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Evaluation of Irish Consumers' Knowledge of Salmonellosis and Foodhandling Practices

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RESEARCH ARTICLE

Evaluation of irish consumers' knowledge of salmonellosis and food-handling practices

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Abstract

Salmonella is one of numerous food-borne pathogens that could possibly pose a major threat to global food safety. *Salmonella* is primarily associated with foods such as poultry, eggs, vegetables, and some dairy products. However, infected food handlers and faecal contaminated environments are also significant sources and reservoirs of this pathogen. This study comprehensively evaluated the Irish consumers' food safety knowledge by exploring their knowledge level, practices and attitudes regarding raw meat handling, cross-contamination while handling different types of food products, and knowledge of *Salmonella* risk and associated food-handling practices. The online SurveyMonkey tool was used to distribute a quantitative survey titled "Evaluation of Knowledge and Food-handling practices of Irish Consumers" from July to November 2020 and generated a total of 1916 responses. Results indicated that 79.9% of the studied Irish population had a good knowledge of salmonellosis and risk perception related to food handling practices. Knowledge of cross-contamination, hygienic practices and pathogens associated with poultry were also considered high. However, knowledge of meat handling was low at 44.9%. It was also observed that age, gender, marital status, gross annual income, and nationality were influential factors regarding the food safety knowledge of consumers, while age, marital status and gender indicated significant differences regarding awareness of correct food hygiene practices.

1 Introduction

Foodborne illness is a major public health issue worldwide and a concern for global economies. Salmonellosis is currently the second most prevalent zoonosis in humans within the EU after campylobacteriosis. The reporting of foodborne salmonellosis outbreaks in humans is mandatory according to zoonosis Directive 2003/99/EC (EFSA 2021). Further monitoring by the European Centre for Disease Prevention

and Control (ECDC) has provided data on zoonotic infections including analyses for EU Summary Reports since 2005. Since 2008, data on human cases have been received via The European Surveillance System (TESSy) and maintained by the ECDC. Furthermore, in 2019 the annual EU Summary Reports regarding zoonosis, zoonotic agents and foodborne outbreaks have been renamed the "EU One Health Zoonosis Summary Report" (EUOHZ) and are co-authored by EFSA and ECDC. In December 2021, EFSA and the ECDC jointly released a report regarding foodborne outbreaks in 2020. The report found that *Salmonella* was the agent most frequently identified in foodborne outbreaks within the EU accounting for 22.5% of outbreaks. Further analysis of the 2020 report revealed a progressive increase in the fatality and hospitalization rates connected with *L. monocytogenes*, which were 62.5% and *Salmonella* 16.7% (ECDC 2019). The report also found the number of reported foodborne outbreaks had decreased when compared to 2019 by 47% with human cases falling by 61%, hospitalizations by 60% and deaths by 43%. Indirect consequences

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of the COVID-19 pandemic among EU populations led to a reduced exposure of people to contaminated food and under-reporting of outbreaks. This decreasing trend for confirmed cases of salmonellosis has stabilized within the EU since 2014 and in 2020 the total number of reported confirmed human cases were at their lowest levels since the initiation of the *Salmonella* surveillance programme in 2007 (EFSA 2021).

A risk assessment of salmonellosis linked to chicken meals prepared in households in China was conducted by Zhu et al. (2017). The report followed a quantitative microbiological risk assessment (QMRA) model which was based on research undertaken by Pouillot et al. (2012). The purpose of the research was to monitor the propagation of salmonellosis from the farm via the slaughterhouse and into the domestic kitchen. It was understood that if *Salmonella* could be identified, controlled, and reduced within the food chain, this could potentially reduce the risk of cross-contamination within the home (Zhu et al. 2017). However, despite the introduction of mitigation controls within the food chain, *Salmonella* continues to survive (EU 2011; European Commission 2014; 2017) Ultimately, at the abattoir and meat processing plants, the meat handling processes are not aiming to sterilizing the meat, instead they seek to reduce the proliferation of pathogens by slowing down their activities. Moreover, when growth conditions for pathogens become favourable, the bacterium will resume its lifecycle and can potentially escalate to dangerous levels of contamination (Ehuwa et al. 2021). Correspondingly, Devleesschauwer et al. (2017) also identified similar activity in fruits and vegetables where proliferation of pathogens was sporadic, and only occurred in response to ambient conditions for growth. Previous research has also shown that salmonellosis is linked to poor hand hygiene, contact with infected pets and consumption of contaminated foods mostly from poultry, pork, and egg products (Munck et al. 2020). Concerns were also raised regarding herbs and spices included in ready-to-eat products, where such condiments are consumed without any further cooking or processing (Zweifel and Stephan 2012). Furthermore, Lins (2018) found that detection of *Salmonella* within dried spices and herbs was difficult to confirm due to the potent antimicrobial activity of the herb/spice matrices therein. While Gorman et al. (2002) also previously highlighted similar cross-contamination in the domestic kitchen.

