ASSESSING CONSUMER FOOD SAFETY BEHAVIOUR IN BANGLADESH: AN EXPLORATION OF KNOWLEDGE, ATTITUDE, PRACTICES (KAP), AND THE INFLUENCES OF COVID-19

A Thesis Submitted by

Rakia Hossain

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ABSTRACT

This thesis reports on results that investigate and compare the pre-pandemic and pandemic food safety knowledge, attitude, and practice (KAP) among the domestic food handlers in Bangladesh utilising the conceptual model - 'knowledge-attitude-practice' (KAP). Also, this study examines general and behaviour-specific risk perception towards food safety and examines the associations between food safety knowledge, attitude, practice and risk perception. The current research conducted a cross-sectional quantitative survey of 503 domestic food handlers in Bangladesh. The findings of this thesis suggest that most urban food handlers had a higher pandemic-related knowledge and hygiene behaviour (PRKHB) than their rural counterparts. Most food handlers did not show increased concern about food safety due to the COVID-19 pandemic. The findings indicated that the food handlers showed a substantial improvement in food safety knowledge, attitude and self-reported practice (KAP) levels after the COVID-19 outbreak in the domestic environment in Bangladesh. Despite the food handlers indicating a satisfactory food safety attitude before and after the pandemic, their food safety knowledge and practice levels were inadequate in both instances. The food handlers also showed that their risk perception towards self-prepared food was low compared to the food prepared by others (e.g., restaurants). This thesis confirmed that food handlers' behaviour risk perception and attitude serially mediate the association between food safety knowledge and practice. In addition, the study scrutinised sociodemographic changes and remarkable divergences between urban and rural locations. This research will provide a robust understanding of food safety knowledge, attitudes, and practices of adult consumers within the domestic environment in Bangladesh, which will become essential for planning and implementing food safety management strategies and developing food safety-related programs in Bangladesh. This study will help to understand the food handler's stance during a public health emergency, which will provide a better management system, decision-making, communication, and implementation of food safety in this community.

Keywords: Foodborne diseases, Food safety knowledge, Food safety attitude, Food safety practice, Pandemic related food safety, Risk perception towards food safety, Behaviour-specific risk perception, Food handler, Domestic food safety, COVID 19, Pandemic, Bangladesh.

CERTIFICATION OF THESIS

I Rakia Hossain declare that the PhD Thesis entitled *Assessing Consumer Food Safety Behaviour in Bangladesh: An Exploration of Knowledge, Attitude, Practices (KAP), and the Influences of COVID-19* is not more than 100,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references, and footnotes.

This Thesis is the work of Rakia Hossain except where otherwise acknowledged, with the majority of the contribution to the papers presented as a Thesis by Publication undertaken by the student. The work is original and has not previously been submitted for any other award, except where acknowledged.

Date: 28/10/23

Endorsed by:

Professor Rasheda Khanam,
Principal Supervisor

Professor Jeffrey Soar,
Associate Supervisor

Student and supervisors' signatures of endorsement are held at USQ.

STATEMENT OF CONTRIBUTIONS

The following research articles have been submitted and published in peer-reviewed journals for this PhD thesis. I am the primary author for all publications and papers. I held ultimate ownership of the submissions and directed the conceptual formulation, data extraction, analysis, and interpretation in addition to the initial drafting and final edits. For each study, I made between 70% and 75% of the overall contribution and solely to the quantitative analysis. I sincerely thank my supervisors and the other co-authors for their advice and assistance with the published and submitted studies that make up this thesis. Below are the specifics of each researcher's scientific contribution:

Paper 1:

Ishra, R., Khanam, R., Soar, J., & Sharif, S. (2023). Food hygiene knowledge and behaviour among domestic food handlers during COVID 19 pandemic in Bangladesh. *Food Control*, *153*, 109945. https://www.sciencedirect.com/science/article/pii/S0956713523003456

The overall contribution of Rakia Hossain was 70% to this paper. Collectively Professor Rasheda Khanam, Professor Jeffrey Soar, and Dr. Saif Sharif contributed the rest.

Paper 2:

Ishra, R., Sharif, S., Soar, J., & Khanam, R: Food Safety Knowledge among adult domestic food handlers in Bangladesh: A COVID-19 Comparative Study. 2023. (Under review in British Food Journal).

Rakia Hossain contribtued 70% to this paper. Collectively Professor Rasheda Khanam, Professor Jeffrey Soar, and Dr. Saif Sharif contributed the rest.

Paper 3:

Ishra, R., Sharif, S., Soar, J., & Khanam, R: Food safety attitude, self-reported practice and risk perception of domestic food handlers before and during the COVID-19 pandemic in Bangladesh. 2023. (Under review in the Current Research in Food Science).

The overall contribution of Rakia Hossain was 70% to this paper. Collectively Professor Rasheda Khanam, Professor Jeffrey Soar, and Dr. Saif Sharif contributed the rest.

Paper 4:

Ishra, R., Sharif, S., Soar, J., & Khanam, R: Role of food safety risk perception and attitude on knowledge and practice of domestic food handlers: A serial mediation model. 2023. (Under review in Food Control journal).

Rakia Hossain contribtued 75% to this paper. Collectively Professor Rasheda Khanam, Professor Jeffrey Soar, and Dr. Saif Sharif contributed the remainder.

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Note: Figures that appear in the thesis chapters of published/submitted papers are **not** included.

LIST OF ABBREVIATIONS

FBD	Foodborne disease
LMIC	Low-Middle income country
KAP	Knowledge, attitude, practice
PRKHB	Pandemic-related food hygiene behaviour
FSC	Food safety concern
FSK	Food safety knowledge
FSA	Food safety attitude
FSP	Food safety practice
SRP	Self-reported practice
ATT	Attitude
BRP	Behaviour-specific risk perception
AUD	Australian Dollar
BDT	Bangladeshi Taka
WHO	World Health Organization
STEC	Shiga toxin-producing Escherichia coli
DALYs	Disability adjusted life years
US	The United states of America
EU	European union
USD	United states dollar
sp.	Species
E. Coli	Escherichia coli
GAP	Good agricultural practice
GMP	Good manufacturing practice
HACCP	Hazard analysis critical control point
GMO	Genetically modified organisms
FDA	Food and Drug Administration
HBM	Health belief model
TPB	Theory of planned behaviour
BSE	Bovine spongiform encephalopathy
DNA	Deoxyribonucleic acid
RNA	Ribonucleic acid

SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
MERS	Middle East respiratory syndrome
ACE 2	Angiotensin-converting enzyme 2
RTE	Ready-to-eat
pH	Potential of hydrogen

CHAPTER 1: INTRODUCTION

1.1 Background

Safe food availability is fundamental for human survival and ensures good health. Even though food is a vital element of living for humans, it might have a variety of hazards that may cause individual illness (Fung et al., 2018). The incidence of foodborne diseases (FBD) is increasingly becoming a public health concern globally due to its significant adverse impacts on the development, national economy and foreign trade (Grace, 2023; Ishra et al., 2022). Due to poor sanitation, a shortage of literacy and education, the use of hazardous water for food preparation, and a lack of adequate food safety legislation, the FBD risk has become more prevalent in developing countries (WHO, 2015a). Over a billion episodes of foodborne-associated diarrhoea are estimated to occur annually worldwide, causing more than 3 million child deaths in developing countries (Fung et al., 2018).

Food contamination may occur at any stage, including during production, processing, transportation, storage, and preparation (WHO, 2016). Globally, food safety is the primary concern for all stakeholders, including the general public and regulatory authorities (Wilcock et al., 2004). It is of the utmost importance for consumers to comprehend their part in preserving the health of the larger community as a collective responsibility (WHO, 2016). Most FBDs linked to food consumed at home among consumers usually remain unreported or undiagnosed (Cho et al., 2020; Odeyemi et al., 2019; Vrbova et al., 2012; Keegan et al., 2009; Redmond & Griffith, 2003). One of the reasons consumers and domestic food handlers do not strive for medical attention for FBD is misinterpreting the condition (Lim et al., 2016). Previous studies have reported that over 35% of FBDs occur at home while handling food (Ishra et al., 2023; Odeyemi et al., 2019; Langiano et al., 2012). Food handlers are significant causes of food contamination because hazardous pathogens are able to transmit through cross-contamination on food handlers' hands (Campos et al., 2009; Baş et al., 2006; Kunadu et al., 2016). Improper food handling procedures of food handlers can lead to food contamination and FBDs. Appropriate hygiene practices by food handlers can minimise cross-contamination and aid in preventing illness among consumers. As the last link in the food supply chain, consumers'

knowledge of and adherence to food safety practices are crucial for halting the spread of FBDs (Jevšnik et al., 2008).

Foodborne infections are a significant public health concern worldwide and a serious threat to public health in low-middle-income (LMIC) countries such as Bangladesh (Ali, 2013). Due to inadequate monitoring systems, Bangladesh lacks reliable assessments of the adverse impacts of food hazards on public health (WHO, 2016). Cholera and diarrhoea are widespread in this country because of the severely unhealthy sanitation systems (Noor, 2016). Bangladeshi consumers are particularly vulnerable to microbiological food hazards since they reside in a highly populated LMIC. Proper sanitary handling and personal hygiene techniques can reduce these food hazards (Noor, 2016).

Since food is susceptible to contamination by food hazards, including bacterial, viral, and chemical (Fung et al., 2018), preventing food contamination and lowering FBD are essential food safety components (Luning & Devlieghere, 2006). Food safety is one of the necessary elements of the food system and has recently been affected by the unprecedented COVID-19 pandemic (Galanakis, 2020). The COVID-19 respiratory disease, which has symptoms that fluctuate from a mild influenza-like sickness to severe pneumonia and acute respiratory distress syndrome, is triggered by the Severe Acute Respiratory Syndrome Coronavirus - 2 (SARS-CoV-2) virus (Olaimat et al., 2020). As of September 13, 2023, 695,189,446 people have been infected, and 6,914,967 have died because of COVID-19 (Worldometer, 2023). Respiratory discharges spread through talking, coughing, sneezing, or close contact with infected individuals are the modes of transmission for COVID-19 (Wang et al., 2020). Although there is no confirmation that COVID-19 is an illness associated with food (Jalava, 2020), the virus can survive for hours on a wide range of surfaces or enter food items and their packaging through an infected individual (Rizou et al., 2020). Therefore, better food safety and hygiene measures are required to control this mode of viral transmission (Shariatifar & Molaee-agree, 2020; Galanakis, 2020).

Studies have been conducted on consumers' food safety knowledge, attitudes, and practices (KAP) throughout the world (Luo et al., 2019; Agüeria et al., 2018; Tomaszewska et al., 2018; Moreb et al., 2017; Stratev et al., 2017; Al-Shabib et al., 2016; Kunadu et al., 2016; Asiegbu et al., 2016; Farahat et al., 2015; Jevšnik et al., 2008; Rao et al., 2007; Sanlier, 2009; Trafialek et al., 2018). However, the COVID-19 pandemic has brought on a pre-and

post-pandemic era and enormous challenges in all aspects of life, including food safety. From the existing literature, it was apparent that no research has been conducted comparing household food handlers' pre- and post-COVID food safety behaviour. Further, in an LMIC such as Bangladesh, no prior studies have been found on knowledge, attitude and practices (KAP) of household food handlers' food safety before the outbreak of this pandemic. In addition, consumers' food safety concerns might have increased after the COVID-19 outbreak (Yang, 2020). Hence, the pandemic might have influenced their KAP and risk perception towards food safety. Because of the significant research gap and inadequate data on food handlers' food safety KAP within the domestic environment before the pandemic and the impact of the current pandemic on the food safety KAP, this study aims to investigate both pre-pandemic and post-pandemic food safety KAP to compare the change. Further, this study examines the food handlers' food safety concerns and food hygiene practices related to the pandemic. Therefore, this research has been conducted specifically to answer the following questions using a cross-sectional survey:

1. What is the adult food handlers' pre- and post-pandemic knowledge, attitude and practice level of food safety within the domestic environment in Bangladesh?
2. What is the difference between adult consumers' pre-pandemic and post-pandemic food safety KAP levels within the domestic environment in Bangladesh?
3. What are adult domestic food handlers' general risk perception and behaviour-specific risk perception towards food safety in Bangladesh?
4. Is there any association between food safety KAP and behaviour-specific risk perception of adult food handlers' within the domestic environment in Bangladesh?
5. What is the effect of the COVID-19 pandemic on the pandemic-related food hygiene behaviour (PRKHB) and food safety concerns of adult food handlers in Bangladesh?

A more in-depth comprehension of food safety knowledge, attitudes, practices, and risk perception among food handlers will be essential for planning and implementing food safety management strategies and developing food safety-related programmes in Bangladesh. Further, this study aims to help understand the consumers' stance during a public health emergency, which will provide a better management system, decision-making, communication and implementation of food safety in future health emergencies.

1.2 Research Gaps

Although the home is the primary site of foodborne outbreaks, many consumers do not consider the domestic environment risky for food poisoning (Redmond & Griffith, 2009). Individuals frequently believe that consuming food from restaurants or commercial manufacturers generally causes FBDs (Janjić et al., 2017). Many people are uninformed that foodborne pathogens are found within the domestic environment most of the time rather than anywhere else such as, restaurants, industrial factories; therefore, FBD is growing globally due to the domestic transmission of these pathogens (Redmond & Griffith, 2009). The majority of consumers are unaware that home food preparation accounts for at least 60% of foodborne infections (Janjić et al., 2017). A variety of foodborne infections occur in the home as a result of improper food handling (Redmond & Griffith, 2009). If consumers can maintain food safety processes such as personal hygiene, proper cooking methods and storage, avoidance of cross-contamination, and temperature control, FBDs can be prevented within the domestic environment (Ruby et al., 2019). Adult consumers are responsible for protecting FBD while cooking meals within the home (Basha & Lal, 2019). Even though consumers are the last line of defence in the food safety chain, most do not have the basic knowledge to prevent food contamination (Janjić et al., 2017). Hence, it is necessary to understand how adult consumers are operationalising their knowledge, attitude, and practice towards food safety in the home before developing strategies to control FBDs (Wilcock et al., 2004).

Recently, food safety has been severely impacted due to the emergence of the COVID-19 pandemic (Osaili et al., 2021). The recent outbreak has shown the global significance of food safety (Kamgain et al., 2022). This pandemic has altered the global food system, consumer food safety awareness, food preparation, hygiene behaviour and eating habits (Osaili et al., 2022; Osaili et al., 2021). To reduce the spread of the SARS-CoV-2 virus, experts have established varied food safety methods and personal hygiene practices (Olaimat et al., 2020). Consumers' knowledge and attitudes towards health issues may be used as health behaviour predictors to analyse individuals' health behaviours in emergencies, for example, the COVID-19 pandemic (Salehi et al., 2022). When individuals are most vulnerable during a pandemic, their pandemic-related cognitive perceptions affect the extent to which they are conscious of food safety (Mucinhato et al., 2022; Yang, 2020). As a result, the COVID-19 pandemic has altered how individuals purchase, prepare, and consume food. The significance of these factors in the context of developing countries such as Bangladesh is still not fully understood.

Bangladesh is dealing with the challenges of FBDs (Ali, 2013). Bangladeshi consumers live in a densely populated LMIC; hence, they are prone to suffer from microbiological food hazards, which can be prevented by proper food safety measures (Noor, 2016). Despite the importance of domestic food handling to prevent food contamination, no studies have investigated food safety attitudes, practices and risk perceptions among food handlers before the COVID-19 pandemic in the domestic environment in Bangladesh. Moreover, the extant literature indicates that no studies have been performed on domestic food handling comparing the pre and post-COVID times. Considering the gravity of food safety on public health and the impact of the recent pandemic, this study highlights an extensive knowledge gap in domestic food safety behaviour and risk perception in LMICs, such as Bangladesh. Therefore, food safety knowledge, attitude, and practice comparing the pre- and post-COVID times and risk perception within the domestic environment should be measured among Bangladeshi food handlers in light of the current pandemic to develop further food safety strategies to alleviate FBDs and related health emergencies in this community.

1.3 Research aims and objectives

The present thesis aims to investigate both pre-pandemic and post-pandemic food safety knowledge, attitudes, and practices of adult food handlers within the domestic environment to compare any changes in Bangladesh. This thesis has examined food safety concerns of the food handlers after the onset of the pandemic and food hygiene practices related to COVID-19. The study has also examined the food safety risk perception in terms of general and behaviour-specific food safety risk perception of the adult food handler. This thesis has explored any association between post-pandemic knowledge, attitude, practice and risk perception level and also evaluated the relationship between their demographic variables and post-pandemic knowledge, attitudes, practice and risk perception level towards food safety. To achieve the research goals outlined above, four studies (Studies 1-4) were conducted, and the objectives were divided through four studies as follows:

Study 1

I. To evaluate food safety concerns (FSC) of the food handler after the onset of COVID-19 pandemic in the domestic environment.

II. To determine food handlers' pandemic-related knowledge and hygiene behaviour (PRKHB) in the domestic environment in Bangladesh and
III. To assess the impact of food safety concerns and sociodemographic factors on pandemic-related knowledge and hygiene behaviour (PRKHB).

Study 2

I. To examine and compare adult consumers' pre-pandemic and post-pandemic food safety knowledge (FSK) who handled food in the domestic environment.
II. To evaluate the association between food handlers' sociodemographic profiles and their food safety knowledge (FSK) level.
III. To investigate the elements that regulate the food handlers' food safety knowledge (FSK) in the domestic environment.

Study 3

I. To explore and compare adult consumers' pre-pandemic and post-pandemic food safety attitude (FSA) and self-reported practice (SRP) in the domestic environment.
II. To inquire the domestic food handlers general risk perception towards food safety.
III. To understand the association between food handlers' demographic factors, pre- and post-pandemic food safety attitude (FSA), self-reported practice (SRP), risk perception towards food safety.

Study 4

I. To examine domestic food handlers' knowledge of food safety (FSK) influences their behavioural risk perception of food safety (BRP) and attitude towards food safety (ATT)
II. To understand the food handlers' behavioural risk perception of food safety (BRP) impacts their self-reported food safety practice (FSP) and attitude (ATT) level.
III. The behavioural risk perception (BRP) and attitude (ATT) mediates the relationship between domestic food handlers' food safety knowledge (FSK) and practice (FSP).

1.4 Significance of the Study

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To reduce the transmission of foodborne infections in the domestic environment, consumers should be aware of correct food-handling procedures, such as the appropriate way of cooking foods, the necessity to separate foods for safety, and the requirement to cook and chill food at optimum temperatures. This study will help the target population better grasp the various hazards related to food and stop the spreading of foodborne pathogens in the domestic setting by educating and strengthening adult consumers' comprehension of these issues. Evaluating the food safety knowledge, attitudes, practices and risk perception during the pandemic will help to gain effective data to implement food safety interventions and explore the impact of an emergency health situation on consumers' food safety awareness. Measuring and comparing the pre-pandemic and post-pandemic food safety KAP will help understand the difference in consumer food safety behaviour and any positive and negative behavioural patterns, which will help implement further food safety strategies according to the adult consumers' KAP level. Food safety programmes should be implemented within low- and high-risk target populations. These initiatives can reduce foodborne disease (FBD) outbreaks by informing people about preventative measures they may take to protect themselves and their families from FBDs.

1.5 Research Methodology

A positivist paradigm approach was the highlighted research problem. The foundation of the positivist paradigm refers to research methodologies as the scientific method of enquiry (Kivunja & Kuyini, 2017). It explains observations of quantifiable objects or facts and offers cause-and-effect associations in nature (Fadhel, 2002). Within the field of epistemology, the positivist paradigm pertains to objectivism, while ontology is characterized by naive realism (Kivunja & Kuyini, 2017). The study of ontology involves the belief in the existence of something (Scotland, 2012), whereas the study of epistemology involves the understanding of reality (Kivunja & Kuyini, 2017). The present research dilemma was steered by the principles of the positivist paradigm, which were grounded by ontological presumptions emphasizing realism. This statement indicates that reality is singular, objective, and independent of the researcher (Sukamolson, 2007). This implies that the researcher was detached from the study as much as possible and adopted techniques that limited the researcher's engagement in the study while maximising objectivity (Sukamolson, 2007). Regarding objective epistemology,

knowledge acquired through rational thought or investigation results in a more objective comprehension of the surrounding world (Fadhel, 2002). Based on this epistemological stance, the present research problem was comprehended through research investigation (Kivunja & Kuyini, 2017).

The positivist paradigm relies on testing hypotheses, formulating operational definitions, and performing computations, equations, and expressions in order to draw conclusions (Kivunja & Kuyini, 2017). In a positivist paradigm, the researcher assesses observations of measurable items or facts and examines the cause-and-effect patterns in nature (Fadhel, 2002). The experimental methodology component of this paradigm concerns the investigation of whether manipulating one variable has an impact on another variable. The antecedent variable denotes the explanatory variable, whereas the consequent variable is the dependent variable (Kivunja & Kuyini, 2017). The positivist paradigm depends on a quantitative technique since it measures relationships between variables. To forecast a measurable outcome, the positivist paradigm uses deductive reasoning, calculations, and extrapolations. Additionally, positivist researchers might draw inductive conclusions that allow them to generalise the specific phenomenon they have observed in the study. The foundation for researchers should be quantitative research methodologies in this paradigm. This method provides a detailed explanation of the parameters and coefficients in the data that are acquired, processed, and interpreted to comprehend relationships embedded in the analysis (Kivunja & Kuyini, 2017).

Consequently, the above-mentioned research problem was addressed using a quantitative research methodology. A quantitative study incorporating multiple numerical procedures to enhance objectivity can identify a research problem that explains the relationship among variables. It illustrates the links between variables or how one variable influences another (Creswell, 2014). Quantitative studies assess individuals' attitudes, behaviours, and opinions (Sukamolson, 2007). Thus, the research inquiry validates this methodology by ascertaining the degree of Bangladeshi adult food handlers' knowledge, attitude, practice, and risk perception concerning food safety. The employment of nondirectional exploratory verbs, such as 'relate', 'influence', or 'impact', indicates the necessity of quantitative research (Creswell, 2009). As a result, it would be appropriate and justified to analyse the proposed research questions using quantitative methodology.

The current study used a convenience sample method to gather quantitative data. Convenience sampling was selected because it is a simple, least time-consuming, and least expensive strategy, considering the time and resources of this particular study (Bornstein et al., 2013). To compare the reactions between urban and rural areas, the present study gathered data from four distinct locations in Bangladesh. The study was carried out in four locations encompassing two urban areas Dhaka and Chittagong, and two rural districts, Faridpur and Cox's Bazar. The capital city of Bangladesh, Dhaka, has an economy based on industry and a population of approximately 14.7 million. With an approximate population of 2.1 million and an economy that revolves around agriculture, Faridpur is situated in the district of Dhaka division (BBS, 2022). The geographical location of both Chittagong and Cox's Bazar is in the coastal region of Bangladesh. Chittagong, boasting a population of approximately 9.1 million, ranks as the second largest city. The district of Cox's Bazar, situated in the Chittagong division, has a population of 2.8 million and is predominantly reliant on agriculture for its economic sustenance (BBS, 2022).

A sample is a group from which information is obtained, and sampling is the process of selecting a sample from a population so that the individuals are representative of the larger group from which they were selected (Fraenkel et al., 1993). Domestic food handlers aged 18 years and above, who prepared food at least 2-4 times per week, were involved in a cross-sectional descriptive survey conducted by the study. A sample size of 385 was determined with a 5% margin of error to calculate a 95% confidence interval based on the adult population of 104.87 million in Bangladesh. The well-accepted notion is that a large sample size improves the study's informativeness and inferential goals. The study team gathered further information with an ultimate sample size of 503. This sample size had been determined after considering the possibility of refusals, losses and missing data, and the need for adjustments for confounding factors, as suggested by (Martínez-Mesa et al., 2014).

After receiving approval from the University of Southern Queensland Human Research Ethics Committee in Australia (USQ HREC ID: H21REA161), the data collection process began. Before beginning the data collection, each research assistant received thorough training in accordance with university standards. The research assistants randomly visited the chosen public locations from the study sites, including local markets, supermarkets, traditional bazaars, schools, colleges, and parks. The research assistants contacted people in front of stores or schools using a convenience sampling strategy to select the participants. After informing them

of the study's goals, maintaining their confidentiality, and obtaining their informed consent, the researcher conducted in-person interviews with each participant from November 2021 to March 2022. It took 20 to 25 minutes to finish each survey. After being translated into Bengali, survey information was gathered electronically using Google forms. As a reward for completing the entire survey, five participants were given gift cards worth about 3000 BDT ($50 AUD) through a raffle draw.

A rigorous quantitative study achieves its aims through validity and reliability. Validity refers to the extent to which an idea is accurately measured, and reliability means the accuracy of the instrument. Although the exact calculation of reliability is not possible, reliability can be estimated through different measures such as internal consistency, stability, and equivalence (Heale & Twycross, 2015) Therefore, to improve the reliability and validity as much as possible of this current study, questionnaires were designed by using valid instruments that had been successfully utilised in previous studies. In contrast, a pilot study was conducted to check the feasibility and functionality of these instruments. The internal consistency has been checked during the data analysis process (Van Gelder et al., 2010).

1.6 Theoretical underpinnings

The KAP (Knowledge, Attitude, and Practice) theory, which emphasises the value of knowledge and attitude in supporting practices, has been selected as the conceptual framework for this study (Mihalache et al., 2021; Zanin et al., 2017). Models for behavioural transformation must include knowledge, attitudes, and practices. Understanding information is the conscious and non-symbolic sense of meaning, known as knowledge (Liao et al., 2022). Attitude can be viewed as a positive or negative assessment (Ajzen & Fishbein, 2000). Practise describes routine actions shaped by commonly accepted social norms and ideas (Bourdieu, 1990).

In the 1950s, KAP surveys were initially established. KAP surveys were widely used in several countries to study family planning practices after 1960. Because they are target-oriented and have a constrained scope, KAP investigations are more resource-efficient and cost-effective than other social research strategies (Marathe et al., 2016). Cunha et al. (2022) have pointed out various limitations of the KAP model. Firstly, the purpose of this model is to explain a complex phenomenon by employing a simplified approach involving two variables: knowledge

and attitudes. Secondly, the correlation between KAP showed variability in different research studies and contexts. Despite these limitations the KAP model remains a widely adopted methodology for food safety research in contemporary studies (Cunha et al., 2022). As the KAP model has the potential to evaluate how knowledge, attitudes, and practices are related (Liao et al., 2022), this research model has been extensively utilised in health education understanding, behavioural changes of the patient and patient health outcomes, and in developing nations for family planning. KAP surveys are currently a popular approach for examining how people behave when impacted by a condition or illness (Marathe et al., 2016). The KAP model is a systematic, standardised questionnaire that a target population is required to complete to measure and analyse what is understood (knowledge), held in belief (attitudes), and practised (practices) concerning a subject in interest (Andrade et al., 2020; Nguyen et al., 2019). Hence, the data from the KAP model may be used to evaluate knowledge gaps, attitude obstacles, and practice patterns that could help individuals comprehend and act on a particular issue (WHO, 2008).

In public health, KAP (knowledge, attitude and practice) is an essential cognitive index considering health promotion. It involves a range of beliefs about the aetiology of a disease, the factors that exacerbate it, symptom identification, available methods of treatments, and consequences of the disease (Ferdous et al., 2020; Szymona-Pałkowska et al., 2016). Various sources such as governmental information, online platforms (i.e., social media), previous personal experiences, medical sources, and even some stereotypical concerns about the disease may influence a person's belief system. Individuals' perceptions and actions about illness prevention and treatment may alter depending on the precision of these beliefs. In many cases, any misconstrued or false belief or the absence of knowledge about a disease may carry a potential health risk (Zhou et al., 2020). Therefore, food safety knowledge, attitudes and practices, and risk perceptions of FBD among adult domestic food handlers in Bangladesh are necessary to alleviate any false beliefs and knowledge deficiency. According to the KAP model, consumer education might lead to better food safety practices (Mihalache et al., 2021; Zanin et al., 2017). If a positive attitude towards food safety is adopted, it will increase food safety awareness when preparing food at home.

A previous study mentioned that consumer food safety concerns may have been raised due to the COVID-19 pandemic (Yang, 2020). A variety of risks are associated with food safety

concerns, such as bacteria, viruses, or chemicals in food and genetic modifications. These concerns positively affect individual attitudes (Yang, 2020). As the risk perceptions increase food safety concerns, it can be assumed that this concern influences an individual's food safety behaviour. Several food hygiene practices are recommended to minimise the cross-contamination of food during the pandemic (Olaimat et al., 2020). Studies show that a pandemic can increase health consciousness (Pu, Zhang, Tang, & Qiu, 2020) and improve healthy eating habits, such as preparing fresh food at home (W. Husain & Ashkanani, 2020). It can be assumed that consumer food safety KAP might have increased because of the pandemic, and their food safety KAP might have influenced the food hygiene practice related to the pandemic. Therefore, this proposed framework considers that the outbreak of a pandemic such as COVID-19 may impact food safety KAP, concern and food hygiene practices related to the pandemic in the domestic environment.

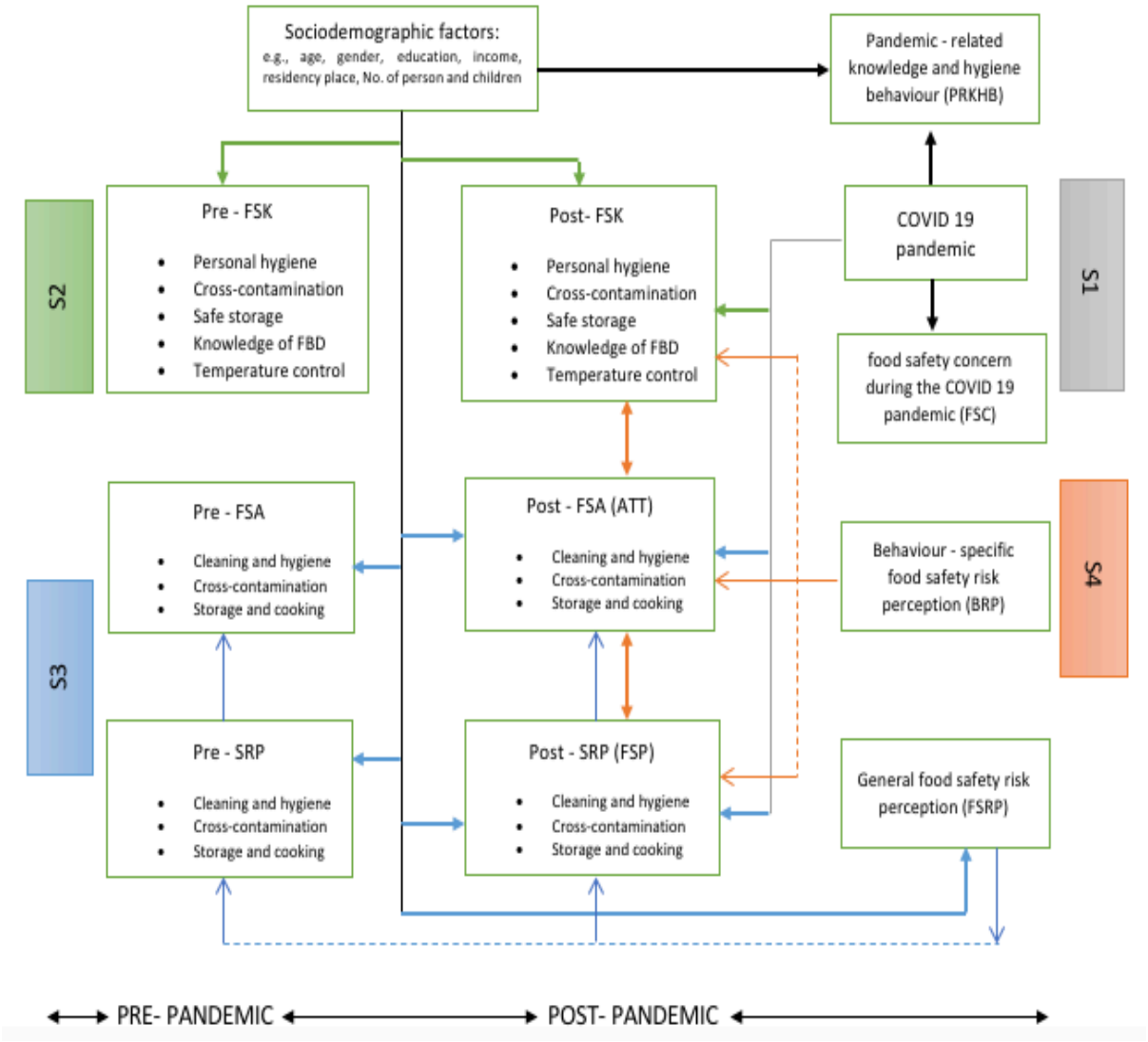

Figure 1: Conceptual framework of the thesis.

Note: S1, S2, S3, S4 indicates study1, 2, 3, 4 respectively. FSK - Food safety knowledge; FSA/ATT - Food safety attitude; SRP/FSP - Self-reported food safety practice.

represents Study 1

represents Study 2,

and represents Study 3

and represents Study 4

1.7 Thesis structure

Chapter one represents the background of the study, research gaps, the aim and objective of the study, significance of the research, methodology of the study and the theoretical underpinnings of this study

Chapter two describes literature review, the statement of the problem, the gap in the literature this thesis addresses.

Chapter three consists of research paper one which looked into the objectives under study 1. The title of this cross-sectional study is *"Food hygiene knowledge and behaviour among domestic food handlers during COVID 19 pandemic in Bangladesh"*. This article is published in *'Food Control'* journal.

Chapter four incorporates research paper two that used objectives under study 2. The title of this study is *"Food Safety Knowledge among adult domestic food handlers in Bangladesh: A COVID-19 Comparative Study"*. This cross-sectional study is under review in *'British Food Journal (BFJ)'.*

Chapter five contains research paper three with the title *"Food safety attitude, self-reported practice and risk perception of domestic food handlers before and during the COVID-19 pandemic in Bangladesh"*. This study used cross-sectional data and currently under review in *'Current Research in Food Science'* journal.

Chapter six includes research paper four that employed research objectives under study 4. The title of this cross-sectional study is "*Role of food safety risk perception and attitude on knowledge and practice of domestic food handlers: A serial mediation model",* which is under review in *'Food Control'* journal.

Chapter seven consists of overall discussion and conclusion of the thesis.

