



Impact of COVID-19 on Chinese urban consumers' food safety knowledge and behavior – A comparative study between pre and post pandemic eras

Ke Wang^{a,b}, Lei Cong^{c,d}, Miranda Miroso^{b,d}, Lan Bai^e, Yakun Hou^{a,b,*}, Phil Bremer^{b,d,**}

^a College of Food Science and Technology, Hebei Agricultural University, Baoding, China

^b Department of Food Science, University of Otago, Dunedin, New Zealand

^c Department of Agribusiness and Markets, Lincoln University, Lincoln, New Zealand

^d New Zealand Food Safety and Science Research Centre, Massey University, Palmerston North, New Zealand

^e College of Economics and Management, Hebei Agricultural University, Baoding, China

ARTICLE INFO

Keywords:

COVID-19

Chinese consumers

Food safety

Household environment

Food poisoning

Negative impact

ABSTRACT

The COVID-19 pandemic caused notable changes to the food-related habits of consumers worldwide due to their concerns about the risk of infection and the requirement to follow government mandates. To investigate the impact of the pandemic on Chinese consumers' food safety knowledge, food safety behaviors, and their most recent food poisoning experiences, we compared the results from an online survey (n = 583, Dec 2019) conducted before the pandemic was officially announced with an identical survey (n = 599, Aug 2023) conducted seven months after the Chinese government downgraded restrictions related to COVID-19. Post-pandemic there was a significant decrease in consumers' food safety knowledge and self-reported food safety behaviors and a significant increase in their self-reported experiences of food poisoning. Despite respondents stating that their food safety knowledge and behaviors had improved since the start of the pandemic, the data obtained from the two surveys and the respondents self-reporting of foodborne illness suggest that in fact their safety knowledge and behaviors had decreased. These findings highlight the need to reinforce food safety education and behaviors during times when the food system is disrupted, and consumers are focusing on what they perceive to be more immediate issues.

1. Introduction

The health and economic impacts of the SARS-CoV-2 coronavirus and the respiratory illness (COVID-19) it caused cannot be overstated. Since the initial reports of illness in 2019, more than 771 million cases have been confirmed with nearly 7 million deaths worldwide (World Health Organization [WHO], 2023). Owing to its high rates of infection, hospitalizations, and deaths, governments all over the world faced formidable challenges to curb the spread of the virus (Ding & Zhang, 2022). Despite the dedicated and collaborative efforts of governments, professionals, and the global community, the virus has yet to be eradicated. Beyond its status as a public health concern, the onset of COVID-19 caused notable changes to the food-related habits of many consumers. These changes have been attributed to the highly contagious nature of the virus, initial but ultimately unfounded concerns that the

virus was being transmitted by food or food packaging (WHO, 2020a), and consumers' strict adherence to government restrictions, such as social distancing (Ferreira Rodrigues et al., 2021).

One of the most obvious changes to food habits during the pandemic was a dramatic reduction in the frequency of dining out, either to purposely reduce the risk of infection or owing to the decreased accessibility of restaurants owing to lockdowns and market closures (Wang et al., 2022). As more people chose to cook and eat at home during the pandemic (International Food Information Council, 2020), the consumption of home-prepared food significantly increased (Coulthard et al., 2021). However, it is worth noting that the home environment is considered to be an important site for the spread of many foodborne diseases (Langiano et al., 2012), and mishandling of food and poor personal hygiene are major causes of foodborne illnesses (Kamboj et al., 2020). Despite the well-recognized importance of appropriate food

* Corresponding author at: College of Food Science and Technology, Hebei Agricultural University, Baoding, China (Y. Hou).

** Corresponding author at: Department of Food Science, University of Otago, PO Box 56, Dunedin 9054, New Zealand (P. Bremer).

E-mail addresses: kewang_nz2018@outlook.com (K. Wang), lei.cong@lincoln.ac.nz (L. Cong), miranda.miroso@otago.ac.nz (M. Miroso), bailan@hebau.edu.cn (L. Bai), houyakun@hebau.edu.cn (Y. Hou), phil.bremer@otago.ac.nz (P. Bremer).

<https://doi.org/10.1016/j.foodres.2024.114905>

Received 21 February 2024; Received in revised form 8 August 2024; Accepted 9 August 2024

Available online 10 August 2024

0963-9969/© 2024 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

handling practices, the COVID-19 pandemic changed consumer's food safety priorities towards practices designed to reduce their risk of becoming infected with SARS-CoV-2. In a 2020 annual survey of 1011 United States consumers by the International Food Information Council, it was found that consumers' greatest concern was food handling/food preparation related to the risk of contracting COVID-19, while concerns about what were the top four food safety issues in 2019—namely: food-borne illness from bacteria; chemicals in food; carcinogens or cancer-causing chemicals in food; and pesticides/pesticide residues—all decreased (International Food Information Council, 2020). Although little evidence was presented that the SARS-CoV-2 virus could be transmitted via food or its packaging, many studies have focused on the importance of improvements in handwashing and disinfecting the surface of food packaging materials (Han et al., 2021; Liu et al., 2022). However, the positive changes in consumers' hygienic behavior designed to reduce their risk of COVID-19 might not result in the improvement of appropriate food handling practices. On the contrary, with the focus being on the impact of COVID-19 on their health, household food safety practices could have waned, increasing their vulnerability of contracting foodborne diseases.

To make things worse, consumers also faced increased difficulties in maintaining good food safety practices in their homes as food became less affordable due to a decrease in their income (Bundervoet et al., 2022) and an increase in the price of many food items (Ruan et al., 2021), and less available due to disruptions to food supply chain caused by lockdowns (Li et al., 2022). In 2019 and 2020, a study on 2631 households in the rural areas of nine provinces in China reported a negative correlation between confirmed cases of COVID-19 and the intake of dietary energy, carbohydrates, fats, and proteins (Han et al., 2022). A further study in 2020 on 1209 urban consumers in China found that they were willing-to-pay 30% more for fresh vegetables and 11 % more for meat products due to their concerns about possible disruptions to their supply and increased costs in the food supply chain (Yue et al., 2021). Moreover, to avoid direct human contact while shopping, consumers had reduced their shopping frequency and increased the quantity of food purchased during each shopping event (Schmidt et al., 2021). Further, consumers had started to hoard food in their homes in response to potential future lockdowns (Wang & Hao, 2020). Consequently, food products were being stored in less-than-ideal environments for extended periods of time, thereby increasing the potential risks of people consuming food that may have become spoiled and/or unsafe. It has previously been reported that improper storage is a significant factor in the incidence of foodborne illness (Kamboj et al., 2020).

Hence, during the initial stages of the COVID-19 pandemic the food safety environment became more challenging, and consumers' food safety knowledge and food handling practices became more critical. Unfortunately, in contrast to the information provided to food catering businesses, little food safety information was provided to consumers during the pandemic. In an ethnographic study on 14 Italian households, which involved kitchen mapping, observations, and interviews, a number of inappropriate food preparation, consumption, and storage practices were revealed which had the potential to expose consumers to increased microbiological and chemical risks (Menini et al., 2022). In China, in 2018, a year before the start of the COVID-19 pandemic, a national survey assessing the knowledge, risk perception and food-handling behaviors of 1,780 consumers revealed an already concerning situation, whereby Chinese consumers' on average only got 54 % of the questions testing their food-handling knowledge correct, with the majority of consumers not always implementing correct procedures for the handling of leftover food or the thawing of raw meat (Wang et al., 2021).