Therefore, in an effort to maintain food safety throughout the food chain, all food businesses must be registered and adhere to mandatory legislation, including Hazard Analysis Critical Control Points (HACCP), which is laid down in EU Regulations 852/2004 and 853/2004 and implemented in compliance with the Irish national standard I.S.340:2007&A1:2015 (NSAI 2015). However, it must be noted, legislation that protects mass food production cannot be legally applied within the domestic home. Therefore, domestic food handling knowledge, cross-contamination awareness and hygiene practices are paramount to ensure the consumers' food safety as the food chain starts at the farm, and extends to the fork/plate (Fung et al. 2018). Therefore, vigilance at every stage of the food chain, including safe domestic handling, is required to prevent pathogenic foodborne outbreaks and ensure food safety (Yemane and Tamene 2022). However, sporadic outbreaks of salmonellosis in Ireland were notified with 363 cases in 2018, and 414 cases in 2017. The cases were associated with international travel, and although cases were increased in Ireland during this period, the overall figures within the EU had decreased (HSE 2019a, 2019b; EFSA 2021). There is limited publication in this area and to date, there have been no published study that investigated the domestic food handling practices that increases the risk of salmonellosis in the Republic of Ireland. Therefore, this study aimed to assess the Irish consumers' food safety knowledge including cross-contamination, food handling practices and knowledge of *Salmonella.* Finally, this study also investigated the relationship between demographic characteristics with food safety knowledge and food hygiene practices.

2 Materials and methods

2.1 Questionnaire design and survey

To assess how the Irish population perceives salmonellosis, a questionnaire was circulated from July to November 2020. The survey tool was designed to explore the demographics of the study population. The five-step Mental Model Approach (MMA) as illustrated by Morgan et al. (2002) was applied. The survey questions were adapted from published articles including Bearth et al. (2014), Kauber et al. (2017), Moreb et al. (2017), and Myintzaw et al. (2020). The questionnaire consisted of 35 multiple choice questions divided into 6 sections:

- Section 1: Screening question to exclude participants who did not handle raw chicken.
- Section 2: Demographics (7 questions).
- Section 3: Meat handling knowledge (7 questions).
- Section 3: Cross-contamination knowledge (5 questions).
- Section 4: Hygiene practices (4 questions).
- Section 5: Knowledge of pathogen (8 questions).
- Section 6: Travel behaviour and attitudes that pose risks to the study population when traveling outside Ireland (3 questions).

A total of 1916 participants contributed to the survey, of which 299 questionnaires were dismissed due to the participants cooking chicken less than twice per week and further 60 questionnaires were removed as incomplete. Thus, the responses of 1557 participants formed the study population of this research.

2.2 Participants

Participants were directed to the SurveyMonkey questionnaire via invitations uploaded to online social media platforms such as LinkedIn, Twitter, Facebook. Furthermore, the Food Safety Authority of Ireland (FSAI) website also hosted the questionnaire. Each participant was screened prior to the acceptance of the survey for eligibility criteria, namely Ireland as place of residence, age above 18 years, cooking chicken at minimum on a bi-weekly basis, and comprehension of English language.

2.3 Data collection

The use of an online survey was particularly expedient in this research. The questionnaire took an average of 5 min to complete. The completion rate was 96%. All survey results were collected using the SurveyMonkey tool, then screened and accepted or dismissed as appropriate. The onset of Covid-19 increased public awareness of personal hygiene and food safety practices (FSAI 2020; EFSA 2021).

2.4 Data analysis

The SPSS 25.0 software package was used to analyse the data collected. Demographic data of all respondents was presented as frequency values and percentages. Mean scores for food safety knowledge and food handling practices were calculated and recorded in the tables. For each question answered correctly, one point was assigned, while incorrect answers obtained zero points. After calculating the participant's correct and incorrect answers their score was determined. The mean and standard deviation of the obtained scores were calculated in all sections. Those who answered more than 50% of the survey questions correctly were considered to have passed, while those with a score of 70% or above were considered to have a good level of knowledge. Scores less than 50% were classed as having a poor level of knowledge, while scores between 51% and 69% were considered as an average level of knowledge (Moreb et al. 2017). In the data analysis, all answers were analysed both as numerical and binomial variables. The demographic characteristics were regarded as independent variables and all responses were analysed as dependent variables.