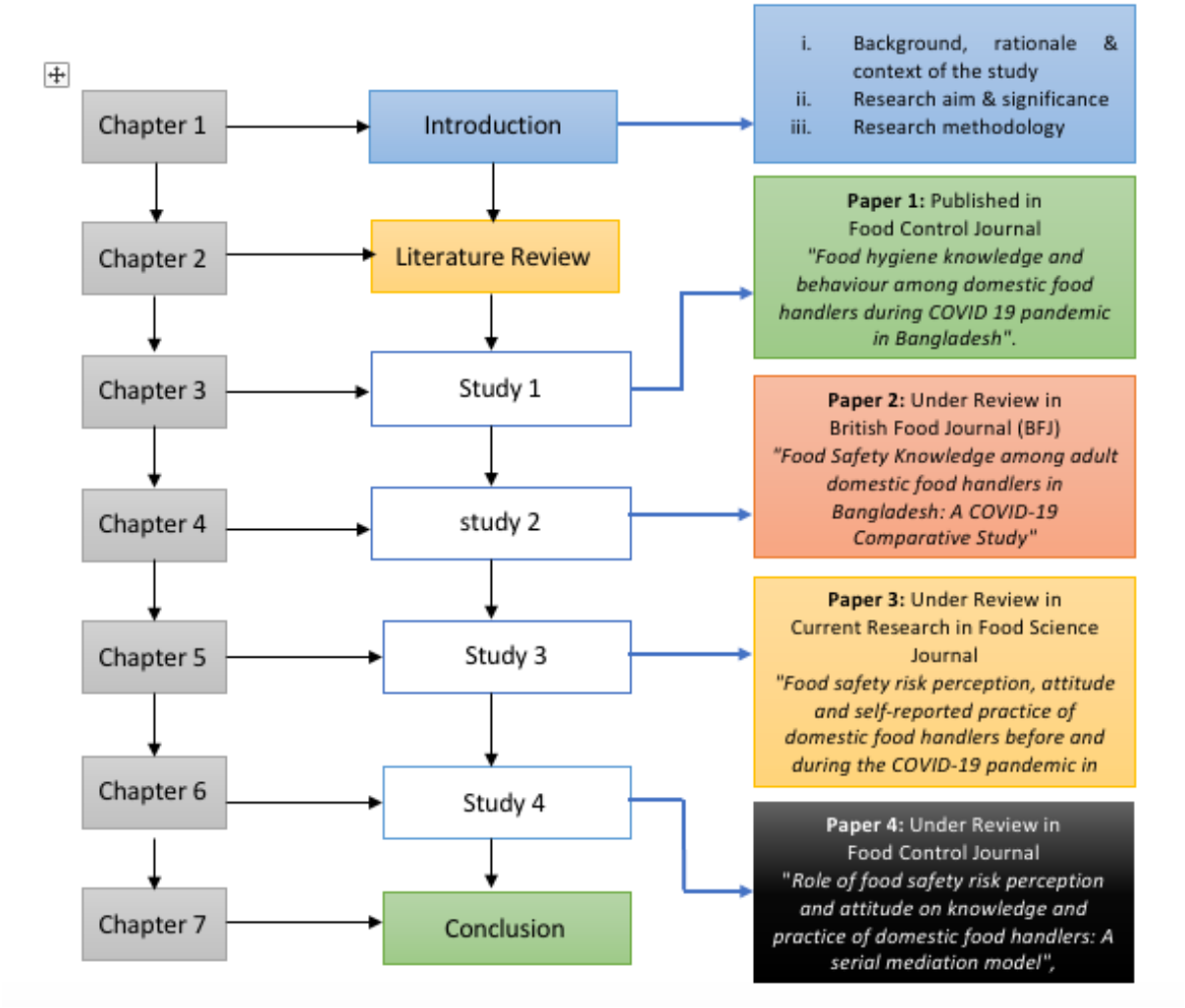

Figure 2: Flow diagram of the thesis structure

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The literature on food safety knowledge, attitude and practice is growing worldwide compared to earlier decades. Food safety knowledge, attitudes, and practice studies primarily focus on commercial food handlers related to foodborne diseases. Although a significant portion of the research covers industrial, restaurant and cafeteria food safety behaviours among food handlers in different countries, household food safety behaviours have always been disregarded. The US and European studies have explored the domestic food handlers' food safety behaviour with greater importance. In low-middle-income countries (LMIC) such as Bangladesh, food safety is considered only the manufacturers' and marketers' responsibility. Hence, very little information can be found about the food safety behaviour of domestic food handlers in Bangladesh. The present research is the first study that investigates the domestic food handlers' knowledge, attitude, practice and risk perception and compares the influence of the COVID-19 pandemic on their food safety behaviour in Bangladesh. This chapter outlines the available evidence on food safety knowledge, attitude, practice and risk perceptions of household food handlers. The reader will better understand the reasons behind the present set of investigations in this thesis by reading the following parts, which discuss in further detail the relevant topics.

2.2 Food hazards

Food hazards are specific agents that can be found in food and may lead to injury or illness if they are not appropriately controlled. It is essential to categorise food hazards to prioritise and manage risk (Schmidt & Rodrick, 2003). Luning and Devlieghere (2006) noted that food contamination may occur due to various hazards, such as physical, chemical, and biological factors. The subsequent sections present a brief overview of food hazards, including microbiological, chemical, and physical hazards.

2.2.1 Microbiological hazards

The biological nature of food makes it susceptible to the growth of microbiological pathogens, which can result in foodborne illnesses (Fung et al., 2018). Microbes that are alive are considered biological hazards, whose development, inability to develop, or demise are influenced by the intrinsic and extrinsic aspects of the food matrix. Food items contaminated with these hazards can lead to health disorders of varying degrees of severity. Food structure and composition are classified as intrinsic factors, whereas temperature, processing, packaging, and the presence of carbon dioxide and oxygen are considered extrinsic factors. Microorganisms such as bacteria, viruses, and fungi are classified as biological hazards (Luning & Devlieghere, 2006).

2.2.1.1 Bacteria

The biological hazards that frequently result in foodborne illnesses are generally caused by bacteria (Luning & Devlieghere, 2006). Bacteria transmit to humans through air, water, food, or living vectors. Bacterial infections occur due to disease-causing bacteria or pathogenic bacteria. Various factors contribute to the development of bacterial infection and disease. Initially, the infectivity of an organism establishes the ratio between infected individuals and those who are susceptible and exposed. Pathogenic bacteria possess specific traits that enable them to evade the body's defensive mechanisms and exploit its resources, resulting in diseases. Virulence pertains to an organism's capacity to induce disease that determines factors like invasiveness and toxin generation. Host factors play a crucial role in the likelihood of disease development in the post-transmission of a bacterial agent. The factors encompass genetic composition, nutritional state, age, length of exposure to the organism, and concurrent medical conditions. The environment additionally contributes to the susceptibility of hosts (Doron & Gorbach, 2008). Bacterial intoxication is caused due to toxins produced by pathogenic bacteria. Bacterial toxins possess pathogenic properties and can adversely affect the human body. These toxins are transported through the blood or lymph, causing various symptoms of illnesses. The effects of toxins can span a wide range, from damaging individual cells to causing tissue or organ failure, manipulating the innate and adaptive immune systems, and impairing the nervous system (Ghazaei, 2022). Bacterial toxicoinfection occurs due to ingesting pathogenic bacteria that can release toxins into the gastrointestinal tract. Several bacteria, such as,

enterotoxigenic *Escherichia coli*, *Clostridium perfringens*, *Aeromonas hydrophila*, *B. cereus (diarrheal type), Plesiomonas shigelloides,* and *Vibrio cholera* is involved in foodborne toxicoinfections (Darwish et al., 2022).

Microorganisms require specific conditions for growth. FATTOM is an acronym that refers to the conditions for microbial growth: food, acidity, temperature, time, oxygen, and moisture (Berger & Parenteau, 2010). Bacteria grow readily in foods rich in protein, mildly acidic or low in acid and at temperatures between 5 and 60 degrees Celsius (the "food danger zone"). Bacteria usually do not grow or grow very slowly below pH 4.6. Additionally, some food varieties, such as shellfish, poultry, eggs, meat, cooked rice, salads, and prepared fruits, encourage the growth and multiplication of bacteria faster than other food types. Even though some foodborne viruses are naturally present in food, at specific temperatures, they become active, proliferate rapidly, and can result in foodborne diseases (WHO, 2016). Time is another vital factor for bacterial growth. Perishable foods should not be kept in a 'Danger Zone' (5 - 60 degrees Celsius) for more than 4 hrs. Under ideal conditions, bacterial cells can double in number every 15 to 30 min (Sharif et al., 2018).
Below is a prompt overview of a few typical foodborne bacteria:

Salmonella

Salmonella can be found on industrial and kitchen surfaces, water, soil, insects, and the intestines of wild and domesticated animals (such as poultry) (Luning & Devlieghere, 2006). It primarily contaminates beef, dairy, eggs, fruits, peppers, poultry, peanut butter, and baked items (Kalyoussef & Feja, 2014). It is responsible for several illnesses, including enteric fever (Kalyoussef & Feja, 2014) and Salmonellosis (Luning & Devlieghere, 2006). In 2017, there were approximately 14.3 million incidents of enteric fever, with a 95% confidence interval of 12.5 to 16.3 (Stanaway et al., 2019).

Escherichia coli (E. coli)

Each year, *E. coli* that produces Shiga toxin (STEC) leads to 2,801,000 acute diseases (Lupindu, 2018). Human faeces, cattle, and other ruminants are the primary reservoirs of *E. coli* (Luning & Devlieghere, 2006). It contaminates spinach, unpasteurised milk, meat, tainted water, kimchi, fresh food, salami (Kalyoussef & Feja, 2014) and undercooked beef (Luning &

Devlieghere, 2006). *E. coli* is responsible for the haemolytic uremic syndrome (Luning & Devlieghere, 2006) and haemorrhagic colitis (Kalyoussef & Feja, 2014).

Shigella

Approximately 125 million cases of diarrhoea are brought on by *Shigella* each year (Baker & The, 2018). *Shigella* is spread through contaminated food handlers, sewage-irrigated vegetables, and human faeces in the water (Luning & Devlieghere, 2006). *Shigella* contaminate food, including ground beef, raw carrots, tomatoes, oysters, and bean salad (Kalyoussef & Feja, 2014). This pathogen causes illnesses such as bacillary dysentery (Luning & Devlieghere, 2006) and reactive arthritis (Kalyoussef & Feja, 2014).

Campylobacter

An estimation suggests that 96 million *Campylobacter* cases occur worldwide annually (Asuming-Bediako et al., 2019). This bacteria harbours in the digestive system of warm-blooded animals such as poultry (Luning & Devlieghere, 2006). It causes Campylobacteriosis, campylobacter enteritis or gastroenteritis. Guillain-Barré syndrome and Reiter syndrome are two severe side effects of this pathogen (Luning & Devlieghere, 2006). The types of food contaminated by *Campylobacter* are - poultry, unpasteurised milk and cheeses, and ice cream (Kalyoussef & Feja, 2014).

Listeria monocytogenes

Listeria monocytogenes is pervasive and usually found in soil and water (Luning & Devlieghere, 2006). In 2020, 23,150 cases were associated with listeriosis (de Noordhout et al., 2014). It results in a spontaneous miscarriage or stillbirth in pregnant women and causes listeriosis, meningitis, septicaemia, encephalitis, and intrauterine infections (Luning & Devlieghere, 2006). Fresh vegetables, Deli meat, soft cheeses, unpasteurised milk, hot dogs, beef, poultry, and ready-to-eat meals are all contaminated with listeria (Kalyoussef & Feja, 2014).

Vibrio

This bacterium is responsible for bacteraemia, acute gastroenteritis, and wound infections (Kalyoussef & Feja, 2014). Globally, between 1.3 million and 4.0 million cases of *Vibrio cholera* infections occur every year (WHO, 2019). *Vibrio* harbours in fish, shellfish and crustaceans (Luning & Devlieghere, 2006) and contaminates undercooked seafood such as oysters, clams, shrimps and crabs (Kalyoussef & Feja, 2014).

2.2.1.2 Viruses

Humans serve as reservoirs for foodborne viruses, and they spread through the faecal-oral system. Poliovirus, hepatitis viruses (Hepatitis A and E), gastrointestinal viruses such as rotavirus, and small round structured viruses (SSRVs) like noroviruses are only a few virus types that may spread through food (Luning & Devlieghere, 2006). After consuming this contaminated food, mild gastroenteritis such as nausea, vomiting, diarrhoea and more severe complications may occur in immunocompromised individuals (Kalyoussef & Feja, 2014). Viruses can spoil foods such as Water, vegetables, salad, fruits, seafood, milk, and dairy products (Luning & Devlieghere, 2006).

2.2.1.3 Fungus or moulds

In general, fungi present minimal risk to people who consume food, but during their development, they produce specific secondary metabolites, such as mycotoxins, that can be hazardous to human health (Luning & Devlieghere, 2006). The consequences of excessive exposure to mycotoxin may cause immunological suppression, acute toxicity, tumour growth, cancer, and even death. Additionally, they can cause neurological abnormalities and are teratogenic and mutagenic. Mycotoxins may grow on various foods and crops, including cereals, dried fruits, nuts, and spices (Luning & Devlieghere, 2006). They can contaminate food during manufacture, storage, and transport, frequently in warm, humid environments. Aflatoxin-A, ochratoxin-A, and fusarium toxins are among the mycotoxins that can be created; however, aflatoxins are the most dangerous (WHO, 2016). *Aspergillus* species generate several aflatoxins, including B1, B2, G1, G2, M1, and M2. They may induce hepatotoxicity, cancer, and teratogenesis and are severely toxic (Luning & Devlieghere, 2006). Foods such as maize,

peanuts and milk from animals fed aflatoxin-contaminated feed are known to be commonly contaminated with aflatoxins (WHO, 2016).

2.2.1.4 Parasites

Parasite refers to biological hazards that can infect food at any point in the food chain, from 'farm to fork'. Protozoa and metazoans (mostly helminths and worms) are the two major categories of the more than 107 parasite species that may be spread by food (Luning & Devlieghere, 2006). *Entamoeba histolytica, Giardia, Toxoplasma gondii and Cyclospora* are common foodborne protozoa, and the illnesses they cause include amoebiasis, giardiasis, toxoplasmosis and cyclosporidiosis, respectively. These illnesses begin with gastrointestinal symptoms such as nausea, tiredness, myalgia, vomiting, diarrhoea, and dysentery (Luning & Devlieghere, 2006). Congenital toxoplasmosis, which has grave symptoms like microcephaly, hydrocephalus, intracranial calcifications, strabismus, retinochoroiditis, blindness, psychomotor retardation, epilepsy, and mental retardation, is also caused by toxoplasma infection during pregnancy (Chaudhry et al., 2014). Foods including fresh vegetables, tainted water, meat, and faeces-contaminated food can be carriers of parasite protozoa (Luning & Devlieghere, 2006). *Taenia solium, Fasciola hepatica, Trichinella spiralis and Diphyllobothrium latum* are examples of parasitic metazoan. They are generally linked to particular meals, including fish, vegetables, and raw or undercooked meat. These parasites can cause hepatic tissue damage, pernicious anaemia, gastrointestinal complaints, muscle dysfunction, and nervous system abnormalities (Luning & Devlieghere, 2006).

2.2.2 Chemical hazards

Chemical food hazards may originate from contaminated food with harmful substances such as pesticides and hazardous food additives (Luning & Devlieghere, 2006). Chemical additives of non-food grade, including preservatives, colourants, and contaminants, including pesticides, are among the chemical risks associated with food. Several food samples might have mercury, lead, arsenic, cadmium and copper higher than the safe level (Fung et al., 2018). Some food systems use artificial ripening agents such as ethephon, ethylene and calcium carbide that accelerate the ripening of fruits, although they decrease the nutritional and biochemical properties of the fruits (Hossain et al., 2015). Furthermore, formalin is widely used to increase

food shelf life in many developing nations (Hossain et al., 2015). They are all potential barriers to safe food consumption since they are all chemical hazards (Fung et al., 2018).

2.2.3 Physical hazards

Physical hazards encompass foreign objects in food that can cause harm, illness, or even psychological distress to the consumer. It is a primary concern for the food producer. A previous study mentions that a quarter of consumers were explicitly concerned about physical hazards in food (Luning & Devlieghere, 2006). The classification of physical hazards encompasses substances such as stones, metal parts, wood, plastic, sand or soil, glass fragments, rubber, and hair in foodstuffs. These substances have the potential to enter the food processing process through various means, such as machinery components (e.g., metal stirrers or rubber seals), equipment, personnel's jewellery, raw materials, and packaging materials. Additionally, it is to be noted that inadequate cleaning processes may cause the presence of soil in food (Van Asselt et al., 2017). Some physical hazards in foods are not the result of unintentional causes. For instance, the deliberate insertion of needles into strawberries in Australia in 2018 was considered an intentional physical hazard in food (Andrejevic, 2019).

2.2.4 Context of food hazards

Food contamination can occur at any level, from the farm, food processing, transportation, storage and food preparation (WHO, 2016). Poor environmental hygiene, such as insufficient recycling programmes and waste disposal facilities, can contaminate food. Numerous foodborne infections are also made possible by unsanitary conditions in the area where food is produced, prepared, and marketed. The contaminants reach the food system via improper food handling, cross-contamination, inadequate personal hygiene, contaminated food supplies, poor storage conditions or inadequate cooking methods (Osaili et al., 2022; WHO, 2015b). In addition, poor personal hygiene during food preparation, such as failing to perform even basic handwashing tasks and inadequate sanitation facilities, might increase the risk of foodborne diseases (Fung et al., 2018). Poor personal hygiene and sanitation, cross-contamination from other foods, insufficient cooking, and temperature abuse (time/temperature) during storage are FBDs' contributing factors (Osaili et al., 2013).

Further, incorrect fertiliser management, soil contamination, and contamination during food processing, packaging, transport, or market operations are additional food hazards (Kalyoussef & Feja, 2014). The rapid expansion of global populations pushes for increased food production and encourages the rigorous use of pesticides and fertilisers to maximise yield. Consequently, this leads to increased pesticide residues in animals and plants, antibiotics, growth hormones in food, and water contamination by heavy metals (Liu & Niyongira, 2017).

In many developing nations, insufficient facilities and inadequate training of food producers, distributors, and sellers pose substantial hazards to public health (Nayeem et al., 2010). Food supply chains have grown more complicated due to the increased food demand, and the LMIC regions are facing additional difficulties securing safe food. (Grace, 2015). Furthermore, in many LMICs, varied and fragmented food systems with large-scale actors, numerous small-scale actors, significant informal sectors, and relatively tiny organisations have contributed to inadequate regulatory enforcement (Alcorn & Ouyang, 2012). In addition, governance issues in LMICs, such as insufficient policy and legislation, numerous organisations with conflicting mandates, inadequate legislation, and a failure to address the informal sector, have made it more challenging to reduce FBDs (Grace, 2015).

2.3 Foodborne diseases (FBDs)

Food is essential for sustaining life, and the availability of safe food is regarded as a fundamental human entitlement (Fung et al., 2018). Food consumption is vital for preserving optimal physical well-being, and it acts as a considerable source of satisfaction, concern, and financial outlay for individuals across the globe (Rozin et al., 1999). Despite being a crucial aspect of life, food can also serve as a medium for transmitting diseases. Food contaminated by disease-causing pathogens, toxins, or chemicals can result in FBDs (WHO, 2016).

2.3.1 Health impact of vital foodborne diseases

The primary factors contributing to foodborne diseases involve ingesting contaminated food that harbours toxins, poisonous chemicals, and infectious agents. Nevertheless, these diseases occur because of contagious bacteria, viruses, and parasites. FBDs such as typhoid fever, shigellosis, salmonellosis, listeriosis, hepatitis A, giardiasis and vibriosis can occur as a result of food contamination by pathogens or growth of foodborne pathogens in the food at any stage

from farm to fork (Kalyoussef & Feja, 2014). FBDs can initiate with mild symptoms such as diarrhoea, vomiting and abdominal cramps within one to three days after consuming contaminated food (WHO, 2016). Although most foodborne diseases can be prevented and are usually self-limiting, it is crucial to acknowledge that some cases can have serious consequences, such as disability and premature death (Kalyoussef & Feja, 2014). Foodborne diseases can have lethal consequences, varying based on the types of pathogens, toxins, and food contamination levels. Possible outcomes include kidney and liver failure, along with neural disorders (WHO, 2016).

Many FBDs are minor and recover rapidly, but there can still be some extremely substantial adverse health effects. More severe sequelae from some conditions include meningitis, bacteraemia, joint infections, and paralysis (Kalyoussef & Feja, 2014). Some long-term consequences of FBDs include Guillain-Barré syndrome (*Campylobacter spp*.), Guillain-Barré syndrome (Escherichia coli), central nervous system abnormalities (*Listeria monocytogenes*), and haemolytic uremic syndrome (*Escherichia coli*) (Ssemanda et al., 2018; Havelaar et al., 2015). Chronic arthritis caused by *Shigella spp., Campylobacter spp., and Salmonella spp.,* deafness, blindness, mental retardation, paralysis, convulsions, and even incurable irritable bowel syndrome caused by bacterial infections is additional long-term effects (FDA, 2012; Ssemanda et al., 2018). Colon cancer and *Salmonella spp.* illness have been linked, according to recent study results (Ssemanda et al., 2018; Mughini-Gras et al., 2018;).

Some foodborne pathogens, such as *Listeria and Toxoplasma*, are responsible for fatal outcomes in pregnancy (Xu et al., 2017). Congenital toxoplasmosis is caused by toxoplasma infection during pregnancy, which increases the possibility of the disease being transmitted to the unborn child and has severe symptoms such as hydrocephalus, microcephaly, intracranial calcifications, retinochoroiditis, and mental retardation (Chaudhry et al., 2014). Pregnant women infected with listeria experience a mild flu-like illness, which may lead to miscarriage, stillbirth, early delivery, or a newborn's acquiring a potentially fatal infection (Xu et al., 2017). Chemical substances contaminating food that are hazardous to human health have also been associated with bladder cancer, stomach cancer, and asthma (WHO, 2016).

2.3.2 Global foodborne disease impacts

All societies and nations have long been concerned about foodborne diseases (WHO, 2015b). The nature and intensity of illnesses have evolved with time, and several foodborne outbreaks frequently go unrecognised, underreported, or are not examined because there is insufficient laboratory facility to identify FBDs and trustworthy epidemiological data (WHO, 2016). As a result, the full impact of the illness burden is yet unclear (WHO, 2015b). Nevertheless, 1 in 10 people worldwide get sick from eating contaminated food annually, and foodborne disease is the primary cause of diarrhoeal disorders (WHO, 2016). According to WHO (2016), there were 600 million FBDs, 420,000 fatalities, and 33 million DALYs in 2010. Foodborne disease, which results in 125,000 child fatalities annually, was shown to put 40% of children under the age of five at risk (WHO, 2015b).

Major FBD outbreaks have been documented from each continent of the world. In mainland China, the majority of FBD incidents (58.5%) and deaths (89.5%) occurred in homes, with 7,073 FBD outbreaks causing 37,454 illnesses and 143 fatalities in 2020 (Li et al., 2021). In Canada, about 4 million individuals contract domestic foodborne infections annually (Nesbitt et al., 2014). Likewise, Angulo et al. (2008) stated that Australia experiences 5.4 million foodborne disease cases annually. According to the Centers for Disease Control and Prevention, there are 48 million foodborne infections each year, which result in 325,000 hospitalisations and 5,000 fatalities in the US annually (CDC, 2018; Fung et al., 2018; Scharff, 2012).

In addition to posing health risks, foodborne infections raise healthcare costs and reduce national income. To incorporate economic projections for medical expenses, lost productivity, and disease-related death constructs a fundamental cost-of-illness model. The improved cost-of-illness model substitutes a more comprehensive measure of suffering, pain, and functional impairment based on monetized quality-adjusted life years for the productivity loss estimate (Fung et al., 2018; Scharff, 2012). The average cost of FBDs in the United States was estimated to be USD$1626 and USD$1068 per episode for the enhanced disease cost and basic model, respectively. According to this economic modelling, enhanced disease cost was estimated to be $77.7 billion annually, whereas the basic models cost $51 billion (Fung et al., 2018; Scharff, 2012). Earlier research revealed that acute gastrointestinal disease in Canada has an annual cost of almost 3.7 billion dollars (Thomas et al., 2013; Nesbitt et al., 2014). The 2011 E. coli

epidemic in Germany cost farmers and industry 1.3 billion USD in losses and resulted in 236 million USD in emergency help allowance to 22 EU member states (Yeni et al., 2016; Fung et al., 2018). As a result, it is evident that millions of people are affected by FBDs every year, and the FBD cost is enormous when factors like the price of medical care, lost productivity, personal suffering, and losses within the public health services are taken into account (Wilcock et al., 2004).

2.3.3 Impact in LMIC (Low and middle-income countries)

Foodborne disease burden varies by country, but it is still a significant public health concern in LMICs (Unnevehr, 2015). The prevalence of FBD has raised awareness of food safety in LMICs (Unnevehr, 2015). Because there has been little investigation into FBDs in LMICs, the actual burden of illness is unknown. In hospital and community surveys in LMICs, prior research indicated a significant frequency of foodborne infections among patients with diarrheal diseases (Fletcher et al., 2013; Grace, 2015).

Microbial infections in LMICs are the primary cause of most FBDs (Fletcher et al., 2013; Grace, 2015). A previous study reported that diarrheal disease causes 99,727,954 DALYs worldwide, with lower- and LMIC countries accounting for 90% of cases (Grace, 2015). The WHO has split its six geographical areas into 14 subregions based on five categories, which include child and adult mortality rates, to evaluate the burden of FBDs. In the WHO Southeast Asia Region, the burden of foodborne illnesses is the second highest compared to other WHO regions (WHO, 2016). The incidence of typhoid fever or hepatitis in this region surpasses 50%, making it the highest contributor to global infections and deaths. In the Southeast Asia Region, the annual toll of FBDs exceeds 150 million cases, resulting in 175,000 fatalities and 12 million DALYs (WHO, 2016).

The tropical environment in many developing nations makes it difficult to provide healthy food since it typically encourages the growth of microbiological diseases, pests, and naturally occurring poisons like aflatoxin (WHO, 2016). Numerous studies also indicate that the incidence of FBDs has grown in LMICs due to widespread chemical abuse, the use of excessively harmful, outlawed, and outdated chemicals, and the use of chemicals in food over the permissible amounts (EUFSA, 2015; Bempah & Donkor, 2011; Van Hoi et al., 2013).

2.3.4 Prevalence of foodborne disease in Bangladesh

Bangladesh, an LMIC, is classified as having a high child and adult death rate from FBDs in WHO's South-East Asia Region D (WHO, 2016). There is no reliable estimate of the public health impact of food contamination in Bangladesh due to a lack of monitoring facilities (WHO, 2016). In 2015, there were 276728 cases of acute watery diarrhoea, 30100 cases of enteric fever, and 516 cases of hepatitis A, according to estimates from the Institute of Epidemiology (2015) (Suman et al., 2021; Institute of Epidemiology, 2015). According to the WHO, 501 hospital admissions for cases of diarrhoea per day were related to water- and foodborne illnesses (Ali, 2013; WHO, n.d.). Studies revealed that number of people suffering from foodborne diseases in Bangladesh reaches approximately 30 million annually (Khairuzzaman et al., 2014; Ishra et al., 2023).

2.4 Food safety

Food safety measures effectively mitigate the risk of food contamination throughout the entire food supply chain, encompassing production to consumption, thereby reducing the incidence of FBDs and promoting optimal health (Wilcock et al., 2004; Behrens et al., 2010; Luning & Devlieghere, 2006). Thus, it is a process that encourages preparing, handling, and storing food that reduces the risk of contracting FBD (Luning & Devlieghere, 2006).

2.4.1 Concept of food safety

Globally, food safety is a significant concern for every stakeholder, including consumers and governing bodies (Wilcock et al., 2004). World Health Organization (WHO) reported that food safety is a collective duty. Accordingly, food providers and patrons must comprehend their obligations to safeguard their and the broader community's health (WHO, 2016). To maintain the safety of food and minimize food risks, several food safety concepts have been developed, namely Good Agricultural Practice (GAP), Good Manufacturing Practice (GMP), and Hazard Analysis Critical Control Point (HACCP). These concepts lay out a framework that effectively mitigates the risks associated with food, offering reassurance to producers and consumers regarding the safety of the supplied products. Food safety concepts inform consumers and food processors about proper food handling practices and methods for preventing FBD. Adopting

universally recognized principles and procedures is essential for the safety of food production (Luning & Devlieghere, 2006).

A risk-based strategy has been developed for food safety management and laws in developed nations. Risk assessment, management and communication are all included in the risk analysis method. Risk assessment, which includes hazard identification and exposure characterisation, provides the foundation for risk management and guides choices for risk reduction strategies. The subsequent stage involves risk communication, encompassing the dissemination of information to the public regarding hazards, risks, uncertainties, and the imperative for risk mitigation measures (Unnevehr, 2015).

2.4.2 Strategies of food safety

A number of food safety measures have been devised, including cooking, pasteurisation, the correct addition of preservatives and storage conditions to lessen the possibility of microbiological risks. Nevertheless, experts recommended several fundamental food safety measures in order to prevent food contamination during manufacturing, storing, transit, and preparation (Luning & Devlieghere, 2006). WHO has created five essential food safety initiatives to inform all the participants in the food distribution network. According to studies, 146 nations have acknowledged adopting the 'Five Keys to Safer Food' as of 2018 to train food workers and inspectors, inform consumers and create safe marketplaces (Fontannaz-Aujoulat et al., 2019). The "Five Keys to Safer Food" include sanitation, segregating raw from cooked food, cooking food thoroughly, keeping a safe temperature, and using safe water and raw materials (Fontannaz-Aujoulat et al., 2019).

2.5 Consumer level of food safety

As the last link in the food safety chain (Luning & Devlieghere, 2006), the consumer should handle food cautiously at home to avoid infection (Azevedo et al., 2014). Basha and Lal (2019) assert that consumers may help ascertain food safety and risk factors by properly preparing and storing food. Despite restaurants and cafeterias being commonly identified locations where foodborne disease outbreaks occur (Redmond & Griffith, 2003), it has been reported that 50 to 87% of FBDs arise from food consumed in private homes (Saeed et al.,

2021). The food consumed in domestic kitchens constitutes a larger quantity than food consumed at restaurants and other food service establishments. Also, the food prepared in domestic kitchens is not made by qualified food workers, so there is reason to believe that food consumed in domestic kitchens contributes to a greater extent to FBD than food consumed at restaurants and similar food service establishments. Nevertheless, not all FBDs occurring in the home are the preparer's fault (Jacob & Powell, 2009). The early elimination of pathogens in the food production chain could have prevented several incidents. Nevertheless, a substantial portion of FBD cases is associated with incorrect consumer food handling or at least, it involves an assortment of shortcomings at different stages of the food production chain, with the consumer also being a factor (Jacob & Powell, 2009).

Previous studies have reported that over 35% of FBDs occur while handling food at home (Langiano et al., 2012). In many nations, including the USA and Canada, the domestic environment poses a significant risk of contracting foodborne diseases (FBD) (Byrd-Bredbenner et al., 2013; Vrbova et al., 2012; Redmond & Griffith, 2003). In recent years, the CDC has noted an increase in FBD outbreaks linked to food prepared at domestic kitchens (CDC, 2023). Identifying the proportion of FBD that originates in the home is challenging because of the difficulty in ascertaining the source of illness when food is consumed from diverse sources and across multiple settings, in addition to the known under-reporting of mild illness (Griffith et al., 1998; Scott, 1996). According to research conducted by (Redmond et al., 2004), a small percentage of foodborne illness outbreaks in England and Wales, ranging from 12-17%, have been attributed to home kitchens. However, other studies suggest that a higher percentage, between 50 - 80%, of illnesses caused by *Salmonella and Campylobacter* have originated in domestic kitchens (Eves et al., 2006; Wills et al., 2015).

Due to the significance of the home as a source of FBDs, surveys have been conducted to assess the various factors contributing to bacterial contamination in the household setting. Studies have documented the presence and density of pathogens, the persistence of microorganisms, and the potential spread of microbial contaminants from contaminated foods in residential settings (Griffith, 2000). Azevedo et al. (2014) assert that foodborne pathogens can develop in the domestic environment, notably in the kitchen, as well as in the bathroom and washing area. According to a prior study, the kitchen area is significantly more contaminated with faecal and total coliforms, including *Escherichia coli, Campylobacter, and Salmonella*, than the bathroom. This indicates that the kitchen environment poses the highest risk of infection

transmission within a household (Redmond & Griffith, 2003). Pathogenic and non-pathogenic organisms are continually introduced into the home by people, food, water, pets, insects and sometimes through the air (Redmond & Griffith, 2003). The food handlers' hands spread harmful microorganisms through cross-contamination, making them a significant cause of food contamination (Baş et al., 2006; Campos et al., 2009; Kunadu et al., 2016). One of the most critical issues of food safety in the domestic setting is that individuals of different ages and health statuses coexist in many households (Azevedo et al., 2014). The most susceptible individuals in the family to acquiring foodborne infections are those with weakened immune systems, such as the older aged, young children and pregnant women (Ruby et al., 2019). Adherence to appropriate hygiene protocols is instrumental for food handlers in preventing cross-contamination and ensuring consumer safety from diseases (Jevšnik et al., 2008). When handling food safely in the home kitchen, the consumer is the "last line of safety" in preventing FBDs since consumers' safety measures constitute the final step in the food preparation process (Redmond & Griffith, 2003). The crucial element is that any food safety strategy aimed at consumers must consider their perceptions of the food safety risk, knowledge, attitudes, and behaviour (Wilcock et al., 2004).

2.5.1 Food safety knowledge

Knowledge refers to the process of acquiring, retaining, and utilizing information or skills. The acquisition of knowledge, known as cognition, entails the process of understanding and is distinct from the experience of feeling (Marathe et al., 2016). Angelillo et al. (2001) mentioned that food handlers who are knowledgeable about safe food handling procedures may be able to reduce the number of occurrences of FBDs. As a result, those handling foods should be knowledgeable and skilled in food safety procedures and comprehend how foodstuff plays a part in spreading foodborne disease (Alqurashi et al., 2019; Glanz et al., 2008).

A meta-analysis of 88 food safety studies conducted from 1970 - 2002 demonstrated that consumers had inadequate knowledge of safe food handling in domestic places, as pointed out in the following illustrations (Redmond & Griffith, 2003). The research data indicates that most consumers were aware of the appropriate method for washing and drying their hands, although a fifth of the consumers questioned in the United States and the United Kingdom were not acquainted with these techniques. At least 22% of consumers in the US were unaware of the

value of using distinct or thoroughly cleaned cutting boards and cutlery. Nearly sixty per cent of consumers were unaware of the proper food refrigeration temperatures, which is crucial for controlling food pathogens. Further, 20% of the consumers were unsure about the minimum internal temperature required for cooked meat to be deemed safe for consumption (Redmond & Griffith, 2003). In recent years, numerous studies have been performed in various nations to evaluate food handlers' understanding of food safety, such as hand washing, temperature management, cross-contamination, food storage and food microbiology (Moreb et al., 2017; Odeyemi et al., 2019; Osaili et al., 2022; Parra et al., 2014; Ruby et al., 2019; Saeed et al., 2021; Wang et al., 2021).

Parra et al. (2014) conducted a study among Mexican Americans living in the United States who cook regularly for their families. A total of ten focus group interviews were conducted with Mexican Americans in Texas and New York during the spring and summer of 2010. The interviews comprised 78 participants, out of which 62 were born in Mexico. The investigations indicated a lack of knowledge about the risks of cross-contamination while handling raw meats and produce, cooked meats handling and hazardous thawing of raw meat by keeping it on the counter or sink. Numerous mistakenly assumed that a food thermometer was not essential and that the cooked meat's appearance was a reliable safety sign. These focus group findings prompted a probability-based online panel survey of Mexican Americans in the United States (N = 468), which discovered inadequate awareness of the hazards of cross-contamination and pathogens associated with uncooked eggs, raw milk, and fresh cheese (Parra et al., 2014).

A study conducted a quantitative survey of the Republic of Ireland among 1069 participants. The researchers determined that the residents of Ireland exhibited an average level of knowledge in food storage, usage and maintenance of kitchen facilities and personal hygiene with a passing rate of 52.8%, 59.0% and 61.0%, respectively. In contradiction, their understanding of food poisoning was significantly inadequate, with a passing rate of 20.1% (Moreb et al., 2017). Likewise, Gong et al., 2016 conducted a national survey of food handlers in Mainland China (n = 482) that demonstrated insufficient knowledge, and they were awarded a mean score of 7.95, while total knowledge scores were from 0 to 26. The survey found that consumer ignorance was highest in food poisoning and personal hygiene awareness (Moreb et al., 2017).

Odeyemi et al. (2019) undertook an international survey on food safety knowledge among consumers in developing countries from Asia and Africa. The survey included 453 participants, with 265 representing Africa and 188 representing Asia. The study revealed a significant discrepancy ($p < 0.05$) in food safety knowledge among consumers in developing countries from Asia and Africa. Consumers in Cameroon exhibited the lowest level of knowledge in Africa, followed by Ghana and Nigeria. Likewise, in Asia, Iranian consumers had the lowest level of food safety knowledge compared to Malaysia and Pakistan. Of all the respondents, 89% displayed knowledge of food poisoning, while 304 individuals (67.1%) admitted consuming food left at room temperature for a prolonged time (Odeyemi et al., 2019).

On the other hand, Ruby et al. (2019) conducted a cross-sectional survey to understand more about Sibu, East Malaysian residents' awareness of food safety issues such as personal hygiene, symptoms of foodborne illness, high-risk foods, cross-contamination, and temperature management. The study showed that 73.9% of consumers had a good mean score (>60%) in food safety knowledge. Meanwhile, only 23.3% were fully aware of how temperature affects bacterial development in food. Despite the consumers being highly knowledgeable about hand hygiene, 37.9% had no idea about the correct duration of this measure, which prompted the authors to expose consumers to foodborne pathogens such as *Staphylococcus* and *Salmonella* (Ruby et al., 2019).

Similarly, in a cross-sectional survey of women in the United Arab Emirates, it was found that the participants had good knowledge of personal hygiene and cleaning (62.9%) and food storage (61.1%) issues but were less knowledgeable about risk factors of FBD (20.0%) and cooking and food consumption (28.0%), suggesting they may be at risk of contracting FBD (Saeed et al., 2021).

