increasingly become popular and are brought into the kitchen. Large numbers of bacteria (including fecal coliforms) were found in every reusable bag collected from consumers outside a grocery store, yet only 3% wash these regularly (Williams et al., 2011). Barbosa et al. (2019) found that reusable plastic bags contained levels of pathogens including *Listeria monocytogenes*, staphylococci, and Enterobacteriaceae. In this study, no correlation was observed between microbial levels and visual appearance of the bag, suggesting that sensory cues cannot inform judgments regarding the bag’s contamination.

Cooking Behaviours

One area which appears that great improvements can be made to reduce foodborne illness centres around cooking temperatures and the use of thermometers (Byrd-Bredbenner et al., 2013).

Cooking Temperatures and Thermometer Use

There appears to be great variability in food handler’s knowledge about correct internal cooking temperatures of meats (Feng & Bruhn, 2019; Bryd-Bredbenner et al., 2013; Nesbit et al., 2014; , 2014). Brown et a. (2013) found that 46% of managers said that food workers used the FDA-recommended method of taking temperatures with a thermometer to determine when chicken had

reached its final cook temperature. When asked to what temperature raw chicken needed to be cooked for it to be safe to eat, 43.3% of managers correctly reported the temperature recommended by the FDA 73.9°C, whereas 25% of managers provided a temperature that was below this temperature. Bogard et al. (2013) reported that a majority (77%) of managers of US restaurants said that they did not always (i.e., sometimes, rarely, or never) measure the final cook temperature of hamburgers with a thermometer. Wohlgenant et al. (2014) found that for child-care facilities and classrooms with separate kitchens, 41.4% did not have food thermometers available (33.3% of centres and 62.5% of homes), and only 34.5% of the facilities' workers had food safety certifications (42.9% of centres and 12.5% of homes). Further, Jones et al. (2017) 12% of the public and 16% of chefs and catering students admitted having served chicken at a barbeque when not totally sure it was fully cooked.

Many individuals acknowledge that using a thermometer is the best way to determine temperature. Nearly two-thirds of respondents in US FDA's surveys between 2006-2016 reported owning a food thermometer, but only about one-third report always using them for roasts (Feng & Bruhn, 2019). The use of thermometers appear to be dependent not only on owning one, but also the type of meat/poultry being cooked. For instance, Kosa et al. (2015a) reported that 62% of consumers stated that they owned a food thermometer and used it for whole turkeys and chickens (73% and 57%, respectively), but used it infrequently for smaller poultry cuts and ground poultry. Similarly, Murray et al. (2017) also reported that thermometers are most frequently used when cooking whole bird poultry and roasts; but very infrequently for smaller cuts of poultry, which are more commonly prepared (12%). Elshahat et al. (2019) noted that meat thermometer ownership and use was not common in the UK, which may attributed to the lack of guidelines explicitly recommending their use in both countries (FSA, 2018).

In the absence of using a food thermometer, the doneness of food is typically determined by heuristic, sensory cues (Byrd-Bredbenner et al., 2013; Sternisa et al., 2018). Meah (2014) suggests that this 'knowledge' is derived from past experience, and often the exact source is precisely unknown. Individuals tend to judge the temperature by the colour, texture and time cooked, rather than the actual temperature. For example, Meysenberg et al. (2014) found that 57% of participants responded that best way to test the doneness of hamburger was to use a meat thermometer, but most participants shared that they cut into meat to check colour for doneness. This visual cue appears to supersede the lack of knowledge regarding the precise temperature. Kosa et al. (2015b) reported that among respondents who owned a food thermometer (62.0%), only 5% used it to check the doneness of baked egg dishes when prepared such a dish; thermometer owners instead relied on other cues such as cooking times and firmness. Maughan et al. (2016) observed that, although 33% of participants used a thermometer to test doneness in a test kitchen, the common method used to determine doneness of a chicken breast was to cut into it (50%), or inspect the internal or external colour. When cooking eggs, individuals relied solely on visual cues, such as overall appearance, yolk consistency, texture, and the amount of liquid in the eggs.