Upon the outbreak of the COVID-19 pandemic, the Chinese government attempted to control the spread of disease through the implementation of strict policies, such as its zero-case policy and all-staff nucleic acid testing (Ding & Zhang, 2022), with many of these policies

remaining in place for three years until the easing of COVID-19 management controls in early 2023. Chinese consumers living under COVID-19 concerns and controls for an extended length of time shifted their behaviors and habits as a means of adaptation, including their shopping behaviors (Chen et al., 2023) and nutrient intake (Han et al., 2022). However, no research has investigated potential changes in food safety behaviors among Chinese consumers during this period. There was a reduction in the reported incidence of foodborne diseases in China at the early stages of the COVID-19 pandemic (Administration, 2021), but it was unclear whether the reduction was the result of consumers' improved food safety behaviors or the decreased focus on the detection of enteric infections in hospitals.

Reflecting on human history, the frequency and severity of worldwide pandemics has increased, particularly since the onset of the 20th century (Piret & Boivin, 2021; Poorolajal, 2021). While little attention has generally been paid to food safety issues during global pandemics, the enduring COVID-19 pandemic presents a unique opportunity to address this gap. In December 2019, as part of a larger research project, we administered a survey to determine Chinese consumers' food safety knowledge, food safety behaviors, and experience of foodborne disease. By conducting an identical survey nearly 4 years after the start of the COVID-19 pandemic (August 2023), this approach allowed us to compare the pre-pandemic and post-pandemic data, and explore the impact of a global pandemic from the perspective of food safety for the first time. Grounded in prior research, the primary objective of this study was to investigate the potential impacts of the COVID-19 pandemic and its associated prevention policies on Chinese consumers' food safety knowledge and behaviors. The findings of this study will provide policymakers with insights on the impact that severe pandemics can have on food safety and facilitate the development of public health strategies during future global health crises that better acknowledge the consumers perspective.

2. Method

2.1. Study design and respondents' recruitment

A nationwide survey was conducted among Chinese urban residents at two different periods: 1) The pre-COVID survey was conducted in December 2019 as part of a larger questionnaire (Wang et al., 2022), right before the official announcement of the COVID-19 pandemic in January 2020 (Allam, 2020). The pre pandemic era is defined as the time when the pandemic had no recognized impact; 2) The post-COVID survey was conducted in August 2023 during the second wave of COVID-19 (China Daily, 2023). As the virus still exists, there has never been an official announcement of the end of the pandemic in China. The post pandemic era in this study is defined as the time after the official downgrade of COVID-19 related policies in China in January 2023 (Xinhua, 2023), after which consumers slowly started to return to their pre COVID-19 lives.

In both surveys, the questionnaire was formatted in Qualtrics (<https://www.Qualtrics.com>). Using the sample size calculator of Qualtrics, the study aimed to collect 601 responses to generate results to approximate 0.9 billion urban residents in China with 95 % confidence level and 4 % margin of error. A market research company, Dynata™ (Mike Petrullo; Shanghai, China), was hired to recruit respondents. To enable a degree of homogeneity between pre- and post-COVID surveys, questionnaires for both were distributed within Dynata™'s nation wide sample pool in China. Respondents were rewarded by Dynata™ upon successful conclusion of the questionnaire, and 650 completed responses were returned in both surveys. For the pre-COVID survey, national representative samples of the population based on gender and age were selected through Dynata's screening process and the quota function of Qualtrics. In addition, the distribution of respondent's income was considered, aiming to match the income distribution of Chinese urban residents. In the post-COVID survey, the same processes were applied to

ensure that the demographic characteristics between the two surveys groups were as similar as possible.

Ethics approval to conduct the study was granted by the University of Otago Human Ethics Committee (reference number D19/312). The information sheet and consent form were placed at the beginning of the questionnaire. Consumers from top-tier cities often have a demonstration effect on consumers from lower-tier cities (Song et al., 2015). Hence, respondents from first or second-tier cities were specifically chosen to serve as representative models for wider Chinese urban residents. Additionally, considering the focus of the study, individuals who regularly prepare meat were targeted. Among the respondents who agreed to take part in this study, only those who met the following criteria were allowed to proceed to answer further questions: 1) residents living in first-tier or second-tier cities; 2) respondents who cooked meat at home at least once every three months.

2.2. Instrument

There were four common sections in the questionnaire which was used in both surveys: 1) consumers' food safety knowledge; 2) consumers' food safety behaviors; 3) their experiences of the most recent food poisoning; 4) demographic information. Questions were worded positively and negatively in the construct of food safety knowledge and behaviors scales to decrease common method bias.

The section on consumers' knowledge of food safety contained two subsections, one testing consumers' general knowledge about foodborne bacteria and the other testing their knowledge about safe food handling practices. Each subsection consisted of 11 objective questions (K1_1-11 and K2_1-11), which were adopted from previous studies (Evans & Redmond, 2016; Low et al., 2016; Odeyemi et al., 2019; Sanlier, 2009). Respondents had to choose one of three options from 'true', 'false' or 'I don't know'.

The next section assessing consumers' food safety behaviors, contained 10 statements (B1-10), which were adopted from previous studies (Evans & Redmond, 2016; Medeiros et al., 2004; Odeyemi et al., 2019; Sanlier, 2009). Respondents were asked to choose the frequency at which they carried out a range of food safety related behaviors, using a Likert-7 scale with ratings from 1 = 'Never', 2 = 'Rarely', 3 = 'Occasionally', 4 = 'Sometimes', 5 = 'Frequently', 6 = 'Usually', to 7 = 'Always'.

Information on respondents' experience of food poisoning was obtained through two questions adopted from related literature (Carbas et al., 2013; Odeyemi et al., 2019), asking about their most recent food poisoning experience and their thoughts on the food that caused it. Demographic data requested was the respondent's gender, age, monthly income, and their education level.

There was one additional section consisting of four questions in the post-COVID survey, where respondents were asked if they paid more attention to food safety knowledge and behaviors, and their frequency of food poisoning during the COVID-19 pandemic (2020–2022) than before its start.

2.3. Reliability and validity

The questionnaire was initially developed in English based on existing research and surveys, and then translated into simplified Chinese (see [supplementary material](#)). Both the English and Chinese versions were proofread by three native speakers. A pilot study was conducted using native Chinese speakers, and their feedback on wording and structure was collected to improve the quality of the survey. Items measuring food safety knowledge, behaviors, and recent food poisoning experiences were analyzed using Harman's single-factor test (Podsakoff et al., 2003), and the 17.5 % total variance of a single factor (under 50 %) indicated the data was not affected by common method bias. Respondents' food safety knowledge and behaviors were represented in scales. Samples from both surveys were combined to validate these

scales through a range of tests before the scores were used to analyze their knowledge or behaviors.