Additionally, a number of studies indicated that women had higher food safety knowledge than men did when comparing the socio-demographic factors of respondents to food safety knowledge (Byrd-Bredbenner et al., 2007; Moreb et al., 2017; Ruby et al., 2019). The reason may be the case since women are traditionally seen to be more active in cooking than men. Akonor and Akonor (2013) revealed that understanding the food safety measures was equivalent for both male and female respondents, making them statistically independent of food safety knowledge.

Age and food safety knowledge were shown to be correlated, although Sanlier and Konaklioglu (2012) found that food safety knowledge tends to rise with age and that younger responders require additional training. While Annor and Baiden (2011) and Martins et al. (2012) indicated that an individual's age had no impact on food safety knowledge, Sun et al. (2012) observed that younger respondents had more robust food safety knowledge than their older counterparts.

In general, it has been found that individuals' knowledge increases with their educational level. For instance, Farahat et al. (2015) cross-sectional research of women in Saudi Arabia found that respondents with greater educational attainment had higher mean knowledge scores across all food safety characteristics examined than respondents with lower educational attainment ($p < 0.05$). In a comparable manner, Martins et al. (2012) identified a significant difference ($p<0.05$) between respondents' educational backgrounds and their understanding of food safety. Thus, a necessary condition for the effectiveness of food safety practices is the level of education attained by food handlers.

It is crucial for consumers to possess adequate knowledge of proper food-handling skills in order to prevent FBDs. This entails acquiring a comprehensive knowledge of food safety protocols throughout the stages of purchasing, storing, refreezing, thawing, preparing, serving, and finally, ensuring proper cooking of meals (Langiano et al., 2012). Poor food safety knowledge in the domestic environment is one of the major obstacles to improving and maintaining the food chain. Ensuring food safety necessitates the exact identification of hygiene errors made by consumers in their home kitchens.

2.5.2 Food safety attitude

In "The Psychology of Attitude", Eagly and Chaiken (2007) defined attitude as a psychological inclination conveyed through evaluating a specific entity with varying degrees of favour or disfavour. Ajzen and Fishbein (2000) suggest utilising the term "attitude" to denote the assessment of an object, concept, or behaviour along a dimension of positive or negative evaluation, good or bad, or preference. The three aspects of attitude are cognition, affect, and behaviour (Briñol et al., 2019; Eagly & Chaiken, 2007; Niewczas-Dobrowolska, 2022). The cognitive component includes beliefs about the attitude object that are either true or false. The

affective part of attitude consists of the complete range of emotions towards all features of the attitude's object. The behavioural elements linked to attitude relate to the inclination to act in particular ways towards the attitude object. Ascertaining consumer attitudes provides information for understanding actual behaviours. For example, studies conducted in Africa and the Middle East identified that although consumer health is significantly at risk due to microbial contamination of milk and dairy products, a good proportion of consumers believed that raw milk consumption was better than pasteurised or boiled milk. This belief is reflected in consumer food safety behaviour when they consume raw milk (Alotaibi et al., 2019; Amenu et al., 2019; Shati et al., 2021). Attitudes are often seen as essential for health promotion because they influence actions and the potential success of activities (Redmond & Griffith, 2003).

A previous study conducted among 1,000 household females in Lahore revealed that 85% expressed a negative attitude toward food safety. For example, 82.7% of women showed a negative attitude towards household outbreaks of foodborne disease. Additionally, 67.5% did not view FBD outbreaks as a vital concern (Naeem et al., 2018). In a previous study, 90% of the participants considered that there was a minimal risk of FBD from eating self-prepared foods at home (Redmond et al., 2004). Many adult consumers believe that the domestic environment is unlikely to cause foodborne illness; instead, those responsible for the food safety network, such as the farm and food industry, should ensure food safety (Brewer & Rojas, 2008). A study by Odeyemi et al. (2019) conducted among Asian and African consumers identified that only a third of consumers mentioned frequent egg washing before cooking.

Sociodemographic information and health incongruity substantially impact the attitude toward food safety. Ethnicity has a significant role in observing the diplomacy of food safety, including vegan lifestyles and farming (Booth et al., 2013). Consumer cultural variations frequently accounted for certain foodborne diseases in some cultures but not others. *Listeria* is a prevalent disease in Hispanic communities because Mexican-style diets include dairy products and raw milk. Conversely, *Yersinia* is particularly prevalent among African Americans because of their livestock-based diet, including dishes like chitterlings. Due to the preference for raw and undercooked foods, Caucasian people are more prone to infection by *E. Coli* (Quinlan, 2013).

Foodborne illness exists in the domestic environment partly because consumer attitudes and behaviours toward food safety place significant barriers to hygienic food preparation. A thorough knowledge of the behavioural and cultural elements that affect how people handle

food is necessary to address consumer concerns about food safety (Mani et al., 2017). Adult consumers often have instinctive attitudes towards food safety, which means they prepare meals according to the same food safety practices and fail to recognise anything wrong with them (Fischer et al., 2006). Therefore, one of the most significant challenges in achieving food safety improvements is to educate consumers about the need for behavioural changes (Azevedo et al., 2014).

2.5.3 Food safety practice

Empirical evidence suggests that knowledge acquisition and misconceptions rectification regarding problems or diseases lead to a transformation in attitudes, resulting in preventive behaviours. Consequently, the demonstration might suggest a mutually reinforcing connection between knowledge and attitude. Practice refers to behaviours or actions that have the potential to prevent a disease or impede its advancement (Marathe et al., 2016). The research by Singh et al. (2011) states that "practice" denotes the execution of skills, techniques, methods, or standard operating procedures. To evaluate the food handling techniques of food handlers, researchers used self-reported questionnaires and observation techniques. Questionnaires are used for self-reported practices and observation to obtain actual practices.

Considering the self-reported food safety practice, Ruby et al. (2019) executed a survey among Malaysian consumers in Sibu. Data were collected in three areas of food handling practices such as cross-contamination, storage and cooking, cleaning and hygiene. The findings indicated that self-reported food safety practices were inadequate since consumers in all sociodemographic profile categories were short of the 60% threshold. The study revealed that 56.5% of respondents always practice hand washing before cooking or eating. Only 12.2% mentioned using different cutting boards to slice raw meat and vegetables. Regarding thermometer usage, this survey revealed that many respondents (89.6%) did not keep a thermometer in their refrigerators (Ruby et al., 2019).

Tabrizi et al. (2017) conducted a cross-sectional and population-based study among 1,500 participants chosen through multistage stratified cluster sampling from East Azerbaijan – Iran. Although the mean score of self-reported practice was good (70.77%), inadequate practice was found in some subsections, such as optimal heating or cooling temperatures and appropriate

methods of thawing and eating raw eggs. Contrarily, Naeem et al. (2018) surveyed consumers who regularly cooked meals at home but were not trained food handlers. Results of the total self-reported food handling practises of household women revealed that the mean and standard deviation was 26.60 ± 3.977 (practise score 0-55), indicating that unsanitary food handling practises were the norm for household women. About 99.7% were practising unsafe food handling measures; for example, keeping hot meals at room temperature for longer than 4 hours or not washing hands with soap and water before preparing meals or eating food.

To prevent foodborne diseases, adult consumers must be knowledgeable about appropriate handling, storage, and preparation procedures for food (Langiano et al., 2012). Since hands are known to be a primary source of the transmission of infectious agents in the kitchen, proper handwashing is one of the most efficient strategies to eradicate foodborne pathogens in the home setting (Bloomfield et al., 2007; Doyle et al., 2000; Taché & Carpentier, 2014). A previous study also found that 40 % of households did not practise handwashing (Mani et al., 2017), while a crucial step in preventing cross-contamination is washing hands (Van Asselt et al., 2008). Another major contributor to foodborne diseases is the domestic handling of raw chicken or poultry. The Centres for Disease Control and Prevention states that bacteria such as *Campylobacter, Salmonella,* and *Clostridium* are frequently present in raw chicken. Washing meat and poultry before cooking may raise the likelihood of cross-contamination with other foods and surfaces (Centers for Disease Control and Prevention, 2018).

Further, several sites in the kitchen might be contaminated, including sink drains, sink handles, cutting boards, sponges, refrigerator door handles and floors, because of the absence of regular handwashing before and after meal preparation (Redmond & Griffith, 2009). A previous study found that kitchen dishcloths and sponges may be contaminated with pathogens, such as *E. coli.* Hence, it is also essential to disinfect dishcloths and sponges in the kitchen (Rossi et al., 2013).

An important step that can help minimise the underlying cause of foodborne diseases is heating food to the correct internal temperature (Yavelak et al., 2018). Using cooking thermometers, consumers can avoid relying on predictions to determine when food is done. Additionally, a cooking thermometer enables the user to cook food properly and eliminate microbes, reducing the chance of contracting a foodborne disease (Kosa et al., 2017; Yavelak et al., 2018). A large number of consumers stated in an earlier survey that they dislike using thermometers because

of the inconvenience and challenges of using them correctly (McCurdy et al., 2005). In a previous study conducted in Ireland, over fifty per cent of adult consumers had at least one foodborne pathogen, such as *Salmonella, E. coli, Staphylococcus aureus, Listeria,* and *Yersinia* in their home refrigerators (Kennedy et al., 2005). In order to lower the number of foodborne pathogens in the home environment, consumers must practise using the proper heating and cooking techniques while preparing meat and poultry to the appropriate temperature (Patil et al., 2005).

It has been acknowledged that the consumer is an important part and the last link in the food chain, and a steadily increasing amount of consumer surveys has been conducted. The advantages of a survey are that a large number of consumers can be surveyed providing a large amount of data. However, it has been found that over-reporting of perceived correct and desirable behaviours, the social desirability bias (Krumpal, 2013; Pouillot et al., 2010), appear more frequently during phone and questionnaire interviews than in-person interviews (Redmond & Griffith, 2003). Observation studies have been found to provide the most reliable data for consumer food handling, but the observation technique is generally expensive and time-consuming (Redmond & Griffith, 2003). Focus groups typically consist of between 8 and 10 respondents (Redmond & Griffith, 2003) and are guided group discussions of different consumer groups. Data from such focus groups has been shown to provide good insight into the varied perceptions consumers have about food handling practices and food safety, however, the results are purely qualitative, and it is not possible to evaluate the precision validity or the repeatability of such data (Redmond & Griffith, 2003). Survey techniques are therefore still the most used methods in consumer food safety research (Azevedo et al., 2005; Bergsma et al., 2007; Brennan et al., 2007; Brewer & Rojas, 2008; Fein et al., 2011; Hoelzer et al., 2012; Kennedy et al., 2011; Lando & Chen, 2012; Moreb et al., 2017; Pouillot et al., 2010; Ruby et al., 2019; Taylor et al., 2012) and such studies are increasingly being performed with the aid of Internet and web-based questionnaires (Byrd-Bredbenner et al., 2007; Faour-Klingbeil et al., 2021; Kosa et al., 2007; Odeyemi et al., 2019; Soon et al., 2021).

2.5.4 Food safety risk perception

Risk is defined as the likelihood of encountering hazards, which are defined as perils to individuals and their possessions, and probability refers to the chance of a hazard happening,

which is usually perceived with some degree of uncertainty. Ambiguity, unpredictability, or probabilistic situations often lead to uncertainty in individuals. The uncertainty surrounding risk is linked to the differences in people's perspectives on the severity and magnitude of a given risk (Slovic, 2016). Slovic (2016) defines risk perceptions as interpretations and subjective judgments concerning risks. Thus, risk perception refers to an individual's perspective on the risk involved in a particular scenario. The constituents involve the perceived likelihood of a prevailing risk, the perceived rationality of the risk by individuals, and the perceived severity of the risk outcomes (Evans & Redmond, 2019).

The perception of risk plays a vital role in determining decisions related to health and risk, including the adoption of healthy behaviours, the reduction of unhealthy behaviours, and the acceptance or rejection of specific risks (e.g., processed meats, GMO foods). An individual's perception of risk may be diminished if they hold a misconception about it. Optimistic bias is the belief that the risk to oneself is lower than the risk to others, thereby misconceiving potential risks (Evans & Redmond, 2019). Perceived risk can be minimised due to optimism bias, which can increase their perception of the safety of the food supply and their present food-handling practices. Consumers frequently believe that they are invulnerable to food poisoning from home-cooked foods, that "it only happens to others," and such notions are the result of "optimistic bias" and the "illusion of control" (Redmond et al., 2004). When consumers perceive they have better knowledge and control over the food that they prepare in their domestic kitchen rather than someone else who prepares an outside home for them, increase their negligence to take preventive measures and consequently increase the incidence of FBD (Byrd-Bredbenner et al., 2013). Constructive information about the safety of the food supply may combine with individuals' excessive optimism in the necessity of exercising caution while handling food safely, increasing the adoption of hazardous behaviours. Individual's views of risk can be increased by negative information regarding food risks, and recent exposure to a foodborne disease reduces optimism bias but does not eliminate it (Evans et al., 2020). It may be essential to encourage better domestic food-safety behaviours by increasing individuals' perceptions of the risk of FBD from their present hazardous food-handling practises, considering the challenges of controlling behaviour in the domestic setting and its susceptibility to FBDs from improper food handling by consumers (Young et al., 2015).

The impact of sociodemographic information and health incongruity is significant in the risk perception towards food safety (Quinlan, 2013). Adult consumers' cultural differences are one

of the usual causes of why certain FBDs are present in one culture and not in others. For example, within Hispanic cultures, *Listeria* is frequently observed due to the inclusion of raw milk and dairy products in their traditional Mexican-style cuisines. On the contrary, *Yersinia* is more widespread among African Americans because of their food culture that involves raising livestock and cooking meals with pork, including chitterlings. In Caucasian people, *E. coli* infection is more prevalent due to their raw and undercooked food preferences (Quinlan, 2013). An essential understanding of the behavioural and cultural components impacting food handling practises is a foundation for consumer food safety (Mani et al., 2017).

In South Wales and the United Kingdom, Evans and Redmond (2019) performed research with one hundred old adult consumers over 60, living individually (not in residential care facilities) and in charge of preparing and storing raw and ready-to-eat food at home. Old adults participated in personal interviews with computer assistance to assess the perception of risk, control, and accountability related to food safety. The study found significant differences between the perceived personal risk, control, and responsibility from those of others. Older adults believed they were less vulnerable to hazards than others, which may indicate that they had an optimistic bias and experienced invulnerability. Showing higher degrees of personal responsibility and control compared to others suggests perceptions related to the illusion of control. High levels of control were associated with lower risk when individual perceptions of risk, control and responsibility were examined ($P < 0.05$). Older respondents (aged over 80 years) asserted higher risk but less control and accountability (Evans & Redmond, 2019).

In China, a nationwide survey examined consumer subgroups' understanding of food handling, perceptions of risk (including perceived susceptibility and severity), and practises (processing leftovers and defrosting raw meat). By using stratified and random sampling, 3050 consumers were questioned, and 1780 valid questionnaires were received. The findings suggested that Chinese consumers had higher perceived severity than perceived susceptibility. Consumers who consider themselves less susceptible than others are less likely to encounter unfavourable experiences and more likely to experience positive ones. The study also found that perceived severity and susceptibility had a significant positive association with normative leftover food processing and raw meat thawing, indicating increased awareness of food safety risks had higher levels of food-handling practices (Wang et al., 2021).

Evans et al. (2020) investigated the relationship between behaviour-specific risk perceptions and three food-handling practises: handwashing, preventing cross-contamination, and appropriate freezing of prepared foods using data from numerous years of the FDA Food Safety Survey. The study notes that existing food-handling practises applied in the house and perceived risks associated with the food supply are the two risk factors that constitute perceptions of food safety concerns in the home. The authors emphasize that analyses of behaviour-specific risk perceptions should control the perceptions of the safety of the food supply. Well-structured targeted information about behaviour-specific risk perception has the potential to effectively improve individuals' unnecessary optimism towards their food handling practices than the general risk perception of food safety could do (Evans et al., 2020).

Although knowledge appears imperative for the proper food safety application, if consumers perceive a risk associated with food low, knowledge does not necessarily translate into behaviour (Evans & Redmond, 2019). Several behaviour theories (e.g., HBM, TPB) have also determined that risk perception is a crucial motivator for consumers to adopt healthy behaviours (Skinner et al., 2015; Wang et al., 2021). Both models suggest that increased perception of risks inclines consumers to adopt normative food-handling behaviours. Previous interventions educating consumers about food safety have demonstrated limited success in altering food handling practices (Young et al., 2015). Nevertheless, promotional activities that emphasise risk perceptions associated with certain behaviours might prove to be a more effective tool (Evans et al., 2020).

2.6 Pandemic and food safety

According to Koos et al. (2017), a crisis is an unexpected event that generates uncertainty, jeopardises daily routines, and places specific personal objectives at risk. Crises are not isolated events but occur within a specific cultural, institutional, and social context (Kitz et al., 2022). Behavioural changes may occur in individuals during crisis events, such as natural disasters and healthcare crises, including the COVID-19 pandemic (Loxton et al., 2020; Mucinhato et al., 2022), as recognised by the field of survival psychology. For example, a Bovine spongiform encephalopathy (BSE) outbreak in Japan was correlated to a marked reduction in beef demand and an observable inclination to pay a premium exceeding 50% for BSE-tested beef (McCluskey et al., 2005). In contrast, the largest food recall ever due to an E. coli outbreak in

ground beef in Canada was observed by Charlebois et al. (2015), who found that Canadian consumers did not exhibit any short-term decline in beef consumption and there was no significant long-term effect on either beef purchasing habits or trust in food safety. Loxton et al. (2020) assert that consumers' perceptions could be influenced by food safety crises, but a particular analysis considering regional and demographic characteristics is necessary.

Amid a health emergency, such as a pandemic, consumers may place great significance on food safety. Maslow's (1943) theory of needs can be employed to gain insight into such issues. Lester (2013) outlined Maslow's Hierarchy of Needs starting from the base of the pyramid as (1) physiological necessities, (2) safety, consumer protection and well-being, (3) love and belonging, (4) self-esteem, and (5) self-actualisation or personal growth. As per the hierarchy, consumers in crisis times tend to prioritise satisfying basic physiological needs before advancing to more luxurious discretionary behaviours (Loxton et al., 2020). According to Maslow's Hierarchy of Needs, since sustenance is the most crucial physiological requirement of human beings (Fung et al., 2018), individuals will invariably prioritise securing food. Despite this, it is vital to acknowledge that food has the potential to transmit diseases (WHO, 2016). Thus, following Maslow's theory, consumers may exhibit increased concern for their health safety (Loxton et al., 2020), such as food safety during a pandemic (Mucinhato et al., 2022), once their fundamental physiological needs are met.

2.6.1 COVID 19 pandemic

WHO announced the COVID-19 pandemic as a global emergency in January 2020 (WHO, 2020a; Mucinhato et al., 2022). A medical syndrome termed COVID-19 arises as a result of SARS-CoV-2 virus infection. The health condition has respiratory symptoms ranging from minor influenza-like illness to life-threatening pneumonia and acute respiratory distress syndrome (Olaimat et al., 2020). A wide range of clinical symptoms is associated with COVID-19 that vary among patients and countries (Petrosillo et al., 2020). This disease is transmitted via respiratory droplets disseminated through sneezing, coughing, speaking, or direct interaction with diseased individuals (Wang et al., 2020). The global count of COVID-19 cases as of August 21, 2023, was 693,688,647, a total of 6,908,737 fatalities (Worldometer, 2023). Notwithstanding worldwide vaccination efforts, the morbidity and mortality rate persist (Salehi et al., 2022). Three years since the onset of the pandemic, individuals have resumed their pre-

pandemic lifestyle. Yet, it has the potential for COVID-19 to cause recurring infections in low-risk individuals and to have significant mortality rates in old and immunocompromised people (Phillips, 2023).

Despite the common misconception that viruses need people or animals to multiply in food (Olaimat et al., 2020), a diverse array of viruses are capable of transmission through food, with Norovirus, Rotavirus, and Hepatitis A being the most commonly implicated in outbreaks resulting from consumption of contaminated food. The viruses can infect water or food as a common trait. They can be single or double-stranded DNA or RNA (Maragoni-Santos et al., 2022). However, food can be a transmission route for other viruses, including hepatitis E, enterovirus, astrovirus, adenovirus and coronavirus (O'Shea et al., 2019). Globally, norovirus accounts for approximately one in five cases of acute gastroenteritis leading to diarrhoea and vomiting. Norovirus remains the most prevalent cause of FBD outbreaks in the USA and Europe (Maragoni-Santos et al., 2022).

Several foodborne viruses can persist for a prolonged duration in food items, on hands, in faecal matter, on floors, and on surfaces that come in contact with food (Lacombe et al., 2021). Respiratory viruses can also spread from foodstuffs to nostrils, hands, eyes, and mouths (Olaimat et al., 2020). Even though coronaviruses have been linked to food contamination (O'Shea et al., 2019), studies have not yet verified the spread of genetically modified SARS-CoV-2 through food (Maragoni-Santos et al., 2022). Research has not shown that COVID-19 spreads through food items (WHO, 2020b), and there is no sufficient documentation that it is the FBD (Jalava, 2020). The COVID-19 virus may persist on various surfaces for several hours or come into contact with food goods and packaging through an infected person. These scenarios have indirect effects on food safety (Rizou et al., 2020). Van Doremalen et al. (2020) mentioned that SARS-CoV-2 can be viable for up to three hours in the air and up to 72 hours on plastic and stainless steel. The virus is relatively stable at 40^0 C and heat-sensitive at 70^0 C. It can be active at room temperature with a pH range of 3 to 10. Although transmission from frozen food may be conceivable, it appears that cooking temperatures ($>70^0$ C) are sufficient to inactivate the virus (Rizou et al., 2020). SARS-CoV-2 can survive at 20^0 C for up to 2 years while still being infectious, much like the SARS-CoV and MERS coronaviruses can (Rizou et al., 2020).

Viral infections can spread by handling or ingesting infected food products (Olaimat et al., 2020). If food is contaminated by the respiratory secretions of a COVID-19 patient, it might become a fomite (carrier). When unhygienic hands touch the nose, mouth, or eyes of individuals, they may expose to the virus that is more likely to infiltrate their respiratory epithelium (BfR, 2020; Olaimat et al., 2020). Given the multiple human-to-human SARS-CoV-2 transmissions, it is clear that the virus may propagate successfully in humans by using the angiotensin-converting enzyme 2 (ACE2) as a receptor for entrance. Additionally, it was found that gastrointestinal epithelial cells have high levels of the viral receptor ACE2. Although these data suggest that the virus may survive and reproduce in the gastrointestinal system, it is not evident if ingesting food infected with SARS-CoV-2 actually causes illness. Viral transmission may also occur via faeces-to-oral transfer. Hence, faecal-oral spread must be prevented to halt the viral spread (Maragoni-Santos et al., 2022). To reduce the likelihood of viral transmission during the COVID-19 pandemic, experts suggested preventative measures, including routine hand washing, fresh produce cleaning and establishing excellent personal hygiene practices among food handlers (Olaimat et al., 2020). The virus can live in frozen storage for up to two years if food is unwashed before freezing. According to studies, maintaining proper cooking procedures (Olaimat et al., 2020), hand washing after handling goods and packages (Seymour et al., 2020), and acceptable hygiene practises are all preventive measures to reduce the risk of exposure to the SARS-CoV-2 virus (FDA, 2020).

2.6.2 COVID 19 pandemic and food safety

The COVID-19 pandemic and quarantine resulted in an enormous adverse effect on the economy, public health, and society. The usual operating procedures of businesses and consumers' purchasing and eating habits have changed due to social distance and safety regulations (Soon et al., 2021). Due to the lockdown limitations during the COVID-19 pandemic, consumer attitudes towards food and food choices altered (Gerritsen et al., 2021). Consumers were cooking at home more often and making their baked products. Individuals reported performing more cooking at home and eating less out during the pandemic in North America, Ireland, Australia and the United Kingdom (Flanagan et al., 2021). Individuals exposed to pandemic hazards may become more aware of possible threats to food safety. The individuals' vulnerability during the pandemic induces their cognitive perceptions, which may impact their food safety awareness (Mucinhato et al., 2022; Yang, 2020). As a result, the

COVID-19 pandemic has altered how individuals purchase, prepare, and consume food. Food safety procedures may be affected by changes in dietary and cooking preferences (Soon et al., 2021).

Faour-Klingbeil et al. (2021) investigated public behaviour changes concerning food handling, purchasing, and safety procedures during the COVID-19 pandemic. A web-based survey was conducted using a snowball sampling approach, with 1074 participants from three Arab nations, Lebanon, Jordan, and Tunisia. The findings indicated that ready-to-eat (RTE) food was less consumed during the COVID-19 pandemic. Compared with pre-pandemic periods, a significant rise in behaviours linked to cleanliness and disinfection practises (22.0%-32.2%) and a slight increase (11.2%) in handwashing before food preparation was noted. In addition, the number of Tunisians using cleaning agents for washing fresh fruits and vegetables (such as soaps or non-food grade chlorine bleach) almost doubled as a result of individuals concerns about acquiring COVID-19 from food, while usage among Jordanians and Lebanese increased by 16% and 26.1%, respectively. However, a third of the respondents did not use chemical goods according to the directions on the label. During COVID-19 in the Arab nations, the researchers mainly discovered culturally specific shortcomings in handwashing and hazardous food handling practices (Faour-Klingbeil et al., 2021).

Another study (Limon, 2021) assessed the self-reported and observed practices operating internet food enterprises among food handlers in the Philippines at home during the COVID-19 pandemic. The web-based poll has 751 participants chosen via criteria sampling. Excluding age, where there is a substantial discrepancy between the food safety practice of the four age groups along with food preparation ($p<0.01$), the author found no correlation between self-reported food safety practice and demographic characteristics in any of the four dimensions (cross-contamination prevention and sanitation, personal hygiene, food preparation, and food delivery). The food handlers at home improperly and insufficiently followed the procedures for maintaining the food's safety. The results revealed very poor adherence to food safety regulations. Osaili et al. (2022) examined female food handlers operating home-based internet food companies in Jordan during the COVID-19 pandemic and investigated their knowledge, attitudes, and practises. The study utilised social media and phone calls to contact the participants. About 204 persons finished the survey in total. With a mean score of 22.6 out of 42 points (53.8%), the findings showed that the respondents had little understanding of

unfavourable attitudes towards and inappropriate practices about food safety (Osaili et al., 2022).

On the other hand, Soon et al. (2021) performed an online survey to ascertain how COVID-19 has impacted Southeast Asian consumers' knowledge, attitudes, and practises regarding food safety and the variables influencing their outdoor eating habits. The intention to employ safe dining practices during COVID-19 was investigated using the Theory of Planned Behaviour (TPB) model. The average knowledge score for food safety was 6.37 ± 1.37 (9.00 - highest score), while 91.3% of participants from Malaysia and Indonesia scored under ≥5. During COVID-19, consumers reported engaging in food safety practices (4.03±0.82) and showed favourable views towards food safety (4.06 ± 0.99). Similarly, Salehi et al., 2022 investigated the knowledge, attitude and practice of food safety and hygiene among Iranian people during the COVID-19 pandemic and showed a satisfactory level of KAP among the respondents. Luo et al., 2020 surveyed Chinese people to evaluate the knowledge, attitudes and practices (KAP) of food safety and nutrition during the COVID-19 pandemic. Their questionnaire comprised sociodemographic data, COVID-19 awareness, and KAP about dietary intake and food safety. The study included 2272 participants, and the results showed that the food nutrition KAP of Chinese individuals optimised during the COVID-19 pandemic due to medical emergencies. 79% of participants altered their eating patterns during this public emergency, increasing their intake of vegetables, fruit, and water and lowering their sugary drinks and snacks (Soon et al., 2021).

2.7 Food safety and food handlers' behaviour in Bangladesh

Restaurants and food sellers now play a significant part in the food supply chain due to the recent urbanisation process and changes in food consumption patterns in Bangladesh. Poor food handling and sanitation practices, lack of understanding about food safety, traditional beliefs, insufficient food safety regulations, weak regulatory systems, and lack of health education for food handlers result in food safety challenges in this country (Riaz et al., 2016). Furthermore, there has been a qualitative transformation of individuals' food preferences in recent decades because of increases in several socioeconomic indices, such as money and education. Household income and spending studies reveal a rise in the consumption of processed and RTE meals, with food handlers being integrally linked to the supply chain and

engaging in food manufacturing and preparation (Mottaleb et al., 2018). People now consume RTE, restaurant-prepared, street-vendor, and processed meals more often than previously due to a discernible change in food culture. In addition, there has been a noticeable rise in the occurrence of FBD; in recent years, hazardous chemicals and microorganisms that are multi-drug resistant are frequently found in food samples in Bangladesh (Noor & Feroz, 2016; Khairuzzaman et al., 2014). Food handlers, particularly domestic food handlers, did not get priority in most food safety-related research conducted in Bangladesh, which focused on the food components concerning their microbiological, chemical, and physical properties. According to Codex Alimentarius, the person directly engaged with handling, packaging and unpackaging goods, food ingredients and utensils, or food contact surfaces is considered a food handler and, therefore, expected to adhere to food hygiene standards (WHO, 2009). As a result, the duties of a food handler include handling, storing, preparing, producing, serving, or cleaning tools, surfaces, and workplaces that come into touch with food (Sani & Siow, 2014).

In Bangladesh, studies have been conducted on food safety knowledge and practice among biscuit factory workers (Jubayer et al., 2020), street vendors (Al Banna et al., 2022; Hassan et al., 2017; Hossen et al., 2020) restaurant food handlers (Nizame et al., 2019), Chicken vendors (Siddiky et al., 2022) and meat handlers (Al Banna et al., 2022). Although improper food handling practices in a domestic environment, such as cross-contamination, improper cooking methods and unsafe storage, have been identified as the contributing factors to a foodborne illness outbreak (Basha & Lal, 2019; Redmond & Griffith, 2009; Ruby et al., 2019; Wilcock et al., 2004), there have been limited studies on adult consumers' knowledge, attitude and practices of food safety in Bangladesh.

A systematic review has recently investigated Bangladeshi food handlers' food safety knowledge and practices (Rifat et al., 2022). The total searched document number was 1609, and twelve studies were included for examination after the first (n = 1609) and full text (n = 20) screening. The studies considered food handlers in various contexts, including households, retail markets, restaurants, and street food. Among the 12 studies, eight mentioned the handlers' familiarity with food safety. Of these, five studies (62.50%) indicated that the food handlers had inadequate understanding of food safety. There were 11 research reported on food safety practises, and eight (72.73%) of those studies mentioned bad food handler behaviour. The research discovered that street and restaurant food handlers had worse habits than others. The evaluation found that more thorough research in this area is needed since Bangladeshi food

handlers' understanding and practises regarding food safety are generally unsatisfactory. Moreover, the research highlighted a lack of reliable food safety studies among the domestic food handlers in Bangladesh (Rifat et al., 2022).

Earlier studies conducted in Bangladesh reported that handwashing could reduce the incidence of diarrhoea in intervention areas (Alam et al., 1989; Stanton & Clemens, 1987). In a study, Nasreen and Ahmed (2014) revealed the magnitude of food adulteration during 1995–2011 about consumer awareness in Dhaka City, Bangladesh. The authors found that consumer with lower socioeconomic status is less concerned with safe food (Nasreen & Ahmed, 2014). A recent study found significant differences in urban and rural Bangladeshi consumers' perceptions of food safety (Ishra et al., 2022). The authors identified that urban consumers in Bangladesh were more concerned about food hazards and safe food purchasing factors (e.g., freshness, expiry dates, origin of the product) than their rural counterparts. Besides, urban and rural consumers perceived chemical food hazards as more deadly than microbiological hazards (Ishra et al., 2022).

Islam et al. (2023) conducted a cross-sectional study among Bangladeshi household food handlers to examine food safety knowledge. The study found that the respondents had an overall food safety knowledge pass rate of 17.6% (knowledge scores from 0 to 26 and awarded mean score was 9.45 2.98), indicating very poor knowledge of food safety, in particular, poor food handling (29.6% passing rate), food poisoning (28.4% passing rate), and food storage (31.6% passing rate) knowledge level. However, the study did not examine the food handlers' attitudes and practices. Further, the study was cross-sectional and conducted in a few districts within a specific group. Thus, it cannot be generalised to all food handlers in Bangladesh (Islam et al., 2023).

2.8 Conclusion

This chapter started with a brief overview of food safety hazards (e.g., biological, chemical, physical), foodborne diseases and their impact on global and low-middle-income country context. The chapter discussed food safety concepts, strategies, consumer liability of food safety and their knowledge, attitude, practice and risk perception in various country contexts. Finally, this chapter ended with discussing the current COVID-19 pandemic, the food safety

situation, and the household food handlers' food safety behaviour, highlighting the knowledge gap in food safety behaviour in Bangladeshi households. In the next chapter, this thesis includes a study examining the domestic food handlers' pandemic-related knowledge and hygiene behaviour (PRKHB) in Bangladesh.

CHAPTER 3: PAPER 1 - FOOD HYGIENE KNOWLEDGE AND BEHAVIOUR AMONG DOMESTIC FOOD HANDLERS DURING COVID 19 PANDEMIC IN BANGLADESH

3.1 Introduction

Chapter 3 addresses a specific research gap identified in Chapter 2 that determined the Bangladeshi food handlers' pandemic-related knowledge and hygiene behaviour (PRKHB) in the domestic environment. The current study evaluates the food safety concerns after the emergence of the COVID-19 pandemic among food handlers in the domestic environment. This study also investigates the role of sociodemographic factors and food safety concerns on their pandemic-related knowledge and hygiene behaviour (PRKHB) in the domestic environment. Chapter 3 includes the paper I published in *'Food Control*', a Q1 journal.

3.2 Published paper

Title: Food hygiene knowledge and behaviour among domestic food handlers during COVID 19 pandemic in Bangladesh.

3.3 Links and implications

This current chapter conducted a cross-sectional study among domestic food handlers to investigate their food safety concerns during the pandemic and pandemic-related knowledge and hygiene behaviour (PRKHB) in Bangladesh. The study identified that most food handlers did not show more awareness towards food safety due to the COVID-19 pandemic. Factors such as food safety concerns and food handlers' place of residence significantly influence their PRKHB in the domestic environment. Male gender and age 50 years and above showed better PRKHB, while food handlers living with a large family (six or more family members) had inadequate PRKHB levels. The results found that most urban (72.3%) food handlers possess a better PRKHB than their rural (3.2%) counterparts. Unexpectedly, only 38.8% of respondents mentioned always washing their hands before meals and after returning home. The study also examined sociodemographic changes and notable distinctions between urban and rural locations. This finding suggests that policymakers should rapidly develop hygiene education for sustainable food safety and hygiene behaviour. The government may, therefore, ascertain the effective dissemination and rapid and easy access to food safety education during an emergency such as a pandemic or foodborne disease outbreak both in urban and rural locations.

As this is a cross-sectional study examining food safety knowledge, attitude and practice (KAP) of domestic food handlers, the next chapter will investigate the food handlers' food safety knowledge level in the domestic environment before and following the COVID-19 pandemic. Furthermore, the study compared the pre-pandemic and post-pandemic food safety knowledge levels, including personal hygiene, cross-contamination, safe storage, foodborne diseases, and temperature control.

CHAPTER 4: PAPER 2 - FOOD SAFETY KNOWLEDGE AMONG ADULT DOMESTIC FOOD HANDLERS IN BANGLADESH: A COVID-19 COMPARATIVE STUDY

4.1 Introduction

The chapter explicitly investigates the food handlers' food safety knowledge level before (pre) and after (post) the onset of the COVID-19 pandemic. This study has given a specific focus to the comparison between pre- and post-pandemic times. It also examined the influence of sociodemographic factors on pre- and post-pandemic food safety knowledge among food handlers in the domestic environment. The findings of this study are under review in the *'British Food Journal',* a Q1 journal.

4.2 Submitted paper

Title: Food Safety Knowledge among adult domestic food handlers in Bangladesh: A COVID-19 Comparative Study.

Food Safety Knowledge among adult domestic food handlers in Bangladesh: A COVID-19 Comparative Study

Abstract

Purpose - The COVID-19 pandemic is having a significant impact on all facets of civilization around the world, including human health. Food handlers' knowledge of food safety have been impacted due to this pandemic.

Design/methodology/approach - The current study performed a cross-sectional comparative survey of 503 domestic food handlers in Bangladesh to assess food safety knowledge, including personal hygiene, cross-contamination, safe storage, foodborne diseases, and temperature control and compared their responses before (pre) and after (post) the COVID-19 pandemic outbreak.