Additionally, there may be psychosocial barriers to use food thermometers. Many domestic food handlers appear to be reluctant to use thermometers due to fear of negative social evaluation. Tache and Carpenter (2014) suggests that many regard food thermometer use as an indication of cooking inexperience. The ability to cook is a source of pride for many of those who have the primary responsibility of preparing meals, and it has been suggested that using a thermometer threatens that source of self-esteem by implicitly calling into question one's ability to cook (Byrd-Bredbenner et al., 2013).

Chilling and Defrosting Behaviours

The FSA (2021) has issued recommendations regarding the storage of foods in the refrigerator. However, refrigerator storage may be an overlooked issue, with individuals storing foods where

space allows, rather than following guidance. Additionally, the proper storage, and subsequent storage length, prepared leftovers is an important consideration for mitigating food risks. We discuss these issues in the current section.

Refrigerator Storage

A primary goal of “store and separate” guidance for refrigerators is to keep raw meat, poultry, and seafood separate from RTE foods like salads and cooked meat. About three-quarters of consumers report keeping raw meat, poultry, and seafood separate from RTE products (Byrd-Bredbenner et al., 2013; Murray et al., 2017). However, people may store food in the refrigerator “where there is space”, rather than by recommended standards (i.e., meats on bottom shelf).

Because refrigerator space may be limited, some households may encounter tightly packing food, which potentially may lead to cross-contamination (Nesbit et al., 2014; Tache & Carpenter, 2014; Wills et al., 2015). Kosa et al (2015a) reported that only 17% of consumers correctly stored raw poultry or raw ground poultry on the bottom shelf of their refrigerators in a sealed container or plastic bag. Donelan et al. (2016) observe that many individuals (59%) stored poultry either in the refrigerator or freezer in its original packaging without storing it in either another plastic bag or container. Although most poultry left the store in a protective layer (for example, an extra bag), most consumers took it out of this protective layer when placing the product in the refrigerator or freezer. Masson et al. (2017) conducted a study in a test kitchen to examine storage behaviours of French consumers. They found that only 20% of participants removed vegetable packaging, as recommended by French food safety authorities. Additionally, less than half stored refrigerated foods first when unpacking their groceries. The location in which they placed most goods appeared random, consistent with a “where there’s room” heuristic. Interestingly, they observed several different strategies for storage: (1) those who sequentially emptied one bag at a time, (2) those who first place all items on the counter before starting to store them; then, stored the refrigerator food first, (3) participants who start by storing refrigerated items from out of the bags. Duthoo et al. (2020) reported that in 42% of Belgian institutional kitchens under study, no clear separation between raw and prepared food in the refrigerator.

Refrigerator Temperature

It is recommended that refrigerators should be 5°C or below (FSA, 2018). However, most fridges are not cool enough (Byrd-Bredbenner et al., 2013). Evans and Redmond (2016b) conducted time-temperature profiling study of UK consumer refrigerators, and found that the domestic refrigerator operating temperatures ranged from -1.72 up to 17.98°C. In this study, no fridge was within the operating temp throughout the entire study, and only 5% were within the guidelines for 80% of the study. Borrusso and Quinlan (2017) reported that 48% of homes had a refrigerator that was too warm, with 11% having temperatures over 7.28°C. In that study, homes that had refrigerators which tested positive for *Listeria* spp. and fecal coliforms, had higher mean operating temperatures than pathogen-negative refrigerators.

Freezing offers an inexpensive intervention to reduce *Campylobacter* on poultry in the domestic stage of the food chain, it adversely affects the quality of the product at 40°C (Patsias et al. 2008). However, Bolton et al. (2014) found that participants noted a significant change in the appearance, firmness, moisture and dryness of the frozen chicken fillets (-20°C), compared with the control (fresh chicken fillets). These sensory cues may inhibit one from freezing to reduce contamination.