Cross tabulation and relationships among multiple variables were carried out through Chi-square. The Chi-square test (Lazou et al. 2012) in this study was used to investigate the relationship between demographic characteristics and food safety knowledge, and the relationship between demographic characteristics and food hygiene practices. Non-parametric tests (Mann-Whitney U and Kruskal-Wallis) were used to analyse the data (Williams et al. 2018). More precisely, the Mann-Whitney U test was used to determine the statistical significance of dichotomous demographic characteristics (gender, marital status, and urban/ rural area group) with the total pass rate. The Kruskal-Wallis test was used to compare the rest of demographic characteristics (age, per capita annual income in Euros, and educational level) with the pass rate.

2.5 Limitations

The objective of the study was to evaluate the knowledge of salmonellosis and food-handling practices of Irish consumers. However, there was a limitation in study design. Irish residents without access to online platforms were excluded from the online survey.

3 Results and discussion

3.1 Demographic characteristics of the participants

A total of 1916 participants contributed to the survey. The responses of 1557 consumers formed the final population of this research with 299 disqualified because they cooked less than twice a week. An additional 60 participants were removed because they did not respond to all questions. Socio-demographic characteristics were used to classify the population and results are depicted in Table 1, where the results were indicative of the surveyed populations' susceptibility to food infections, exposure to food safety information, including techniques and procedures when handling foods.

The age demographic of the study population showed that higher percentage of participants were aged between 18 and 25 years (Table 1). More unmarried female than married persons and men responded. In addition, almost half of the participants had a gross annual income of 30,000 euro or below. According to Wertheim-Heck et al. (2019) annual incomes of consumers and gender group are directly connected with food choices and associated food safety. Research has shown that economic disadvantage is primarily defined by income as it affects purchasing power, potentially creates barriers to healthy foods and often limits food choices. Therefore, ensuring food security for

Table 1 Demographic characteristics of participants

Demographic characteristics	n	Category	Participants (n)	Percentage (%)
	1553	18–25	522	34
Age		26–35	259	17
		36–50	372	24
		51 above	400	26
	1555	Male	343	22.1
Gender		Female	1211	77.9
		Other	1	0.1
	1555	Unmarried	775	49.8
Marital status		Married with children	544	35.0
		Married without children	95	6.1
		Other	141	9.1
	1556	Primary school	12	0.8
Education level		Secondary school	444	28.5
		University/College/ Institute of Technology degree	1098	70.6
	1551	<30,000	758	48.9
Gross annual income Euro (€)		30,000–60,000	560	36.1
		60,000–100,000	190	12.3
		100, 000 and above	43	2.8
Residence	1498	City/Town	848	56.6
		Countryside	650	43.4
Nationality	1554	Irish	1400	86.8
		Other	154	9.6

low-income groups is among the toughest challenges confronting policymakers globally today (Wertheim-Heck et al. 2019). Research undertaken by Cohen (Cohen 2018; Cohen and Ilieva 2021) also found that a significant difference in incomes was a contributing factor regarding the gentrification of low-income communities worldwide. Furthermore, Wertheim-Heck et al. (2019) found that changes in the food retail environment could potentially adversely impact the diets of low-income urbanities. The studied population by Wertheim-Heck et al. (2019) included women of reproductive age as they were considered most likely to be the caregiver in the home, and primarily responsible for the purchasing and preparing of foodstuff. However, supermarket development as a component of progressive gentrification, primarily targets middle and higher-income areas, with low-income neighbourhoods essentially becoming "supermarket deserts". To date, gentrification is linked to "food mirages" which refers to regions where grocery stores offering healthy foods are plentiful but prices are beyond the purchasing power of low-income households, making their food environments functionally equivalent to "food deserts" (Breyer and Voss-Andreae 2013; Sullivan 2014; Sonnino et al. 2019). Furthermore, retail policies and eventual regional

gentrification are often driven by food safety issues in an effort to provide safe food to low-income consumers, as an alternative to perceived unsafe food previously found in local markets (Wertheim-Heck et al. 2019).

3.2 Meat handling knowledge

Table 2 presents meat handling knowledge and Table 3 the pass rates achieved by respondents. A high percentage of the study population did not wash the meat before cooking. A high percentage of participants (49.8%) purchase meat at the end of their shopping trip before going home but almost 4% do not know the recommended core temperature of 75 ºC for correctly cooked chicken and approximately 34% believe that pathogens can possibly grow at refrigeration temperatures of 0–5 °C.