Findings - Only 28.8% of food handlers demonstrated good food safety knowledge during the pre-pandemic, but this figure considerably increased to 38.2% following the pandemic. Although personal hygiene knowledge significantly improved after the pandemic, only 30.6% of participants reported the correct duration (20 seconds) of hand washing. More than half (50%) of the participants showed poor knowledge of cross-contamination, safe storage, foodborne disease and temperature control knowledge and there was no significant difference between pre-and post-pandemic times in these parameters. In the sociodemographic analysis, this study revealed that food handlers over the age of 50, men, higher family incomes, university graduates, families with 0-2 children, families with 3-5 members, and urban respondents had a good understanding of food safety both in pre-and post-pandemic.

Originality/value – This study compares domestic food handlers pre-and post-COVID 19 food safety knowledge that was previously unknown in Bangladesh. The findings have made a significant contribution to the existing knowledge on food safety in Bangladesh, which can be utilized to adapt policies and structure training programs for food handlers in the country.

Key words
Food safety knowledge, Foodborne disease, Food handler, Household, COVID-19, Bangladesh

Paper type - Research paper

Abbreviations
Foodborne Disease - FBD
Food Safety Knowledge - FSK

1. Introduction

Food safety is a shared responsibility and an utmost concern for consumers, food traders, and governing agencies. World Health Organization (WHO) reported that approximately 600 million individuals become ill, and 420,000 deaths occur annually worldwide due to microbiologically or chemically contaminated food consumption (WHO, 2015). Further documents suggest that contaminated food is the source of the spreading of 200 different disease types. Certain foodborne diseases (FBDs) can lead to severe health consequences, including hypertension, diabetes, and renal and central nervous system dysfunctions. The fatal outcome usually occurs in pregnant women, children and older adults (Al Banna et al., 2022).

Food can contaminate at any level, from the farm, food processing, transportation, storage and food preparation (WHO, 2016). These contaminants reach the food system via improper food handling, cross-contamination, inadequate personal hygiene, contaminated food supplies, poor storage conditions or inadequate cooking methods (WHO, 2015, Osaili et al., 2022). Studies have shown that the FBD outbreak caused because of the deficiency of proper food safety knowledge (FSK) in domestic food preparation (Ruby et al., 2019, Langiano et al., 2012, Al-Sakkaf, 2015, WP et al., 2013, Wu et al., 2018). Many cases of FBDs among consumers have been linked to food consumed in the home, though it is likely that some have gone undetected or misdiagnosed (Keegan et al., 2009, Redmond and Griffith, 2003, Vrbova et al., 2012). Misinterpretation of FBD is one reason why consumers and food handlers at home do not seek medical treatment (Lim et al., 2016). Previous studies have reported that more than 35% of FBDs occur at home while handling food (Langiano et al., 2012). The hands of food handlers spread harmful microorganisms through cross-contamination, making them a significant cause of food contamination (Baş et al., 2006, Campos et al., 2009, Kunadu et al., 2016). Proper hygiene practices among food handlers can reduce cross-contamination and help to protect consumers from diseases (Jevšnik et al., 2008).

The prevalence of FBDs obtained from domestic kitchens considerably differs between countries (Al-Shabib et al., 2016, Islam et al., 2023). Previous studies revealed that 20 - 50% of FBDs occurred in Australia and New Zealand due to homemade food (Redmond and Griffith, 2009). In mainland China, households had the highest number of outbreaks (58.5%) and deaths (89.5%), with 7,073 FBD outbreaks resulting in 37,454 illnesses and 143 fatalities in 2020 (Li et al., 2021). In the European Union, 36.4% of FBD outbreaks occurred because of

the food prepared in homes (European Food Safety Authority, 2017). The CDC has reported a rise in FBD outbreaks due to home-prepared food in the last few years (CDC, 2023).

While FBD continues to be a significant public health issue worldwide, in developing countries such as Bangladesh, this impact is severe in developing countries such as Bangladesh because of its dense population, inadequate infrastructure, and scarcity of services for clean water, sanitation, and hygiene (Noor and Feroz, 2016, Ishra et al., 2022). Each year over 30 million people are infected with FBDs in this country (Khairuzzaman et al., 2014, Ishra et al., 2023). The Institute of Epidemiology, Disease Control and Research (IEDCR) noted that in 2015, there were 0.28 million individuals in Bangladesh who experienced acute gastroenteritis, a common symptom of food poisoning. According to estimates from the Institute of Epidemiology (2015), 30,000 and 500 people, respectively, contract enteric fever and hepatitis each year (Institute of Epidemiology, 2015, Suman et al., 2021). The consequences of FBDs can lead to financial costs for both the individual and the nation, in addition to physical and mental impairment or even death (Fung et al., 2018).

Consumers are the ultimate link in the food supply chain to come into contact with food; studies have shown that consumer knowledge of food safety plays a significant role in preventing FBD outbreaks while handling food in the domestic kitchen (Mullan et al., 2015, Odeyemi et al., 2019, Ruby et al., 2019, Traversa et al., 2015, Worsley et al., 2013). Numerous researchers have found that consumers' age, gender, level of education and cooking experience influence their FSK (Burke and Dworkin, 2015, Farahat et al., 2015, Lazou et al., 2012, Motta et al., 2014, Ruby et al., 2019, Sanlier, 2010, Shori, 2017). Experts have successfully designed food safety education programs that are effective for developing food safety proficiency among different country consumers (Da Costa et al., 2016, Jevšnik et al., 2013, Majowicz et al., 2015, Meysenburg et al., 2014, Ruby et al., 2019, Tabrizi et al., 2017, Talaei et al., 2015).

Recently food safety has been severely impacted due to the emergence of the COVID-19 pandemic (Osaili et al., 2021). The COVID-19 pandemic has altered the global food system, consumer food safety awareness, food preparation, hygiene behaviour and eating habits (Osaili et al., 2021, Osaili et al., 2022). The transmission routes of this virus are through person-to-person contact and respiratory droplets via sneezing, coughing or talking (Osaili et al., 2021, Wang et al., 2020). No evidence suggests that COVID-19 is a FBD; however, the entire phenomenon encircling food products may act as a route of virus transfer (Jalava, 2020, WHO,

2020). For example, if an infected person comes into contact with food, food packages, machinery or utensils, the food can become the vehicle of the disease transmission (Osaili et al., 2021). Experts recommend preventive measures, including hand washing and maintaining good personal hygiene to reduce SARS-cov-2 virus transmission and cross-contamination among food handlers during the COVID-19 pandemic (Olaimat et al., 2020). When individuals are most vulnerable during a pandemic, their pandemic-related cognitive perceptions affect the extent to which they are conscious of food safety (Yang, 2020, Mucinhato et al., 2022). Hence, this study presumes that consumer FSK may have influenced due to this COVID-19 pandemic.

In Bangladesh, various studies have been conducted among street vendors, restaurant and factory food handlers to understand their FSK level (Al Banna et al., 2022, Nizame et al., 2019, Al Mamun et al., 2013, Siddiky et al., 2022, Jubayer et al., 2020, Hashanuzzaman et al., 2020). Despite the importance of domestic food handling to prevent food contamination, to the best of our knowledge, no studies have investigated FSK among domestic food handlers before (pre) the COVID-19 pandemic. However, limited studies have highlighted domestic food handler knowledge levels after (post) the pandemic started. Therefore, the objectives of this research are -

1. To examine and compare adult consumers' pre-pandemic and post-pandemic FSK who handled food in the domestic environment.
2. To evaluate the association between food handlers' sociodemographic profiles and their FSK level.
3. To investigate the elements that regulate FSK.

Measuring and comparing the pre-pandemic and post-pandemic FSK will help understand the difference in consumer food safety behaviour and any positive and negative behavioural patterns, which will help implement food safety strategies according to their knowledge level. Executing food safety interventions in low-socioeconomic and high-risk target groups will aid in the reduction of FBD by informing the public about the precautions they can take to protect themselves and their families from FBDs.

2. Methods

2.1 Study design and sampling

To compare the responses between urban and rural areas, the present research acquired data from four locations in Bangladesh between November 2021 and March 2022. The research sites included two metropolitan cities (Dhaka and Chittagong) and two rural districts (Faridpur and Cox's Bazar). Dhaka, the capital of Bangladesh, is a bustling metropolis home to an industry-based economy and a population of approximately 14.7 million. Faridpur is a district in the Dhaka division with a population of about 2.1 million and an agriculture-based economy (BBS, 2022). The coastal region of Bangladesh is home to Chittagong and Cox's Bazar. With a population of about 9.1 million, the second-largest city is Chittagong, and its local economy mostly depends on industry, agriculture, and fishing. The district of the Chittagong division, Cox's Bazar, has 2.8 million people and a predominantly agricultural economy (BBS, 2022).

This study conducted a cross-sectional descriptive survey targeting domestic food handlers aged 18 years or above who prepared food at least 2-4 times per week. Based on the estimated 104.87 million adult population in Bangladesh, the study determined a sample size of 385, utilizing a 5% margin of error and a 95% confidence interval. It is generally accepted that a large sample size increases the study's accuracy, given its inferential objectives. Consequently, the study obtained more data, and the total sample was 503.

2.2 Data collection

The data collection procedure commenced following approval from the relevant University Human Research Ethics Committee. According to university regulations, all of the research assistants received thorough training before starting the data collection. The research assistants randomly visited the preferred sites, including local markets, grocery stores, bazaars, colleges, parks, and schools. The research assistants made their way up to individuals outside stores or schools using a convenience sampling strategy to select the participants. After outlining the research objectives and receiving informed permission, the researcher completed a face-to-face survey with the participants. Each survey took between 15 and 20 minutes to finish. After being translated into Bengali, survey data were collected electronically using Google Forms. The responses were transferred into an Excel file sheet after completing the survey. The Excel file

was secured with a password, and survey data was entered into a password-secured SPSS (Statistical Package for the Social Sciences) spreadsheet. Finally, all data were stored in a password-secured Google drive and also in a separate hard drive.

2.3 Survey instruments

This study employed a questionnaire with validated scales that were used in the previous studies (Gong et al., 2016, Lihan et al., 2019, Moreb et al., 2017, Soon et al., 2020, Soon et al., 2021, Odeyemi et al., 2019, Ruby et al., 2019, Tabrizi et al., 2017). The survey instruments are divided into two sections: sociodemographic characteristics and questions on consumers' knowledge of food safety.

The demographic information comprised age, gender, education, family income, occupation, place of residence, total number of individuals, and the number of children in the household. The participants were asked questions on their knowledge of personal hygiene, cross-contamination, safe storage, foodborne diseases, and temperature control using a set of 21 items in the FSK area. Each question had three alternative answers: "Yes," "No," and "Don't know." A correct response received one point, whereas an incorrect or "don't know" response received zero points. 'Don't know' was added to the multiple-choice answers to reduce the likelihood that participants would select the correct response accidentally. Both pre-and post-pandemic food safety knowledge data were collected using the same questionnaire and response scale. Each respondent could get a maximum of 3 to 8 points for each subsection of the knowledge section and 21 points for the entire knowledge section for both pre-and post-pandemic responses. If participants correctly responded more than half of the questions in each area (such as personal hygiene, cross-contamination, and safe storage), they were considered to have good knowledge. Participants who received 5 to 11 out of a possible 21 points for overall FSK were deemed to have poor knowledge, and those with 12 to 21 points were considered to have good knowledge (Gong et al., 2016).

2.4 Validity, reliability and data analysis

A bilingual translator translated the survey materials into Bengali while another research team member reviewed the translations. Prior to the launch of the final survey, researchers conducted a pilot study to test the validity of the instruments among a small group of domestic food

handlers (n = 30). The final results did not include the pilot study. Cronbach's alpha tests were used to determine each scale's internal consistency. The Cronbach's alpha for the pre-pandemic and post-pandemic constructs of FSK were 0.838 and 0.904, respectively, showing satisfactory reliability (Taber, 2018).

The data were analyzed using SPSS (Statistical Package for the Social Sciences) software (Mac OS version 29). To compare demographics between two residential places (such as urban and rural), a Chi-square test was used. The pre-and post-pandemic responses in the study were determined by frequency analysis. To assess pre- and post-pandemic levels of knowledge on food safety, the non-parametric Wilcoxon signed-rank test was used. Chi-square tests were used to compare the responses received from urban and rural food handlers regarding their awareness of food safety. Several Mann-Whitney U tests and Kruskal-Wallis H tests were carried out to contrast food handlers' pre- and post-pandemic food safety scores with demographic factors. The effects of pre-and post-pandemic FSK and sociodemographic variables such as gender, age, and income on the probability of respondents considering a good level of knowledge were evaluated through binary logistic regression.

3.Result

3.1. Demographic characteristics

Domestic food handlers' socioeconomic statuses in urban and rural locations are outlined in Table 1. Among 503 participants, respectively, 250 (or 49.7%) and 253 (or 50.3%) were from rural and urban areas. Table 1 shows that females were the majority of respondents in both regions (90.3%). A large proportion of urban participants reported having a master's degree or higher (96.6%) and a monthly family income of more than 100,000 BDT (56.1%). Conversely, the participants residing in rural areas mentioned having secondary education (71.6%) and a monthly salary ranging from 20,000 to 39,000 BDT (72%).

Table 1: Sociodemographic Characteristics of the domestic food handlers

N = 503		Urban	Rural	χ^2 *P* value
	n (%)	n (%)	n (%)	
Age in years				$\chi^2 = 43.11$ p <0.001
18 - 29	134 (26.6)	48 (19)	86 (34.4)	
30 - 39	196 (39)	112 (44.3)	84 (33.6)	
40 - 49	136 (27)	59 (23.3)	77 (30.8)	
50 and above	37 (7.4)	34 (13.4)	3 (1.2)	
Gender				$X^2 = 27.23$ P <0.001
Female	454 (90.3)	211 (83.4)	243 (97.2)	
Male	49 (9.7)	42 (16.6)	7 (2.8)	
Education				$\chi^2 = 354.24$ p <0.001
School	199 (39.6)	20 (7.9)	179 (71.6)	
College	60 (11.9)	5 (2.0)	55 (22)	
University (Bachelor)	114 (22.7)	102 (40.3)	12 (4.8)	
University (Masters and above)	130 (25.8)	126 (49.8)	4 (1.6)	
Occupation				$\chi^2 = 172.78$ p <0.001
Student	10 (2.0)	8 (3.2)	2 (0.8)	
Housewife	349 (69.4)	108 (42.7)	241 (96.4)	
Govt. employee	29 (5.8)	29 (11.5)	0	
Non-govt. employee	80 (15.9)	77 (30.4)	3 (1.2)	
Business	31 (6.2)	27 (10.7)	4 (1.6)	
Unemployed	4 (0.8)	4 (1.6)	0	
Family Income (BDT/month) [a]				$\chi^2 = 348.15$ p <0.001
less than 20,000	15 (3.0)	11 (4.3)	4 (1.6)	
20,000 to 39,000	198 (39.4)	18 (7.1)	180 (72)	
40,000 to 59,000	88 (17.5)	24 (9.5)	64 (25.6)	
60,000 to 79,000	30 (6.0)	30 (11.9)	0	
80,000 to 99,000	29 (5.8)	28 (11.1)	1 (0.4)	
100,000 and over	143 (28.4)	142 (56.1)	1 (0.4)	
Number of persons in family				$\chi^2 = 151.19$ p <0.001
1 - 2	40 (8.0)	35 (13.8)	5 (2.0)	
3 - 5	228 (45.3)	168 (66.4)	60 (24)	
6 and more	235 (46.7)	50 (19.8)	185 (74)	

Number of children in family				$\chi^2 = 174.13$ p <0.001
0	130 (25.8)	121 (47.8)	9 (3.6)	
1 - 2	203 (40.4)	101 (39.9)	102 (40.8)	
3	114 (22.7)	30 (11.9)	84 (33.6)	
4 and more	56 (11.1)	1 (0.4)	55 (22)	

Note: ***p<0.001, **p<0.01, *p<0.05; [a] $ 1 USD = 106.38 BDT (Bangladeshi Taka) while writing this article

3.2 Food safety knowledge (FSK)

Table 2 demonstrates that, before the commencement of COVID-19, less than half of the (44.3%) consumers reported that hand washing minimizes the risk of food contamination before and after cooking a meal. This percentage of respondents increased to 99% after the pandemic started. Despite this being the most discussed and well-campaigned concept, 69.4% of consumers were unaware of the correct duration of handwashing in the post-pandemic. Yet, 99.2% of consumers knew that abdominal pain, diarrhoea, vomiting, and nausea are FBD symptoms both in pre-and post-pandemic time, while 11.1% and 10.9% reported *Hepatitis A* virus, *Salmonella,* and *Staphylococcus* are foodborne pathogens before and after the COVID - 19 started respectively. In pre-and post-pandemic responses, the majority of consumers were unaware that healthy people have microorganisms on their skin, nose, and mouth (60%), headaches are a symptom of FBD (86%), poached eggs, raw milk, and soft cheese are bad for pregnancy (80%), or FBDs can cause abortion (92%). The analysis also revealed that consumers knew less about temperature regulation. Only 11.5% (pre-pandemic) and 12.3% of respondents (post-pandemic) claimed that germs may reproduce quickly at a temperature of 37 °C. Additionally, in the pre-and post-pandemic period, more than 60% of consumers did not know refrigerator and freezer operating temperatures.

Table 2: Responses of food safety knowledge of adult food handlers in Bangladesh

Questions	Pre-pandemic (%)			Post-pandemic (%)		
	Yes	No	Do not Know	Yes	No	Do not Know
Personal hygiene						
Hand washing before and after cooking reduces the risk of food contamination	44.3	43.5	12.1	99.0	0.6	0.4
20 seconds duration is enough for hand washing.	6.2	46.1	47.7	30.6	23.1	46.3

It is necessary to wash hands after touching your body parts.	8.9	39.0	52.1	27.6	20.5	51.9
Cross-contamination						
Uncovered abrasion or cuts can cause cross contamination of food.	42.3	12.7	44.9	44.5	10.7	44.7
It is necessary to wash the knife that has been used to cut raw meat with soap and water before using it again	77.9	10.5	11.5	85.9	2.6	11.5
Storing raw and cooked food together can cause food contamination	47.5	4.2	48.3	47.9	3.8	48.3
Safe storage						
Leftover food smelling good is not safe to eat.	30.4	45.3	24.3	30.6	45.1	24.3
It is ideal not to keep leftover food in the fridge for more than 2 days.	48.1	27.0	24.9	49.1	26.2	24.7
Storing leftover food on the table or kitchen shelf is not good.	44.7	29.0	26.2	44.9	28.8	26.2
Foodborne disease						
Abdominal pain, diarrhoea, vomiting, nausea is foodborne illnesses symptoms.	99.2	0.2	0.6	99.2	0.2	0.6
Headache is a symptom of food borne illnesses.	13.3	25.8	60.8	13.5	25.8	60.6
Children, pregnant women and older people are more at risk of food borne illnesses.	53.7	6.6	39.8	53.3	6.6	40.2
Abortion in pregnant women can be induced by food-borne disease.	7.4	11.7	80.9	7.4	11.5	81.1
Poached egg, raw milk and soft cheese are not good for pregnancy.	19.7	47.3	33.0	19.3	47.7	33.0
Microorganisms can be found on skin, nose and mouth of healthy handlers.	39.0	11.5	49.5	39.0	11.3	49.7
Hepatitis A virus, *E. coli, Salmonella and Staphylococcus* are food borne pathogen.	11.1	4.4	84.5	10.9	4.8	84.3
Inadequate cooking of raw food (meat, chicken, vegetable) can cause outbreak of food borne illness.	83.5	1.2	15.3	83.7	1.0	15.3

Temperature control						
-18 degree C or below is the optimal temperature for freezing food.	22.1	4.2	73.8	22.3	3.8	74.0
1 - 5 degree C is the refrigerator operating temperature.	36.6	1.8	61.6	36.6	1.4	62.0
Bacteria that cause food poisoning multiply rapidly at a temperature of 37 °C.	11.5	5.2	83.3	12.3	5.0	82.7
Bacterial growth does not accelerate at a temperature of 75 °C.	11.9	6.2	81.9	11.1	7.4	81.5

The Wilcoxon signed-rank test showed that pandemic has caused a significant increase in food handlers personal hygiene (Z = - 16.7, p<.001) and overall FSK (Z = -5.47, p<.001) (Table 3).

Table 3: Wilcoxon signed rank test showing comparison of pre- and post-pandemic food safety knowledge

Food safety knowledge	Pre-pandemic		Post-pandemic			
	Mean score± SD	Percentage[a]	Mean score± SD	Percentage[a]	Z	p
Personal hygiene	0.59 ± 0.772	10.1	1.57 ± 0.829	36.4	-16.7	<.001***
Cross contamination	1.67± 1.160	46.9	1.78 ± 1.333	48.5	-1.81	0.07
Safe storage	1.23 ± 1.287	38.6	1.24 ± 1.283	39.2	-0.19	0.84
Foodborne disease	3.26 ± 1.830	35	3.26 ± 1.766	35.6	-0.06	0.94
Temperature control	0.82 ± 1.268	24.9	0.82 ± 1.260	25	-0.36	0.71
Overall knowledge	7.59 ± 4.129	28.8	8.68 ± 4.975	38.2	-5.47	<.001***

Note: p<0.001***, a = Shows 'Good' level of knowledge

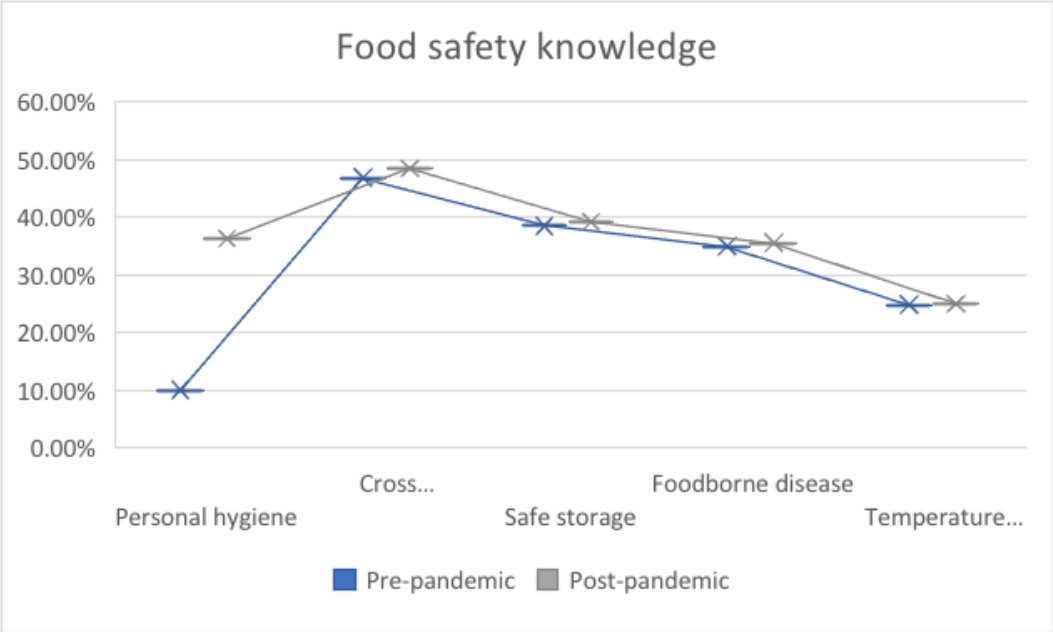

Fig 1: Comparison of food handlers good knowledge level percentages between pre- and post-pandemic

Chi-square tests were used to compare FSK scores based on the location where consumers resided (e.g., urban and rural) (Table 4). Significant differences have found between the urban and rural food handlers' knowledge level in the pre-and post-COVID time. However, as shown in Table 4, post-pandemic personal hygiene knowledge related to "hand washing before and after cooking" showed no significant differences between the residency places (p = 1.0).

Table 4: Food handlers pre- and post-pandemic correct knowledge responses considering their place of residence

Questions	Pre-pandemic (%)				Post-pandemic (%)			
	Urban	Rural	X^2	*p* value	Urban	Rural	X^2	*p* value
Personal hygiene								
Hand washing before and after cooking reduces the risk of food contamination	83	5.2	308.43	0.001***	99.2	98.8	0.19	1.00
20 seconds duration is enough for hand washing.	12.3	0.0	32.64	0.001***	48.2	12.8	74.27	0.001***
It is necessary to wash hands after touching your body parts.	17.0	0.8	40.49	0.001***	41.9	13.2	51.78	0.001***

Cross-contamination								
Uncovered abrasion or cuts can cause cross contamination of food.	75.1	9.2	223.66	0.001***	70.0	18.8	133.24	0.001***
It is necessary to wash the knife that has been used to cut raw meat with soap and water before using it again	85.4	70.4	16.39	0.001***	92.9	78.8	20.57	0.001***
Storing raw and cooked food together can cause food contamination	83.0	11.6	257.08	0.001***	75.5	20.0	155.16	0.001***
Safe storage								
Leftover food smelling good is not safe to eat.	47.0	13.6	66.41	0.001***	47.4	13.6	67.75	0.001***
It is ideal not to keep leftover food in the fridge for more than 2 days.	69.6	26.4	93.85	0.001***	68.8	29.2	78.8	0.001***
Storing leftover food on the table or kitchen shelf is not good.	71.5	17.6	147.99	0.001***	69.6	20.0	124.85	0.001***
Foodborne disease								
Abdominal pain, diarrhoea, vomiting, nausea is foodborne illnesses symptoms.	100	98.4	3.98	0.124	99.6	98.8	1.03	0.371
Headache is a symptom of food borne illnesses.	19.4	7.2	16.12	0.001***	22.1	4.8	32.31	0.001***
Children, pregnant women and older people are more at risk of food borne illnesses.	77.1	30.0	112.07	0.001***	77.9	28.4	123.6	0.001***
Abortion in pregnant women can be induced by food-borne disease.	9.5	5.2	3.39	0.06	10.7	4.0	8.21	0.004**
Poached egg, raw milk and soft cheese are not good for pregnancy.	30.4	8.8	37.23	0.001***	29.2	9.2	32.47	0.001***
Microorganisms can be found on skin, nose and mouth of healthy handlers.	60.9	16.8	102.68	0.001***	62.5	15.2	118.04	0.001***
Hepatitis A virus, *Salmonella and Staphylococcus* are food borne pathogen.	15.0	7.2	7.77	0.005**	17.0	4.8	19.2	0.001***

Inadequate cooking of raw food (meat, chicken, vegetable) can cause outbreak of food borne illness.	93.7	73.2	38.26	0.001***	92.1	75.2	26.3	0.001***
Temperature control								
-18 degree C or below is the optimal temperature for freezing food.	24.5	19.6	1.76	0.185	29.2	15.2	14.39	0.001***
1 - 5 degree C is the refrigerator operating temperature.	38.3	34.8	0.67	0.410	52.2	20.8	53.35	0.001***
Bacteria that cause food poisoning multiply rapidly at a temperature of 37 °C.	14.2	8.8	3.63	0.057	16.2	8.4	7.08	0.008**
Bacterial growth does not accelerate at a temperature of 75 °C.	14.2	9.6	2.56	0.109	15.0	7.2	7.77	0.005**

Note: ***p<0.001, **p<0.01, *p<0.05; percentages (%) show food handlers correct response

Table 5 shows that non-parametric tests Kruskal Wallis H and Mann Whitney U were conducted to investigate the relationship between food handlers' sociodemographic factors and their FSK level. The analysis found both in pre- and post-pandemic period the knowledge score was significantly ($p<0.05$) differed among the subgroups (e.g., age, education, occupation, income).

Table 5: Association between sociodemographic factors and food handlers pre- and post-pandemic food safety knowledge scores

	Pre-Pandemic		Post-Pandemic	
Sociodemographic factors	Mean Rank	H/U	Mean Rank	H/U
Age in years c		25.961***		28.278***
18 - 29	250.16		247.55	
30 - 39	251.31		259.68	
40 - 49	225.01		216.76	
50 and above	361.50		356.95	
Gender b		7471.5***		8430.5**
Male	326.52		306.95	
Female	243.96		246.07	
Education c		238.5***		179.5***
School	146.38		154.68	

College	190.19		223.88	
University (Bachelor)	340.17		340.03	
University (Masters and above)	364.88		336.76	
Occupation [c]		127.01***		91.11***
Student	324.50		319.30	
Housewife	204.51		213.79	
Govt. employee	363.97		384.91	
Non-govt. employee	372.40		337.12	
Business	349.44		332.00	
Unemployed	239.50		132.00	
Family Income (BDT/month) [a c]		234.8***		172.6***
less than 20,000	310.77		288.97	
20,000 to 39,000	143.24		155.42	
40,000 to 59,000	234.34		251.44	
60,000 to 79,000	325.62		322.18	
80,000 to 99,000	357.79		359.74	
100,000 and over	370.40		345.62	
Number of persons in family [c]		99.33***		82.34***
1 - 2	286.45		274.60	
3 - 5	316.20		311.52	
6 and more	183.85		190.40	
Number of children in family c		78.28***		72.35***
0	267.89		296.39	
1 - 2	284.22		266.78	
3	254.00		247.21	
4 and more	94.22		105.13	
Residency Place [b]		6649.5***		10943***
Urban	350.72		333.75	
Rural	152.10		169.27	

Note: p<0.001***; [a] $ 1 USD = 106.38 BDT (Bangladeshi Taka); b = Mann - Whitney U test; c = Kruskal Wallis H test; Mean rank - The mean rank is the average of the ranks for all observations within each sample.

Binary logistic regressions were utilised to ascertain the influence of sociodemographic variables (e.g., gender, age, education) on pre- and post-pandemic FSK. The logistic regression models were statistically significant both in pre-pandemic, $\chi2(17) = 220.162$, $p < 0.001$ and post-pandemic cases, $\chi2(17) = 191.925$, $p < 0.001$. The pre-pandemic logistic model explained 50.7% (Nagelkerke R2) of the variance and correctly classified 80.9% of cases, and the post-pandemic model explained 43.1% (Nagelkerke R2) of the variance and correctly classified 75.1% of cases. In pre-pandemic binary logistic regression analysis, respondents who had

university masters and above formal education (B = 1.46, p < 0.05) was positively associated with a good level of FSK compared to those who had school level education. On the other side, respondents with family income 20,000 to 39,000 BDT/month (B = - 2.22, p < 0.01) and three children in family (B = 1.26, p < 0.001) had comparatively poor knowledge about food safety during the pre - pandemic time. The binary logistic regression analysis showed that respondents aged between 40 to 49 years were less knowledgeable about food safety compared to their younger peers (18 - 29 years) during post - pandemic period (B = 1.06, p < 0.05). The post-pandemic regression analysis also observed that university bachelors (B = 1.93, p < 0.001), masters and above level graduates (B = 1.69, p < 0.01) and households occupying 3 - 5 family members (B = 1.18, p < 0.05) had positive associations with FSK compared to those who had school level education and 1 -2 members in the family respectively (Table 6).

Table 6: Binary logistic regression analysis showing sociodemographic factors and pre- and post-pandemic food safety knowledge level

	Pre - Pandemic				**Post - Pandemic**			
Variables	B	S.E.	Sig	OR (95% C.I.)	B	S.E.	Sig	OR (95% C.I.)
Age in years								
18 - 29	Ref		0.62				<0.001	
30 - 39	-.103	.412	.803	.902 (.40, 2.02)	-.614	.342	.073	.541 (.27, 1.05)
40 - 49	-.086	.440	.845	.918 (.38, 2.17)	-1.066	.357	.003**	.344 (.17, .69)
50 and above	.484	.548	.377	1.622 (.55, 4.74)	.620	.527	.240	1.859 (.66, 5.22)
Gender								
Male	Ref							
Female	-.792	.478	.097	.453 (0.17,1.15)	-.567	.447	.204	.567 (.23, 1.36)
Education								
School	Ref		.003				0.004	
College	-.785	.801	.327	.456 (.09, 2.19)	.639	.611	.296	1.89 (.57, 6.27)
University (Bachelor)	1.142	.612	.062	3.134 (.94, 10.41)	1.932	.569	<.001***	6.901 (2.26, 21.05)

University (Masters and above)	1.461	.621	.019*	4.309 (1.27, 14.55)	1.690	.580	.004**	5.417 (1.73, 16.8)
Family Income (BDT/month) [a]								
less than 20,000	Ref		.009				.527	
20,000 to 39,000	-2.225	.786	.005**	.108 (.02, .50)	-.151	.734	.837	.860 (.20, 3.62)
40,000 to 59,000	-.535	.758	.480	.586 (.13, 2.58)	-.031	.752	.967	.970 (.22, 4.23)
60,000 to 79,000	-.363	.806	.652	.695 (.14, 3.37)	.184	.799	.817	1.203 (.25, 5.76)
80,000 to 99,000	.033	.878	.970	1.034 (.18, 5.77)	1.076	.886	.225	2.933 (.51, 16.6)
100,000 and over	.261	.811	.748	1.298 (.26, 6.36)	.553	.809	.494	1.739 (.35, 8.48)
Number of persons in family								
1 - 2	Ref		.663				.058	
3 - 5	.468	.518	.366	1.597 (.57, 4.4)	1.181	.496	.017*	3.259 (1.23, 8.6)
6 and more	.408	.577	.480	1.503 (.48, 4.65)	.996	.542	.066	2.708 (.93, 7.83)
Number of children in family								
0	Ref		.001				.133	
1 - 2	.020	.306	.947	1.020 (.56, 1.85)	-.022	.282	.937	.978 (.56, 1.70)
3	-1.269	.368	<.001***	.281 (.13, .57)	-.643	.310	.038*	.526 (.28, .96)
4 and more	-19.057	4956.931	.997	.000	-19.976	5150.453	.997	.000

Note: ***p<0.001, **p<0.01, *p<0.05; [a] $ 1 USD = 106.38 BDT (Bangladeshi Taka) while writing this article

4. Discussion

The findings of this study indicate that Bangladeshi domestic food handlers had poor personal hygiene knowledge (89.9%) in the pre-pandemic period. In the post-pandemic period, the percentage (63.6%) slightly declined, which was attributable to the fact that 99.0% of food handlers displayed a higher understanding of hand washing at that time. During this pandemic, frequent hand washing has been considered the best hygiene method to reduce the spread of COVID-19 infection (Almanasrah et al., 2022). Studies conducted in other countries, such as Brazil (93.4%) and Jordan (77.5%), reported that the majority of consumers had higher

knowledge of handwashing after COVID-19 started (Almanasrah et al., 2022; Mucinhato et al., 2022). Studies mention that washing hands with warm water and soap for at least 20 seconds will prevent FBDs and the transfer of microorganisms to food (Burton et al., 2011, Luby et al., 2011, Saeed et al., 2021, Todd et al., 2010). Most (93.8%) of the food handlers in the present research did not know the correct duration (20s) of handwashing before the COVID-19 pandemic. Though this notion received the most extensive discussion and promotion at the start of the pandemic, this study expected that a substantial proportion of food handlers must have received guidance on the proper timing of handwashing during this phase. Unexpectedly, only 30.6% of consumers reported having this knowledge during that time, and the result was lower than the previous studies (Almanasrah et al., 2022; Osaili et al., 2022; Saeed et al., 2021). These findings suggest some lack of knowledge in personal hygiene among domestic food handlers that should be improved to minimize FBD incidence.

Although cross-contamination accounts for most FBD outbreaks in households (Redmond & Griffith, 2003), 46.9% of food handlers showed a good level of this knowledge during the pre-pandemic time, and the post-pandemic result did not show significant improvement in this understanding (48.5%) (Fig 1). Less than half of the consumers (pre- and post-pandemic) in this study reported that uncovered abrasions or cuts cause cross-contamination of food, contrasting a previous study where 88.3% of consumers from Asia and Africa reported the correct answer (Odeyemi et al., 2019). Studies mentioned that cutting boards and knives should properly clean for handling vegetables, poultry, or raw meat to reduce the FBD risk (De Jong et al., 2008, Almanasrah et al., 2022). More than 75% of participants in this study demonstrated to have this knowledge (pre- and post- pandemic), higher than the knowledge of consumers in Jordan (44.6%) (Osaili et al., 2022), Philippines (26%) (Limon, 2021); however, lower than the women in UAE (95%) (Saeed et al., 2021). In the present finding, less than half of the participants (pre- and post-pandemic) indicated that storing raw and cooked food together can cause food contamination; in comparison, a study by Odeyemi et al. (2019) where 72.8% of consumers answered the question correctly.

The knowledge of safe storage is another critical process to control pathogens from food. Less than one-third of respondents in pre- and post-pandemic mentioned that they knew leftover food smelling good is not safe to eat aligns with the previous study that found 32.5% of consumers knew such fact (Odeyemi et al., 2019). Aligning previous studies, about half of the food handlers (pre- and post-pandemic) in this study did not know that leftover food should not

be in the fridge for more than 2 days (Gong et al., 2016; Osaili et al., 2022) or leftover food should not be stored on the table or kitchen shelf (Osaili et al., 2022). Over 60% of food handlers indicated poor safe storage knowledge in pre- and post-pandemic findings.