A main barrier is that most do not know what their current refrigerator temperature is, or what the correct temperature should be (Byrd-Bredbenner et al., 2013; Smadi & Sargeant, 2013; Stefancic & Jevsnik, 2020; Tache & Carpenter, 2014). Many may also be unaware that the temperature in the refrigerator door is warmer than the main compartment (Evans & Redmond, 2016b).

According to the F&Y2 study (FSA, 2021a), 65% of UK respondents knew the correct temperature that a refrigerator should be. Fifty-nine percent of respondents stated that they monitor refrigerator temperatures. Evans and Redmond (2016a) found, though, that 84% older adults studied were unaware of recommended temps, and 65% never checked the temperature.

McWilliams et al. (2017) found that nearly 20% of older participants' homes had a temperature exceeding 4.4°C. Yet, 99% believed that their refrigerator was "cold enough," suggesting sensory heuristic judgements were being applied. A Thaivalappil et al. (2020) found that knowledge on the safe operating temperatures of refrigerators was less than 50% on average (median equals 43% over 11 studies).

Fewer than 1/3 of individuals have a thermometer in their refrigerator (Byrd-Bredbenner et al., 2013; Nesbit et al., 2014; Stefancic & Jevsnik, 2020). There may be a confusion between the temperature and the coldness dial inside the refrigerators (Evans & Redmond, 2016b). Additionally, the number of times that a domestic refrigerator door opens can impact the internal temperature. For instance, Evans and Redmond (2016b) found that the temperature rises 2.51 C on average 6 minutes after storage; takes 36 minutes to return. This appears to be independent of such factors as household size, refrigerator type and performance, and its age, though room temperature is associated with greater refrigerator temperatures. However, there is great variability in the degree to which doors are open, which may increase potential risks (Masson et al., 2017). Food microbiologists and food engineers can encourage thermometer use compliance by validating and optimizing the temperature recommendations and developing user-friendly and cost-effective temperature control sensors (Feng & Bruhn, 2019).

Leftovers

It is recommended that leftovers be stored in the refrigerator within 2 hours (Byrd-Bredbenner et al., 2013; FSA, 2018). The F&Y2 survey (FSA, 2021a) reported that 82% of respondents typically placed leftovers in the fridge or freezer within 2 hours, with 71% intending to eat the leftovers within 2 days. This rate of storage is consistent with an earlier study with Canadian consumers (Murray et al., 2017).

One concern might be that vulnerable groups like the elderly may leave leftovers out for too long. McWilliams et al. (2017) found that when questioned about how long it is safe to leave cooked meat, seafood, eggs, or poultry out of the refrigerator, 32% reported that they either did not know (11%) or gave responses that were greater than the recommended 2 hours. However, in their review, Thaivalappil et al. (2020) found that older adults showed high rates of leftover storage within the 2 hour window (average prevalence equals 87%).

Often, individuals cannot recall the storage duration of many high-risk food products. Evans and Redmond (2015, 2016a) found that majority of participants in this study (56 – 84%) thought that all food products associated with *L. monocytogenes* could be stored and remain safe for consumption for longer than the FSA recommendation of two days after purchase or opening. In another study, when asked how many days cooked meat, seafood, eggs, or poultry are safe to eat when kept in the refrigerator, McWilliams et al. (2017) reported that 47% of older participants either did not know the answer, or gave an answer greater than four days. This study only distinguished between 0 to 4 days and more than 4 days. It should be noted that current recommendations in the UK are 2 days (NHS, 2021) Complicating this matter, people tend to not date their leftovers (Nesbit et al., 2014).