The current study found that 43.8% of Irish consumers cooked poultry until a core temperature of 75 °C was reached, as recommended by the FSAI (2020). The core temperature of 75 °C or higher is based on the poultry being stuffed, which is a traditional method of preparation and cooking within Irish households. Furthermore, stuffing the poultry prior to cooking reduces the surface area within the cavity, increases the overall weight of the joint and will extend the cooking time required to properly cook the foodstuff (FSAI 2020; Safefood 2022). However, a study undertaken by Teffo and Tabit (2020), found that 9.05% of native food handlers in South African hospitals identified that an internal core temperature of 74 °C for 15 s was required to properly cook chicken as recommended by The United States Department of Agriculture (2020). Therefore, the difference in core temperature knowledge between the Irish households and the South African employees was due in part to the meat handling knowledge and requirements they were familiar with. A paucity of knowledge regarding food safety procedures could ultimately cause proliferation of numerous pathogenic bacteria, thus causing illness or death. Around 26% of participants used a thermometer to check the correct temperature of a chicken while cooking. In addition, in order to know when chicken is properly cooked, more than one third of households use timing based on experience, and approximately one third of households used surface colours or use colours of the interior or base their judgments on texture. The results of the present study suggest that in the absence of thermometers, almost half of Irish consumers believe that chicken is well cooked when the juice runs clear. The scientific consensus to ensure *Salmonella* is heated to its inactivation temperature of 73.9 °C is to verify it with a thermometer. The use of thermometers increased from 49% to 1998 to 70% in 2010 in the United States (Lando and Chen 2012). Interestingly, Thomas and Feng (2021) reported that consumers increased the use

Table 2 Knowledge of participants of meat handling

Questions	n	Category	Participants (n)	Percentage (%)
1. When is the best time to buy raw meat?	1557	At the beginning of the shopping, then shop for the rest	50	3.2
		At the end of the shopping just before heading home	**775**	**49.8**
		Whenever as long as separate from other products	507	32.6
		Does not matter	225	14.5
2. You wash the chicken to:	1556	Remove blood	64	4.1
		Wash to be safe	404	26.0
		I don't normally wash	**1077**	**69.2**
		Remove odour	11	0.7
3. For raw frozen chicken, how do you thaw before cooking?	1555	I defrost them in the water in the sink	154	9.9
		I defrost them in the fridge	**754**	**48.5**
		I thaw them leaving overnight at room temperature	613	39.4
		I don't thaw, I cook from frozen	34	2.2
4. How do you tell; your chicken is properly cooked?	1551	Visual check	489	31.5
		When juice run clear	**771**	**49.7**
		I know by touching it	63	4.1
		Length of cooking	228	14.7
5. Recommended temperature for properly cooked chicken is	1555	At least 60 °C on the surface	34	2.2
		At least 75 °C in the middle	**681**	**43.8**
		At least 80 °C at the saucepan	143	9.2
		I don't know	697	44.8
6. While the food is kept under refrigeration if the pathogen/ bugs present in the food, they can	1553	**Grow**	**532**	**34.3**
		not grow	458	29.5
		be killed by cold temperature	217	14.0
		Don't know	346	22.3
7. A meat thermometer or digital food probe can be used to determine if the meat is cooked	1553	It is only for restaurant use	84	5.4
		I confident with my own method	1011	65.1
		I have one, I am using it	**407**	**26.2**
		It is a waste of money to buy one	51	3.3
Total Pass			662	44.9
Mean score ± standard deviation			3.22 ± 1.64	

Passing scores: 4 or more correct answers out of 7 questions

The correct answers are highlighted in bold

Table 3 Evaluation of pass rates

Food safety knowledge	Pass rates (%)	Evaluation*
Knowledge of participants of meat handling	44.9	Poor
Knowledge of participants on cross-contamination	79.7	Good
Hygiene practices of participants	87.6	Good
Knowledge of pathogen associated with poultry	91.8	Good

*Percentages < 50% being poor, 51–69% average, and > 70% are good

of domestic thermometers during the recent COVID-19 pandemic, though their use decreased in recent years in European households (Langsrud et al. 2020) where subjective methods are used instead of thermometers recommended by governmental agencies (USDA 2020; FSAI 2020). The long response time of domestic thermometers, national differences in acceptable contamination levels, culture, and economy are factors that hamper consumers' acceptance of these scientific recommendations (Langsrud et al. 2020). However, it is interesting to note, as highlighted by Borda (2020), that a previous study by Anon (2015)

Table 4 Knowledge of participants on cross-contamination

Questions	n	Category	Participants (n)	Percentage (%)
1. A refrigerator has three shelves; on which shelf do you think ready to eat food should be placed?	1543	**At the top shelf with protective cover**	**700**	**45.4**
		On the middle shelf	133	8.6
		At designated shelf as long as not next to raw food	619	40.1
		It doesn't matter	91	5.9
2. After buying fresh chicken you should …	1553	**Keep it in the bottom of the fridge with the single airtight container**	**1158**	**74.6**
		Keep in the top shelf in an original packaging	192	12.4
		Keep in the fridge anywhere	181	11.7
		Marinade for few hours to improve taste	22	1.4
3. I use a separate chopping board and knife to prepare raw meat and ready to eat food	1554	Not aware of the need	38	2.4
		It doesn't matter	25	1.6
		I rinse them in between	371	23.9
		Yes, I have a separate set.	**1120**	**72.1**
4. *Salmonella* contaminates kitchen wall, worktop and cookery can be effectively cleaned with the following.	1534	**Antibacterial spray and wipe with a kitchen towel**	**956**	**62.3**
		Detergent and warm water using a kitchen towel	477	31.1
		May not clean, *Salmonella* can be resistant to the antimicrobial agent	89	5.8
		Just wipe away with a kitchen towel	12	0.8
5. What is the recommended temperature for a refrigerator?	1553	0 °C	112	7.2
		4 °C	**1266**	**81.5**
		12 °C	61	3.9
		Below 0 °C	114	7.3
Total Pass			1194	79.7
Mean score ± standard deviation		3.35 ± 1.14		