Comprehending the causes and symptoms of FBD is essential to reducing the likelihood of infection and obtaining prompt medical attention (Almanasrah et al., 2022). Concerning the symptoms of FBDs, 81.7% of food handlers in restaurants in Jordan (Osaili et al., 2013), 85% of participants in Portugal (Carbas et al., 2013), and 66% of food handlers in UAE (Taha et al., 2020) knew FBD symptoms. In the current study, most (99.2%) food handlers knew the general symptoms of FBDs, such as abdominal pain, diarrhoea and vomiting (Osaili et al., 2013; Ruby et al., 2019), unlike the study by Osaili et al. (2022) they were less aware of symptoms such as headache. *E. coli, Salmonella, L. monocytogenes, S. aureus, Campylobacter, and C. botulinum* are the numerous bacterial species that can commonly result in FBDs. (WP et al., 2013).This study found that 11.1% and 10.9% food handlers had correct knowledge about pathogens (e.g., Hepatitis A virus, *E. coli, Salmonella* and *Staphylococcus*) that cause FBDs respectively, pre- and post-pandemic time, which complies with the previous studies where Kennedy et al. (2011) found that 45.2 and 19.2% of participants knew the risk of *Salmonella* and *E. coli*, while Osaili et al. (2011) identified approximately 18% of the respondents knew the FBD pathogens. Studies conducted among street-food consumers found that less than 45% of Bangladeshi consumers knew that the Hepatitis A virus, *Salmonella* and *Staphylococcus* are among the foodborne pathogens (Al Banna et al., 2022). The above finding implies that consumers are not fully informed about food safety. Although it might be challenging to identify specific food pathogens, a lack of knowledge about these organisms explains inadequate food safety issues that can lead to FBDs.

While asking about food safety knowledge (FSK) related to high-risk groups (e.g., children, pregnant women, elderly and immunocompromised), 50% of consumers agreed that children, pregnant women and older people are more at risk of FBDs in pre-and post-pandemic time, similar to the street-food consumers of Haiti (Samapundo et al., 2015) and Bangladesh (Al Banna et al., 2022). Additionally, the majority (> 80%) of the respondents were not aware of the consequences of consuming high-risk foods such as poached eggs and raw milk during pregnancy (pre- and post-pandemic). Literature suggests that due to long-time food habits and various misconceptions, many rural individuals in Bangladesh consume raw milk, which has significant health consequences (Reza et al., 2021). The current study found only 7.4% (pre-

and post-pandemic) respondents agreed that FBDs induce abortion, suggesting a lack of awareness for high risks groups (e.g., pregnant) that contrasts with the previous studies (Al Banna et al., 2022, Ma et al., 2019). Moreover, this study identified no significant difference in FBD knowledge between the pre-and post-pandemic period among domestic food handlers. These results indicate that more attention must be paid to the food handlers in households, considering the heterogeneous nature of the domestic environment (e.g., various ages, sex, and health conditions) in order to reduce the prevalence of FBDs at home.

Based on their lowest percentage of correct answers, the current food handlers had a limited understanding of temperature management. Very few proportions of them exactly reported the operating temperatures of the freezer (22%) and refrigerator (36%) in pre-and post-pandemic responses. In agreement with this research, less than 30% of women in the UAE (Saeed et al., 2021) and adult consumers in East Malaysia (Ruby et al., 2019) mentioned having this knowledge. Refrigeration is a widely used practice for food storage, but inadequate temperature regulations can result in food spoilage, especially for perishable items, such as milk and meat (Aung and Chang, 2014, Marklinder and Eriksson, 2015). According to the survey, only 24.9% of food handlers demonstrated adequate knowledge of temperature management before the COVID-19 outbreak. Nevertheless, there was a slight rise of 25% after the pandemic.

In addition, the COVID-19 pandemic caused a hike in home-based cooking (Husain and Ashkanani, 2020, Soon et al., 2021). Food handlers concerned about the possibility of FBDs from their kitchen because of inappropriate food handling were more aware of complying with food safety procedures or avoiding cross-contamination of the SARS-CoV-2 virus. This study found a rise in overall food safety and personal hygiene knowledge level during the post-pandemic than the pre-pandemic, which is consistent with the study conducted in China that highlights the effects of COVID-19 have considerably enhanced consumer behaviour and awareness of food safety (Soon et al., 2021, Shi et al., 2020). A previous study mentions pandemic has raised food safety concerns among 76.5% of Jordanian women who engaged with home-based online food businesses (Osaili et al., 2022). In studies conducted in Brazil, 90% of respondents stated they were more careful about food hygiene practices, and approximately 72% of the respondents were keen to learn about cleaning and sanitation of food contact surfaces due to the pandemic (Osaili et al., 2022, Rodrigues et al., 2021). Although this present research found an increased overall FSK among the respondents, it was complimented by the high personal hygiene knowledge of food handlers during the post-pandemic period.

However, cross-contamination, safe storage, FBDs, and temperature control knowledge have not increased notably after the pandemic outbreak. A possible reason for this may be that SARS-CoV-2 is spread from person to person through respiratory droplets that enter the human body through the nose, mouth or eyes by contaminated hands. Hence, frequent personal hygiene measures such as hand washing have been widely encouraged to reduce this virus transmission. The results of this study indicate that hand washing is highly valued, yet there is still a need for community outreach and education regarding correct hand washing techniques.

Food handlers aged 50 years and over, tertiary graduates, male, higher family income, families with 0 - 2 children, 3 - 5 family members and urban residents scored good levels of FSK in pre-and post-pandemic time. However, the post-pandemic regression model suggested that tertiary graduates and food handlers with 3 - 5 members in the family had significantly good knowledge scores. On the contrary, ages 40 - 49 years and families with three children showed poor scores.

As predicted, the pre-pandemic result indicated that university graduates with a master's degree or above have a better food safety understanding than their peers. The post-pandemic knowledge level also showed that tertiary graduates (bachelor, master, and above) have good food handling skills (Ruby et al., 2019, Carbas et al., 2013, Moreb et al., 2017, Tomaszewska et al., 2018) , as consumers who have higher levels of education are more sceptical of food hygiene and are more worried about the possibility of FBDs occurring at home (Parra et al., 2014). This group of consumers may understand the risks of FBD due to their prior knowledge from direct or indirect input through their education.

The post-pandemic regression model found that consumers aged 40 - 49 years were significantly less knowledgeable than their younger counterparts (18 - 29 years). Young adults tend to use internet services more (Osaili et al., 2021), which might have enabled them to access information made public by the government and the media during this pandemic crisis which might influence the above findings. However, in this study, the older people (50 years and older) scored higher for having better knowledge about food safety in pre- and post-pandemic times than their other peers that complied with previous studies (Carbas et al., 2013, Rimal et al., 2001, Wang et al., 2009, Limon, 2021, Ishra et al., 2023, Osaili et al., 2022), possibly due to their experience and superior insights into food safety issues (Worsley et al., 2013).

Unexpectedly, this research found a higher knowledge score among male food handlers contrasting previous studies where the females had shown good FSK compared to the males (Da Costa et al., 2016; Shori, 2017; Ruby et al., 2019). In this study, the majority of male food handlers were younger and more educated. Additionally, men are now more frequently involved in household food preparation due to the rise in the number of working women. Moreover, there were fewer men than women participants in this study. For a comprehensive knowledge of this gender issue, additional research using a sizable sample of male gender would be required.

Aligning with Islam et al. (2023), the current study highlighted that food handlers with 3 - 5 members and 0 - 2 children in the family possess a good knowledge than those with over six family members and three children (pre- and post-pandemic). The reason behind such findings may be food handlers with the above characteristics were mostly residing in urban places. Urban individuals in the present research had higher levels of education (university bachelor's and above) than rural residents, which may have allowed them to acquire information about food safety from a number of sources, including the media, online sources, or their own experience.

Further, urban residents showed significantly good FSK than respondents from the rural areas in both pre-and post-pandemic findings. This study found significantly different responses between the urban and rural food handlers in all food safety measures except their knowledge of temperature control before the pandemic and hand hygiene after the pandemic, where more than 95% of urban and rural respondents agreed that hand washing before and after cooking reduces the food contamination risks. Rural residents often have little access to quality education; therefore, it's possible that their weak cognitive abilities and financial circumstances prevent them from having the luxury of understanding all the necessary food safety precautions.

5. Conclusion

The current study revealed Bangladeshi domestic food handlers' pre- and post-COVID-19 food safety knowledge (FSK) through measuring knowledge of their personal hygiene, cross-contamination, safe storage, foodborne disease and temperature control. Before the COVID-19 outbreak, the majority (71.2%) of food handlers showed poor FSK. This percentage reduced

(61.8%) after the pandemic started. Although the COVID-19 pandemic has resulted in significant changes in personal hygiene measures, such as knowledge of handwashing, there is still an insufficiency in food handlers' understanding of the appropriate duration of handwashing. The current study provides a strong foundation for local authorities to increase FSK among consumers, particularly in temperature control and foodborne diseases (FBDs). This research has revealed that proper dissemination and effective campaigns of food safety can improve the food handlers' knowledge level, which has been evident through their improvement of handwashing knowledge during the post-pandemic time. The data from this study showed that stronger reinforcement is needed for instructional programs on domestic food safety. The local government agencies and educational institutions could utilize this data to identify food safety issues and potential target audiences (e.g., rural consumers) for FBD prevention. To ensure that knowledge is implemented into practice, educational programs should be repeated at predetermined intervals. In order to reach a large number of people, educational messages should also spread through official and informal education as well as the media. Future studies can better concentrate on examining the perceived obstacles that consumers face in obtaining knowledge about food safety.

6. Strengths and Limitations

There are several limitations associated with the study. To the best of our knowledge, this is the first study that compared the domestic food handlers' food safety knowledge (FSK) before and after the outbreak of the COVID-19 pandemic in Bangladesh. Since no prior study measured household food handlers' FSK before the COVID-19 pandemic in Bangladesh, it contributes knowledge to the growing body of literature on domestic food handlers' awareness of food safety issues. Another significant strength is that the diversified sample clearly illustrates the urban and rural settings of the country with regard to food safety issues. Limitation included the inability to generalise food handlers in Bangladesh due to the convenience sample approach. Besides, a chance of recall bias is possible in the case of pre-pandemic answers, as the data were collected after the onset of the pandemic. To reduce the recall bias, research questions have been selected carefully, validated data collection instruments were used, and participants were allowed sufficient time for adequate recall of long-term memory by the well-trained surveyors (Bradburn et al., 1987, Grimes and Schulz, 2002).

Declaration of competing interest

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4.3 Links and implications

This chapter identified that although most of the domestic food handlers in Bangladesh had insufficient food safety knowledge both in the pre- and post-pandemic period, especially in cross-contamination, safe storage, temperature control and foodborne illnesses knowledge, a significant difference was found between these two periods. A slight increase in food safety knowledge has been observed after the COVID-19 outbreak. The study also revealed substantial sociodemographic variations both in pre-and post-pandemic times. This study's findings, therefore, suggest that policymakers and government could identify potential target audiences, such as rural consumers. Further, educational messages should be disseminated through formal and informal education through the media to reach a broad audience.

As this study investigates the KAP of food safety, the following chapter addresses the domestic food handlers' food safety attitudes and self-reported practices before and after the pandemic outbreak. Additionally, the study also revealed the general risk perception towards food safety among these food handlers. Further, robust sociodemographic associations have been identified with food safety attitudes, practices and risk perceptions.

CHAPTER 5: PAPER 3 - FOOD SAFETY RISK PERCEPTION, ATTITUDE AND SELF-REPORTED PRACTICE OF DOMESTIC FOOD HANDLERS BEFORE AND AFTER THE COVID-19 PANDEMIC IN BANGLADESH

5.1 Introduction

This chapter presents the third paper of the thesis that reveals the food handlers' attitude, practice and general risk perception towards food safety. The current study investigated and compared the domestic food handlers' food safety attitudes and self-reported practices in the domestic environment before and after the COVID-19 pandemic onset. To evaluate the attitudes and practices, this study examined the cleaning-hygiene, cross-contamination, and storage-cooking procedures. Further, this study assessed the food handlers' general risk perception towards food safety. The sociodemographic variations have also been investigated in this paper. The findings of this study are under review in the 'Current Research in Food Science' a Q1 journal.

5.2 Submitted paper

Title: Food safety risk perception, attitude and self-reported practice of domestic food handlers before and during the COVID-19 pandemic in Bangladesh

Food safety risk perception, attitude and self-reported practice of domestic food handlers before and after the COVID-19 pandemic in Bangladesh

Abstract

The recent COVID-19 pandemic has substantially affected numerous aspects of life, including food safety. The current study conducted a cross-sectional comparative survey of 503 domestic food handlers in Bangladesh to compare food safety attitudes and self-reported practises in the domestic environment before (pre) and after (post) the COVID-19 pandemic and to assess adult food handlers' food safety risk perception. The results of this study show that Bangladeshi domestic food handlers' "cleaning and hygiene", "storage and cooking", and overall food safety attitude (FSA) have significantly improved, except their attitude towards "cross-contamination" in the wake of the COVID-19 pandemic. Overall, during the pre-and post-pandemic periods, 82.7% and 87.1% of participants had a satisfactory level of FSA, respectively. The food handlers in this study had low self-reported food safety practice (SRP) levels in "cross-contamination" and "storage and cooking". The participants' hand-washing habits support the good "cleaning and hygiene" practice (pre: 77.7%, post: 83.3%) level. Above 55% of individuals demonstrated a low SRP for overall food safety before and during the pandemic. 58.7% of the food handlers in this study perceived that self-prepared food possesses a very low or low risk for foodborne disease. Contrarily, 98% of participants thought that food cooked by others, such as at restaurants, increased the risk of contracting foodborne illness. The research findings revealed a significant variation in FSA, SRP, and risk perception levels before and after the pandemic between socio-demographic factors. A more comprehensive understanding of how COVID-19 has influenced the attitudes, practices, and risk perceptions of Bangladeshi domestic food handlers will allow the government to design health promotion strategies in the future.

Key words

Food safety attitude, Food safety practice, Risk perception, Foodborne disease, Food handler, COVID-19, Bangladesh

Abbreviations

Food Safety Attitude - FSA
Self-reported practice - SRP
Foodborne Disease - FBD

1. Introduction

World Health Organization announced the COVID-19 pandemic as a worldwide emergency in 2020 (WHO, 2020). Halting the transmission of coronavirus necessitated the implementation of a comprehensive range of strategic measures. Various countries implemented social-distancing measures, including restricting business hours or closing restaurants (Qureshi et al., 2021). Food preparation and consumption at home increased due to the COVID-19 pandemic aggression and related business constraints (Oliveira et al., 2020). In many nations, including the USA and Canada, the domestic environment poses a significant risk of contracting foodborne diseases (FBD) (Byrd-Bredbenner et al., 2013; Redmond & Griffith, 2003; Vrbova et al., 2012). Previous studies mentioned that the domestic environment is responsible for occurring approximately 30-40% of FBDs (Langiano et al., 2012). FBD burden varies among nations, and it is particularly severe in LMICs (Low and Middle-Income Countries) (Unnevehr, 2015). Studies conducted worldwide have provided evidence of numerous FBDs outbreaks that took place in domestic environments before the COVID-19 pandemic. Bangladesh is known to have a high prevalence of FBDs and other food safety risks due to the factors such as its dense population, inadequate infrastructure, insufficient access to clean water, and the deficiency of sanitation and hygiene (WASH) facilities (Ishra et al., 2022; Noor & Feroz, 2016). Around 30 million individuals in Bangladesh experience FBDs annually (Ishra et al., 2023; Khairuzzaman et al., 2014). The absence of monitoring systems has led to the unavailability of a reliable evaluation of the public health consequences of food contamination in Bangladesh (WHO, 2016). Because of the heterogeneous profiles of residents and the varied uses of domestic kitchen environments, food handling, storing, and preparation guidelines in the home kitchen are dissimilar to those in commercial establishments such as hotels, restaurants, or canteens. This also expedites the routes for FBDs in the domestic environment (Mucinhato et al., 2022).

Several factors, including attitude and risk perception, contribute to a rational decision-making process that leads to appropriate food-handling behaviour (Young et al., 2017). Attitude pertains to the positive or negative emotions of an individual towards behaviour (Cheng et al., 2016), which assesses the conduct of individuals (Ajzen et al., 1991). Consumer attitudes and behaviours towards food safety create substantial barriers to hygienic food preparation in domestic environments, leading to FBDs. Many adult consumers assume that the responsibility for food safety is only in the hand of food manufacturers, farms and restaurants and do not consider domestic kitchens unsafe places to occurring FBDs (Brewer & Rojas, 2008). Several

attitudes towards food safety are intrinsic to adult consumers, as they repeat the same food safety practices while preparing food and remain unaware of any issues with their food preparation (Fischer et al., 2006). It is an utmost challenge to educate consumers about behavioural changes to improve food safety (Azevedo et al., 2014). Due to a lack of knowledge about food safety risks, the home is becoming more responsible for the spread of this disease globally (Redmond & Griffith, 2003).

Risk perception indicates an individual's view of the risk implicit in a situation (Slovic, 1987; Zanetta et al., 2022). It includes the perceived likelihood of a predominant risk, the perceived sensibility to the risk by individuals, and the perceived intensity of the risk results. Individuals' risk perception may be low if they possess a misconception about a risk. Optimistic bias is the misconception of any potential risk to self and the understanding that the risk is low to self than to others (Evans & Redmond, 2019). Consumers frequently believe that they are invulnerable to food poisoning from home-cooked foods, that "it only happens to others," and such notions are the result of "optimistic bias" and the "illusion of control" (Redmond et al., 2004). When consumers perceive they have better knowledge and control over the food that they prepare in their domestic kitchen rather than someone else who prepares an outside home for them augments their negligence to take preventive measures and consequently increases the incidence of FBD (Byrd-Bredbenner et al., 2013). Although knowledge appears imperative for the proper food safety application, if consumers perceive a risk associated with food low, knowledge does not necessarily translate into behaviour. Behaviour theories such as the Theory of Planned Behaviour (Ajzen et al., 1991) and the Health Belief Model (Becker, 1974; Hochbaum, 1958) link risk perception of an individual as a significant motivational element in changing behaviour (Evans et al., 2020; Glanz et al., 2008). The impact of sociodemographic information and health incongruity is significant in the attitude and risk perception towards food safety. Adult consumers' cultural differences are one of the usual causes of why certain FBDs are present in one culture and not in others. For example, within Hispanic cultures, listeria is frequently observed due to the inclusion of raw milk and dairy products in their traditional Mexican-style cuisines. On the contrary, *Yersinia* is more widespread among African Americans because of their food culture that involves raising livestock and cooking meals with pork, including chitterlings. In Caucasian people, *E.Coli* infection is more prevalent due to their raw and undercooked food preferences (Quinlan, 2013). Consumer food safety prerequisite a significant comprehension of behaviours and cultural elements that determines food handling practices (Mani et al., 2017). Adult consumers'

better understanding of safety and hygiene practices within food storing, handling and preparation would control FBDs (Langiano et al., 2012).

As mentioned earlier, the COVID-19 pandemic has altered the global food system, consumer food preparation and hygiene behaviour (Osaili et al., 2022; Osaili et al., 2021). Although studies have not yet confirmed that SARS-CoV-2 directly transmits through food and water, researchers acknowledged that this virus survives several days on different surfaces, particularly in substandard hygienic conditions (Duda-Chodak et al., 2020). Experts have recommended precautionary actions, including good personal hygiene and hand-washing practices, to reduce the cross-contamination and transmission of this virus among food handlers during the pandemic (Olaimat et al., 2020). The individuals' vulnerability during the pandemic induces their cognitive perceptions, which may impact individuals' food safety awareness (Mucinhato et al., 2022; Yang, 2020). As a result, the COVID-19 pandemic has altered how individuals purchase, prepare, and consume food. The significance of these factors in the context of developing countries such as Bangladesh is still not fully understood. Therefore, in the future, government efforts regarding health promotion opportunities will be guided by a deeper understanding of the effects of COVID-19 on Bangladeshi domestic food handlers' attitudes, practises, and perceptions of risk (Rodrigues et al., 2021).

In Bangladesh, various studies have been conducted among street vendors, restaurant and factory food handlers to understand their food safety knowledge level (Al Banna et al., 2022; Al Mamun et al., 2013; Hashanuzzaman et al., 2020; Jubayer et al., 2020; Nizame et al., 2019; Siddiky et al., 2022). Despite the importance of domestic food handling to prevent food contamination, no studies have investigated food safety attitudes, practices and risk perceptions among food handlers before the COVID-19 pandemic in the domestic environment in Bangladesh. This study aimed to establish adult food handlers' risk perception and compare the food safety attitude and self-reported practices in the domestic environment before and after the COVID-19 pandemic onset.

2. Methods

2.1 Study design and sampling

From November 2021 to March 2022, the current study gathered data to compare the responses between urban and rural areas in Bangladesh. Dhaka and Chittagong were chosen as urban research locations, and Cox's Bazar districts and Faridpur were included as rural study locations. With a population of around 14.7 million and an industry-based economy, Dhaka is the capital of Bangladesh. The Dhaka division's Faridpur district has over 2.1 million people and an agriculturally based economy (BBS, 2022). Both Chittagong and Cox's Bazar are situated in the coastal region of Bangladesh. With a population of about 9.1 million, Chittagong is the second-largest metropolis. The economy of this city is focused on manufacturing, agriculture, and fishing. Cox's Bazar is a district in the Chittagong division with a population of 2.8 million and a primarily agricultural economy (BBS, 2022).

A cross-sectional descriptive survey was performed among domestic food handlers (18 years or older) who participated in food preparation at least twice per week or more. A sample size of 385 was calculated based on Bangladesh's adult population of 104.87 million, with a 5% margin of error and a 95% confidence interval. Given the study's inferential objectives, it is widely acknowledged that a large sample size increases the accuracy of the study. As a result, the research team obtained additional data; the ultimate sample size was 503.

2.2 Procedure of data collection

The data-gathering procedure started following ethical permission. Each research assistant received thorough training prior to data collection in compliance with the university policies. Randomly chosen public locations from the selected study sites were visited by the research assistants, including supermarkets, local markets, traditional bazaars, schools and parks. The participants were selected using a convenience sample technique, which involved research assistants approaching people outside the shops or schools. After informing them of the purpose of the research and getting their informed consent, the researcher conducted face-to-face interviews with each participant. It took 15 to 20 minutes to complete each survey. After being translated into Bengali, survey information was collected electronically using Google Forms.

2.3 Survey instruments, validity and reliability

The validated scales in the questionnaire used in this study were based on research from comparable studies (Evans & Redmond, 2019; Gong et al., 2016; Lihan et al., 2019; Moreb et al., 2017; Odeyemi et al., 2019; Ruby et al., 2019; Soon et al., 2021; Soon et al., 2020; Tabrizi et al., 2017). This paper included the survey instruments that consist of four parts - sociodemographic factors and items related to consumers' food safety attitude (FSA), self-reported food safety practice (SRP) and food safety risk perception.

Gender, age, income, education, occupation, and place of residence were all listed in the demographic section. The FSA section involved the questioning of participants on 14 items, using a 5-point Likert scale, from "strongly disagree" (1 point) to "strongly agree" (5 points). Similarly, the SRP section includes a set of 13 questions, employing a 5-point Likert scale, from "never" (1 point) to "always" (5 points). All these items were related to their attitudes towards cleaning and hygiene, cross-contamination, storage, and cooking. Responses were collected for both pre-and post-pandemic periods. The maximum possible score for the FSA was 70 and SRP was 65. If respondents correctly answered more than half of the questions in each category (such as cleaning and hygiene, cross-contamination, storage, and cooking), they were considered to have good attitudes or practice levels. Participants with an overall FSA score of 42 or less are considered to have poor FSA, while those with more than 42 points are deemed to have a good level of attitude. Similarly, an overall SRP score of 39 or less is considered poor, while more than 39 points are considered a good level of SRP (Gong et al., 2016). Both pre-and post-pandemic FSA and SRP data were collected using the same questionnaire and response scale.

The food safety risk perception includes questions to determine their perceptions of the risk of acquiring FBDs after consuming self-prepared food or food prepared by others on a five-point Likert scale from "very low" to " very high".

A bilingual translator translated the survey materials into Bengali, and another research staff member with Bengali language proficiency reviewed the translation. Before the official survey was launched, a pilot survey was carried out to evaluate the validity of the instruments among a small sample of domestic food handlers (n = 30). The final survey did not incorporate the results of the pilot study. The internal consistency of each scale was assessed using Cronbach's

alpha tests. Internal consistency (Cronbach's alpha) for the different questionnaire sections ranged from 0.702 to 0.954, indicating acceptable reliability (Taber, 2018).

2.4 Data analysis

SPSS software (MacOS version 29) was used to analyse the data. A Chi- square test was conducted within two residency locations (e.g., urban and rural) for the demographic comparison. Frequency analysis was performed to ascertain the pre- and post-pandemic FSA and SRP and risk perception responses in the study. The Non-parametric Wilcoxon signed-rank test conducted to compare pre- and post-pandemic FSA and SRP level. To compare food handlers pre- and post-pandemic food safety scores with demographic variables, several Mann Whitney U tests and Kruskal Wallis H tests were conducted. Further, several Mann Whitney U tests and Kruskal Wallis H tests were conducted to compare self-risk perception and risk perception by others with demographic variables and the pre- and post-pandemic FSA and SRP level. Pearson correlation was conducted to determine the correlation between pre- and post-pandemic FSA and SRP scores.

3.Result

3.1. Demographic Information

Table 1 presents the data on domestic food handlers, which indicates that there were 503 individuals. Of these, 50.3% were from urban areas, and 49.7% were from rural areas. In both locations, 39% of respondents were 30 to 39 years of age, and the majority of participants (90.3%) were female and housewives (69.4%). 56.1% of urban participants reported monthly incomes over 100,000 BDT, and 96.6% held master's degrees or above from universities. Contrarily, more than 70% of rural participants claimed primary or secondary education and monthly incomes of between 20,000 and 39,000 BDT (Table 1).

Table 1: Demographic information of the domestic food handlers

N = 503	Urban (%)	Rural (%)	Total (%)	χ^2 *P* value
Age in years				χ^2 = 43.11 p <0.001
18 - 29	19	34.4	26.6	
30 - 39	44.3	33.6	39	
40 - 49	23.3	30.8	27	
50 and above	13.4	1.2	7.4	
Gender				X^2 =27.23 P <0.001
Male	16.6	2.8	9.7	
Female	83.4	97.2	90.3	
Education				χ^2 =354.24 p <0.001
School	7.9	71.6	39.6	
College	2.0	22	11.9	
University (Bachelor)	40.3	4.8	22.7	
University (Masters and above)	49.8	1.6	25.8	
Occupation				χ^2 = 172.78 p <0.001
Govt. employee	11.5	0	5.8	
Housewife	42.7	96.4	69.4	
Student	3.2	0.8	2.0	
Business	10.7	1.6	6.2	
Non-govt. employee	30.4	1.2	15.9	
Unemployed	1.6	0	0.8	
Family Income (per month)				χ^2 =348.15 p <0.001
less than 20,000	4.3	1.6	3.0	
20,000 to 39,000	7.1	72	39.4	
40,000 to 59,000	9.5	25.6	17.5	
60,000 to 79,000	11.9	0	6.0	
80,000 to 99,000	11.1	0.4	5.8	
100,000 and over	56.1	0.4	28.4	

Note: ***p<0.001, **p<0.01, *p<0.05
[a] $ 1 USD = 108.58 BDT (Bangladeshi Taka)

3.2. Pre- and post-pandemic food safety attitude (FSA)

Table 2A demonstrates the food handlers' attitude towards food safety (FSA) before and after the COVID-19 pandemic onset. The data presented in the table shows that 40% of food handlers expressed strong agreement with the notion that hand-washing before and after cooking is essential, along with the practice of using hands to cover the mouth while coughing or sneezing, as part of pre-pandemic responses. The hand-washing attitude increased to more than 80% after the pandemic onset. However, only 42.3% strongly agreed to cover their mouth

with their hands while sneezing and coughing during post-pandemic. About 36.4% of participants indicate strong agreement to use a different set of cutting boards and knives for meat and vegetables in pre-and post-pandemic responses (Table 2A).

Table 2 indicates the pre-pandemic FSA scores significantly differed between gender ($Z = -2.19$, $p < 0.05$), education [$\chi2(3) = 50.40$, $p < 0.001$], income [$\chi2(5) = 67.87$, $p < 0.001$], and residency place ($Z = -6.77$, $p < 0.001$). While significant differences were found between age [$\chi2(3) = 8.72$, $p < 0.05$], education [$\chi2(3) = 53.96$, $p < 0.001$], income [$\chi2(5) = 44.71$, $p < 0.001$], and residency place ($Z = -6.02$, $p < 0.001$) in post-pandemic FSA scores (Table 2). The Wilcoxon signed-rank test showed that the pandemic caused a significant increase in food handlers' cleaning and hygiene ($Z = -14.79$, $p < .001$), storage and cooking ($Z = -10.02$, $p < .001$) and overall FSA ($Z = -16.0$, $p < .001$) (Table 3).

Table 2: Comparison of pre- and post-pandemic food safety attitude (FSA) level

Questions	**Pre-pandemic FSA**			**Post-pandemic FSA**		
Variables	**Poor (%)**	**Good (%)**	**U/H**	**Poor (%)**	**Good (%)**	**U/H**
Age in years [bc]			5.94			**8.72***
18 - 29	21.6	78.4		12.7	87.3	
30 - 39	12.2	87.8		8.2	91.8	
40 - 49	19.9	80.1		18.4	81.6	
50 and above	18.9	81.1		18.9	81.1	
Gender [bd]			**9733.5***			10703.5
Female	16.1	83.9		12.6	87.4	
Male	28.6	71.4		16.3	83.7	
Education [bc]			**50.4*****			**53.96*****
School	26.6	73.4		21.1	78.9	
College	33.3	66.7		30.0	70.0	
University (Bachelor)	11.4	88.6		4.4	95.6	
University (Masters and above)	0.8	99.2		0.0	100.0	
Family Income (BDT/month) [abc]			**67.87*****			**44.71*****
less than 20,000	60.0	40.0		40.0	60.0	

20,000 to 39,000	26.8	73.2		19.7	80.3	
40,000 to 59,000	23.9	76.1		19.3	80.7	
60,000 to 79,000	3.3	96.7		3.3	96.7	
80,000 to 99,000	6.9	93.1		3.4	96.6	
100,000 and over	0.7	99.3		0.7	99.3	
Residency place [bd]			**24392.0*** **			**25917.5*** **
Urban	5.9	94.1		4.0	96.0	
Rural	28.8	71.2		22.0	78.0	

Note: ***p<0.001, **p<0.01, *p<0.05; [a] $ 1 USD = 108.58 BDT (Bangladeshi Taka); b Chi-square (χ2) test was conducted; c Kruskal Wallis H test was conducted; d Mann-Whitney *U* test was conducted. percentages (%) represent the food handlers' 'poor' or 'good' level of food safety.

Table 3: Wilcoxon signed rank test showing comparison of pre- and post-pandemic food safety attitude (FSA)

Food safety attitude (FSA)	Pre-pandemic		Post-pandemic			
	Mean± SD	Percentage [a] (%)	Mean± SD	Percentage [a] (%)	Z	p
Cleaning and hygiene	23.9 ± 4.95	82.5	24.5 ± 4.54	91.7	-14.79	<.001***
Cross-contamination	14.6 ± 3.77	62.2	15.1 ± 2.56	62.2	.000	1.00
Storage and cooking	14.8 ± 2.49	80.9	14.6 ± 3.77	82.5	-10.02	<.001***
Overall FSA	53.4 ± 10.77	82.7	54.3 ± 10.48	87.1	-16.00	<.001***

Note: p<0.001***, a = Shows 'Good' level of food safety attitude

3.3. Pre- and post-pandemic self-reported food safety practice (SRP)

In pre-pandemic SRP responses, only 4% of respondents mentioned always washing or sanitizing their hands after sneezing and coughing, and 35% sometimes preferred to keep the meal in the refrigerator if their family member is going to be several hours late for a hot meal, and 53.5% never used different cutting boards or knife to slice raw meat and to cut fruits and vegetables. The post-pandemic responses (Table 4A) indicate a slight improvement in the above percentages.

Food handlers' pre-pandemic SRP scores indicate significant differences between age [$\chi2(3) = 9.65$, $p < 0.001$], education [$\chi2(3) = 111.8$, $p < 0.001$], income [$\chi2(5) = 107.83$, $p < 0.001$], and residency place ($Z = -8.26$, $p < 0.001$). Significant differences are observed in pre-pandemic SRP scores of food handlers based on age [$\chi2\ (3) = 9.65$, $p < 0.001$], education [$\chi2\ (3) = 111.8$,

p <0.001], income [χ2 (5) =107.83, p <0.001], and residency place (Z= -8.26, p <0.001). Table 4 displays significant differences in post-pandemic FSA scores based on education [χ2(3) =120.6, p <0.001], income [χ2(5) =111.0, p <0.001], and residency place (Z= -8.70, p <0.001). The Wilcoxon signed-rank test demonstrates that the pandemic led to a significant improvement in cleaning and hygiene (Z = -10.81, p<.001), cross-contamination (Z = -3.74, p<.001), storage and cooking (Z = -10.17, p<.001), and overall SRP (Z = -13.94, p<.001) of food handlers (Table 5).

Table 4: Comparison of pre- and post-pandemic food safety SRP level

Questions	**Pre-pandemic SRP**			**Post-pandemic SRP**		
Variables	**Poor (%)**	**Good (%)**	**U/H**	**Poor (%)**	**Good (%)**	**U/H**
Age in years [bc]			**9.65***			7.59
18 - 29	69.4	30.6		64.9	35.1	
30 - 39	54.6	45.4		52.0	48.0	
40 - 49	62.5	37.5		59.6	40.4	
50 and above	48.6	51.4		45.9	54.1	
Gender [bd]			10490.0			10630.5
Female	60.8	39.2		57.5	42.5	
Male	55.1	44.9		53.1	46.9	
Education [bc]			**11.85*****			**120.67*****
School	86.4	13.6		84.4	15.6	
College	61.7	38.3		60.0	40.0	
University (Bachelor)	47.4	52.6		43.0	57.0	
University (Masters and above)	30.8	69.2		26.2	73.8	
Family Income (BDT/month) [abc]			**107.83*****			**111.0*****
less than 20,000	80.0	20.0		80.0	20.0	
20,000 to 39,000	84.8	15.2		82.3	17.7	
40,000 to 59,000	59.1	40.9		55.7	44.3	
60,000 to 79,000	46.7	53.3		40.0	60.0	
80,000 to 99,000	27.6	72.4		27.6	72.4	
100,000 and over	34.3	65.7		30.1	69.9	

Residency place [bd]			**20206.0*** **			**19463.5*** **
Urban	42.3	57.7		37.9	62.1	
Rural	78.4	21.6		76.4	23.6	

Note: ***p<0.001, **p<0.01, *p<0.05; [a] $ 1 USD = 108.58 BDT (Bangladeshi Taka); b Chi-square (χ2) test was conducted; c Kruskal Wallis H test was conducted; d Mann-Whitney *U* test was conducted.

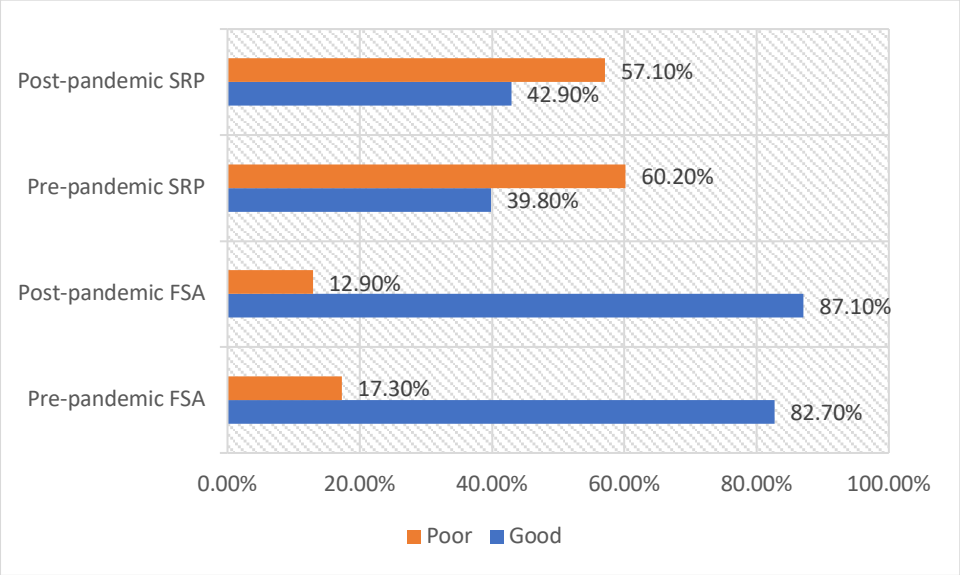

Figure 1: The level of food safety attitude and self-reported practice.