Defrosting

It is recommended that poultry be fully defrosted in the refrigerator or in a microwave on the defrost setting directly before cooking (FSA, 2018). However, Sternisa et al. (2018) reported that participants in their study preferred defrosting poultry meat on kitchen surfaces at room temperature (59.7%), followed by defrosting in a refrigerator (25.1%), under tap water (23.5 %)

and in a microwave (12.8 %). The F&Y2 survey (FSA, 2021a) reported that 46% of respondents reported that they leave the meat or fish at room temperature.

Safety Instructions on Food Packaging and Adherence to Use-by Dates

FSA recommends to check the advice on food packaging and follow the cooking instructions provided. When unprompted, many individuals do not know the correct cooking temperatures (Nesbit et al., 2014; Tache & Carpenter, 2014). However, many are unaware of the safety instructions on food labels. If they are aware, they may read it the first time that they use the product, but not on subsequent purchases. (Nisbett et al., 2014). In a Dutch study of poultry safety instructions, Antonise-Kamp et al. (2018) reported 15.4% of respondents had never read safety instructions on poultry packaging.

Adherence to Use-by Dates

The use-by date is typically considered the most important information that people attend to on food labels (Sternisa et al., 2018; Tiozzo et al., 2017). Researchers have noted wide variability in attitudes regarding use-by dates, ranging from ambivalence to uncertainty to cynicism, and subsequently, little, if no, consistent adherence to them (Dickinson et al., 2014; Wills et al., 2015). Some individuals may be confused by the meaning of the best-by and use-by dates (Evans & Redmond, 2016a), leading to further inaction. With respect to use-by dates, Kosa et al. (2015b) reported that over 60% of consumers checked the sell-by or expiration date on egg cartons before purchase. However, Maughan et al. (2016) reported that many of their respondents reported that they always finished their egg carton, regardless of other factors such as age of the eggs. Evans and Redmond (2015) found that 41% of refrigerators in older adults' home kitchens in this study contained food products that were beyond the use-by date. Evans and Redmond (2016a) found that 2/3 of older adults sampled believed food was safe to eat beyond its use-by date. Jones et al. (2017) found 22% of the public admitted having served meat "on the turn" and 33% of chefs and catering students admitted working in kitchens where such meat was served. According to the F&Y2 survey (FSA, 2021a), most respondents reported that they never ate cooked meats (64%), smoked fish (85%), cheese (52%), bagged salads (49%) or milk (67%) past the use-by date. Conversely, some respondents reported that they had eaten those foods past the use-by date. For example, almost half of respondents had eaten bagged salad past the use-by date (6% every week, 21% some weeks and 17% just one week in the last month).

Instead of printed use-by dates on packaging, consumers tend to rely on other cues to assess food safety. Wills et al. (2015) reported that many UK consumers often relied on senses (smell, touch, visuals, coldness) to assess freshness. Evans and Redmond (2016a) found that 62% of older adults believed that smell and appearance of food was a reliable indicator that it is safe to eat. Stefancic and Jevsnik (2020) found that 43.1% incorrectly 'agreed' or 'strongly agreed' that the smell and appearance of food can be used as an indicator for food safety, and 64.1 percent self-reported often or always using this practice.

The reduction of food waste may be promoted by either social responsibility norms, which may have the unintended effect of increasing the risk of foodborne illness (Tache & Carpenter, 2014), or perceptions of food insecurity. Many expressed attitudes that food was precious and not to be wasted (Antonise-Kamp et al., 2018; Evans & Redmond, 2016a; Wills et al., 2015). In the F&Y2 survey (FSA, 2021a), 58% of respondents stated that they were concerned about food waste; older adults and those who were primarily responsible for cooking and shopping reported greater food waste concerns. McWilliams et al. (2017) reported that many older adults (36%) found it difficult to discard food, and some concerned about running out of food (17%). Food insecurity is also a factor in the reduction of food waste. It has become more prevalent during the COVID-19 pandemic (see Behaviour Change in Domestic and Business Kitchens during the COVID-19 Pandemic section for more details).