2.3.1. Discriminating power

Discriminating power (DP) indicates how well a certain question separates respondents who know the correct answer from those who don't (Karim et al., 2021). To evaluate the discriminating power of the items assessing their food safety knowledge (true/false questions), the number of correct answers in the lower group (lowest 27 % scores) was subtracted from the number of correct answers in the upper group (highest 27 % scores), and divided by half of the total respondent number (Escudero et al., 2000). Items with discriminating power smaller than 0.2 are considered to be of poor quality and should be removed from the scale. In this study, the discriminating power for all the questions was above 0.2 (Table S1).

$$DP = \frac{\text{correct answers in the upper group} - \text{correct answers in the lower group}}{n/2}$$

Food safety behaviors were assessed using multiple-choice questions which were normally distributed (skewness index < |2.00| and kurtosis index < |7.00|). To evaluate their discriminating power, the scores of the lowest (27 %) and highest groups (27 %) were compared by the use of an independent *t*-test (Wang et al., 2021). The results (Table S2) showed that the scores between the lowest and highest groups were significantly different for every item, indicating an acceptable discriminating power.

2.3.2. Item fit and scale reliability

The item fit for the questions designed to test food safety knowledge was evaluated through Rasch analysis (David & Ida, 2019). Infit and Outfit mean square (MNSQ) between 0.5 and 1.5 indicates a good fit (Linacre, 2012); numbers beyond this range mean that there is too much predictable redundancy or too many unpredictable observations (Wang et al., 2006). The point-measure correlation, which measures the association of a single item and the total score, should also be greater than 0.3 (Nunnally & Bernstein, 1994).

The Outfit MNSQ for K1_4, K1_11, K2_5, and K2_11 was larger than 1.5, and point-measure correlation of K1_4, K1_11, and K2_11 was under 0.3 (Table S3). Therefore, items K1_4, K1_11, K2_5, and K2_11 were not included in subsequent analyses, with the score of the remaining 18 items being used to portray respondents' food safety knowledge. The Cronbach's alpha coefficient of the 18 items was 0.78 (greater than 0.7), indicating an acceptable overall reliability (Taber, 2018). Subsequently, the total score of the remaining eighteen items was used to evaluate consumers' knowledge of food safety, providing a range of scores between 0 and 18 points.

2.3.3. Exploratory factor analysis

Exploratory factor analysis (EFA) was used to test the correlation among items in the scale of food safety behaviors. The scores for items B1, B6, B7, and B8 were reversed before EFA was carried out. The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.832, and Bartlett's test of sphericity was significant (<0.001), indicating that the samples met the requirements of EFA (Shrestha, 2021). Two factors with total initial eigenvalues greater than 1 were reported, explaining 56.5 % of the variance. Factor 1 consisted of B1, B5, B6, B7, B8; Factor 2 consisted of B2, B3, B4, B9, and B10. The loading of B5 was -0.715, and the loadings of the rest of the items were above 0.4 (Table S4). B5 was not included in subsequent analyses owing to its negative correlation with the other items, which meant that only 9 out of the 10 items were used for further tests.

2.3.4. Confirmative factor analysis

To validate the structure that was found by EFA, confirmative factor analysis (CFA) was conducted using SPSS AMOS Version 26. The criteria

of model fit suggest that minimum discrepancy divided by degrees of freedom ($CMIN/DF$) ≤ 5 is reasonable (Marsh & Hocevar, 1985), that the root mean square error of approximation (RMSEA) value should be less than 0.05, and that the goodness of fit index (GFI) and adjusted goodness of fit index (AGFI) values should be greater than 0.9 (Brown & Moore, 2012). However, the $CMIN/DF$ of the hypothesized structure from EFA was 9.99. After checking the item loadings, parameter estimates, and modification indices, item B10 was removed, and two covariances were added between the errors of measurement of B1-B7 and B4-B9. The factor loadings ranged from 0.31 to 0.86. Subsequently, the calculated value for $CMIN/DF = 3.434$, $RMSEA = 0.049$, $GFI = 0.988$, and $AGFI = 0.974$ all met the criteria for an acceptable model fit. The Cronbach's alpha coefficient of what was now 8 items was 0.79 (greater than 0.7), indicating an acceptable overall reliability (Taber, 2018). Thus, items B1-B4 and B6-B9, were used in further analyses to represent respondents' food safety behaviors, with scores ranging between 8 and 56.

2.4. Data analysis

To ensure good quality data, three types of responses were screened out: 1) where the response time was shorter than one-third of the median time for all respondents completing the survey; 2) responses with seven or more consecutive identical answers; 3) responses with five or more missing answers. After the data screening, 583 samples from the pre-COVID survey and 599 samples from the post-COVID survey were used for further data analysis. Statistical analyses were conducted and interpreted using IBM SPSS® version 23, IBM SPSS® Amos version 26, and Winsteps version 3.80.

The discriminating power of the food safety knowledge questions (true/false) was tested using the method described by Karim et al. (2021). Rasch analysis was used to evaluate the item fit for the questions designed to test respondents' food safety knowledge. Exploratory factor analysis (EFA) was used to identify the relationships among items in the scale used to assess food safety behaviors, and confirmatory factor analysis (CFA) was used to confirm the results. The final constructs of the scales were validated through Cronbach's alpha. Chi-square test was used to assess the difference in the distribution of demographic

characteristics and recent food poisoning occurrences in the two surveys. Independent *t*-test was used to examine: 1) the discriminating power of each question (Likert scale) in the sections of food safety behaviors; 2) the differences in food safety knowledge and behaviors between respondents in the two surveys; and 3) the differences in food safety knowledge and behaviors and recent food poisoning experience across demographic categories between respondents in the two surveys. Two-way ANOVA was used to examine the effect of demographic characteristic and the survey period (pre-COVID or post-COVID) on respondents' food safety knowledge, behaviors, and their recent experiences of food poisoning, as well as the interaction between demographic characteristic and the survey period.

3. Results

3.1. Demographic characteristics

Respondents' demographic characteristics are shown in Table 1. The results of Chi-square (χ^2) show that there was no significant difference ($p > 0.05$) between the two surveys with regard to the respondent's gender, age, income, or level of education.

3.2. Food safety knowledge

Respondents got one point for every correct answer and zero points for a wrong answer or "I don't know", with the percentage correct for all questions being shown in Table 2. The eighteen items in the validated final scale with nine items in both subsections, were used to analyze the impact of the COVID-19 pandemic on food safety knowledge. Regarding consumers' general knowledge about foodborne bacteria and food poisoning, the question with the highest percentage correct was K1_8 (87.82 %) in the pre-COVID survey and K1_10 (82.14 %) in the post-COVID survey, while the question with the lowest percentage correct was K1_6 in both surveys, with the percentage correct being 39.79 % and 43.91 %, pre and post COVID-19, respectively. In terms of consumers' knowledge of safe food handling practices, the highest percentage correct was seen for question K2_7 (89.37 %) in the pre-COVID survey and K2_1 (83.97 %) in the post-COVID survey, while the lowest percentage

Table 1
Demographic characteristics of survey respondents.

	Total	Pre-COVID n = 583 (%)	Post-COVID n = 599 (%)	χ^2	DF	p
Gender	Male	308 (52.83)	306 (51.09)	0.360	1	0.548
	Female	275 (47.17)	293 (48.91)			
Age	18–24	96 (16.47)	89 (14.86)	6.616	5	0.251
	25–34	123 (21.10)	155 (25.88)			
	35–44	134 (22.98)	140 (23.37)			
	45–54	95 (16.30)	104 (17.36)			
	55–64	71 (12.18)	58 (9.68)			
	64–75	64 (10.98)	53 (8.85)			
Income (RMB/month)	Below 4 k	62 (10.63)	39 (6.51)	7.505	6	0.277
	4–7 k	118 (20.24)	114 (19.03)			
	7–10 k	113 (19.38)	130 (21.7)			
	10–15 k	105 (18.01)	116 (19.37)			
	15–20 k	83 (14.24)	92 (15.36)			
	20–30 k	60 (10.29)	64 (10.68)			
	30 k+	42 (7.20)	41 (6.84)			
Education	Middle school or below	12 (2.06)	10 (1.67)	9.144	5	0.103
	High school	48 (8.23)	69 (11.52)			
	Professional college	93 (15.95)	102 (17.03)			
	Bachelor's degree	364 (62.44)	355 (59.27)			
	Masters	59 (10.12)	47 (7.85)			
	PhD	7 (1.20)	16 (2.67)			

Table 2
Percentage of correct results for respondents' food safety knowledge.