Table 5: Wilcoxon signed rank test showing comparison of pre- and post-pandemic self-reported food safety practice (SRP)

Self-reported practice (SRP)	Pre-pandemic		Post-pandemic			
	Mean± SD	Percentage [a] (%)	Mean± SD	Percentage [a] (%)	Z	p
Cleaning and hygiene	14.3 ± 2.50	77.7	14.8 ± 2.69	83.3	-10.81	<.001***
Cross-contamination	11.8 ± 3.12	37.8	11.8 ± 3.14	38	-3.74	<.001***
Storage and cooking	11.2 ± 3.28	9.9	11.8 ± 3.31	11.7	-10.17	<.001***
Overall SRP	37.3 ± 7.58	39.8	38.3 ± 7.93	42.9	-13.94	<.001***

Note: p<0.001***, a = Shows 'Good' level of food safety practice

3.4 Food safety risk perception

More than half (53.1%) of the participants perceived a low risk of acquiring Foodborne disease (FBD) from consuming food they prepared in their homes. About 48.9% of the participants believed that the likelihood of causing FBD from their household kitchen was low (Fig 2). In contrast, food made by someone else was considered to be high risk (40.4%) for FBD, while more than half of the respondents (53.7%) believed that food in restaurants posed a very high risk of contracting FBD (Fig 3).

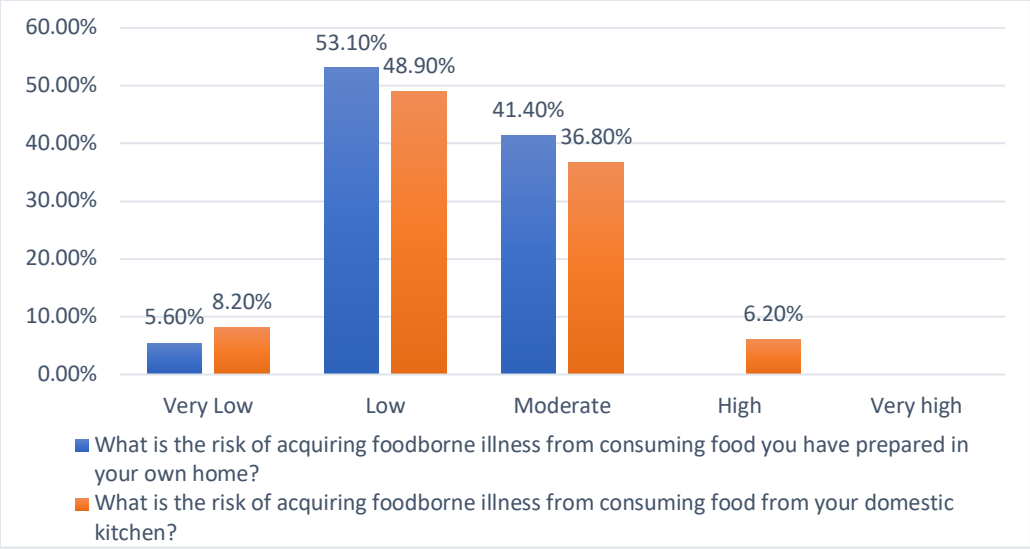

Figure 2: Risk perception of acquiring foodborne disease from self-prepared food consumption

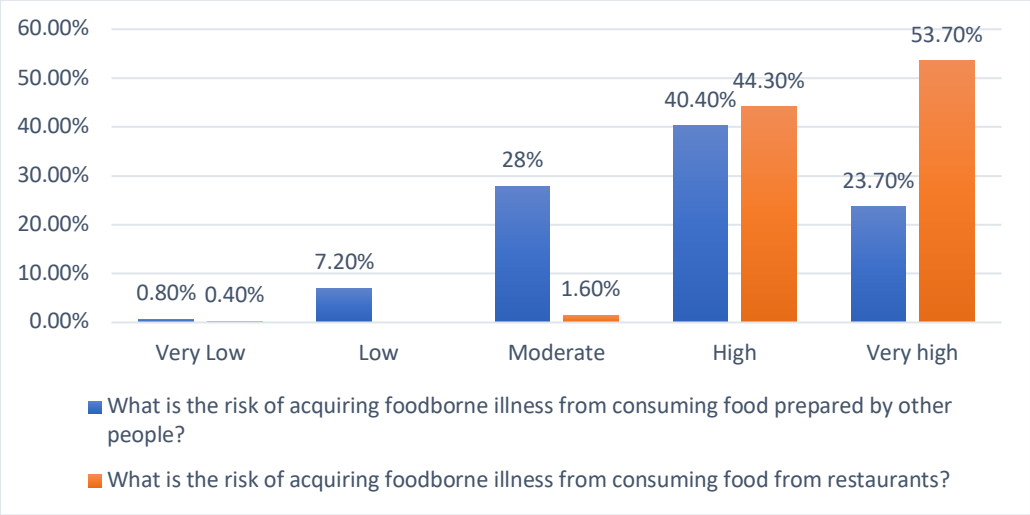

Figure 3: Risk perception of acquiring foodborne disease from consuming food prepared by others

3.5 Association of Food Handlers' pre- and post-pandemic food safety Attitude (FSA), Self-Reported Practice (SRP), Risk Perception and Demographic factors

Table 6 indicates that food handlers aged 50 years and above [$\chi2(3) = 17.25$, $p < 0.001$], university graduates (Masters and above) [$\chi2(3) = 66.37$, $p < 0.001$] and urban residents ($Z = -5.75$, $p<0.001$) had significantly higher self-risk perception than their other counterparts. The risk perception for self-prepared food consumption was significantly higher among participants with good pre-pandemic FSA ($Z = -2.25$, $p<0.05$) and pre- ($Z = -4.37$, $p<0.001$) and post-pandemic SRP ($Z = -3.97$, $p<0.001$). On the contrary, primary graduates [$\chi2(3) = 88.57$, $p < 0.001$], rural residents ($Z = -7.58$, $p<0.001$), food handlers who had poor pre-pandemic FSA ($Z = -3.07$, $p<0.01$), post-pandemic FSA ($Z = -2.86$, $p<0.01$), pre- ($Z = -4.83$, $p<0.001$) and post-pandemic SRP ($Z = -5.09$, $p<0.001$) had significantly increased risk perception from food prepared by others. Gender shows no significant differences in the food safety risk perception (Table 6).

Table 6: Association between food handlers risk perception, sociodemographic factors and pre- and post-pandemic food safety attitude and practice

	Risk perception by self			Risk perception by others		
Sociodemographic factors	**Mean Rank**	***df***	**H/U**	**Mean Rank**	***df***	**H/U**
Age in years [b]		3	**17.256*** **		3	2.78
18 - 29	232.84			265.20		
30 - 39	263.31			240.96		
40 - 49	235.00			257.33		
50 and above	323.92			243.08		
Gender [a]			9577.0			9668.0
Male	283.55			222.31		
Female	248.59			255.20		
Education [b]		3	**66.37*** **		3	**88.51*** **
School	210.21			314.01		
College	240.32			287.60		
University (Bachelor)	241.41			200.84		
University (Masters and above)	330.65			185.52		
Residency Place [a]			**6649.5*** **			**19785*** **
Urban	350.72			205.20		
Rural	152.10			299.36		
Pre-pandemic FSA [a]			**15554.5***			**14462****
Poor	222.79			293.77		
Good	258.11			243.26		
Post-pandemic FSA [a]			12977.5			**11235****

Poor	232.65		298.15	
Good	254.87		245.15	
Pre-pandemic SRP [a]		**23910.5*** **		**22919*** **
Poor	230.91		276.36	
Good	283.95		215.10	
Post-pandemic SRP [a]		**25128.0*** **		**23129*** **
Poor	231.55		279.41	
Good	279.17		215.58	

Note: p<0.001***, p<0.01, p<0.05; a = Mann - Whitney U test, b = Kruskal Wallis H test

Pearson correlation coefficient test was conducted to determine the correlation between pre- and post-pandemic FSA and SRP scores. A moderate positive correlation which was greater or equal to r = + .40 displayed between post-pandemic FSA and post-pandemic SRP, post-pandemic FSA and pre-pandemic SRP, pre-pandemic FSA and post-pandemic SRP, pre-pandemic FSA and pre-pandemic SRP and was statistically significant (P < 0.001). Similarly, post-pandemic FSA and pre-pandemic FSA, post-pandemic SRP and pre-pandemic SRP demonstrate very high positive correlations (greater or equal to r = +.90) and were statistically significant (P < 0.001) (Table 7).

Table 7: Correlation of pre- and post-pandemic food safety attitude and self-reported practices among food handlers (n = 503)

Level	Pearson Correlation	p
Post-pandemic FSA - Pre-pandemic FSA	0.997**	<.001
Post-pandemic FSA - Post-pandemic SRP	0.459**	<.001
Post-pandemic FSA - Pre-pandemic SRP	0.437**	<.001
Pre-pandemic FSA - Post-pandemic SRP	0.453**	<.001
Pre-pandemic FSA - Pre-pandemic SRP	0.432**	<.001
Post-pandemic SRP - Pre-pandemic SRP	0.987**	<.001

**. Correlation is significant at the 0.01 level (2-tailed).

4. Discussion

The findings of this study indicate that the "cleaning and hygiene", "storage and cooking", and overall food safety attitude (FSA) of Bangladeshi domestic food handlers have been enhanced significantly, except for the "cross-contamination" attitude in the aftermath of the COVID-19 pandemic. Overall, 82.7% and 87.1% of participants showed a satisfactory level of food safety attitude (FSA) during the pre-and post-pandemic period, respectively (Fig. 1). This finding is

inconsistent with a previous study that reported 85% of women in Lahore had negative attitude towards food safety (Naeem et al., 2018).

In pre-pandemic responses, only 40% of food handlers strongly agreed with the necessity of hand washing before and after cooking aligns previous study (Ishra et al., 2023), whereas 61.8% of participants in a previous study from Asia and Africa mentioned frequent hand washing before the pandemic (Odeyemi et al., 2019). Amidst the pandemic, hand hygiene emerged as a crucial measure to regulate the transmission of the COVID-19 virus. This factor may have contributed to the participants' favourable stance towards hand washing, with 82.5% strongly endorsing its importance in their post-pandemic responses. Participants were predicted to wash eggs before storing them to prevent improper handling of animal products because washing makes eggs more porous and may result in the transfer of microorganisms into the internal part of the egg (Osaili et al., 2021). Surprisingly more than half of the participants did not express a favourable attitude toward this idea in either the pre-pandemic or post-pandemic reactions. Similar findings were obtained in a prior study, which revealed that 90.4% of Jordanian students did not wash eggs before storing them in the refrigerator (Osaili et al., 2021). Experts advised consuming well-cooked eggs as raw eggs are categorised as the second level of food vehicles that may cause Salmonella infection (de Oliveira Elias et al., 2015; Ruby et al., 2019; Whiley et al., 2017). In the pre-pandemic responses, 46% of the participants expressed a positive attitude towards avoiding undercooked eggs. This percentage marginally increased to 54.1% in their post-pandemic attitudes, potentially due to the respondents' increased pandemic-related anxiety. In a previous study, more than 75% of Malaysian consumers said they fried eggs until the white and yolk became firm (Ruby et al., 2019). This study's findings regarding the use of thermometers are consistent with the previous study result (Ruby et al., 2019), which found that many respondents (89.6%) had an unfavourable opinion of having a thermometer in their freezers. Food kept above the optimum refrigerator temperature of 4 °C may be a prime environment for foodborne pathogen growth. Despite the fact that the study found a satisfactory level (62.2%) of attitude towards cross-contamination during pre- and post-pandemic periods, no significant disparities were noted in cross-contamination attitude between the two periods.

In spite of a good FSA level, the food handlers of this study showed poor self-reported food safety practice (SRP) in "cross-contamination" (pre - 62.2%, post - 62%), "storage and cooking" (pre - 90.1%, post - 88.3%) level. The "cleaning and hygiene" practice indicates a

good (pre - 77.7%, post - 83.3%) level, and this is complimented by the participants' hand washing practice (pre - 96.8%, post - 98.2%). Overall, more than 55% of participants showed poor SRP towards food safety in pre- and post-pandemic results (Fig. 1). Studies from other countries have produced similar findings to the current research, with Malaysian and Jordanian consumers finding poor scores in food safety practices (Osaili et al., 2021; Ruby et al., 2019). Conversely, 80% of women in Sharjah-United Arab Emirates showed a high level of food safety practice (Saeed et al., 2021).

This study identified that less than one-fifth of food handlers reported 'always' washing or sanitizing their hands after sneezing or coughing before (4%) and after (10.7%) the pandemic. This finding contrasts the previous study that found 83% of female food handlers in Jordan who operated home-based online food businesses during the COVID-19 pandemic used to wash their hands after sneezing and coughing (Osaili et al., 2022). If a kitchen sink is not routinely cleaned, it is considered a source of contamination. Warm water and soap should be used to scrub the kitchen sink before disinfecting it (Limon, 2021). Less than one-third (31.2%) of the respondents of this study reported 'always' or 'most of the time' washing the kitchen sink after every use. This result was lower than that of Lebanese food handlers (86.8%) (Hassan et al., 2018) and higher than that of women in Lahore (17.9%) (Naeem et al., 2018).

Without routine washing, using the same cutting board and knife set for raw meat, poultry, and vegetables can lead to foodborne disease (FBD) (Saeed et al., 2021). Only 7.8% of participants in this study's pre- and post-pandemic results indicated that they always or frequently used different cutting boards and knives to slice raw meat and cut fruits and vegetables. The findings are comparable to those from consumers in Malaysia, where 32.7% of respondents reported using different cutting boards to slice raw meat and cut tomatoes 'most of the time' or 'always' before the pandemic (Ruby et al., 2019). Similarly, Limon (2021)found that during the COVID-19 pandemic in the Philippines, 76.6% of food handlers operating online food businesses from home used the same knife to cut poultry and vegetables. A different finding was identified about women in Saudi Arabia before COVID-19 when 82.1% of the respondents utilized separate sets of knives and cutting boards for meat and vegetables (Alsayeqh, 2015).

One of the prime causes of FBDs is improper time-temperature management (Osaili et al., 2022). An improper food reheating develops a favourable environment for the growth of pathogenic bacteria and the production of microbial toxins, including staphylococcal

enterotoxins (Saeed et al., 2021). In our study, less than 20% of participants reported 'always' heating leftovers until boiling in pre- and post-pandemic responses. Due to the rapid growth of microbes between (21–52 ◦C) in comparison to other temperatures, it is recommended to thaw frozen food in the refrigerator to prevent storing food in a temperature danger zone (Badrie et al., 2006). Freezing or cold temperature delays the movement of microbes' molecules in food by entering bacteria into the dormant stage rather than killing microorganisms. However, when the food is thawed, the bacteria can reactivate and cause FBD (Russell, 2002). More than 80% of the respondents in this study defrosted frozen food or raw meat in the refrigerator during the two periods. In contrast, females from Lahore attained a higher percentage (90.7%) (Naeem et al., 2018). Additionally, storing potentially perishable items in the danger zone (4 to 60 °C) for longer than two hours may facilitate the growth of harmful microorganisms (Jevšnik et al., 2008). In this study, over 55% of the respondents mentioned that they never, rarely or sometimes preferred keeping a meal in the refrigerator if their family member would be several hours late for a hot meal before and after COVID-19 onset. The aforementioned data show that this study's food handlers did not adequately adhere to international guidelines for food safety.

Considering the food safety risk perception, more than half (58.7%) of the food handlers in this study perceived that self-prepared food possesses a very low or low risk for FBD. Contrarily, 98% of participants thought that food cooked by others, such as at restaurants, increased the risk of contracting a FBD. This finding is consistent with a previous study where participants perceived home as the least likely location to acquire a FBD, and 90% of participants perceived the implausibility of infecting with FBD from food prepared and consumed at home (Evans & Redmond, 2019; Zorba & Kaptan, 2011). The data from this study suggests that food handlers are likely to underestimate the risk of FBDs in their domestic kitchens, thus indicating their optimistic bias. The "illusion of control" is exhibited through their lack of worry regarding homemade food - showing that food handlers believe in having adequate food safety control when preparing food at home (Redmond et al., 2004). Such food safety misperception and failure to identify domestic kitchens as a likely source of FBD may have food safety implications in the home.

Additionally, this study discovered a substantial difference between pre-and post-pandemic FSA, SRP, and risk perception levels across several socio-demographic characteristics. The pre-pandemic FSA showed that gender has significantly influenced consumer food safety attitudes, with women performing better than men. The results show that males are the high-

risk group in comparison to females (Gong et al., 2016; Luo et al., 2019), which is consistent with earlier studies (Gong et al., 2016; Hassan & Dimassi, 2014; Moreb et al., 2017; Wang et al., 2021). In this study, good levels of post-pandemic FSA were present in 91.8% of respondents between the ages of 30 and 39. Previous research found that respondents aged 35 - 44 had the best food-handling behaviour, while those below and above this age had poor behaviour. These respondents generally have both young children and elderly parents under their care, which prompts them to adopt normative food-handling practices as part of their family healthcare responsibilities (Wang et al., 2021). Bangladesh has a collectivist society, where people are more concerned about their families than the individuals themselves (Azim, 2008), and concern for the health of family members is a significant motivator for consumers to adopt a normative attitude toward food safety, particularly amid a public health emergency such as COVID-19 pandemic.

In the pre-pandemic SRP, 51.4% of elder food handlers (50 years and older) demonstrated a high degree of practice, but there were no age-related differences in the post-pandemic SRP. The current results also indicate that elder food handlers' self-risk assessment toward food safety was much greater than that of their younger counterparts, in contrast to (Evans & Redmond, 2019) and (Redmond et al., 2004) investigations. An explanation could be that senior food handlers may perceive risks more seriously due to their long-time experience in food handling and familiarity with food safety issues. Further, food handlers with higher incomes, university graduations (Masters and above), and urban residences had good pre- and post-pandemic FSA, SRP, and higher self-risk perception. According to earlier research, tertiary graduates typically handle food more safely than their other counterparts (Carbas et al., 2013; Moreb et al., 2017; Ruby et al., 2019). As the awareness level of individuals (Knight & Warland, 2005) form their risk perceptions, an educated individual might be more aware of FBDs in the domestic environment because of their previous knowledge and better exposure to information (Ruby et al., 2019). Urban residents in Bangladesh are more educated than rural ones (BBS, 2022). Most of the urban people in this survey (90.1%) held bachelor's degrees or higher from universities, which may be a logical explanation for the above findings. The current study also observed that the food handlers' pre- and post-pandemic food safety attitudes significantly affected their self-reported practice. Therefore, to decrease FBD in this community, ongoing food safety training and monitoring are advised for home food handlers.

5. Limitations

Several studies (Hessel et al., 2019; Wang et al., 2021; Woh et al., 2016) have employed a self-reported approach to quantify food-handling behaviours, and this study is no exception. Nevertheless, according to some academics (Kormos & Gifford, 2014), self-reports cannot accurately reflect the actual situation. Future research can evaluate food handling behaviours more precisely by using observational approaches. Furthermore, generalizations regarding food handlers in Bangladesh are constrained by the convenience sample method. There is also a risk of recall bias in the case of pre-pandemic responses, as the data was collected after the pandemic. To reduce the recall bias, research questions have been selected carefully, validated data collection instruments were used and participants were allowed sufficient time for adequate recall of long-term memory by the well-trained surveyors (Bradburn et al., 1987; Grimes & Schulz, 2002).

6. Policy implications and conclusion

The results of this study have significant implications for policymakers. Although the food handlers in this study have indicated an overall positive food safety attitude in the pre-and post-pandemic period, their self-reported food safety practices were unsatisfactory and demanded critical attention in cross-contamination, storage and cooking practices. In order to stop foodborne disease (FBD) in this community, it is crucial that people are aware of and follow food safety regulations. Therefore, the government and policymakers should implement food safety strategies, including the Hazard Analysis Critical Control Point (HACCP) concepts, to educate domestic food handlers and prevent all types of food hazards in the household kitchen. Besides, the 'Five Keys to Safer Food' should be practised by providing training to food handlers and food inspectors and educating consumers to improve food safety in this community. The government ought to insist that written teaching materials, such as flyers and handouts placed in grocery stores or local bazaars, be made available to adult consumers to educate them with crucial information about handling food safely before consumption. This can help raise awareness of the signs of contracting a foodborne disease and promote understanding of food safety in the home environment.

Although this study identified that food handlers' food safety attitudes and practices significantly improved during the COVID-19 pandemic, they did not consider their domestic

kitchen a risk of FBD infection; contrarily, they thought that food cooked at restaurants or by others increased the risk of contracting an FBD. One strategy to enhance food safety practise is to design focused communication tactics to directly raise individual awareness of the risk associated with their existing food-handling practises. The findings imply that raising awareness of the risk associated with present unsafe food handling practices may encourage people to take more precautions in their food safety behaviour. Hence, programs should heighten the perception of FBD and the necessity of personal responsibility to lower the 'optimistic bias' and 'illusion of control' for adopting a risk-reducing food safety behaviour at home. Further, identifying food safety risks should be addressed in this community.
The current study observed a significant increase in overall food safety attitudes and self-reported practices after the COVID-19 pandemic emergence. To improve and maintain post-pandemic food safety behaviour, the government should also promptly develop food safety guidelines for household food handlers. Effective and organized education is necessary for domestic food handlers to prevent FBDs in themselves and their families. For example, the government might insist on local NGOs in rural areas and government community clinics such as UPHCSDP (Urban Primary Health Care Services Delivery Project) to develop a food safety education corner along with their adolescent counselling corner (UPHSCDP-II, n.d.) for counselling the riskiest food safety behaviour (e.g., drinking raw milk, eggs).

The study's outcome is significant in identifying the most appropriate individuals for interventions based on observable demographics that regulators can monitor. For example, individuals who were young, low educational background and resided in rural areas indicate an unsatisfactory level of food safety risk perception, attitude and practice. As a low-middle-income country, urban and rural disparities are much more pronounced in Bangladesh. The findings of this study call for the attention of government agencies, policymakers and researchers to implement significant initiatives in well-structured educational programs, with particular emphasis on high-risk groups (such as young people, those with low educational backgrounds, and individuals residing in rural areas). Policymakers should start food safety education during childhood by including food safety guidelines in formal education to spread the message to the masses, particularly to develop awareness in rural regions.

Prior research revealed that the favoured method for acquiring knowledge about food safety was through small group sessions on food safety and nutrition, printed materials, and cooking shows on television (Parra et al., 2014). Cooking programs might incorporate tailored

recommendations for the community, such as guidelines on defrosting raw meats. This could involve emphasizing the hazards of defrosting raw fish, poultry or meat in the sink, educating individuals on sanitization practices between uses, using separate cutting boards for vegetables and meat, and reinforcing existing messages on the dangers of salmonella in raw eggs. Although many consumers were dependent on the internet and social media during the pandemic for regular health updates, within the scope of food safety, social media has yet to replace traditional media. The increase in personalisation on social media may cultivate a forthcoming era in which food safety messages can be customised to individuals based on their previous online interactions. It is evident that such personalisation has the potential to allow policymakers to leverage psychometric findings for the purpose of influencing food safety behaviours through targeted messaging. Social media's shortcoming is its potential to disseminate inaccurate or false information from multiple sources through various channels, potentially damaging the original message's reliability and legitimacy (Evans et al., 2020).

The results of this study suggest that researchers, educators, food safety communicators, and the media devote their time and resources to conceptualising and developing programmes that teach domestic food handlers about food safety procedures and enable them to apply knowledge in a real-life context. On the basis of the research findings, future research may involve developing focused instructional programmes and evaluating their efficacy. Another area for future study is the discrepancy between food handlers' knowledge, attitudes, and practices in the cultural context of Bangladesh.

Data availability

The data supporting this study's findings are available from the corresponding author upon reasonable request.

Declaration of competing interest

None.

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Ethical statement

Ethical approval was obtained from the Australian University of Southern Queensland Human Research Ethics Committee (USQ HREC ID: H21REA161).

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Appendix

Table 2A: Responses of pre- and post-pandemic food safety attitude of adult food handlers in Bangladesh

Statements	Pre-pandemic FSA responses				
	Strongly disagree (%)	Disagree (%)	Neither agree nor disagree (%)	Agree (%)	Strongly agree (%)
Cleaning and hygiene					
Washing hand is necessary before and after cooking.	-	-	4.6	55.5	40
Washing hand is necessary before handling raw food	-	2.2	14.7	43.7	39.4
Hands should be used to cover mouth while coughing or sneezing	-	-	3	57.1	40
Fruits and vegetables should be washed before eating	-	-	5.8	54.5	39.8
Eggs should be washed before storing them in refrigerator	13.1	13.5	26.2	10.3	36.8
Dishes should be washed with detergent before preparing food	16.7	17.7	23.3	9.9	32.4
Cross-contamination					
Wearing accessories like rings, bracelets are not fine when cooking food	15.9	22.7	29	18.3	14.1
It is necessary to cover your cut with bandage and use gloves while preparing food	-	2.2	14.7	43.7	39.4
It is unhealthy to taste dish out food with unprotected hands	-	13.9	28	21.7	36.4
Use cutting board and knives set for meat and another set for vegetables	-	17.7	31.6	14.3	36.4
Storage and cooking					
It is necessary to read conditions of use and storage of packaged food	-	2.2	6.6	49.1	42.1
I don't prefer half-boiled or half-cooked eggs	8.5	16.5	28.6	27.4	18.9
It is unhealthy to consume expired food		2	7.2	35	55.9
Thermometer is necessary to keep in the refrigerator	3	24.3	62.4	10.3	-
		Post-pandemic FSA responses			
	Strongly disagree (%)	Disagree (%)	Neither agree nor disagree (%)	Agree (%)	Strongly agree (%)
Cleaning and hygiene					
Washing hand is necessary before and after cooking.	-	-	-	17.5	82.5
Washing hand is necessary before handling raw food	-	2.2	12.7	44.7	40.4
Hands should be used to cover mouth while coughing or sneezing	-	-	3	54.7	42.3
Fruits and vegetables should be washed before eating	-	-	4.8	49.3	45.9
Eggs should be washed before storing them in refrigerator	13.1	13.5	25.4	9.5	38.4
Dishes should be washed with detergent before preparing food	16.7	17.7	23.3	9.9	32.4
Cross-contamination					
Wearing accessories like rings, bracelets are not fine when cooking food	15.9	22.7	29	18.3	14.1
It is necessary to cover your cut with bandage and use gloves while preparing food	-	2.2	14.7	43.7	39.4

It is unhealthy to taste dish out food with unprotected hands	-	13.9	28	21.7	36.4
Use cutting board and knives set for meat and another set for vegetables	-	17.7	31.6	14.3	36.4
Storage and cooking					
It is necessary to read conditions of use and storage of packaged food	-	2.2	6.6	43.7	47.5
I don't prefer half-boiled or half-cooked eggs	8.5	16.1	21.3	29.8	24.3
It is unhealthy to consume expired food	-	2	5.8	32.4	59.8
Thermometer is necessary to keep in the refrigerator	3	24.3	62.4	10.3	-

Table 4A: Responses of pre- and post-pandemic self-reported food safety practice (SRP) of adult food handlers in Bangladesh

Statements	Pre-pandemic SRP responses				
	Never (%)	Rarely (%)	Sometimes (%)	Most of the time (%)	Always (%)
Cleaning and hygiene					
Do you wash hands with soap after using the toilet?	-	-		3.2	96.8
Do you clean the food preparation area as soon as you finished cooking?	2	8.3	28.2	31.8	29.6
Do you wash/sanitize hands after sneezing and coughing?	13.1	34.2	35.2	13.5	4
Do you clean the kitchen sink after every wash?	7.6	25.2	36	21.5	9.7
Cross-contamination					
Do you use different cutting boards or knife to slice raw meat and to cut fruits and vegetables?	53.5	25.8	12.9	6.8	1.0
Do you store raw and cooked food separately?			1.8	4.4	93.8
Do you store raw meat at the lower shelf of the fridge (not freezer) in your house?	45.7	25.6	17.9	9.7	1.0
Do you use different towel to wipe kitchen surfaces and to dry your hands?	25.4	15.7	14.9	8.9	35
Storage and cooking					
Do you prefer keeping the meal at refrigerator, if your family member is going to be several hours late for a hot meal?	12.9	16.7	35.2	23.7	11.5
Do you reheat leftover food until it is boiling hot?	6.4	14.5	41.6	26	11.5
Do you defrost frozen food or meat/chicken by leaving it in the fridge for a few hours?	82.3	10.7	5.8	1.2	-
Do you thaw frozen food by putting it under running water for 1 hour?	37.4	17.3	32	11.3	2
Do you prefer throwing defrosted food once it is thawed?	73	12.5	8.9	4.4	1.2
		Post-pandemic SRP responses			
	Never (%)	Rarely (%)	Sometimes (%)	Most of the time (%)	Always (%)
Cleaning and hygiene					
Do you wash hands with soap after using the toilet?	-	-	-	1.8	98.2
Do you clean the food preparation area as soon as you finished cooking?	2	5.6	34.8	21.5	36.2
Do you wash/sanitize hands after sneezing and coughing?	10.5	24.3	34.6	19.9	10.7

Do you clean the kitchen sink after every wash?	6.6	25.4	34.4	21.5	12.1
Cross-contamination					
Do you use different cutting boards or knife to slice raw meat and to cut fruits and vegetables?	53.5	25.8	12.7	7.0	1.0
Do you store raw and cooked food separately?				4	96
Do you store raw meat at the lower shelf of the fridge (not freezer) in your house?	45.7	25.6	17.3	10.3	1.0
Do you use different towel to wipe kitchen surfaces and to dry your hands?	25.4	14.1	15.7	6.2	38.6
Storage and cooking					
Do you prefer keeping the meal at refrigerator, if your family member is going to be several hours late for a hot meal?	12.1	15.5	31.2	26.6	14.5
Do you reheat leftover food until it is boiling hot?	3.0	10.9	35.4	33.6	17.1
Do you defrost frozen food or meat/chicken by leaving it in the fridge for a few hours?	82.3	10.7	5.8	1.2	-
Do you thaw frozen food by putting it under running water for 1 hour?	37.4	17.3	32	11.3	2.0
Do you prefer throwing defrosted food once it is thawed?	73	12.5	8.9	4.4	1.2

5.3 Links and implications

Chapter 5 findings indicate that Bangladeshi household food handlers had a satisfactory food safety attitude before and after the onset of the pandemic. However, a noteworthy increase in attitude was observed after the pandemic outbreak. Although the food handlers showed a significant improvement in the self-reported practice level during the pandemic in their domestic kitchen, inadequate practice had been found in both times. Moreover, the food handlers also showed that their perceived risk towards self-prepared food was low compared to the food prepared by others (e.g., restaurants). These results indicated unsatisfactory food safety behaviour among domestic food handlers in Bangladesh. Based on the findings of the current study, it is recommended that researchers, policymakers, and the media prioritize the development of programs aimed at educating domestic food handlers on food safety procedures and facilitating the practical application of this knowledge. Further, the program is to amplify the recognition of foodborne diseases and stress the significance of personal responsibility to counteract the 'optimistic bias' and 'illusion of control' that hinder the adoption of risk-reducing food safety practices at home.

As a part of KAP research, the following chapter reveals the relationship between food handlers' knowledge, attitudes and practice. Further, this study highlights that these food handlers' behaviour-specific risk perception has a substantial impact on their food safety KAP. Thus, the next chapter includes cross-sectional research that evaluates the association between food safety knowledge, attitudes and practice and investigates the mediating role of behaviour-specific risk perception and attitude towards food safety on the relationship between food safety knowledge and practice.

CHAPTER 6: PAPER 4 - ROLE OF FOOD SAFETY RISK PERCEPTION AND ATTITUDE ON KNOWLEDGE AND PRACTICE OF DOMESTIC FOOD HANDLERS: A SERIAL MEDIATION MODEL

6.1 Introduction

This chapter presents the fourth and last study of this thesis. This study examines the correlation between food handlers' food safety knowledge (FSK), attitude (ATT), self-reported practice (FSP) and behaviour-specific risk perception (BRP) in the domestic environment. This study mainly focused on the serial mediation effects of behaviour-specific risk perception (BRP) and attitude (ATT) towards food safety on the relationship between food safety knowledge (FSK) and self-reported practice (FSP) among domestic food handlers in Bangladesh. This study also investigated the mediating role of behaviour-specific risk perception and attitude towards food safety on the association between food safety knowledge and practice level in the domestic environment. The findings of this study are under review in *'Food Control'* a Q1 journal.

6.2 Submitted paper

Title: Role of food safety risk perception and attitude on knowledge and practice of domestic food handlers: A serial mediation model

Role of food safety risk perception and attitude on knowledge and practice of domestic food handlers: A serial mediation model

Abstract

This study aimed to determine the serial mediation effects of behaviour specific risk perception (BRP) and attitude (ATT) towards food safety on the relationship between food safety knowledge (FSK) and self-reported practice (FSP) among domestic food handlers in Bangladesh. The current study conducted a cross-sectional survey on cross-contamination, safe storage and cooking towards food safety among 503 domestic food handlers. The serial mediation effects were examined by using the Hayes' PROCESS macro Model 6 for SPSS. The results showed that FSK among domestic food handlers had a direct positive relationship with their FSP (Effect = 0.221, 95% CI: 0.089 to 0.0354). In addition, BRP partially mediated the relationship between FSK and FSP independently (Effect = 0.175, 95% CI: 0.06 to 0.141). Although, ATT showed no independent mediation effect, BRP was significantly positively associated with ATT (Effect = 1.28, $p < 0.001$), and FSP (Effect = 0.532, $p < 0.001$), forming a serial mediation pathway (Effect = 0.037, 95% CI: 0.021 to 0.058). The total indirect effect of all mediation paths was 48%. This study provided justification in highlighting the role of food handlers behaviour specific risk perception towards food safety for escalating a positive attitude to perform safe food handling practices in the domestic environment. From a practical standpoint, government agencies, policymakers and researchers should implement significant initiatives in well-structured educational programs, with particular emphasis on behaviour specific risk communication strategies towards food safety for better safe handling of food in the domestic kitchen.

1. Introduction

Foodborne diseases (FBDs) have impacted the global and domestic food sectors and posed a hazard to public health. The World Health Organization (WHO) evaluates that unsafe food is responsible for illness in almost 1 in 10 individuals globally, approximately 600 million individuals. As a result, there are 420,000 fatalities and a loss of 33 million healthy life years (DALYs) each year (WHO, 2022). The accuracy of this approximation has underestimated the exact FBD rate, as a substantial proportion of individuals do not seek medical attention, leading to an underestimation of cases (Mullan et al., 2015). The burden of FBDs is much worse in developing nations (Lee & Lien, 2015; Wang et al., 2021). Low- and middle-income countries are combating unsafe food, which results in a yearly loss of USD 110 billion in productivity and medical costs (WHO, 2022). Owing to its dense population, inadequate infrastructure, limited access to clean water, and absence of sanitation and hygiene (WASH) facilities, FBDs are prevalent in low-middle-income countries such as Bangladesh (Ishra et al., 2022; Noor & Feroz, 2016). Approximately 30 million individuals in Bangladesh suffer from FBDs annually (Khairuzzaman et al., 2014; Ishra et al., 2023).

Earlier research has reported that handling food at home accounted for over 35% of FBDs (Langiano et al., 2012). The prevalence rate of FBD detected in the household kitchen greatly varied within nations (Al-Shabib et al., 2016; Islam et al., 2023). Prior research highlights that home-cooked meals may have contributed 20% – 50% of FBDs in Australia and New Zealand (Redmond & Griffith, 2009). With morbidity and mortality of 37,454 and 143, respectively, in 2020, China had massive household FBD outbreaks (58.5%) and fatalities (89.5%) (Li et al., 2021). The European Food Safety Authority reported that home-cooked food was a factor in 36.4% of FBD outbreaks in the European Union (European Food Safety Authority, 2017). One efficient strategy to lower FBDs is to improve consumer food handling practices. Furthermore, theory-based educational initiatives more effectively encourage altering consumer food safety practices (Young et al., 2017). The basis for creating a theory-based education programme is investigating the primary influences on food-handling practises (Wang et al., 2021).