Demographic Factors potentially impacting Food Hygiene and Safety Practices

Vulnerable groups

Immunocompromised individuals, the elderly, and pregnant women are typically considered high risk for complications associated with foodborne illness (Byrd-Bredbenner et al., 2013). The elderly, for example, are vulnerable for a variety of many reasons, including age-related changes in their gastrointestinal tract, cognitive and vision declines, and taking certain types of medication that can raise food risks (McWilliams et al., 2017). Complicating matters, individuals in vulnerable populations may also be susceptible to optimistic biases surrounding their own risks. Evans and Redmond (2016a) found that only 30% of older adults felt that 'vulnerable' elderly groups were at increased risk for listeriosis. A follow-up study suggested the older adults reported having total or nearly total control of food safety, and thought that their home was the least likely place to cause food poisoning (Evans & Redmond, 2019).

Special attention should be made to effectively and accurately communicate the potential severity of food risks and guidance to reduce it. This appears to be lacking with some populations. For example, Evans and Redmond (2017) noted that food safety information is lacking, inconsistent and varied between resources for chemotherapy patients.

Age

Younger food handlers may show less food hygiene behaviours due to inexperience (Byrd-Bredbenner et al., 2013). Beyond the research that has been previously discussed in this review, it is important to note that older adults may also demonstrate riskier practices, due in part to knowledge gaps and possibly the excessive reliance on experience (i.e., "I've always done it this way"; Thaivalappil et al., 2020). After a lifetime of unsafe food-handling practices without acknowledging or remembering the potential consequences, they resist the idea that continuing these practices puts them at risk. Seniors are especially at higher risk for foodborne illness due to cognitive impairment, age-related changes in GI tract, vision problems, and use of some prescription drugs.

Gender

Females may be more likely to know recommended awareness of health risks, storage procedures and cleanliness (Byrd-Bredbenner et al., 2013; McWilliams et al., 2017; Moreb et al., 2017; Sternisa et al., 2018). Antonise-Kamp et al. (2018) reported safer food-handling was more often reported by women. Researchers have found that women were more likely to wash their hands with hot water and soap (Evans & Redmond, 2018; Thomas & Feng, 2021). These lower compliance rates may be related to males reporting greater confidence in their kitchen hygiene (Evans et al., 2020). However, women were also more likely to eat raw cookie dough and cake batter, a risky practice at the time (Kosa et al. (2015b). Since this study, guidance on raw egg consumption has changed in the UK, such that raw eggs with a British Lion stamp are deemed safe for consumption for the general public (NHS, 2021). Additionally, though not necessarily gender-specific, Meysenberg et al. (2014) noted that women with small children also reported barriers for maintaining food safety, including distractions, fatigue, and time limitations. This is consistent with Wills et al. (2015), who observed that when young children are present in the kitchen, focus shifts from food safety to vivid, dreadful risks (for example, burns, knife injuries), rather than food hygiene risks (though see Young & Waddell, 2016).

Home Occupancy

Single occupant households, especially for males, are likely to show lower kitchen hygiene behaviours. For instance, Evans and Redmond (2018) found that older adults who lived alone were less likely to adequately decontaminate their hands before food preparation. Additionally, the reported duration for hand towel usage without replacement was found to be longer in single occupant households than in multi-occupant households (Evans & Redmond, 2019). In this study, living alone also was related to inadequate kitchen equipment decontamination.

Behaviour Change in Domestic and Business Kitchens during the COVID-19 Pandemic

This section aims to broaden our understanding of the behavioural changes that have occurred in domestic and business kitchens during the Covid-19 pandemic. We provide the findings from the Covid-related literature, FSA reports, and expert interviews to reveal behavioural changes in domestic and business kitchens during the Covid-19 pandemic.