Item	Statements	Pre-COVID (n = 583)	Post-COVID (n = 599)	Difference
Subsection one: Knowledge about foodborne bacteria and food poisoning				
K1_1	Bacteria don't always need air to survive.	72.38 %	79.13 %	6.75 %*
K1_2	Every type of bacteria can give people food poisoning.	80.10 %	71.45 %	-8.65 %**
K1_3	Freezing food kills the bacteria in it, making the food safe to eat.	78.56 %	79.63 %	1.07 %
K1_4 ^x	You can tell whether a food is contaminated by bacteria by visual, smell or taste checks.	31.39 %	24.87 %	-6.51 %*
K1_5	Food poisoning bacteria can be found on the skin of healthy food handlers.	73.76 %	69.78 %	-3.97 %
K1_6	The most suitable temperature for bacteria to grow is the temperature of the refrigerator (4–7 °C).	39.79 %	43.91 %	4.11 %
K1_7	Children, pregnant women and older people are more at risk of food poisoning.	83.53 %	75.63 %	-7.91 %**
K1_8	Bacteria causing diarrhea can be transmitted through contaminated food.	88.51 %	80.47 %	-8.04 %**
K1_9	Pasteurization of milk and fruit juice helps prevent foodborne illness.	86.11 %	76.13 %	-9.98 %**
K1_10	Eating raw seafood or undercooked seafood increases one's risk of suffering foodborne illness.	87.82 %	82.14 %	-5.68 %**
K1_11 ^x	Eating canned vegetables consumed without prior heating increases one's risk of suffering foodborne illness.	17.50 %	19.53 %	2.04 %
Subsection two: Knowledge about safe food handling practices				
K2_1	Uncovered cuts on hands increase the risk of food becoming contaminated.	88.85 %	83.97 %	-4.88 %*
K2_2	If I have diarrhea, it is okay to prepare food for others as long as I first wash my hands.	72.56 %	73.12 %	0.57 %
K2_3	Holding my hands under running cold water before touching food is sufficient to get rid of the bacteria on them.	71.70 %	63.27 %	-8.43 %**
K2_4	Food contact surfaces should be cleaned using hot water and detergents.	76.50 %	74.79 %	-1.71 %
K2_5 ^x	Washing of hands after handling raw food doesn't help prevent foodborne diseases.	36.19 %	40.23 %	4.04 %
K2_6	After cutting raw meat you can use the same knife to cut fruit.	88.68 %	81.47 %	-7.21 %**
K2_7	Storing raw and cooked food together is an unsafe practice.	89.37 %	79.47 %	-9.90 %**
K2_8	Inadequate cooking of red meat or chicken can cause foodborne illness.	86.96 %	79.30 %	-7.67 %**
K2_9	Using gloves correctly or good hand washing practices reduce the risk of food contamination.	89.19 %	81.97 %	-7.22 %**
K2_10	To avoid foodborne illness, chicken must be cooked to an internal temperature of 72 °C or until the juices are clear.	66.72 %	63.27 %	-3.45 %
K2_11 ^x	If a cutting board is used to cut different types of food such as vegetables and meat, cleaning the board with a clean towel is sufficient to prevent bacterial growth.	40.48 %	34.72 %	-5.76 %*

^x indicates the item is not included in the final scale. * differ significantly ($p < 0.05$). ** differ significantly ($p < 0.01$).

correct was observed of K2_10 (66.72 %) in the pre-COVID survey and K2_3/10 (63.27 %) in the post-COVID survey.

The total score (number of correct answers) across all 18 questions decreased significantly ($p < 0.01$) from 14.21 ± 3.24 before the pandemic to 13.39 ± 3.52 after the start of the pandemic, with the average percentage correct for all questions decreasing by 4.57 % between the two surveys. The percentage correct increased on only 1 out of 18 questions (K1_1, +6.75%).

Table 3
Mean score of respondents' food safety behaviors.

Item	Statements	Pre-COVID (n = 583)	Post-COVID (n = 599)	Difference
B1	I thaw perishable food on the kitchen counter.	3.52 ± 1.64	3.34 ± 1.52	-0.18*
B2	I wash my hands before preparing and eating food.	6.23 ± 1.18	5.96 ± 1.36	-0.27**
B3	I use packaged food before its use-by date.	6.30 ± 1.07	5.85 ± 1.34	-0.45**
B4	After cutting raw meat or chicken, I wash the cutting board, knife, and countertop with hot soapy water before continuing cooking	5.48 ± 1.45	5.24 ± 1.44	-0.24**
B5 ^x	I use a meat thermometer when cooking large cuts of meat.	2.95 ± 2.01	3.41 ± 1.94	0.45**
B6	I eat alfalfa and other raw sprouts	2.36 ± 1.85	2.58 ± 1.84	0.22*
B7	I eat perishable food that has been kept at room temperature for over 6 h.	2.81 ± 1.69	3.01 ± 1.67	0.20*
B8	I buy raw/unpasteurized milk.	2.54 ± 1.89	3.00 ± 1.85	0.46**
B9	I read the use and storage instructions for packaged food.	5.68 ± 1.32	5.35 ± 1.41	-0.33**
B10 ^x	I check my refrigerator temperature to ensure it is not higher than 5 °C.	4.96 ± 1.56	4.82 ± 1.52	-0.14

Data is presented as the mean ± standard deviation. Likert-7 Scale: 1 = 'Never', 2 = 'Rarely', 3 = 'Occasionally', 4 = 'Sometimes', 5 = 'Frequently', 6 = 'Usually', to 7 = 'Always'.

^x indicates the item is not included in the final scale. * differ significantly ($p < 0.05$). ** differ significantly ($p < 0.01$).

Table 4

The timeframe of the most recent food poisoning experience.

No.	Time	Frequency		χ^2	DF	p
		Pre-COVID (n = 583)	Post-COVID (n = 599)			
1	Within the last month	29 (4.97 %)	29 (4.84 %)	28.87	5	0.01
2	Within the last three months	53 (9.09 %)	103 (17.20 %)			
3	Within the last six months	50 (8.58 %)	65 (10.85 %)			
4	Within the last year	51 (8.75 %)	59 (9.85 %)			
5	More than a year ago	137 (23.50 %)	148 (24.71 %)			
6	I can't remember.	263 (45.11 %)	195 (32.55 %)			

Table 5

Suspected causes of the most recent food poisoning experience.