Consumer food safety knowledge has been found to significantly influence their level of food safety behaviours (Gong et al., 2016). The prevalence of consumers with inadequate food safety knowledge is notable in many countries, such as Ireland, Iran, China, Cameroon and Jordan (Gong et al., 2016; Moreb et al., 2017; Odeyemi et al., 2019). The knowledge of how

to handle food varies significantly among groups (Gong et al., 2016). For example, age, education, gender, income, and residency place are significant predictors of varying knowledge levels (Gong et al., 2016; Luo et al., 2019; Moreb et al., 2017). Studies have suggested that food safety knowledge has a positive influence on normative food safety behaviours. However, several elements, such as attitude and risk perception, allow individuals to make reasonable decisions that result in correct food-handling behaviours (Young et al., 2017). Previous research mentions that food safety education programmes considerably increase knowledge and improve food safety practices (Marklinder et al., 2020). Some research considers that food safety knowledge and practice are weakly co-related, and that increasing food safety knowledge does not always result in healthier food safety practices (Gong et al., 2016; Kwol et al., 2020).

While it is necessary to possess food safety knowledge to implement good hygiene practices, research has shown that this knowledge alone does not adequately equip consumers to perceive food risks. Thus, Debucquet et al. (2007) commonly encountered outdated "beliefs" about food safety. As a case in point, prior research has documented that despite most individuals having adequate knowledge about the crucial role of cooking in preventing foodborne illness caused by cross-contamination, it did not necessarily manifest in their behaviour (Fischler et al., 2007; Phang & Bruhn, 2011). It is noteworthy that food safety risk awareness affects the behaviour of individuals. Additionally, the preceding research indicates that motivation significantly influenced consumer behaviour compared to food safety knowledge (Fischer et al., 2007; Taché & Carpentier, 2014).

Despite the apparent necessity of knowledge for the proper application of food safety, the perception of consumers regarding low-risk food may hinder the translation of knowledge into behaviour (Evans et al., 2020; Glanz et al., 2008). Health Belief Model (HBM) and Protection Motivation Theory (PMT) explain that risk perception is a crucial motivator for consumers to adopt healthy behaviours (Skinner et al., 2015; Wang et al., 2021). Both models suggest that increased perception of risks inclines consumers to adopt normative food-handling behaviours. Risk perception is a commonly observed element in consumer food handling that has become a reliable predictor of food safety behaviours (Young et al., 2017).

The notion of risk pertains to the likelihood of encountering hazards. Hazards are characterised as dangers that endanger the safety of individuals and their possessions. Probability is related

to the possibility of a hazard happening, which is perceived with some uncertainty. The uncertainty surrounding risk pertains to the variation in people's assessment of the extent and severity of the risk in question. Ambiguous, unpredictable, or probabilistic situations often lead to individuals feeling a sense of uncertainty. The term risk perceptions is used to describe subjective judgments and interpretations of risks (Slovic et al., 2016). An individual's evaluation of the potential risk in a certain scenario is known as their perception of risk (Slovic, 1987; Zanetta et al., 2022). Young et al. (2017) found a causal link between behaviour and perceived risk for food safety. A study among Mexican Americans in the United States revealed a significant relationship between their food safety risk perception and self-reported food-handling behaviours (Parra et al., 2014). Research conducted earlier has explored food handling practices in domestic environments and the foodborne disease risk perception. Few researchers, meanwhile, have looked into the perceived risk connected to certain food handling practices, like leaving cooked food out of the refrigerator for more than two hours (Levy et al., 2008; Young et al., 2015). Campaigns that emphasize behaviour-specific risk perceptions may prove to be a more constructive instrument, even though past interventions focused on educating consumers about food safety have shown little impact on food handling practice changes (Young et al., 2015).

Attitude is another motivating factor that transfers knowledge into practice (Zanin et al., 2017). Attitude is a pre-existing tendency to respond to an object rather than an actual conduct towards that object. An individual's attitude is considered a permanent trait that can only be altered through prolonged periods of pressure and time. This dormant variable has significant behavioural consequences and is primarily associated with a predisposition towards evaluations or feelings towards an object (Niewczas-Dobrowolska, 2022). The KAP model suggests that knowledge shapes an individual's attitude, which, in turn, influences their practices or behaviour. Numerous studies have discussed this proposition and analyzed attitude as a motivating factor (Baser et al., 2017; Sani & Siow, 2014; Sanlier & Baser, 2020; Taha et al., 2020). The perception of risks is the fundamental element that shapes people's attitudes. Individuals' risk perception affects microbiological hazards and food handling, including handwashing and preventing cross-contamination in the kitchen. Further, risk perception is a dominant phenomenon in understanding consumer food safety attitudes (van der Vossen-Wijmenga et al., 2022). Even though several behaviour theories (e.g., HBM, TPB) determine risk perception as a vital element in a motivational change of behaviour (Glanz et al., 2008),

little research has been done on the relationship between food safety knowledge (FSK), risk perception, attitude (FSA), and practice (FSP) in Bangladesh.

Cross-contamination accounts for most FBD outbreaks in households (Redmond & Griffith, 2003); for example, without routine washing, using a similar cutting board and knife set for poultry, raw meat and vegetables can lead to FBD (De Jong et al., 2008, Almanasrah et al., 2022). In an earlier study, over 60% of consumers in Bangladesh failed to demonstrate the correct way of cross-contamination practices. For instance, using a chopping board for raw meat and fresh fruit was shown to have the lowest level of comprehension (19.9%). Safe storage is another key procedure to control foodborne pathogens. A previous study found that around 75% of consumers in Bangladesh failed to indicate the safe storage of food, such as handling freshly cooked food that would not be eaten for three or more hours (Islam et al., 2023). Despite the importance of domestic food handling to prevent food contamination, no studies have investigated the association between domestic food handlers' cross-contamination, safe storage and cooking-related knowledge, attitude, risk perception and practice towards food safety in Bangladesh. The current study focuses on cross-contamination, storage and cooking-related behaviour-specific risk perception of food safety. Bangladeshi coastal residents follow a way of life and a culture that includes consuming raw milk for nourishment, which presents a risk for foodborne disease with a number of harmful bacteria, including *Campylobacter jejuni, Brucella spp,* Shiga toxin-producing *E. coli (E. coli O157:H7), Bacillus cereus, Listeria monocytogenes, Salmonella spp, Mycobacterium tuberculosis, Mycobacterium bovis, Yersinia enterocolitica.* This study evaluates the impact of such behaviour-specific risk perceptions (BRP) on the food handlers' cross-contamination, storage and cooking-related knowledge (FSK), attitude (ATT) and practice (FSP) in Bangladesh. Considering the above literature review, the current study hypothesised:

H1. Domestic food handlers' cross-contamination, storage and cooking-related FSK influences their BRP level.

H2. Food handlers' cross-contamination, storage, and cooking-related FSK influences their level of ATT in the domestic environment.

H3. Food handlers' BRP mediates the relationship between FSK and FSP levels in the domestic environment.

H4. Food handlers' ATT mediates the relationship between domestic food handlers' FSK and FSP in Bangladesh.

H5. BRP and ATT play a serial mediating role in the relationship between domestic food handlers' FSK and FSP levels in cross-contamination, storage and cooking.

2. Methods

2.1 Sampling and study outline

This study collected data from two metropolitan cities (Dhaka and Chittagong) and two rural districts (Faridpur and Cox's Bazar) in Bangladesh between November 2021 and March 2022. This study recruited domestic food handlers aged 18 years or older and prepared food at least 2-4 times per week with a cross-sectional descriptive survey. Considering a 5% margin of error and a 95% confidence interval, the study calculated a sample size of 385 based on the estimated 104.87 million adult population in Bangladesh. Given the inferential goals of this study, the large sample size is often thought to enhance accuracy. The study gathered additional data, and the ultimate sample was 503.

2.2 Data collection

The data collection process was underway following approval from the Australian University of Southern Queensland Human Research Ethics Committee (USQ HREC ID: H21REA161). Before commencing the data collection, all of the research assistants had extensive training in accordance with university guidelines. The study assistants attended randomly selected locations, such as local markets, bazaars, schools, colleges, and parks. In order to choose the participants, the research assistants approached people outside of shops or schools using a convenience sampling procedure. A face-to-face survey was conducted with the participants after the researcher explained the study's goals and obtained informed consent. It took between 15 and 20 minutes to complete each survey. A bilingual translator translated the survey materials into Bengali, and the data was collected electronically using Google Forms.

2.3 Survey instruments

This study employed a questionnaire with validated scales that were used in earlier research, and initially, the items of food handlers' cross-contamination, storage and cooking-related knowledge (6 questions), self-reported practice (9 questions), attitude (8 questions) and behaviour-specific risk perception (5 questions) adapted from the previous studies (Evans et al., 2020; Gong et al., 2016; Levy et al., 2008; Lihan et al., 2019; Moreb et al., 2017; Odeyemi et al., 2019; Ruby et al., 2019; Soon et al., 2021; Soon et al., 2020; Tabrizi et al., 2017). The survey instruments are divided into four sections: sociodemographic characteristics and questions on food handlers' knowledge (FSK), attitude (ATT), behaviour risk perception (BRP) and practice (FSP) of food safety.

The demographic information comprised age, gender, education, family income, occupation, place of residence, total number of individuals, and the number of children in the household. The participants were asked questions on their food safety knowledge, including three alternative answers: "Yes," "No," and "Don't know"; for example, " Uncovered abrasion or cuts can cause cross contamination of food" or " Storing leftover food on the table or kitchen shelf is not good". A correct response received one point, whereas an incorrect or "don't know" response received zero points. 'Don't know' was added to the multiple-choice answers to reduce the likelihood that participants would select the correct response accidentally. The food safety practice section includes questions such as, "Do you reheat leftover food until it is boiling hot?" or " Do you use different cutting boards or knives to slice raw meat and to cut fruits and vegetables?" employing a 5-point Likert scale, from "never" (1 point) to "always" (5 points). The food safety attitude includes questions such as, "It is necessary to use cutting board and knives set for meat and another set for vegetables" on a 5-point Likert scale, from "strongly disagree" (1 point) to "strongly agree" (5 points). The behaviour risk perception of food safety includes questions to determine the participants' perceptions of the risk of acquiring FBDs after a specific behaviour associated with their food safety practice on a five-point Likert scale from "very low" to " very high". A sample item for behaviour risk perception is " What is the risk of acquiring foodborne disease if you do not heat food properly or eat raw food (e.g., consume raw milk or egg)?"

2.4 Data analysis

The data were analysed using SPSS software Mac OS version 29. This study used the conventional two-step methodology (Anderson & Gerbing, 1988). In order to evaluate structural models in the second stage, the method enables researchers to validate the applicability of the study data via the evaluation of the measurement model. All latent variables (food safety knowledge, attitude, practice, and risk perception) were subjected to an exploratory factor analysis during the evaluation of the measurement model. The researcher can then evaluate the discriminant and convergent validity of the data. Hayes (2017) PROCESS macro program was used in the next step, which required evaluating the structural model. Sociodemographic factors were the subject of descriptive statistical studies. Other statistical analyses, such as frequencies and correlations, and collinearity statistics were conducted.

3. Results

4.1 Participant profile and descriptive statistics

The majority of study respondents were female (90.3%) and housewives (69.4%). 39% of participants were aged between 30 to 39 years. More than 45% of food handlers reported having a university degree while 39.6% mentioned having a school-level education (Table 1). The percentage scores for the FSK items in Table 2 ranged from 27.6 to 53.3%. BRP item percentage ratings varied from 13.7 to 17.7%. The range of percentage scores for the FSP items was 1.0 to 36.2%. The percentage score for the ATT items ranges from 14.1 to 47.5%.

Table 1: Demographic information of the domestic food handlers

N = 503	Frequency	%
Age in years		
18 - 29	134	26.6
30 - 39	196	39
40 - 49	136	27
50 and above	37	7.4
Gender		
Female	454	90.3

Male	49	9.7
Education		
School	199	39.6
College	60	11.9
University (Bachelor)	114	22.7
University (Masters and above)	130	25.8
Occupation		
Student	10	2.0
Housewife	349	69.4
Govt. employee	29	5.8
Non-govt. employee	80	15.9
Business	31	6.2
Unemployed	4	0.8

Table 2: Descriptive statistics (statement, mean, standard deviation and percentage) of domestic food handlers' responses

Expression	Scale item	Mean (SD)	Correct answer (%)	High and very high response (%)	Always response (%)	Strongly agree (%)
Knowledge	**FSK**					
Uncovered abrasion or cuts can cause cross contamination of food.	FSK1	0.44 (0.497)	44.5	-	-	-
It is necessary to wash the knife that has been used to cut raw meat with soap and water before using it again.	FSK2	0.85 (0.348)	85.9	-	-	-
Storing raw and cooked food together can cause food contamination.	FSK3	0.47 (0.50)	47.9	-	-	-
Leftover food smelling good is still safe to eat.	FSK4	0.30 (0.461)	30.6	-	-	-
It is ideal not to keep leftover food in the fridge for more than 2 days.	FSK5	0.49 (0.50)	49.1	-	-	-
Storing leftover food on the table or kitchen shelf is not good.	FSK6	0.44 (0.497)	44.9	-	-	-
Behaviour risk perception	**BRP**					
What is the risk of acquiring foodborne disease if you do not heat food properly or eat raw food (e.g., consuming raw milk or egg)?	BRP1	2.64 (0.846)	-	17.7	-	-
What is the risk of acquiring foodborne disease if you use the same cutting board or knife to slice raw meat and to cut fruits and vegetables?	BRP2	2.66 (0.869)	-	13.7	-	-
What is the risk of acquiring foodborne disease if you keep food in	BRP3	2.75 (0.865)	-	15.1	-	-

the room temperature for more than 2 hours?						
Practice	**FSP**		**-**			
Do you use different cutting boards or knife to slice raw meat and to cut fruits and vegetables?	FSP1	1.76 (0.987)	-		1.0	-
Do you use different towel to wipe kitchen surfaces and to dry your hands?	FSP2	3.98 (1.653)	-		38.6	-
Do you prefer keeping the meal at refrigerator, if your family member is going to be several hours late for a hot meal?	FSP3	3.15 (1.21)	-		14.5	-
Do you reheat leftover food until it is boiling hot?	FSP4	3.50 (0.995)	-		17.1	-
Attitude	**ATT**					
Wearing accessories like rings, bracelets are not fine when cooking food.	ATT1	2.92 (1.267)	-			14.1
it is necessary to cover your cut with bandage and use gloves while preparing food.	ATT2	4.20 (0.766)	--			39.4
it is unhealthy to taste dish out food with unprotected hands.	ATT3	3.8 (1.079)	-			36.4
Use cutting board and knives set for meat and another set for vegetables.	ATT4	3.69 (1.138)	-			36.4
it is necessary to read conditions of use and storage of packaged food.	ATT5	4.36 (0.703)	-			47.5
I don't prefer half-boiled or half-cooked eggs.	ATT6	3.45 (1.25)	-			24.3
it is unhealthy to consume expired food.	ATT7	4.50 (0.696)	-			59.8

4.2 Measurement model

To assess the items' competency with variance, the Kaiser-Meyer-Olkin (KMO) and Bartlett's tests of sphericity were run. The KMO test is employed to check sample adequacy and applicability for the purpose of factor analysis to demonstrate the level of variance among the variables. The correlation matrix is compared to the identity matrix using Bartlett's test of sphericity to determine whether there is a significant difference. The test findings were 0.862 (> 0.60) and significant (P 0.001), suggesting the presence of some correlations between the variables and the lack of an identity correlation matrix, respectively. This study conducted exploratory factor analysis (principal component with varimax rotation) and internal consistency tests to verify the convergent and discriminant validity of the study measures. At the 0.4 cut-off, all factor loadings were significant. (Hair et al., 2010). Accordingly, two items from behaviour risk perception, five from self-reported practice and one from attitude were extracted.

Scale items, exploratory factor analysis findings, and internal consistency data are included in Table 3. Each factor is precisely based on its underlying construct. The validity of the constructs was confirmed by the average variance extracts (AVE > 0.5) (Rothstein et al., 1990). Table 3 results also indicated good reliability ($\alpha > 0.70$) in all measures (Taber, 2018).

Table 4 shows means, standard deviations, and correlations of the study variables. The findings indicate that food safety knowledge, practice, behaviour risk perception and education all significantly correlated except for the relationship between gender and age. Food safety knowledge (FSK) was significantly positively correlated with behaviour risk perception (BRP) ($r = 0.302$, $p < 0.01$), food safety practice (FSP) ($r = 0.259$, $p < 0.01$) and food safety attitude (ATT) ($r = 0.119$, $p < 0.05$). Similarly, BRP was positively correlated with FSP ($r = 0.499$, $p < 0.01$) and ATT ($r = 0.532$, $p < 0.01$). As the correlations between the research variables are lower than 0.70, the findings of the correlation analysis offer additional support for the claim that discriminant validity exists. Using the variance inflation factor (VIF < 3.5), collinearity was confirmed (Rothstein et al., 1990). Table 5 shows that all VIF values for the predictor are lesser than 5, which alleviates the multicollinearity issue in the regression model.

Table 3: Validity and reliability of the study constructs

Expression	Scale item	Factor Loadings (FL)	AVE	Cronbach's Alpha
Knowledge	**FSK**		0.633	.891
Uncovered abrasion or cuts can cause cross contamination of food.	FSK1	.882		
It is necessary to wash the knife that has been used to cut raw meat with soap and water before using it again.	FSK2	.448		
Storing raw and cooked food together can cause food contamination.	FSK3	.883		
Leftover food smelling good is still safe to eat.	FSK4	.835		
It is ideal not to keep leftover food in the fridge for more than 2 days.	FSK5	.774		
Storing leftover food on the table or kitchen shelf is not good.	FSK6	.864		
Behaviour risk perception	**BRP**		0.735	.956
What is the risk of acquiring foodborne disease if you do not heat food properly (e.g., consuming raw milk or egg)?	BRP1	.815		
What is the risk of acquiring foodborne disease if you use the same cutting board or knife to slice raw meat and to cut fruits and vegetables?	BRP2	.885		
What is the risk of acquiring foodborne disease if you keep food in the room temperature for more than 2 hours?	BRP3	.871		
Practice	**FSP**		0.576	.793
Do you use different cutting boards or knife to slice raw meat and to cut fruits and vegetables?	FSP1	.565		
Do you use different towel to wipe kitchen surfaces and to dry your hands?	FSP2	.696		

Do you prefer keeping the meal at refrigerator, if your family member is going to be several hours late for a hot meal?	FSP3	.879		
Do you reheat leftover food until it is boiling hot?	FSP4	.855		
Attitude	**ATT**		0.671	.919
Wearing accessories like rings, bracelets are not fine when cooking food.	ATT1	.725		
it is necessary to cover your cut with bandage and use gloves while preparing food.	ATT2	.887		
it is unhealthy to taste dish out food with unprotected hands.	ATT3	.849		
Use cutting board and knives set for meat and another set for vegetables.	ATT4	.843		
it is necessary to read conditions of use and storage of packaged food.	ATT5	.881		
I don't prefer half-boiled or half-cooked eggs.	ATT6	.742		
it is unhealthy to consume expired food.	ATT7	.793		

Table 4: Descriptive statistics and correlations of the study variables

Variables	Mean	SD	FSK	ATT	FSP	BRP
Food safety knowledge	3.0298	2.271	1	.119**	.259**	.302**
Food safety attitude	26.9404	5.827	.119**	1	.425**	.532**
Food safety practice	11.6123	3.90	.259**	.425**	1	.499**
Behaviour risk perception	8.0636	2.47	.302**	.532**	.499**	1

Notes: **p < 0.01 Two-tailed test.

Table 5: Collinearity statistics of the independent variables

Variables	Regression coefficient (95% CI)	Tolerance	VIF
Food safety knowledge	0.222 (.089, .355)	0.906	1.103
Behaviour risk perception	0.154 (.095, .212)	0.715	1.399
Food safety attitude	0.532 (.389, .675)	0.659	1.518
R^2 = .299, F = 71.03, p <.001			

Note: Dependent Variable - Food safety practice

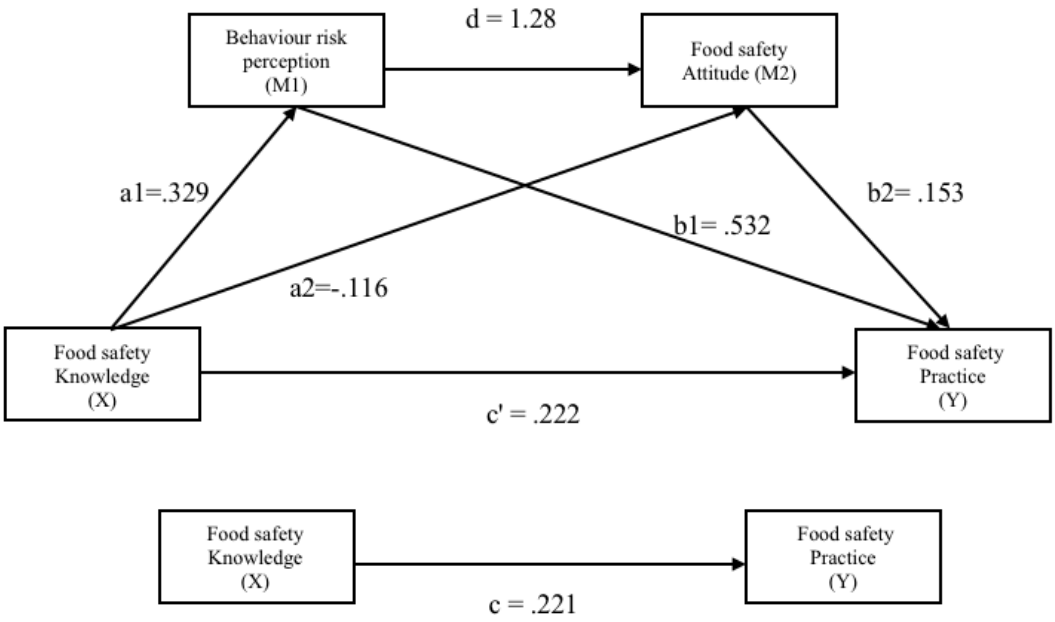

Figure 1: PROCESS serial Mediation model.

Note: a1=straight effect of X on M1,

b1= straight effect of M1 on Y,

a2 = straight effect of X on M2,

b2= straight effect of M2 on Y,

c= straight effect of X on Y,

c'= indirect effect of X on Y through M.

4.3 Regression analysis

Hayes (2017) PROCESS macro was applied to evaluate the association between food safety knowledge (FSK), attitude (ATT), practice (FSP) and behaviour risk perception (BRP). The mediator variable is considered to have a mediating impact if Hayes' (2013) Macro Process bootstrapping approach identifies the indirect effect (IE) of the independent variable (X) on the dependent variable (Y) through the mediator (M) and the bias-corrected 95% CI around the IE from 5000 bootstrap resamples. If the bias-corrected 95% confidence interval for the indirect effect (IE) excludes zero, it is deemed statistically significant.

In Table 6, path a1 indicates the direct relationship that FSK exerts a significant positive effect on BRP ($\beta = 0.329, p < 0.001$), supporting Hypothesis H1. Path b1 shows BRP was significantly and positively associated with FSP ($\beta = 0.532$, $p < 0.001$). Simultaneously, the direct effect of FSK on FSP was significant in path c ($\beta = 0.221$, $p < 0.001$). Path c' shows an

indirect effect (IE) of FSK on FSP through the mediator variable BRP was statistically significant (β = 0.222, p < 0.001). Additionally, the bias-corrected 95% CI = .06 to .141 that excluded zero (Table 7). Hence, BRP is considered as a mediator for FSK on FSP, supporting Hypothesis H3. In contrast, the direct path a2 shows that the association between FSK and ATT was not significant (β = − 0.116, p = 0.251) (Table 6). Thus, rejecting Hypotheses H2 and H4. Finally, BRP was significantly positively associated with ATT (β = 1.28, p < 0.001) and FSP (β = 0.532, p < 0.001), establishing a sequential mediation pathway supporting Hypothesis H5. Fig. 1 shows the detailed model path.

In Table 7, the bootstrap test results showed that BRP mediated the relationship between FSK and FSP, with a total indirect effect of 0.222 and 95% CI (.0298 to .1201) that excluded zero. Specifically, the serial mediating effect was composed of an indirect effect generated by FSK → BRP → ATT → FSP (effect = 0.037, 95% CI: 0.021 to 0.058). The result was partial mediation due to the total and indirect effects both were significant. Hence, it can be concluded that food handlers' behaviour risk perception of food safety partially mediated the relationship between their food safety knowledge and practice, and there is partial serial mediation of behaviour risk perception and attitude on the relationship between knowledge and practice.

Table 6: The Process macro-mediation model shows the regression analysis of variable relationships

		β	SE	t	p (CI)	
Outcome variable	***Predictor variable***					
						R2 = .091 F = 50.34 P < 0.001
BRP	FSK	0.329	0.046	7.09	<.001*** (.238, .420)	
						R2 = .285 F = 99.72 P < 0.001
ATT	FSK	-0.116	0.101	-1.14	0.251 (-.316, .083)	
	BRP	1.28	0.093	13.76	<.001*** (1.10,1.46)	

						R2 = .299 F = 71.03 P < 0.001
FSP	FSK	0.221	0.067	3.28	.001** (.089, .354)	
	BRP	0.532	0.072	7.31	<.001*** (.389, .675)	
	ATT	0.153	0.029	5.18	<.001*** (.095, .212)	

Note: FSK - Food safety knowledge, FSP - Food safety practice, ATT - Food safety attitude, BRP - Behaviour risk perception, CI - 95% confidence interval, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$,

Table 7: The PROCESS Mediation model shows the total, direct and indirect effect of food safety knowledge (FSK) on food safety practice (FSP)

	Effect (β)	**Boot SE**	**Boot LLCI**	**Boot ULCI**
Total effect	0.444	0.074	0.298	0.589
Direct effect	0.221	0.067	0.089	0.354
Total indirect effect	0.222	0.038	0.150	0.297
Indirect effect 1: FSK → BRP → FSP	0.175	0.019	0.066	0.141
Indirect effect 2: FSK → ATT → FSP	- 0.010	0.008	- 0.027	0.007
Indirect effect 3: FSK → BRP → ATT → FSP	0.037	0.009	0.021	0.058

Note: Boot SE = standard error, Boot LLCI = lower bounds and Boot ULCI = upper and of the 95% confidence intervals indirect effects estimated by the bootstrap method

Table 8: Results of hypothesis testing

Hypotheses	**Hypotheses path**	**Decision**
Hypothesis 1 (H1)	FSK → BRP	Supported
Hypothesis 2 (H2)	FSK → ATT	Not supported
Hypothesis 3 (H3)	FSK → BRP → FSP	Supported
Hypothesis 4 (H4)	FSK → ATT → FSP	Not supported
Hypothesis 5 (H5)	FSK → BRP → ATT → FSP	Supported

5. Discussion

The present study aims to evaluate how domestic food handlers' cross-contamination, storage and cooking-related food safety knowledge influences their behaviour risk perception and attitudes toward food safety and food safety practices. Furthermore, it examines the mediating effects of behaviour risk perception and attitudes toward food safety on the relationship between food safety knowledge and self-reported food safety practice.

In the current study, on average, 50.4% of food handlers reported correct responses about food safety knowledge, and 15.5% responded high to very high-risk perceptions towards their food safety behaviour. Besides, 17.8% of participants mentioned 'always' practising, and 36.8% showed a strong attitude towards the mentioned food safety measures (Table 2).

The present research identified that food handlers' food safety knowledge positively influences their perceived risk of food safety behaviour (Table 8). The proposed model has evaluated a positive impact on the knowledge-risk perception relationship. Thus, it can be concluded that the awareness of food safety is enhanced when consumer knowledge of food handling interferes with perceived risk. This finding aligns with earlier studies that stated knowledge is a prerequisite for assessing the risk factors (De Boer et al., 2005). Several researchers mentioned knowledge as a crucial factor that affects risk evaluation (Fife-Schaw & Rowe, 1996; Frewer et al., 1994; McCarthy et al., 2007).

Studies have highlighted that knowledge is one of the factors that regulate appropriate food safety practices (Lim et al., 2016; Mucinhato et al., 2022). A number of elements, including knowledge (Gong et al., 2016), attitude (Ajzen et al., 2007), and risk perception (Young et al., 2017), impact a reasoned choice process that leads to a correct food safety practice (Smith et al., 2007). This study found that food handlers' knowledge of food safety has a direct and positive influence on their food safety practices. This finding is in line with those of Lim et al. (2016), who discovered that knowledge had a direct impact on behaviour.

Although knowledge is imperative, it is not adequate for changing behaviour (Taché & Carpentier, 2014). In addition to knowledge, the perception of risk can act as a motivator for consumers to take action, including avoidance, prevention, adaptation, or even neglect of the associated risks.(Wachinger et al., 2013). Thus, risk perception guides practices (McCarthy et

al., 2007; Parra et al., 2014), supporting the current study finding that revealed food handlers' perceived behaviour risk of food safety positively influences their food safety practices (Table 8).

The current mediation analysis revealed that food handlers' behaviour-specific risk perception partially mediated the relationship between food safety knowledge and practice. As the food handlers' knowledge in this study directly and indirectly (via behaviour risk perception) act on food safety practices, behaviour modifications occurred in both processes from the direct effect of knowledge and through the mediator variable behaviour risk perception. Studies suggest that enhancing communication to increase risk perception and modify general behaviour is the optimal strategy for improving practices (Parra et al., 2014; Byrd-Bredbenner et al., 2013; McCarthy et al., 2007).

On the other hand, this study explored that the domestic food handlers' cross-contamination, storage and cooking-related knowledge and attitude towards food safety are not significantly associated. Similar findings were found by Rebouças et al. (2017) and Akabanda et al. (2017), showing that improved food safety knowledge has not led to a rise in positive attitudes towards food safety. Contrarily, Taha et al. (2020) found a significant positive relation between food safety knowledge and attitude. The current study also found no evidence of a mediating role for food handler attitudes in the relationship between their knowledge of food safety and practice, in contrast to Ko (2013) study, which found that positive attitudes are essential for food handlers' conversion of food safety knowledge into proper food safety practices, acting as a mediator between food safety knowledge and practices.

The main result of the current study was that the behaviour risk perception and attitude towards food safety partially mediated the relationships between food safety knowledge and practice through a serial mediation pathway. Few previous studies have examined the role of perceived risk and attitude in the relationship between knowledge and practice towards food safety; however, they have not adequately investigated the mechanism of this sequential path. An extended TPB model by Mucinhato et al. (2022) revealed that perceived risk has a more robust relation to food safety attitudes in the household food safety practice during the COVID-19 pandemic. Further, considering the influence of attitudes on practices, this study shows that these constructs are significantly and positively related, aligning with previous research (Al-Kandari et al., 2019; Aquino et al., 2021; Asmawi et al., 2018). this sequential mediation model

in the current study contributes novel perspectives on the consequences of domestic food handlers' cross-contamination, storage and cooking-related food safety knowledge, with their perceived behaviour-specific risk and attitude towards food safety mediating the effect of knowledge on practice.

5.1. Implication of theory

The knowledge-risk perception-attitude-practice paradigm is extended in this study to the context of domestic food handlers in Bangladesh. The recently established food safety authority is supervising food safety concerns in Bangladesh, but it has mostly ignored the issue of domestic food handling in favour of the food supply chains. Interestingly, our results indicate that the model performs well in the Bangladeshi environment, demonstrating the model's applicability globally in preventing the spread of pandemic diseases transmitted by food.

5.2. Practical implication

Scholars and practitioners have posited and ascertained that supervisors, managers, and leaders should be responsible for creating an essential food safety culture that encourages behavioural changes, thereby ensuring food handlers' compliance with mandatory standards (Zanin et al., 2017). The present research highlights that it is inadequate to launch food safety knowledge education alone to reduce the knowledge-practice gap. To enhance food safety practices, policymakers must design focused communication tactics to directly raise individuals' risk perception and attitude associated with their existing food-handling practices. The findings imply that increasing behaviour-specific risk perception related to present unsafe food handling practices will enhance their attitude level and consequently may encourage people to take more precautions in their food safety practice. The government may implement regulations that surround food safety education initiatives on a national level. For example, the government might insist on placing flyers and handouts in grocery stores or local bazaars, available to adult consumers to educate them with crucial information about the riskiest food safety behaviours (e.g., storing food at room temperature for several hours or not boiling and cooking food well).

The findings imply that raising awareness of the risk associated with specific unsafe food handling practices may encourage people to take more precautions in their food safety behaviour. In other words, it could be necessary for people to have less optimism about their

current methods of handling food. Lowering the optimism bias would encourage people to look for and be receptive to new knowledge and to obtain a positive attitude towards food safety to enhance their food handling methods. Hence, programs should heighten the perception of FBD and the necessity of personal responsibility to lower the 'optimistic bias' and 'illusion of control' for adopting a risk-reducing food safety behaviour at home. Further, identifying food safety risks should be addressed to build a positive food safety attitude in this community.

Cooking programs might incorporate tailored recommendations for the community, such as guidelines on cross-contamination, safe storage and cooking methods. These programs could involve the hazards of not storing food in the refrigerator or not reheating leftover food until boiling, educating individuals on hygiene practices between uses, using separate cutting boards for vegetables and meat, and reinforcing existing messages on the dangers of salmonella in raw eggs.

The levels of knowledge, risk perception, attitude, and food-handling practices varied significantly across sociodemographic groups. These variations will change based on different food handling situations. Therefore, target-oriented education programmes should be implemented into different subgroups (e.g., age, gender, education, residency place). Researchers have identified numerous media factors that can impact individuals' risk perceptions (McCarthy et al., 2008), such as types of media and amount of media coverage. For instance, the issue of chemical risks (e.g., formalin, pesticide residues) in food is a matter of substantial concern for Bangladeshi consumers than microbiological food risks, perhaps due to numerous media coverage, reports, and talk shows (Ishra et al., 2022). On the other hand, after media reports of food-borne diseases and recalls, significant behaviour changes were noted (Brady et al., 2009; De Jonge et al., 2010). Hence, the government, policymakers, researchers, and the media devote their time and resources to conceptualising and developing proper risk communication strategies that teach domestic food handlers about food safety procedures and enable them to apply knowledge in a real-life context.

6. Study limitation and future research

The cross-sectional nature of the study is an evident constraint of this study. Due to their nonrandomized nature and the indeterminate directionality between associated variables, cross-sectional studies cannot determine causality conclusively. These limitations were mitigated as

much as possible by collecting a large sample size of data. Nonresponse and recall bias were compensated by collecting data from trained research assistants and providing enough time for the respondents to recall. The inference of causal relationships between the variables of the study could be impacted due to the use of self-reported data in the analysis. According to some academics (Kormos & Gifford, 2014), self-reports cannot accurately reflect the real situation. Future research can evaluate food handling behaviours more precisely by using observational approaches. Another limitation included the inability to generalise food handlers in Bangladesh due to the convenience sample approach. The scope of this empirical analysis restricts behaviour risk perceptions specific to a sole psychometric variable. Future researchers should expand upon previous data collection efforts by measuring risk perceptions as a multidimensional concept and observing the incongruity between self-reported behaviours and factual observations. Further, exploring the effectiveness of behaviour-specific risk communication strategies and identifying behaviour-specific food safety risks should be addressed in this community. Future studies may endeavour to enhance this serial mediation effect of food safety risk perception and attitude by employing a risk perception attitude framework (RPA) for a better understanding of the effect. The least effective components that contributed to the consumer's intent to practice food safety were attitude and food safety knowledge. It is advised that future research should focus on moderators that can enhance these aspects, such as age, gender, and experience.

7. Conclusion

The purpose of the current investigation was to examine the indirect effects of food safety knowledge and practice through behaviour-specific food safety risk perception and attitude. Results from a sample of Bangladeshi adult domestic food handlers show that food handlers' knowledge of food safety positively influences their self-reported practice through behaviour risk perception of food safety. Moreover, the key findings indicate that behaviour-specific risk perception and attitude partially mediate the association of food safety knowledge with practice. The findings of this study call for the attention of government agencies, policymakers and researchers to implement significant initiatives in well-structured educational programs, with particular emphasis on behaviour-specific risk communication strategies towards food safety. The government must introduce food safety education during childhood by including food safety guidelines in formal education for escalating a positive attitude to the masses.