Passing scores: 3 or more correct answers out of 5 questions

The correct answers are highlighted in bold

found that only 2% of the studied population possessed a fridge thermometer.

The current study detected a poor knowledge of the effect of refrigeration on the growth of pathogens. Only around one third of responses were correct while the rest indicated a lack of knowledge. Similarly, in a previous study by Bearth et al. (2014) consumers displayed a paucity of knowledge regarding temperatures required to inhibit bacterial growth. 48.5% of Irish residents thawed their meat in the refrigerator while only 31.9% of South African meat handlers thawed meat in refrigerators (Teffo and Tabit 2020). Knowledge of when to buy meat while shopping, correct storage and thawing procedures during refrigeration prior to cooking are important factors regarding the spread of pathogenic bacteria.

The level of awareness of pathogenic risk factors was low since less than half of the study population indicated an awareness of risk factors associated with meat handling as indicated by responses to questions such as when to buy chicken, how to thaw raw chicken, how to tell if the chicken was properly cooked etc. The studied population also had poor knowledge of food pathogen survival in refrigeration conditions. Further efforts need to be made to educate the Irish population on the importance of using thermometers to ensure food safety and not just depend on arbitrary methods.

3.3 Cross-contamination

Participants were required to score 3 correct answers to attain a pass grade (Table 4). The survey results fell within the range of 0–7, yielding a mean score of 3.35 ± 1.14, and an overall pass rate of around 80% Furthermore, approximately 70% of the respondents owned a set of chopping boards and knives which were specifically used for segregated preparation of ready-to-eat foods and raw meats. Bacteria can potentially survive on the surface of a chopping

board for at least four hours and successfully cross-contaminate fresh vegetables if the same board is used for both tasks. In a study conducted by Zhao et al. (1998), slicing vegetables on cutting boards following the cutting of raw poultry was found to transfer large populations of bacteria (10^3 to 10^4 CFU/g) from the cutting board to vegetables also cut on the board. Therefore, the cutting board must be disinfected or decontaminated between tasks as rinsing with water is not sufficient to remove the bacteria.

Most of the respondents, knew that raw chicken should be stored at the bottom of the fridge in an airtight container. Previously, Moreb et al. (2017) found that 48% respondents believed chunks of meat should be sealed and stored in the refrigerator, while Balzan et al. (2014) noted that their studied population stored raw fish and meat on the first shelf (25%) and the middle shelf (50%), respectively. However, in the current studied population only 45.4% recognized that ready-to-eat foods should be placed on the top shelf of the fridge with a protective cover. Moreover, in a study carried out by Masson et al. (2017), 90% of the respondents failed to differentiate where vegetables and ready-to-eat meals should be stored (Masson et al. 2017).

With respect to how "*Salmonella*-contaminated" kitchen wall, worktop and cooker can be effectively cleaned, around 60% of the respondents believed that using antibacterial spray and wiping with a kitchen towel was sufficient to remove *Salmonella* from cooking utensils and walls, while less than 6% of respondents believed that *Salmonella* could remain present after using an antibacterial spray, soap, and warm water to clean surfaces. Cross-contamination from raw meat to ready-to-eat foodstuffs and food preparation utensils is a major cause of foodborne illness outbreaks (Dantas et al. 2018; Ravishankar et al. 2010) found that the cleaning of utensils with soap and hot water is necessary, as bacterial counts of *Salmonella* are relatively unaffected by rinsing alone. Furthermore, Gorman et al. (2002) carried out a study to detect the levels of cross-contamination in a domestic kitchen, resulting from the preparation of a roast chicken dinner. The data from this study revealed that 80% of chickens used in the experiment contained one or more pathogenic bacteria, with these bacteria causing cross-contamination on 12% of dishcloths, 24% of individuals hands, 4% of fridge door handles, 20% oven door handles, 24% countertop surfaces and 32% draining boards. That study displayed the high levels of cross-contamination that could occur during food preparation if correct hygiene practices were not followed. In the current study, a high pass rate of almost 80% indicates a good knowledge of the study population within the cross-contamination section.