No.	Causes	Frequency	
		Pre-COVID (n = 583)	Post-COVID (n = 599)
1	Undercooked food**	122	206
2	Leftover food**	99	199
3	Store-bought prepared salad*	54	104
4	Cold processed meat, such as ham and salami	38	47
5	Take-away food	87	110
6	Restaurant food	54	57
7	Other food	6	7
8	I don't know**	13	67

Multi select choice question. * differ significantly ($p < 0.05$). ** differ significantly ($p < 0.01$).**Table 6**

Respondents' self-evaluated reaction to COVID-19 (n = 599).

Item	During the COVID-19 pandemic (2020–2022)	Frequency		
		Yes	No	
E1	Did you pay more attention to information of food safety knowledge?	91.3 %	8.7 %	
E2	Did you purposely learn more food safety knowledge?	84.8 %	15.2 %	
E3	Did you pay more attention to food safety while handling food, e.g. while cooking?	93.5 %	6.5 %	
E4	Did you have food poisoning	More often than before 9.2 %	Less often than before 61.4 %	The same as before 29.4 %

usually) for the pre-COVID survey and B2 – “I wash my hands before preparing and eating food.” (5.96, about usually) for the post-COVID survey. In both surveys, the behavior with the poorest score was B1 – “I thaw perishable food on the kitchen counter” with scores of 3.52 and 3.34 (occasionally), for the first and second survey, respectively.

Respondents' food safety behaviors declined significantly ($p < 0.05$) for 7 items after the start of the COVID-19 pandemic, with the score dropping by 0.20–0.46 points in the Likert-7 scale. The only food safety behavior which showed a significant improvement was B1- I thaw perishable food on the kitchen counter (−0.18 as this is not a desirable behavior).

The total score of eight items was used to evaluate consumers' food safety behaviors. The mean total score was 44.47 ± 7.61 in the pre-COVID survey, and it decreased significantly ($p < 0.01$) to 42.47 ± 8.16 after the start of the pandemic. On average, the frequency in which consumers engaged in proper food handling behaviors dropped by 3.75 %.

3.4. Food poisoning experience

The timeframe of respondents' self-reported most recent food poisoning experience is shown in Table 4. The occurrence of their most recent food poisoning experience was more recent in the post-COVID survey than in the pre-COVID one. The results of Chi-square (χ^2) showed that the distributions of food poisoning experiences between the two surveys were significantly different ($p < 0.01$), with the proportion

of respondents who remembered the time of their most recent food poisoning experience increasing (No. 1–5) by 12.56 % after the start of the pandemic. In particular, it is worth noting that the number of cases of food poisoning that happened in “the last three months” nearly doubled in the second survey, indicating a higher frequency of recent food poisoning experiences.

As shown in Table 5, the self-reported suspected causes of food poisoning remained consistent across both surveys, with undercooked food, leftover food, and take-away food being the top three suspects. The total reported frequency of suspected causes (No. 1–7) increased by 58.70 % in the survey taken after the start of the pandemic. In particular, the frequency of food poisoning blamed on undercooked food, leftover food, and store-bought prepared salad significantly increased ($p < 0.05$) by 68.86 %, 100.10 % and 92.59 %, respectively.

3.5. Self-evaluation of the influence of COVID-19

Contrary to the trends observed from the objective questions above, the majority of respondents in the post-COVID survey believed they paid more attention to food safety knowledge and food handling practices than they did before the start of the pandemic (Table 6). In response to the pandemic, approximately 85 % of respondents actively sought to acquire additional food safety knowledge. Further, respondents believed that after the start of the pandemic they experienced incidences of food poisoning either equally (29.4 %) or less frequently (61.4 %) than before the pandemic.

Table 7

Analysis of variance (ANOVA) of food safety knowledge, food safety behaviors, and the most recent food poisoning experience by demographic characteristics and survey period (pre-COVID n = 583, post-COVID n = 599).

No.		Knowledge			Behavior			Food poisoning		
		F	p	eta	F	p	eta	F	p	eta
1-1	Gender	4.37	0.04	0.004	0.00	0.95	0.000	0.11	0.74	0.000
1-2	COVID	17.01	0.01	0.014	18.49	0.01	0.015	19.18	0.01	0.016
1-3	Gen * Cov	0.15	0.69	0.000	1.23	0.27	0.001	17.10	0.01	0.014
2-1	Age	30.80	0.01	0.116	5.96	0.01	0.025	9.05	0.01	0.037
2-2	COVID	48.69	0.01	0.040	45.74	0.01	0.038	26.00	0.01	0.022
2-3	Age * Cov	13.44	0.01	0.054	14.77	0.01	0.059	5.41	0.01	0.023
3-1	Income	4.89	0.01	0.025	5.63	0.01	0.028	1.78	0.10	0.009
3-2	COVID	11.32	0.01	0.010	14.40	0.01	0.012	19.94	0.01	0.017
3-3	Inc * Cov	2.34	0.03	0.012	2.18	0.04	0.011	2.30	0.03	0.012
4-1	Education	25.43	0.01	0.098	4.07	0.01	0.017	3.37	0.01	0.014
4-2	COVID	3.84	0.05	0.003	4.70	0.03	0.004	6.19	0.01	0.005
4-3	Edu * Cov	2.03	0.07	0.009	6.65	0.01	0.028	2.33	0.04	0.010

COVID indicates the effect of survey period: pre- or post-COVID survey.

3.6. Impact of COVID-19 on demographic groups

The results of two-way ANOVA (Table 7) highlighted the significant ($p < 0.05$) impact that COVID-19 had on every demographic group, with regard to their food safety knowledge and behaviors and the frequency of their most recent food poisoning experience (Table 7 row 1-2, 2-2, 3-2, 4-2).

There were significant ($p < 0.05$) differences in food safety knowledge and behaviors observed among respondents from different age, income, and education groups (Table 7 row 2-1 and 4-1), and gender also had a significant influence ($p < 0.05$) on food safety knowledge (Table 7 row 1-1). In addition, respondents from different age and education groups reported distinct recent food poisoning experiences (Table 7 row 1-1 and 3-1).

A significant interaction ($p < 0.05$) was found between the influence of the pandemic with age, income, and education level on consumers' food safety knowledge, food safety behaviors, and their most recent food poisoning experience, which indicated that the impact of the pandemic varied among respondents from different age, income, and education groups (Table 7 row 2-3, 3-3, 4-3).

By comparing the detailed scores (Table S5) obtained for their food safety knowledge, behaviors, and most recent food poisoning experience, across the different demographic groups from the two surveys, it was found that the negative impact of COVID-19 was generally stronger on respondents aged between 45 and 75 years, those with an income under 15,000 RMB, and those whose education level ranged from middle school to a bachelor's degree. In contrast, COVID-19 had less impact on respondents aged between 18 and 34 years old, those with a monthly income over 15,000 RMB, or those with Masters or Doctoral degrees, with exceptions noted in the most recent food poisoning experience of the 30 k + income group and 25–34 age group. Moreover, the greatest difference was seen in the impact of COVID-19 on different age groups (Table 7 row 2-2), with there being a more negative impact for the older age groups.

4. Discussion

In this study, Chinese consumers' food safety knowledge, food safety behaviors, and their most recent food poisoning experience were assessed before and after the start of the COVID-19 pandemic through the use of nationwide online surveys. The findings of this study present a comprehensive picture of the impact of COVID-19 on in-home food safety knowledge and behaviors. This was achieved through examining and comparing the results of carefully validated questionnaires, offering

valuable insights into diverse dimensions of the pandemic's influence.