Cleaning: Hand-washing, food, food packaging, and kitchen surfaces

Thomas and Feng (2021) conducted a survey study accompanied by online focus groups to assess US consumers' food safety practices during the COVID-19 pandemic. Both survey respondents and focus group participants reported higher levels of hand washing in response to the pandemic (see also FSA, 2021c). In relation to this behavioural change, this study found that participants with higher annual income had higher levels of hand washing with soap than those with lower income. However, survey and focus group participants anticipated less frequent hand washing with soap and less use of hand sanitizer in the aftermath of the pandemic indicating a likely negative shift in cleaning behaviours. Use of hand sanitiser was associated with negative perceptions and experiences regarding hand sanitisers such as skin irritation, killing regular germs on the skin, and being toxic to the body. These perceptions may be inaccurate, but are barriers against use of hand sanitisers. Additionally, some individuals have reported that they consider the home a "safe space", which may reduce the use of hand washing and sanitizing once in the home (FSA, 2021c). In line with these findings, one of the interview participants with expertise in academia, mentioned the huge efforts by researchers and practitioners such as new mobile phone apps to make people wash their hands more frequently and properly.

Regarding the business kitchens, one of the interviewees with extensive management experience in the hospitality industry emphasized that good practice in the kitchens of the hospitality industry have continued after the Covid-19 pandemic, and hand washing and kitchen hygiene practices have been improved, particularly frequency of cleaning has increased. This improvement was due to successful communication efforts of employers during the pandemic. It was also added that one of the important changes that was done in the hospitality was asking employees not to use gloves to enhance hand washing practices and prevent cross-contamination.

A multi-country survey study conducted in 825 food companies across 16 European countries highlighted that these companies reported implementation of more restrictive hygiene procedures in their premises during the pandemic (Djekic et al., 2021). Wang et al. (2021) suggested that this is to ensure the safety of staff and in response to consumers' raising concerns about eating out.

On the other hand, two interviewees working as senior environmental health officers referred to their recent inspection experiences with staff and managers working in business kitchens, who reported to have improved cleaning practices in kitchens. They mentioned that there is no solid evidence to support such claims because local authorities' inspection procedures changed during the pandemic. In particular, local authorities need to inform businesses before they make their inspection visits unlike pre-covid times, when businesses had been inspected without any earlier

notice. However, one of these interviewees mentioned that even before Covid-19, the kitchen staff needed to be compliant with hand washing practices as a requirement of the law. Therefore, the businesses that had already adapted this good practice should be safe during the pandemic.

One of these interviewees also indicated that a lot of guidance and advice were given out to businesses struggling as a result of business closures during lockdowns. In particular, they provided guidance with regards to storage and distribution of foods with cardboard box (for example, pizza) and cool bags. Recent research indeed suggest food packaging for off-premise dining as a concern for some consumers due to possible transmission of Covid-19 through contaminated surfaces (Bryd et al., 2021).

Thomas and Feng (2021) reported an increase in washing fruits and vegetables during the pandemic, as well as an increase washing them with soap. The recommended practice of washing fruits and vegetables under running tap water or in a bowl of fresh water is to make sure that fruits and vegetables are clean and harmful bacteria can be removed from the outside (FSA, 2018). However, it was not recommended cleaning fruits and vegetables with cleaning agents such as soap and detergents because these may not rinse off the fresh produce and make people ill when ingested. In relation to this, US Centre for Disease Control and Prevention (CDC) conducted a survey in response to increase in calls to poison centers in US regarding exposures to cleaners and disinfectants since the beginning of the pandemic. It was found that one third of survey respondents used bleach on food products with the intent of preventing Covid-19 transmission (Gharpure et al., 2020)

Cooking

One of the practitioner interviewees working at the FSA referred to research conducted by the agency showing that people have been cooking from scratch more, as well as eating more with the family. FSA's recent report on food during the pandemic has indeed revealed a complex shift in people's diets during Covid-19, with more home cooking and more healthy meals (FSA, 2021b). Similarly, FSA's Covid-19 Consumer Tracker (2020) demonstrates that 9 in 10 respondents cooked from scratch in the last month, with two thirds have done so at least once a week. In addition, 1 in 8 respondents reported eating together with the family. The increase in cooking frequency and amount in domestic kitchens may have implications in terms of food safety behaviours, such as cooking food at right temperature and efforts to reduce the potential for cross-contamination.