Table 5 Hygiene practices of participants

Questions	n	Category	Participants (n)	Percentage (%)
1. How do you clean your chopping board and knife after preparing raw chicken?	1555	With cold water and wipe dry	18	1.2
		With warm water and wipe dry	75	4.8
		With hot water and a washing up liquid and dry	**1456**	**93.6**
		Away with a wet towel	6	0.4
2. While handling raw chicken when do you wash hands?	1555	If my hands are dirty, I wash beforehand	16	1.0
		Wash hand after handling raw chicken	488	31.4
		I always wash hand before and between handling different food items	**1044**	**67.1**
		I don't remember	7	0.5
3. How do you clean your hands after handling raw meat?	1553	Wipe with a tea-towel, dishcloth, J-cloth	6	0.4
		Rinse them under tap water	52	3.3
		Wash with ordinary soap and tap water	**513**	**33.0**
		Wash with antibacterial soap, warm water	982	63.2
4. To wash your hands properly, after applying soap to wet hands, how long should you rub your hands together for?	1556	At least 5–10 s	72	4.6
		At least 10–15 s	156	10.0
		At least 15–20 s	632	40.6
		At least 20–30 s	**696**	**44.7**
Total Pass			1334	87.6
Mean score ± standard deviation		2.38 ± 0.86		

Passing scores: 2 or more correct answers out of 4 questions

The correct answers are highlighted in bold

3.4 Hygiene practices

Table 5 presents the hygienic food preparation practices of the surveyed participants. Results displayed a mean score of 2.38 ± 0.86, and a total pass mark of over 87% indicative of good hygiene practices.

Poor hygiene practices during food preparation could be the starting point for *Salmonella* contamination. This issue is routinely highlighted by Safefood Ireland (2022) that

provides informative television adverts on cross-contamination and hand hygiene. When respondents were questioned regarding "hand washing procedures after handling raw meat" (Table 5), more than 96% of respondents advocated the use of soap and water. Mama and Alemu (2016) reported that almost 72% of food handlers in a student cafeteria of Arba Minch University in South Ethiopia admitted to rinsing their hands with water without using soap after handling meat. As shown in Table 5, almost 45% of the respondents believe that 20–30 s are sufficient for proper handwashing thus indicating that a significant proportion of the studied Irish population understands the appropriate hygiene practices necessary for maintaining food safety. A previous study carried out in the US observed that 85% of cross-contamination occurred due to improper handwashing procedures, which subsequently led to illness (Mazengia et al. 2015). Furthermore, Pouillot et al. (2012) indicated that an increased risk of salmonellosis could be attributed to raw chicken sources combined with poor hygiene practices within a domestic setting.

It must be noted that washing with antibacterial soaps containing triclosan and triclocarban only increases antibacterial resistance and hence ordinary soaps are better for hand washing (American Society for Microbiology 2017). A Korean study showed that 0.3% triclosan had no significant difference in its bactericidal effects during hand washing compared to plain soap (Wise 2015).

3.5 Knowledge of *Salmonella* associated with poultry

Table 6 presents the respondent's knowledge of *Salmonella* associated with poultry and answering correctly at least 4 questions was considered a pass mark. A range of 0–8 was used and a mean score of 5.46 ± 1.35 was obtained. A total passing rate of almost 92% indicated good knowledge of this pathogen. A high percentage of respondents correctly identified the population groups most susceptible to *Salmonella* infections and the vast majority recognised *Salmonella* as a bacterium.

A comparative study by Henke et al. (2020) reported that 77.3% of German participants were aware of *Salmonella* and knew how to protect themselves indicating a strong awareness. Most of the respondents (94%) of the present study knew *Salmonella* could potentially cause disease in poultry or humans, and approximately 62% believed it could be found on all parts of the egg, 58% recognized that salmonellosis is not solely associated with poultry and 72% correctly identified the different modes of transmission. However, a study by Zhu et al. (2017) reported that frozen packaged poultry contained less *Salmonella* than freshly chilled packaged poultry at retail level. It was also noted that unpackaged poultry available in the farmers' market and in the supermarket, both contained a higher bacterial count (CFU/g) than their packaged chilled and frozen counterparts.

A relevant study concerning *Salmonella* knowledge, attitudes, and practices by Kauber et al. (2017) indicated that 40% of the participants believed it could cause disease in poultry, while 98% believed it could cause disease in humans, 86% knew it is not exclusively associated with poultry, 54% believed it can be found on all parts of the egg, while 94% of the flock owners correctly identified all modes of transmission. Henke et al. (2020) found that Irish residents were aware of *Salmonella* as a pathogen associated with poultry. However, less than 5% of the participants in the present study (Table 6) knew that symptoms of salmonellosis could take 4 to 5 days to appear.