The findings of this study reveal that there had been a decrease in consumers' food safety knowledge and behaviors after almost four years of the pandemic, indicating its negative influence. This finding contrasts with survey data obtained during the early stage of the pandemic, which suggested that awareness of the virus had improved consumers' food safety knowledge and behaviors (Min et al., 2020). It is postulated that the negative impact of the pandemic on food safety knowledge and behaviors reported in the current study could be attributed to the following four reasons. Firstly, over the course of the pandemic consumers became focused on implementing protective measures against COVID-19, which ultimately resulted in them paying less attention to food safety. It has previously been reported that consumers' food safety behavior is directly determined by their self-protection consciousness, primarily their awareness or concern of perceived risks (Lin et al., 2005; Wang et al., 2020). During the pandemic, a heightened concern and fear of COVID-19 led people to prioritize information related to the virus. For example, in 2020, nucleic acid tests (PCR) taken of frozen food samples in cold-chain transportation in several Chinese cities were reported to give a positive result for the presence of the SARS-CoV-2 virus (Liu et al., 2020). A subsequent lockdown, triggered by what was reported to be the detection of the virus on frozen cod packaging (Wang et al., 2022), raised awareness among Chinese consumers that low storage temperatures did not eliminate the SARS-CoV-2 virus. This increased awareness of the "risk" posed by the virus associated with frozen foods may be reflected in the results of the current study, in which the only statement to show an improvement in food safety behavior from before to after the start of the pandemic was "I thaw perishable food on the kitchen counter" and that the number of correct responses to question K1_3 "Freezing food kills the bacteria in it, making the food safe to eat" remained stable, despite a general trend of a decrease in food safety knowledge and behavior. Further, in a recent worldwide study assessing 157 respondents' food safety knowledge, it was found that the majority of respondents still believed that the disease COVID-19 could be transmitted through contaminated food (Liu et al., 2022), despite the FAO and WHO stating that there is no validated scientific evidence of COVID-19 being transmitted owing to the presence of SARS-CoV-2 on food or food packaging (WHO, 2020a). Likewise, consumers' fear of COVID-19 may be manifested by an extreme attitude found in the current study, whereby there was an 8.65 % increase in consumers believing that "every type of bacteria can give people food poisoning" (K1_2).

Secondly, consumers' caution eroded after an extended period of heightened concern about COVID-19 infection. For example, although handwashing as recommended by the WHO (WHO, 2020b) became a

key preventive measure for COVID-19, with much effort being given to promoting correct hand washing procedures, the correct answer rate for question K2.3 (“Holding my hands under running cold water before touching food is sufficient to get rid of the bacteria on them”) decreased in the later survey. This observation is supported by a study in the US, which reported that while US consumers maintained a high level of handwashing with soap during the pandemic, a decline was anticipated beyond COVID-19 (Thomas & Feng, 2021) due to “caution fatigue” (Paul, 2020). Similarly, in the current study, 91.3 % of respondents believed that they paid more attention to “information about food safety knowledge” during the pandemic (E1). It seems that Chinese consumers are losing the motivation to maintain appropriate practices after their heightened effort in response to COVID-19. For instance, a significant decrease was observed in knowledge and behaviors associated with pasteurization, the most common way of controlling foodborne bacteria in dairy products. The percentage of correct answers testing knowledge about pasteurization (K1.9) dropped by almost 10 %, aligning with an increase in reported purchase of raw/unpasteurized milk (B8).

Thirdly, consumers hold an optimistic bias about their degree of food safety knowledge and behaviors. The majority of the respondents in this study believed that their food safety knowledge and behaviors improved and that they had a lower incidence of food poisoning (E2-4). These self-evaluated results contradicted the trends observed in the scores obtained from objective questions, revealing a great discrepancy between consumers’ perceived status and their actual status. Miles et al. (1999) argued that consumers are subject to the effect of optimistic bias, where they believe that they are less likely to be affected by food safety risks than other people. Consumers who had confidence in their food handling practices were found to be less concerned with food safety issues, making them believe they were immune to food safety issues, although their food-handling practices did not necessarily support this confidence (Wilcock et al., 2004). Hence, optimistic bias could have partially contributed to poor food handling practices and the reported increase in the instance of recent food poisoning experiences obtained in the later survey.

Fourthly, protection measures put in place against COVID-19 by the government may have contributed to a decline in food safety knowledge and behaviors. Throughout the pandemic, consumers’ access to food was not consistently assured due to social isolation and disruptions to the food supply chain (Han et al., 2021). Lockdowns of varying durations were imposed in cities across China, exemplified by a two-month stringent lockdown in Shanghai, which significantly impacted residents’ daily lives and the local economy (Cai, 2023). Personal experiences and reports on social media of such incidents had a negative psychological impact, leading to excessive purchasing and stockpiling of food products (Cruz-Cárdenas et al., 2021). In the current study, almost 10 % more consumers no longer considered that “storing raw and cooked food together is an unsafe practice” (K2.7), and the frequency of using “packaged food before its use-by date” also significantly decreased (B3). Consumers’ intention to engage in safe food handling practices during the pandemic was intricately linked to their perceived ease of performing such behaviors (Mucinhato et al., 2022), and consumers’ food insecurity and concerns about possible food shortages may have overridden their concerns about the adoption of inappropriate food storage practices.

Based on the abovementioned reasons, the decline in both food safety knowledge and behaviors may have contributed to the notable increase in the proportion of respondents self-reporting that they had more recent food poisoning experiences (Table 4). Previous research suggests that consumers with better food safety knowledge exhibit increased awareness of potential food safety risks and are more likely to have a deeper risk perception of foodborne diseases (Ling, 2018; Wang et al., 2019). A comparative analysis of 646 adolescents and 815 adults in Turkey regarding their knowledge and food safety practices revealed that poor personal hygiene and inadequate hygiene in the food preparation environment were linked to a lack of knowledge about bacteria

(Sanlier, 2009). The authors argued that enhancing knowledge about food pathogens would motivate consumers to handle food more carefully. Moreover, consumers’ inappropriate food handling practices constituted a major contributing factor to the high incidence of foodborne diseases in home settings (Menini et al., 2022). The dramatically increased frequency of food poisoning, which was speculated to be caused by undercooked food or leftover food reported in the later survey (Table 5), may be a consequence of a reduced adherence to appropriate food handling practices within households.

A 2018 nationwide study in China found that consumers’ gender, age, income, and education levels significantly influenced their knowledge, risk perception, and certain food-handling behaviors (Wang et al., 2021). Similarly, in the current study, age, income, and education level emerged as significant determinants of food safety knowledge and behavior. More importantly, the influence of COVID-19 on different demographic groups varied. For instance, younger consumers’ food safety knowledge and behaviors were less affected by COVID-19, which is consistent with a previous study (Thomas & Feng, 2021). This difference may be attributed to the fact that COVID-19 posed a greater health threat to elderly individuals, especially those in the vulnerable 65–75 age groups (Han et al., 2021). The negative impact of COVID-19 on lower-income groups has also previously been reported (Min et al., 2020; Thomas & Feng, 2021). Instead of being inclined to adopt appropriate food behaviors, consumers with a lower income tended to focus more on life essentials. A longitudinal survey of 1199 Chinese rural households indicated that households with a lower income, which often contained older residents with a lower education level, were more likely to have fallen into poverty during the pandemic (Luo et al., 2020), and to have experienced deteriorating food safety conditions at home. Lastly, education level played an important role in coping with the impact of COVID-19. It is postulated that consumers who had a higher education level were less likely to have been affected by food insecurity (Dasgupta & Robinson, 2022) and that they would have had better access to food safety information (Thomas & Feng, 2021).