Data availability

The data supporting this study's findings are available from the corresponding author upon reasonable request.

Declaration of competing interest

None.

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Ethical statement

Ethical approval was obtained from the Australian University of Southern Queensland Human Research Ethics Committee (USQ HREC ID: H21REA161).

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6.3 Links and implications

The current chapter assessed the indirect impacts of knowledge and practice on food safety by examining behaviour-specific risk perception (BRP) and attitude (ATT). A study conducted on adult domestic food handlers in Bangladesh reveals that there is a positive relationship between food handlers' knowledge of food safety (FSK) and their self-reported practice (FSP), mediated by their perception of behaviour risks (BRP) related to food safety. Additionally, the results indicate that behaviour-specific risk perception (BRP) and attitude (ATT) serially mediate the relationship between food safety knowledge and practice. The conclusions drawn from this study necessitate that government agencies and policymakers should consider implementing significant initiatives in well-structured educational programs, with particular emphasis on behaviour-specific risk communication strategies pertaining to food safety.

This thesis put its efforts to accomplish four studies in four thematic areas of food safety among food handlers: i) pandemic-related knowledge and hygiene behaviour, ii) food safety knowledge level in the domestic environment, iii) attitude, practice and general risk perception towards food safety and iv) the relationship between knowledge, attitude, practice and risk perception. The following chapter addresses the concluding discussion and policy implications derived from the study's findings.

CHAPTER 7: DISCUSSION AND CONCLUSION

7.1 Introduction

To prevent foodborne disease outbreaks, the World Health Organisation (WHO) has identified 'five key' food handling factors: (a) improper cooking, (b) exploitation of storage temperature, (c) cross-contamination between cooked and raw food, (d) inadequate hygiene and sanitation, and (e) use of contaminated water and raw materials (Fontannaz-Aujoulat et al., 2019). Four of these five attributes were associated with individuals who handle food. As an endpoint in the food safety chain, domestic food handlers are responsible for 50 - 87% of foodborne disease (FBD) outbreaks (Saeed et al., 2021). However, due to misinterpretation and underreporting, the exact burden of FBD is unknown, particularly in low-middle-income countries (LMIC) such as Bangladesh (Ishra et al., 2022; WHO, 2016). Even though FBDs have had significant negative consequences on health around the globe (Medeiros et al., 2011; Ishra et al., 2022), the recently discovered COVID-19 pandemic has affected food safety awareness and practises (Galanakis, 2020). Experts advised various personal hygiene measures, such as hand washing, to prevent the spread of this viral transmission and cross-contamination among food handlers during this pandemic. Knowledge and attitudes towards health issues may be used as health behaviour predictors to analyse consumer health behavioural patterns in emergencies such as the COVID-19 pandemic (Salehi et al., 2022). Therefore, this study undertook a cross-sectional and descriptive survey with 503 household food handlers aged 18 years or above who cooked meals at least 2-4 times/week. This thesis mainly compares the domestic food handlers' knowledge, attitude, practice and risk perception towards food safety before and after the onset of the COVID-19 pandemic. The findings from this thesis may be valuable for the government, policymakers and researchers to understand food handlers pre- and post-pandemic food safety knowledge, attitude, practice and risk perception that will help in gathering pertinent information to implement food safety actions and investigate the impact of an emergency health condition on consumer understanding of food safety. The following discussion briefly highlights findings from Study 1, study 2, study 3, and Study 4, presented elaborately in chapters 3, 4, 5 and 6.

7.2 Summary of the key findings

A total of 503 people participated, and 253 (50.3%) and 250 (49.7%) were from urban and rural regions, respectively. 90.3% of responders from both districts were female, 69.4% were housewives, and 39% were between 30 and 39 years old. More than 45.3% and 40.4% of respondents indicated having a family of three to five people and one to two children, respectively. Most urban participants (96.6%) reported having a master's degree or above and making more than 100,000 Bangladeshi Taka per month (56.1%). The majority of rural participants reported having at least a primary or secondary education (71.6%), and a monthly income of between 20,000 and 39,000 Bangladeshi Takas (72%).

The major findings of the present research are divided as follows:

Study 1

This study sheds light on Bangladeshi domestic food handlers' pandemic-related knowledge and hygiene behaviour (PRKHB). Less than half (50%) of the food handlers showed better knowledge while inquiring if coronavirus can be transmitted through food or is thermolabile and can deactivate in traditional high-temperature cooking (70 0C). This survey found that only 38.8% of food handlers reported washing their hands after arriving home or before preparing meals every time, despite frequent hand washing being highly encouraged during the pandemic. This suggests that food handlers' hand hygiene practices have regressed to pre-pandemic levels. In total, 62% of domestic food handlers showed poor PRKHB in Bangladesh. This study revealed that one-third of food handlers (35.8%) were more aware of food safety issues due to the COVID-19 pandemic. The study found that food safety concern has a positive association with the PRKHB, while respondents who lived in rural areas were negatively associated with the PRKHB. In this study, 72.3% of domestic food handlers residing in urban locations indicated a good level of PRKHB; in contrast, a small percentage of rural participants were able to answer correctly about PRKHB queries, for example, disinfecting (4.3%) or disposing (2.6%) of food packages, hand hygiene (4.6%), or storing food in refrigerators (1.2%). Food handlers aged between 50 years and over and male had shown higher PRKHB than others, while food handlers who lived with vulnerable people (e.g., living in a large family or with six or more children) found poor PRKHB.

Study 2

This study compares Bangladeshi domestic food handlers' pre- and post-COVID-19 food safety knowledge (FSK) by measuring knowledge of their personal hygiene, cross-contamination, safe storage, foodborne disease and temperature control. The findings of this study indicate that the majority (89.9%) of Bangladeshi domestic food handlers had poor personal hygiene knowledge in the pre-pandemic period. In the post-pandemic period, the percentage slightly declined (63.6%) because 99.0% of food handlers showed a higher understanding of hand washing. A small percentage of food handlers demonstrated a correct knowledge about foodborne pathogens such as Hepatitis A virus*, E. coli, Salmonella and Staphylococcus* in pre- (11.1%) and post-pandemic (10.9%) responses. Both pre-and post-pandemic results suggested that most (more than 80%) of the food handlers were unaware of the consequences of consuming high-risk foods such as poached eggs and raw milk during pregnancy or FBDs that may result in abortion in pregnant women. More than half (50%) of the participants showed poor knowledge of cross-contamination, safe storage, foodborne disease and temperature control knowledge, and there was no significant difference between pre- and post-pandemic responses in these parameters. However, the overall pre- and post-pandemic food safety knowledge levels (FSK) showed significant differences. Only 28.8% of food handlers demonstrated good food safety knowledge during the pre-pandemic, but this figure considerably increased to 38.2% following the pandemic outbreak. In the sociodemographic analysis, this study revealed that food handlers 50 years and over, men, higher family incomes, university graduates, families with 0-2 children, families with 3-5 members, and urban respondents had a good understanding of food safety both in pre-and post-pandemic.

Study 3

This study explores pre- and post-pandemic food safety attitudes (FSA) and self-reported practises (SRP) of food handlers related to cleaning and hygiene, cross-contamination, storage and cooking in the domestic environment and assesses adult food handlers' food safety risk perception. The results showed that Bangladeshi food handlers' "cleaning and hygiene", "storage and cooking", and overall food safety attitude (FSA) have significantly improved in the domestic kitchen, except for their attitude towards "cross-contamination" in the wake of the COVID-19 pandemic. Overall, during the pre- and post-pandemic periods, 82.7% and 87.1% of participants had a satisfactory level of FSA, respectively. The respondents' hand-

washing behaviour supports good "cleaning and hygiene" practices (pre: 77.7%, post: 83.3%) level. However, they had shown low self-reported food safety practices (SRP) in "cross-contamination" and "storage and cooking" practices. Only 7.8% of participants in this study's pre- and post-pandemic results indicated that they always or frequently used different cutting boards and knives to slice raw meat and cut fruits and vegetables. Both in pre- and post-pandemic responses, over 70 % of participants mentioned that they had never thrown defrosted food once it was thawed. Above 55% of individuals demonstrated a low SRP for overall food safety before and during the pandemic. 58.7% of the food handlers in this study perceived that self-prepared food possesses a very low or low risk for foodborne disease (FBD). Contrarily, 98% of participants thought that food cooked by others, such as at restaurants, increased the risk of contracting FBDs. Higher education, income and urban residents showed good levels of FSA and SRP in pre- and post-pandemic times. Although women showed more FSA during the pre-pandemic, no significant gender differences were found in pre- and post-pandemic SRP levels. Perceived risk by self-prepared food was higher among food handlers in urban areas, aged between 50 years and above, highly educated individuals (Master's and above degree), and those who practised better food safety before and after the onset of the COVID-19 pandemic.

Study 4

This study examined how domestic food handlers' cross-contamination, storage and cooking-related food safety knowledge (FSK) influences their behaviour risk perception (BRP) and attitudes toward food safety (ATT) and food safety practices (FSP). The present research identified that food handlers' FSK positively influences their BRP ($\beta = 0.329$, $p < 0.001$). Food handlers' BRP was significantly and positively associated with FSP ($\beta = 0.532$, $p < 0.001$). This study found that FSK was significantly positively related to the BRP ($\beta = 0.221$, $p < 0.001$). Domestic food handlers' BRP partially mediated the relationship between FSK and FSP independently ($\beta = 0.175$, 95% CI: 0.06 to 0.141). ATT showed no direct relationship with FSK and independent mediation effect between FSK and FSP, however, the BRP was significantly positively associated with ATT ($\beta = 1.28$, $p < 0.001$). Significant correlation has been found between FSK, ATT, FSP and BRP among these domestic food handlers. This study revealed that domestic food handlers BRP and ATT partially mediate the relationship between FSK and FSP through a serial mediation pathway. (FSK → BRP → ATT → FSP: $\beta = 0.037$, 95% CI: 0.021 to 0.058).

7.3 Recommendations and policy implications

The results of this thesis contribute to the theory of consumer food safety behaviour. Exploring the adult consumer food safety KAP during the pandemic in Bangladesh contributes to the theory of consumer response to food safety during a public health event in the context of a developing country. This research extends the application of the knowledge-risk perception-attitude-practice model to the Bangladeshi domestic food handlers context. The results indicate that the model performs effectively in the Bangladeshi setting, demonstrating its applicability globally in preventing the spread of foodborne infections.

The results of this thesis have significant implications for policymakers. This research indicated that the domestic food handlers in Bangladesh had inadequate pandemic-related knowledge and hygiene behaviour (PRKHB) after the onset of the COVID-19 pandemic. The majority of rural residents (96.8%) showed an unsatisfactory level of pandemic-related knowledge and hygiene behaviour (PRKHB) compared to their urban counterparts (27.7%). Although rural residents were much more reluctant to hand washing after the emergence of the pandemic, urban individuals showed more responsiveness towards this personal hygiene measure. The policymakers should take this opportunity as a part of the behaviour change communication (BCC) strategy for the domestic food handlers so that the urban food handlers can maintain this hand-washing behaviour while raising awareness among rural individuals. Further, the government must ensure early dissemination of health-related strategies in urban and rural areas during health emergencies that might be achieved through encouraging digital learning processes, effective mass media communications, and building trustworthy relationships between local government health institutions and the mass people.

Although the food handlers in this study have indicated an overall positive food safety attitude in the pre-and post-pandemic period, their food safety knowledge and self-reported practices were unsatisfactory. Therefore, critical attention is necessary for cross-contamination, storage and cooking practices and foodborne disease-related knowledge. People must follow food safety regulations to stop foodborne disease (FBD) in this community. Therefore, the government and policymakers should implement food safety strategies, including the Hazard Analysis Critical Control Point (HACCP) concepts, to educate domestic food handlers and prevent all food hazards in the domestic kitchen. Besides, food handlers, inspectors, and consumers should be provided with instructions on the "Five Keys to Safer Food" to increase

food safety in this community. The government ought to insist that written teaching materials, such as flyers and handouts placed in grocery stores or local bazaars, be made available to adult consumers to educate them with crucial information about handling food safely before consumption. Additionally, policymakers should ensure that all grocery stores have access to food safety education resources that can help raise awareness of the signs of contracting a foodborne disease and promote understanding of food safety in the domestic environment.

Even though this study identified that food safety knowledge, attitudes and practices among food handlers significantly improved during the COVID-19 pandemic, they did not consider their domestic kitchen risk of foodborne infection; contrarily, they thought that food cooked at restaurants or by others increased the risk of contracting an FBD. one strategy to enhance food safety practise is to designing focused communication tactics to directly raise individual awareness of the risk associated with their existing food-handling practises. The findings imply that raising awareness of the risks associated with present unsafe food handling practices may encourage people to take more precautions in their food safety behaviour. In other words, it could be necessary for people to have less optimism about their current methods of handling food. Lowering the optimism bias would encourage people to look for and be receptive to new knowledge to enhance their food-handling practices. Hence, programs should heighten the perception of FBD and the necessity of personal responsibility to lower the 'optimistic bias' and 'illusion of control' for adopting a risk-reducing food safety behaviour at home. Further, identifying food safety risks should be addressed in this community.

As this study observed a significant increase in overall food safety knowledge, attitudes and self-reported practices after the COVID-19 pandemic emergence, the government should also promptly develop food safety guidelines for household food handlers to improve and maintain post-pandemic food safety behaviour. A newly formed food safety authority in Bangladesh has started monitoring food safety issues, but most of the focus has been on the food supply chains, ignoring the area of household food handling. Effective and organized education is necessary for domestic food handlers to prevent FBDs in themselves and their families. The earlier study mentions that fear-based messaging is most effective when it incorporates a message proposing a new, easily implemented effective practice while emphasizing the insufficiency of current practices (Evans et al., 2020). Nonetheless, prudence is advised when developing and executing these campaigns, as they may foster a fixed perception, have ethical and psychological implications, and prompt inattention, aggression and defensive avoidance.

The present research highlights that launching food safety knowledge education alone to reduce the knowledge-practice gap is insufficient. To enhance food safety practice, design focused communication tactics to raise individuals' risk perception and attitude associated with their existing food-handling practises. The findings imply that increasing behaviour-specific risk perception with present unsafe food handling practices will enhance their attitude level and, in turn, may encourage people to take more precautions in their food safety practices. On a national level, the government may implement regulations focused on education and awareness campaigns for food safety. For example, the government might insist on local NGOs in rural areas and government community clinics such as UPHCSDP (Urban Primary Health Care Services Delivery Project) to develop a food safety education corner along with their adolescent counselling corner (UPHCSDP - II, n.d.) for counselling of riskiest food safety behaviour (e.g., drinking raw milk, eggs or date juice) according to the guidelines from Bangladesh Food Safety Authority.

The study's outcome is significant in identifying the most appropriate individuals for interventions based on observable demographics that regulators can monitor. For example, individuals who were young, low educational background and resided in rural areas indicate an unsatisfactory level of food safety risk perception, knowledge, attitude and practice. As a low-middle-income country, urban and rural disparities are much more pronounced in Bangladesh. The findings of this study call for the attention of government agencies, policymakers and researchers to implement significant initiatives in well-structured educational programs, with particular emphasis on high-risk groups (such as young people, those with low educational backgrounds, and individuals residing in rural areas). Policymakers should start food safety education during childhood by including food safety guidelines in formal education to spread the message to the masses, particularly to develop awareness in rural regions.

Prior research revealed that the favoured method for acquiring knowledge about food safety was through small group sessions on food safety and nutrition, printed materials, and cooking shows on television (Parra et al., 2014). Cooking programs might incorporate tailored recommendations for the community, such as guidelines on defrosting raw meats, which could involve emphasising the hazards of defrosting raw fish, poultry or meat in the sink, educating individuals on sanitisation practices between uses, using separate cutting boards for vegetables and meat and reinforcing existing messages on the dangers of salmonella in raw eggs. Although

many consumers were dependent on the internet and social media during the pandemic for regular health updates, within the scope of food safety, social media has yet to replace traditional media. The increase in personalisation on social media may cultivate a forthcoming era in which food safety messages can be customised to individuals based on their previous online interactions. Such personalisation allows policymakers to leverage psychometric findings to influence food safety behaviours through targeted messaging. Social media's shortcoming is its potential to disseminate inaccurate or false information from multiple sources through various channels, potentially damaging the original message's reliability and legitimacy (Evans et al., 2020). The results of this study suggest that researchers, educators, food safety communicators, and the media devote their time and resources to conceptualising and developing programmes that teach domestic food handlers about food safety procedures and enable them to apply knowledge in a real-life context.

7.4 Limitations

The limitations of this study should be considered when evaluating the findings. The convenience sample approach used in this study presents the first weakness, hence, the findings cannot be generalised to all domestic food handlers in Bangladesh. Future research should also consider using a bigger sample size and a more representative sample to improve generalizability. Another limitation of the current study is the cross-sectional nature of the study. Since cross-sectional studies are intrinsically nonrandomized, and it is not always possible to identify the directionality of linked variables, this is their main shortcoming since it prevents the conclusion of causation. The limitations of the study were mitigated as much as possible by collecting a large sample size of data. Nonresponse and recall bias were compensated by collecting data from trained research assistants and providing enough time for the respondents to recall. According to Cunha et al. (2022), the KAP model has some limitations. Firstly, this model attempts to explain a complex phenomenon such as safe food handling with only two variables, knowledge and attitudes and disregards several well-known cognitive factors that affect health behaviour, such as risk perceptions, beliefs, and motivation. This current study utilised risk perception variables such as general and behavioural risk perception to alleviate such issues. Secondly, the correlation between KAP varied among different research and contexts. This research conducted several regression and mediation analyses among constructs such as attitude and behaviour risk perception as mediators to

overcome this limitation. The third limitation is the measurement of practices, a common problem with studies measuring actual practices and behaviour. Some studies have highlighted the discrepancy between food safety self-reported and observed practices. When surveys on behaviour or practice in a large population, self-reported data is more feasible than observation. Finally, the reliability and validity problem has been approached by using known scales and constructs, and each KAP construct and subconstruct was under assessment for reliability check (Cronbach's alpha) (Cunha et al., 2022).

7.5 Future research

Additionally, further information is essential about food handlers' actual practices, as opposed to self-reported ones, which can be accomplished by more precisely measuring food-handling habits using observational approaches. Future research will use qualitative methods to understand the factors that promote and obstruct food safety practices. Future studies can examine the perceived obstacles that consumers face in obtaining knowledge about food safety. Future studies may use alternative theoretical viewpoints, such as the Hazard Analysis and Critical Control Point (HACCP), to further confirm the importance of the results of this study.

The current study noticed specific alterations in the behaviours of food handlers at a particular period when individuals were more aware of the epidemic and its effects. Although this data offers significant insight into a certain period of time, it will be fascinating to see whether food handlers continue to adopt the behavioural modifications they made during the epidemic (such as 'always' washing their hands). This information provides crucial context for a particular time period, but if food handlers continue to behave differently in the future—for example, by constantly washing their hands—it will be remarkable to observe. Therefore, it would be vital to notice the long-term effects of the pandemic on whether expected behavioural changes will occur and be sustained.

This empirical analysis limits the mapping of behaviour-specific risk perceptions to a single psychometric variable. Future researchers contemplate extending previous data-gathering initiatives to evaluate risk perceptions as a multidimensional notion and observe the discrepancy between what people say they do and direct observation of what they actually do. Further, exploring the effectiveness of behaviour-specific risk communication strategies and

identifying behaviour-specific food safety risks should be addressed in this community. Future studies endeavour to enhance this serial mediation effect of food safety risk perception and attitude by employing a risk perception attitude framework (RPA) for a better understanding of the effect.

7.6 Conclusion

This research examined the adult food handlers' food safety knowledge, attitude and practice (KAP) level before and after the emergence of the COVID-19 pandemic and measured their food safety concerns and pandemic-related food knowledge and hygiene behaviour (PRKHB) within the domestic environment in Bangladesh. This study also evaluated the difference between pre-pandemic and post-pandemic food safety KAP levels and investigated adult food handlers' general risk perception and behaviour-specific risk perception towards food safety in the domestic environment in Bangladesh. Further, this research inquired into the association between adult food handlers' food safety KAP and behaviour-specific risk perception within the domestic environment in Bangladesh. This research revealed good pandemic-related knowledge and hygiene behaviour (PRKHB) among urban food handlers; however, an enormous knowledge gap has been observed in this community, especially in rural areas. Although this current research found overall significant improvement in the food handlers' food safety KAP during the post-pandemic times and showed a positive attitude towards food safety before and after the onset of the pandemic, their food safety knowledge and self-reported practices were unsatisfactory in both of the times. Considering food safety risk perception, most domestic food handlers did not consider their home kitchen a risky place for FBD and perceived that food prepared by others (e.g., restaurants) was more dangerous than by themselves. Further, this research revealed that food handlers' behaviour-specific risk perception and attitude towards food safety influence their food safety knowledge on practice through a sequential pathway. The data derived from this study suggests the necessity for expanded consumer education regarding knowledge, attitudes, and practices about food safety. The government should contemplate a more focused distribution of food safety information to maximise the specific advantages, particularly to individuals in the lower socioeconomic bracket. Furthermore, the initiation and execution of food safety-related initiatives should be undertaken to enhance food safety practices, with the overarching objective of mitigating foodborne illnesses in Bangladesh.

Lastly, the COVID-19 pandemic has brought enormous changes and challenges in all aspects of life. These modifications provide valuable lessons on how to prevent or minimise the risk of future health emergencies. COVID-19 has caused a paradigm change in safe food practices and strengthened workers' and consumers' safety behaviours. The community of food scientists and technologists will be in a position to proactively plan and support the resurgence of the food industry in the years to come. Even though science has made great strides and led to the creation of several medications and vaccinations, the phenomena of globalisation have created a network of links between individuals worldwide that aid in the spread of disease. This situation presents both opportunities and challenges in terms of food safety. The interconnectedness of food supply chains across multiple countries means that a localized outbreak of a foodborne illness can quickly escalate into a global public health challenge. Therefore, cooperation with other related disciplines and stakeholders will be necessary to guarantee that the food supply chain is prepared to respond to the fight against FBDs.

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APPENDIX A

Example of survey information sheet for the research participants

Participant Information for USQ Research Project Questionnaire

Project Details

Title of Project:	Food safety: knowledge, attitude, practices (KAP) and the impact of COVID 19 on food safety behaviour among consumers in Bangladesh
Human Research Ethics Approval Number:	HXXREAXXX

Research Team Contact Details

Principal Investigator
Rakia Hossain
[redacted]

Principal Supervisor
Dr. Rasheda Khanam
[redacted]

Associate Supervisor
Professor Jeffrey Soar
[redacted]

Description

This project is being undertaken as part of Doctor of Philosophy program.

The purpose of this project is to examine both pre-pandemic and pandemic food safety knowledge, attitude, and practices of adult consumers within the domestic environment to compare any changes and examines their association with food safety concern and food hygiene practices related to the pandemic.

The research team requests your assistance because you are a Bangladeshi and above 18 years old.

Participation

Your participation will involve completion of an online or a face-to-face questionnaire that will take approximately 15 - 20 minutes of your time. For example, questions in the survey will include:

- Perceptions of COVID transmission by food - " Does Coronavirus (COVID 19) transmit by food?"
- Food preparation practices and knowledge - "Do you use same cutting boards or knife to slice raw meat and to cut fruits and vegetables?"
- Food consumption practices and knowledge
- Attitudes to food safety

Your participation in this project is entirely voluntary. If you do not wish to take part, you are not obliged to. If you decide to take part and later change your mind, you are free to withdraw from the project at any stage. You may also request that any data collected about you be withdrawn and confidentially destroyed. If you do wish to withdraw from this project or withdraw data collected about you, please contact the Research Team (contact details at the top of this form).

Your decision whether you take part, do not take part, or to take part and then withdraw, will in no way impact your current or future relationship with the University of Southern Queensland.

Expected Benefits

It is expected that this project will not directly benefit you. However, it may benefit to the theory on consumer food safety behaviour, as well as in future research related to this area. it may also help the safe food policy makers and other stakeholders of Bangladesh for the better planning and implementation of food safety in Bangladesh.

Terms and Conditions of Prize Draw Entry

1. The prize draw is being run by University of Southern Queensland researcher to encourage participation in a questionnaire on food safety knowledge, attitude and practice within the domestic environment in Bangladesh.
2. By electing to participate, you accept these terms and conditions as governing the prize draw. To enter the prize draw please provide your details on the next page. Any personal information you provide to us in the course of entering the prize draw will be dealt with by us in accordance with our privacy policy (published at: http://policy.usq.edu.au/documents/13404PL).
3. Five gift vouchers each containing $50 AUD (Total $250 AUD) will be awarded in the prize draw.
4. There is no cost to you for entry into the competition.
5. To enter the prize draw you must: a) complete the prize draw entry form b) participate into this research activity. However, failure to fully complete the participation requirements (for example, but not limited to, completion of a survey) and/or withdraw from the Research Activity early will not disqualify from entry into the prize draw.
6. You may only submit one entry in the prize draw.

7. All survey and other materials provided by you becomes our property. No responsibility is taken for late, lost or misdirected surveys or entries.
8. Following the closing date, the prize winner will be selected randomly from valid entries received. Each entry can only be drawn once.
9. Subject to system malfunction, the draw will occur on December 1st, 2021. If the systems supporting the draw are not functioning as they should when the draw is due, the draw will be held as soon as possible once the systems become functional again.
10. Prize winner names will not be published.
11. The prize winner will be sent an SMS to the mobile number they have provided in the prize draw entry form during the survey. After acknowledging receipt of the prize draw notification (maximum within twenty-one (21) days of receipt of prize draw notification), winner will be sent the prize (e.g., online gift voucher) through the nominated mobile number. The sms will be sent to the prize winner within two weeks of the draw.
12. If the prize is not successfully claimed, a second chance draw will occur as the original draw within twenty-five (25) days of the expiry of the claim period. If the second draw prize is not successfully claimed, the prize will not be awarded.
13. Prizes cannot be substituted for another prize at the election of the prize-winner.
14. We do not accept any responsibility for late, lost, incomplete, incorrectly submitted, delayed, illegible, corrupted, or misdirected entries, claims or correspondence, whether due to error, omission, alteration, tampering, deletion, theft, destruction, transmission interruption, communications failure or otherwise.
15. We may suspend the promotion if we determine that the integrity or administration of the promotion has been adversely affected due to circumstances beyond its control. We may disqualify any individual who tampers with the entry process.

Risks

In participating in the questionnaire, there are no anticipated risks beyond normal day-to-day living.

Privacy and Confidentiality

All comments and responses will be treated confidentially unless required by law. The information collected is confidential and will not be disclosed to third parties without your consent, except to meet government, legal or other regulatory authority requirements. A de-identified copy of this data may be used for other research purposes. However, your anonymity will at all times be safeguarded. A one-page summary report on the project findings will be provided to the online platform from where the survey participants selected and If you would like to receive a brief summary of the study findings, please contact Rakia Hossain [redacted]

Any data collected as a part of this project will be stored securely as per University of Southern Queensland's Research Data Management policy.

Consent to Participate

In case of face-to-face survey, a written consent is required from you before participating in this study. In providing your consent, you confirm that you have read this information sheet and understand why the study is being conducted and any potential risks to you.

If you are an online participant, clicking on the 'Next' button at the end of the consent form is accepted as an indication of your consent to participate in this project.

Questions or Further Information about the Project

Please refer to the Research Team Contact Details at the top of the form to have any questions answered or to request further information about this project.

Concerns or Complaints Regarding the Conduct of the Project

If you have any concerns or complaints about the ethical conduct of the project, you may contact the University of Southern Queensland Manager of Research Integrity and Ethics on +61 7 4631 1839 or email researchintegrity@usq.edu.au. The Manager of Research Integrity and Ethics is not connected with the research project and can facilitate a resolution to your concern in an unbiased manner.

Thank you for taking the time to help with this research project. Please keep this sheet for your information.

APPENDIX B

Example of survey questionnaire for the participants

Project Title - Assessing Consumer Food Safety Behaviour in Bangladesh: An Exploration of Knowledge, Attitude, Practices (KAP), and the Influences of COVID-19

Demographic variables	
Gender	Female Male
Age	18 - 29 30 - 39 40 - 49 50 and above
Education	Secondary (year 6 - 10) College (year 11 - 12) University (Honours) University (Masters and above)
Occupation	Student Housewife Govt. employee Non-govt. employee Businessmen Unemployed
Monthly family income	< 20,000 BDT 20,000 - 39,000 BDT 40,000 - 59,000 BDT 60,000 - 79,000 BDT 80,000 - 99,000 BDT > 100,000 BDT
Number of persons in the family	1 - 2 3 - 5 6 and more
Number of children in the family	0 1 2 3 4 and more
Place of residence	Urban (e.g., City) Rural (e.g., District, Upazilla, village)

Food safety concern	**Yes**	**No**
1. I am more aware of food safety because of COVID 19.	1	2
2. I am concerned about the safety of food.	1	2
3. The quality and safety of food nowadays concerns me.	1	2
Pandemic related knowledge and hygiene behaviour	**Yes**	**No**
1. Does Coronavirus (COVID 19) transmit by food?	1	2
2. Can Store food in the refrigerator (4-8°C) disable the Coronavirus?	1	2
3. Can High-temperature heating (70°C) inactivate viruses, including the Coronavirus?	1	2
4. Do you use gloves and wash hands rather than sanitizing the packages after purchasing food?	1	2
5. Do you dispose of all food and ready-to-eat foods shopping bags?	1	2
6. Do you disinfect food packaging before storing it at home?	1	2

7. Do you Wash hands after returning home?	1	2

Food safety knowledge	What did you think before COVID 19					What do you think now during COVID 19				
Knowledge of Personal hygiene	strongly disagree 1 strongly agree 5					strongly disagree 1 strongly agree 5				
1. Hand washing before and after cooking reduces the risk of food contamination.	1	2	3	4	5	1	2	3	4	5
2. 20 seconds duration is enough for hand washing.	1	2	3	4	5	1	2	3	4	5
3. It is necessary to wash hands after touching your body parts.	1	2	3	4	5	1	2	3	4	5
Knowledge of Cross contamination										
1. Uncovered abrasion or cuts can cause cross contamination of food.	1	2	3	4	5	1	2	3	4	5
2. It is not necessary to wash the knife that has been used to cut raw meat with soap and water before using it again.	1	2	3	4	5	1	2	3	4	5
3. Storing raw and cooked food together can cause food contamination.	1	2	3	4	5	1	2	3	4	5
Knowledge of Safe Storage										
1. Leftover food smelling good is still safe to eat.	1	2	3	4	5	1	2	3	4	5
2. It is fine to keep leftover food in the fridge for more than 2 days.	1	2	3	4	5	1	2	3	4	5
3. Store leftover food on the table or kitchen shelf.										
Knowledge of Foodborne Disease										
1. Abdominal pain, diarrhoea, vomiting, nausea are foodborne illnesses symptoms.	1	2	3	4	5	1	2	3	4	5
2. Headache is a symptom of foodborne illnesses.	1	2	3	4	5	1	2	3	4	5
3. Children, pregnant women and older people are more at risk of foodborne illnesses.	1	2	3	4	5	1	2	3	4	5
4. Can abortion in pregnant women be induced by food-borne disease?	1	2	3	4	5	1	2	3	4	5
5. Poached egg, raw milk and soft cheese are good for pregnancy.	1	2	3	4	5	1	2	3	4	5
6. Microorganisms can be found on skin, nose and mouth of healthy handlers.	1	2	3	4	5	1	2	3	4	5
7. Hepatitis A virus, *Salmonella and Staphylococcus* are foodborne pathogen.	1	2	3	4	5	1	2	3	4	5
8. Inadequate cooking of raw food (meat, chicken, vegetable) can cause outbreak of food borne illness.	1	2	3	4	5	1	2	3	4	5
Knowledge of Temperature Control (TC)										
1. -18 degree C or below is the optimal temperature for freezing food.	1	2	3	4	5	1	2	3	4	5
2. 1 - 5 degree C is the refrigerator operating temperature.	1	2	3	4	5	1	2	3	4	5
3. Bacteria that causes food poisoning multiply rapidly at a temperature of 37 °C.	1	2	3	4	5	1	2	3	4	5
4. Bacterial growth accelerates at a temperature of 75 °C.	1	2	3	4	5	1	2	3	4	5
Food safety Attitude	**What was your attitude before COVID 19**					**What is your attitude now during COVID 19**				
Cleaning and hygiene	Never 1 always 5					Never 1 5				always
1. I wash my hands before and after cooking?	1	2	3	4	5	1	2	3	4	5
2. I wash my hands before handling raw food?	1	2	3	4	5	1	2	3	4	5
3. I use my hand to cover mouth while coughing or sneezing?	1	2	3	4	5	1	2	3	4	5
5. I wash fruits and vegetables before eating?	1	2	3	4	5	1	2	3	4	5
7.Do you wash eggs before cooking or frying them?	1	2	3	4	5	1	2	3	4	5

10.Do you wash dishes with detergent before preparing food?	1	2	3	4	5	1	2	3	4	5
Cross contamination										
1. I wear accessories like rings, bracelets when cooking food?	1	2	3	4	5	1	2	3	4	5
2. I cover your cut with bandage and use gloves?	1	2	3	4	5	1	2	3	4	5
3. I taste and dish out food with unprotected hands?	1	2	3	4	5	1	2	3	4	5
Storage and cooking										
1. I read conditions of use and storage of packaged food	1	2	3	4	5	1	2	3	4	5
2. I prefer half-boiled or half-cooked eggs	1	2	3	4	5	1	2	3	4	5
3. I consume the food that has expired	1	2	3	4	5	1	2	3	4	5
4.I think thermometer is necessary to keep in the refrigerator	1	2	3	4	5	1	2	3	4	5
Food safety Practice	**How did you practice before COVID 19**					**How do you practice now during COVID 19**				
Cleaning and hygiene	Never 1				always 5	Never 1				always 5
1. Do you wash hands with soap after using the toilet?	1	2	3	4	5	1	2	3	4	5
2. Do you clean the food preparation area daily?	1	2	3	4	5	1	2	3	4	5
3. Do you wash/sanitize hands after sneezing and coughing each time?	1	2	3	4	5	1	2	3	4	5
4. Do you clean the kitchen sink after every wash?	1	2	3	4	5	1	2	3	4	5
Cross contamination										
1. Do you use same cutting boards or knife to slice raw meat and to cut fruits and vegetables?	1	2	3	4	5	1	2	3	4	5
2. Do you store raw and cooked food together?	1	2	3	4	5	1	2	3	4	5
3. Do you store raw meat at the lower shelf of the fridge (not freezer) in your house?	1	2	3	4	5	1	2	3	4	5
4. Do you use same towel to wipe kitchen surfaces and to dry your hands?	1	2	3	4	5	1	2	3	4	5
Storage and cooking										
2. Do you cover and place the meal at room temperature, if your family member is going to be several hours late for a hot meal?	1	2	3	4	5	1	2	3	4	5
3. Do you reheat leftover food until it is boiling hot?	1	2	3	4	5	1	2	3	4	5
4. Do you defrost frozen food or meat/chicken by leaving it in the fridge for a few hours?	1	2	3	4	5	1	2	3	4	5
5. Do you thaw frozen food by putting it under running water for 1 hour?	1	2	3	4	5	1	2	3	4	5
6. Do you keep defrosted food in the freeze again?	1	2	3	4	5	1	2	3	4	5

General Risk perception	very low 1				very high 5
1. What is the risk of acquiring foodborne illness from consuming food you have prepared in your own home?	1	2	3	4	5
2. What is the risk of acquiring foodborne illness from consuming food prepared by other people (e.g., friends, family) in their own homes?	1	2	3	4	5
3. What is the risk of acquiring foodborne illness from consuming food from restaurants?	1	2	3	4	5
4. What is the risk of acquiring foodborne illness from consuming food from domestic kitchen?	1	2	3	4	5
Behaviour specific risk perception	1	2	3	4	5
1. What is the risk of acquiring foodborne disease if you do not heat food properly (e.g., consuming raw milk or egg)?	1	2	3	4	5
2. What is the risk of acquiring foodborne disease if you use the same cutting board or knife to slice raw meat and to cut fruits and vegetables?	1	2	3	4	5
3. What is the risk of acquiring foodborne disease if you keep food in the room temperature for more than 2 hours?	1	2	3	4	5

APPENDIX C

Appendix C contains the published paper in a Q1 journal that was written during the PhD but not included in this thesis.