3.6 *Salmonella* infections associated with travel

Travel-related data could possibly help identify the routes of exposure to salmonellosis while abroad. The Health Protection Surveillance Centre (2019) declared that 51% of Irish *Salmonella* cases were travel-related. Around 40% of the participants in this study exhibited foodborne illness while abroad. Kendall et al. (2012) found that 32% of Americans contracted non-typhoidal *Salmonella* while on holidays. Table 7 indicates that almost 70% of the participant in the current study prefer to eat out when abroad, a behaviour that increases the risk and exposure to foodborne illness such as salmonellosis.

3.7 The relation between the demographic characteristics and food safety knowledge

Consumer food safety knowledge was assessed in terms of meat handling practices, cross-contamination, and knowledge of pathogens (Table 8). The test was regarded as "passed" a respondent obtained 10 or more points. The mean score of the overall food safety knowledge was 12.03 ± 2.9 and the overall pass rate of 79.8% indicated a positive relationship between demographic characteristics and food safety knowledge. The results showed that age, gender, marital status, gross annual income, and nationality were statistically important factors ($p < 0.05$) that impacted heavily on the food safety knowledge of the participating consumers (Table 8). Lower income residents in Ireland (below 30,000 Euro) had more knowledge of food safety compared to the higher income group (100,000 and above). On the other hand, education and residence did not have any significant effect ($p < 0.05$), which suggested that efforts could be directed towards these 2 demographics to increase the knowledge level. Females aged over 50, unmarried, earning

Table 6 Knowledge of pathogen associated with poultry

Questions	n	Category	Participants (n)	Percentage (%)
1. *Salmonella* is a:	1556	**Bacterium**	**1477**	**94.9**
		Virus	25	1.6
		I don't know	54	3.5
2. *Salmonella* can cause severe disease in poultry/human	1556	**Yes**	**1462**	**94.0**
		No	39	2.5
		I don't know	55	3.5
3. *Salmonella* is only found in poultry and poultry products	1555	Yes	409	26.3
		No	**907**	**58.3**
4. *Salmonella* can be found on which part of the egg	1552	Egg white (albumin)	481	31.0
		External eggshell	110	7.1
		All parts of the egg	**961**	**61.9**
5. *Salmonella* can be transmitted by	1556	Eating undercooked/raw eggs	234	15.0
		Handling chicks/chickens	32	2.1
		Contact with eggs	10	0.6
		Contaminated surfaces	164	10.5
		All of the above	**1116**	**71.7**
6. When you buy the chicken from supermarket *Salmonella* can be present….	1553	On the skin	188	12.1
		Outside the packaging	38	2.4
		Only inside the body cavity	187	12.0
		All of the above	**1140**	**73.4**
7. *Salmonella* food poisoning symptoms occur…	1556	Within an hour	296	19.0
		Within 24 h	875	56.2
		Within 4 to 5 days	**74**	**4.8**
		I don't know	311	20.0
8. Which group of people is most likely to get Salmonellosis after eating *Salmonella* contaminated food?	1554	Elderly	53	3.4
		Young children	17	1.1
		Pregnant women	44	2.8
		Individual with weak immunity	100	6.4
		All of the above	**1340**	**86.2**
Total Pass			1419	91.8
Mean score ± standard deviation		5.46 ± 1.35		

Passing scores: 4 or more correct answers out of 8 questions

The correct answers are highlighted in bold

below 30,000 Euro and Irish national respondents residing in cities exhibited a good level of food safety knowledge.

3.8 The relation between the demographic characteristics and food hygiene practices

As shown in Table 5, 4 questions were used to analyse the hygienic food preparation practices of respondents. The test was regarded as "passed" if a respondent obtained at least two points. The mean score was 2.38 ± 0.86 and the total pass mark 87.6%. The relationship between demographic characteristics and food hygiene practices were subsequently correlated (Table 9). The results show that age, gender, and marital status were statistically significant factors ($p < 0.05$) that determine food hygiene practices among the participants (Table 9) whereas educational level, gross annual income, nationality, and residence do not have any significant effect ($p < 0.05$). This gives an indication as to where efforts should be directed to improve knowledge of hygienic food practices in the Republic of Ireland. Females had a significant ($\chi2$: 0.00) higher knowledge of hygienic practices (pass rate 70%) than males, while the Irish had a significant ($\chi2$: 0.188) higher knowledge (pass rate 79.5%) than other nationalities. The prominence of nationality (Tables 8 and 9) can be ascribed to the fact that the focus of this research was Irish residents. Females involved in food

Table 7 Behaviours and attitudes that pose risks to respondents when travel outside Ireland