4.1. Limitations and implications of this study

As the respondents in two surveys were not the same, this study only attempted to compare the changes in food safety knowledge and behaviors at a population level over the course of COVID-19 pandemic, rather than changes at an individual level. However, the vast size and population of China posed challenges in obtaining data which fully represents all consumers. The uneven distribution of COVID-19 cases across cities further complicates the generalization of results. Some cities only reported sporadic cases, while others experienced major waves of the virus. In addition, the types, duration, and strength of the prevention and controlling strategies implemented by local governments also varied across different regions (Ding & Zhang, 2022). The second survey, conducted towards the end of the second wave of COVID-19, is unlikely to have reflected the overall impact of prevention and control strategies nationwide, resulting in respondents experiencing differences in how the COVID-19 pandemic was impacting on their lives. Further, since the food handling behaviors and food poisoning experiences were self-reported, and the two online surveys were from the same company’s sample pool, the methodology employed may have increased common method bias. Future studies could involve household observations and/or data on the number of epidemic cases from local hospitals to improve the variety of data sources. In addition, if the same group of individuals could be followed over time, more detailed and dynamic analysis of changes would be possible.

By adopting and adapting the questions used in previous studies, this study built and validated scales designed to measure consumers’ food safety knowledge and behaviors, which will provide useful instruments for future studies. In addition, a change in consumers’ food safety knowledge and behaviors under the influence of a pandemic was reported for the first time. As shown in the current study, the COVID-19

pandemic has indirectly had an adverse impact on the food safety environment and led to at least a perceived increase in the incidence of foodborne diseases. In the past, the focus of food safety control has been on the manufacturing side and the supply chain (Han et al., 2021). The findings of the current study provide a rationale for governments to implement actions that improve the food safety of consumers at home during and after severe pandemics. The government, as well as food safety experts and educators, should popularize awareness of food safety, guiding consumers toward cultivating appropriate food handling habits and behaviors. Providing consumers with correct and useful information will help relieve the burden caused by foodborne diseases during already challenging pandemic situations. More importantly, governments should seek to establish appropriate and standard protocols to cope with public health incidents, minimizing the negative impact on food security and food safety while implementing prevention policies during future large-scale pandemics.

5. Conclusion

This is the first study that has investigated the impact of COVID-19 on Chinese consumer's food safety knowledge and behaviors, and their most recent food poisoning experiences. The findings reveal a concerning decline in the level of food safety awareness and practices among consumers, leading to a higher perceived frequency of recent foodborne diseases primarily attributed to unsafe food handling. However, despite this trend, a dominant optimistic bias was observed, with the majority of consumers perceiving an improvement in their food safety knowledge and behavior during COVID-19. This apparent contradiction highlights a critical need for government intervention to heighten consumer awareness of food safety, particularly targeting vulnerable elderly, lower-income, and lower-educated groups who experienced a more pronounced decline in food safety knowledge and behaviors. Providing additional support and education resources to these at-risk populations is crucial to mitigate the adverse consequences of inappropriate food handling practices.

Funding

This study was supported by New Zealand Food Safety Science Research Centre; Provincial Colleges and Universities Scientific Research Funding (Grant No. KY2023004); Social Science Funding of Hebei Province (Grant No. HB20GL024).

CRedit authorship contribution statement

Ke Wang: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation. **Lei Cong:** Writing – review & editing, Writing – original draft. **Miranda Miroso:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Lan Bai:** Software, Methodology, Funding acquisition, Data curation. **Yakun Hou:** Writing – review & editing, Funding acquisition, Formal analysis. **Phil Bremer:** Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

Appendix A. Supplementary material

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.foodres.2024.114905>.

References

- Allam, Z. (2020). The first 50 days of COVID-19: A detailed chronological timeline and extensive review of literature documenting the pandemic. In *Surveying the Covid-19 pandemic and its implications* (pp. 1–7). doi: 10.1016/B978-0-12-824313-8.00001-2.
- Brown, T. A., & Moore, M. T. (2012). Confirmatory factor analysis. In R. H. Hoyle (Ed.), *Handbook of structural equation modeling* (pp. 361–379). The Guilford Press.
- Bundervoet, T., Dávalos, M. E., & García, N. (2022). The short-term impacts of COVID-19 on households in developing countries: An overview based on a harmonized dataset of high-frequency surveys. *World Development*, 153, Article 105844. <https://doi.org/10.1016/j.worlddev.2022.105844>
- Cai, V. (2023). *Study reveals mental health impact of Shanghai's harsh Covid lockdown*. Retrieved from <https://www.scmp.com/news/china/politics/article/3214767/study-reveals-mental-health-impact-shanghai-harsh-covid-lockdown>. Accessed December 19, 2023.
- Carbas, B., Cardoso, L., & Coelho, A. C. (2013). Investigation on the knowledge associated with foodborne diseases in consumers of northeastern Portugal. *Food Control*, 30(1), 54–57. <https://doi.org/10.1016/j.foodcont.2012.06.028>
- Chen, D., Wang, C., & Liu, Y. (2023). How household food shopping behaviors changed during COVID-19 lockdown period: Evidence from Beijing, China. *Journal of Retailing and Consumer Services*, 75, Article 103513. <https://doi.org/10.1016/j.jretconser.2023.103513>
- China Daily. (2023). *COVID wave on decline, say experts*. Retrieved from http://www.china.org.cn/china/2023-06/13/content_87278050.htm. Accessed December 15, 2023.
- Coulthard, H., Sharps, M., Cunliffe, L., & van den Tol, A. (2021). Eating in the lockdown during the Covid 19 pandemic; self-reported changes in eating behaviour, and associations with BMI, eating style, coping and health anxiety. *Appetite*, 161, Article 105082. <https://doi.org/10.1016/j.appet.2020.105082>
- Cruz-Cárdenas, J., Zabelina, E., Guadalupe-Lanas, J., Palacio-Fierro, A., & Ramos-Galarza, C. (2021). COVID-19, consumer behavior, technology, and society: A literature review and bibliometric analysis. *Technological Forecasting and Social Change*, 173, Article 121179. <https://doi.org/10.1016/j.techfore.2021.121179>
- Dasgupta, S., & Robinson, E. J. Z. (2022). Impact of COVID-19 on food insecurity using multiple waves of high frequency household surveys. *Scientific Reports*, 12(1), 1865. <https://doi.org/10.1038/s41598-022-05664-3>
- David, A., & Ida, M. (2019). *A course in Rasch measurement theory: Measuring in the educational, social and health sciences*. Springer.
- Ding, D., & Zhang, R. (2022). China's COVID-19 control strategy and its impact on the global pandemic. *Frontiers in Public Health*, 10, Article 857003. <https://doi.org/10.3389/fpubh.2022.857003>
- Escudero, E. B., Reyna, N. L., & Morales, M. R. (2000). The level of difficulty and discrimination power of the Basic Knowledge and Skills Examination (EXHCOBA). *Revista Electrónica de Investigación Educativa*, 2(1), 2.
- Evans, E. W., & Redmond, E. C. (2016). Older adult consumer knowledge, attitudes, and self-reported storage practices of ready-to-eat food products and risks associated with Listeriosis. *Journal of Food Protection*, 79(2), 263–272. <https://doi.org/10.4315/0362-028X.JFP-15-312>
- Ferreira Rodrigues, J., dos Santos, C., Filho, M. T., Aparecida de Oliveira, L. E., Brandenburg Siman, I., Barcelos, A. F., de Paiva Anciêns Ramos, G. L., Almeida Esmerino, E., Gomes da Cruz, A., & Arriel, R. A. (2021). Effect of the COVID-19 pandemic on food habits and perceptions: A study with Brazilians. *Trends in Food Science & Technology*, 116, 992–1001. <https://doi.org/10.1016/j.tifs.2021.09.005>
- Han, X., Guo, Y., Xue, P., Wang, X., & Zhu, W. (2022). Impacts of COVID-19 on nutritional intake in rural China: Panel data evidence. *Nutrients*, 14(13), Article 2704. <https://doi.org/10.3390/nu14132704>
- Han, S., Roy, P. K., Hossain, M. I., Byun, K.-H., Choi, C., & Ha, S.-D. (2021). COVID-19 pandemic crisis and food safety: Implications and inactivation strategies. *Trends in Food Science & Technology*, 109, 25–36. <https://doi.org/10.1016/j.tifs.2021.01.004>
- International Food Information Council. (2020). *2020 food & health survey*. <https://foodinsight.org/2020-food-and-health-survey/>.
- Kamboj, S., Gupta, N., Bandral, J. D., Gandotra, G., & Anjum, N. (2020). Food safety and hygiene: A review. *International Journal of Chemical Studies*, 8(2), 358–368.
- Karim, S. A., Sudiro, S., & Syarifah, S. (2021). Utilizing test items analysis to examine the level of difficulty and discriminating power in a teacher-made test. *EduLite Journal of English Education Literature and Culture*, 6(2), 256–269.
- Langiano, E., Ferrara, M., Lanni, L., Viscardi, V., Abbatecola, A. M., & De Vito, E. (2012). Food safety at home: Knowledge and practices of consumers. *Z Gesundh Wiss*, 20(1), 47–57. <https://doi.org/10.1007/s10389-011-0437-z>
- Li, S., Kallas, Z., & Rahmani, D. (2022). Did the COVID-19 lockdown affect consumers' sustainable behaviour in food purchasing and consumption in China? *Food Control*, 132, Article 108352. <https://doi.org/10.1016/j.foodcont.2021.108352>
- Lin, C.-T.-J., Jensen, K. L., & Yen, S. T. (2005). Awareness of foodborne pathogens among US consumers. *Food Quality and Preference*, 16(5), 401–412. <https://doi.org/10.1016/j.foodqual.2004.07.001>
- Linacre, J. M. (2012). *A user's guide to Winsteps ministep. Rasch-model computer program*. Retrieved from <http://www.winsteps.com/winman/>. Accessed December 18, 2023.
- Ling, W. (2018). Consumers' food safety risk perception of and consumption decision-making behaviour. *NeuroQuantology*, 16(6).