Regarding business kitchens, however, two practitioner interviewees mentioned that there are less staff working in business kitchens due to social distancing rules and less demand. This creates more time for kitchen staff to make better cleaning and have more time for date labelling needed for proper storage.

A study conducted in US found that participants' behaviours in relation to thermometer use and heating practices during the pandemic significantly improved. This was attributed to the incorrect belief that Covid-19 can spread from food (Thomas and Feng, 2021). However, this potential misunderstanding that led to correct behaviour may not apply to the UK context. A comparison of the results of the UK Food and You surveys conducted during and pre-pandemic (FSA, 2021a; 2019) indeed suggests no behavior change. In both UK surveys, a great majority (77%) reported that they always cook food until steaming hot and cooked all the way through, as recommended by the FSA.

Freezing and Defrosting

Two practitioner interviewees highlighted that more food is kept frozen in business kitchens to prevent wasting food. However, this may lead to some risks in relation to how long frozen food is kept in the refrigerator and defrosting practices. Three interviewees were mainly concerned due

to the incorrect practice of defrosting food, particularly meat under sink or on top of a counter. The FSA does not recommend defrosting food at room temperature but fully in the fridge or in a microwave on the defrost setting directly before cooking because most harmful bacteria grow at temperatures above 8°C (FSA, 2018).

In relation to domestic kitchens, 46% of respondents of the F&Y2 survey reported that they leave the meat or fish at room temperature to defrost (FSA, 2021a). This is slightly lower than the reported practice (54%) in response to the previous Food and You survey (FSA, 2019). Although this slight change is encouraging, there is still room for improvement regarding defrosting practices in both domestic and business kitchens.

Use-by date

The FSA does not recommend eating, cooking or freezing food after its use-by date because it could be unsafe to eat or drink, even if it has been stored correctly and looks and smells fine. According to Food and You survey results before and after the Covid-19 pandemic (FSA, 2019; 2021), great majority of respondents (76% and 71%, respectively) identified the use-by date as the information which shows that food is no longer safe to eat. However, F&Y2 results show that respondents often eat food passed its use-by date (FSA, 2021a). In particular, they reported consuming out of date cheese (38%), bagged salad (44%) cooked meat (28%), milk (28%), and smoked fish (10%). These results are in line with those reported in the FSA's Covid-19 Consumer Tracker (FSA, 2020) that also shows that people having cut or skipped meals for financial reasons were likely to report eating food past its use-by date in the last month, compared to those who hadn't. An increase in food insecurity has been reported with an estimate of 14% of households (compared to 11.5% before the pandemic) experiencing moderate or severe food insecurity in the 6 months following the first national lockdown. Similarly, FSA's Covid-19 Consumer Tracker (2020) and F&Y2 survey (FSA, 2021a) have indicated increase in food insecurity during the pandemic.

One of the interviewees, who is an academic concluded that changing consumer behaviour in the kitchen is challenging because food safety is not a primary concern for consumers who believe that their actions do not cause any ill health.

Overall, these findings suggest that there is an increase in (1) hand washing in both domestic and business kitchens, (2) cleaning frequency of business kitchens, and (3) washing of fruits and vegetables in domestic kitchens. However, there is a need to conduct observational studies to assess whether reported behaviour indeed translates to actual behaviour in kitchens. In addition, observational studies need to examine whether UK consumers use soap or detergents when washing fruits and vegetables. Cooking more from scratch in domestic kitchens and storing more food as frozen in business kitchens may have food safety implications such as cross-contamination. The increase in eating food past its use by date is concerning and need to be studied further.

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