Questions	n	Category	Participants (n)	Percentage (%)
1. Did you ever fall sick due to food poisoning while on holiday/abroad? If yes, which food caused the food infection?	1531	I never had food poisoning while abroad	912	59.6
		Chicken/eggs	136	8.9
		Other meats	144	9.4
		Fruits or vegetables	41	2.7
		I can't remember	298	19.5
2. How do you dine while on holiday/abroad?	1553	I love street food	68	4.4
		I prefer buying groceries and self-cooking	138	8.9
		I prefer to eat out most of the time	1071	69.0
		I eat outside a few times	276	17.8
3. How much do you care about food safety while you are in abroad?	1539	I like to live free and bother less about food safety	79	5.1
		I trust food business such as street food venders, hotels restaurants always prepare/cook safe foods	596	38.7
		I am very concerned about how my food is processed	516	33.5
		I trust the official food regulations of the country	348	22.6

Table 8 The relation between the demographic characteristics and food safety knowledge (meat handling, cross contamination and knowledge of pathogens)

Variables	n	Pass rate %	p-value	Mean score	p-value
Age					
18–25	1492	23.8	0.00[a]	11.2	0.00[c]
26–35		13.1		11.5	
36–50		20.1		12.3	
51 above		22.8		12.9	
Gender					
Male	1494	13.9	0.00[a]	10.9	0.00[c]
Female		65.9		12.3	
Other		0		7.	
Marital status					
Unmarried	1493	37.2	0.00[a]	11.5	0.00[c]
Married with children		29.9		12.4	
Married without children		5.3		12.5	
Other		7.3		12.4	
Educational level					
Primary school	1494	0.4	0.232[a]	9.7	0.176[c]
Secondary school		22.2		11.9	
University/College/Institute of Technology degree		57.2		12.1	
No formal education		0.1		10.5	
Gross annual income Euro (€)					
<30,000	1489	37.0	0.003[a]	11.6	0.00[c]
30, 000–60, 000		30.2		12.2	
60, 000–100, 000		10.1		12.3	
100, 000 and above		2.4		13.1	
Nationality					
Irish	1492	73.1	0.001[a]	12.1	0.001[b]
Other		6.7		11.0	
Residence					
City/Town	1493	42.9	0.119[a]	11.9	0.231[c]
Countryside		34.4		12.2	

[a] Pearson Chi-square (χ2) test was conducted

[b] Mann Whitney U test conducted

[c] Kruskal Wallis test conducted

handling often have a higher significant knowledge of food hygiene practices (Baluka et al. 2015; Luo et al. 2019) and this group poses the least risks to food safety.

4 Conclusion and recommendation

The results of this survey indicate that the population of the study had a good knowledge of some aspects of preventing salmonellosis. The studied population had a variable knowledge of food-handling practices including meat-handing knowledge, hygiene practices and an excellent knowledge of the *Salmonella* bacterium. Overall, the study population was aware that raw foods especially meat, fish, and vegetables should be segregated from cooked and ready-to-eat foodstuffs at all times. It was also found that the majority of the study population used colour coded chopping boards to facilitate safe and segregated preparation of foodstuff.

However, although the use of domestic thermometers is highly recommended to correctly measure cooking temperatures and eliminate *Salmonella* from home cooked foodstuffs, the studied population preferred to use their own traditional methods to confirm the safety of the food. Further research needs to be undertaken to determine which thermometers would be suitable for convenient and accurate readings when cooking in a domestic setting. Educational programmes could possibly be circulated on social media platforms to further encourage the use of domestic thermometers so that consumers can accurately determine the safety of their home cooked meals.

Table 9 The relation between the demographic characteristics and food hygiene practice

Variables	n	Pass rate %	p-value	Mean score	p-value
Age					
18–25	1503	29.3	0.412[a]	2.31	0.004[c]
26–35		14.2		2.28	
36–50		20.7		2.42	
51 above		23.4		2.51	
Gender					
Male	1503	17.6	0.00[a]	2.12	0.000[c]
Female		70.0		2.45	
Other		0.0		1.00	
Marital status					
Unmarried	1503	43.3	0.383[a]	2.33	0.034[c]
Married with children		30.4		2.38	
Married without children		5.7		2.55	
Other				2.38	
Educational level					
Primary school	1505	0.6	0.826[a]	2.0	0.222[c]
Secondary school		25.4		2.34	
University/College/Institute of Technology degree		61.6		2.40	
No formal education		0.1		3.0	
Gross annual income Euro (€)					
<30,000	1499	42.9	0.600[a]	2.35	0.787[c]
30,000–60,000		31.7		2.42	
60,000–100,000		10.6		2.38	
100,000 and above		2.3		1.37	
Nationality					
Irish	1502	79.5	0.188[a]	2.39	0.906[b]
Other		8.0		2.34	
Residence					
City/Town	1503	47.9	0.333[a]	2.37	0.617[c]
Countryside		36.8		2.39	

[a] Pearson Chi-square ($\chi 2$) test was conducted

[b] Mann Whitney U test conducted

[c] Kruskal Wallis test conducted

Declarations

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