- Liu, Z., Mutukumira, A. N., & Shen, C. (2022). Food safety knowledge, attitudes, and eating behavior in the advent of the global coronavirus pandemic. *PLoS One*, *16*(12), Article e0261832. <https://doi.org/10.1371/journal.pone.0261832>
- Liu, P., Yang, M., Zhao, X., Guo, Y., Wang, L., Zhang, J., Lei, W., Han, W., Jiang, F., Liu, W. J., Gao, G. F., & Wu, G. (2020). Cold-chain transportation in the frozen food industry may have caused a recurrence of COVID-19 cases in destination: Successful isolation of SARS-CoV-2 virus from the imported frozen cod package surface. *Biosafety and Health*, *2*(4), 199–201. <https://doi.org/10.1016/j.bsheal.2020.11.003>
- Low, W. Y., Jani, R., Halim, H. A., Alias, A. A., & Moy, F. M. (2016). Determinants of food hygiene knowledge among youths: A cross-sectional online study. *Food Control*, *59*, 88–93. <https://doi.org/10.1016/j.foodcont.2015.04.032>
- Luo, R., Liu, C., Gao, J., Wang, T., Zhi, H., Shi, P., & Huang, J. (2020). Impacts of the COVID-19 pandemic on rural poverty and policy responses in China. *Journal of Integrative Agriculture*, *19*(12), 2946–2964. [https://doi.org/10.1016/S2095-3119\(20\)63426-8](https://doi.org/10.1016/S2095-3119(20)63426-8)
- Marsh, H. W., & Hocevar, D. (1985). Application of confirmatory factor analysis to the study of self-concept: First-and higher order factor models and their invariance across groups. *Psychological Bulletin*, *97*(3), Article 562.
- Medeiros, L. C., Hillers, V. N., Chen, G., Bergmann, V., Kendall, P., & Schroeder, M. (2004). Design and development of food safety knowledge and attitude scales for consumer food safety education. *Journal of the American Dietetic Association*, *104*(11), 1671–1677. <https://doi.org/10.1016/j.jada.2004.08.030>
- Menini, A., Mascarello, G., Giaretta, M., Brombin, A., Marcolin, S., Personeni, F., Pinto, A., & Crovato, S. (2022). The critical role of consumers in the prevention of foodborne diseases: An ethnographic study of Italian families. *Foods*, *11*(7), Article 1006. <https://www.mdpi.com/2304-8158/11/7/1006>.
- Miles, S., Braxton, D. S., & Frewer, L. J. (1999). Public perceptions about microbiological hazards in food. *British Food Journal*, *101*(10), 744–762. <https://doi.org/10.1108/00070709910293670>
- Min, S., Xiang, C., & Zhang, X.-H. (2020). Impacts of the COVID-19 pandemic on consumers' food safety knowledge and behavior in China. *Journal of Integrative Agriculture*, *19*(12), 2926–2936. [https://doi.org/10.1016/S2095-3119\(20\)63388-3](https://doi.org/10.1016/S2095-3119(20)63388-3)
- Mucinhato, R. M. D., da Cunha, D. T., Barros, S. C. F., Zanin, L. M., Auad, L. I., Weis, G. C. C., Saccol, A. L. F., & Stedefeldt, E. (2022). Behavioral predictors of household food-safety practices during the COVID-19 pandemic: Extending the theory of planned behavior. *Food Control*, *134*, Article 108719. <https://doi.org/10.1016/j.foodcont.2021.108719>
- Nunnally, J., & Bernstein, I. (1994). *Psychometric theory* (3rd ed.). New York: McGraw-Hill.
- Odeyemi, O. A., Sani, N. A., Obadina, A. O., Saba, C. K. S., Bamidele, F. A., Abughoush, M., Asghar, A., Dongmo, F. F. D., Macer, D., & Aberoumand, A. (2019). Food safety knowledge, attitudes and practices among consumers in developing countries: An international survey. *Food Research International*, *116*, 1386–1390. <https://doi.org/10.1016/j.foodres.2018.10.030>
- Paul, M. (2020). 'Caution fatigue' could dent our efforts to stay safe. Retrieved from <http://news.northwestern.edu/stories/2020/04/caution-fatigue-could-dent-efforts-to-stay-safe>. Accessed December 15, 2023.
- Piret, J., & Boivin, G. (2021). Pandemics throughout history. *Frontiers in Microbiology*, *11*, Article 631736. <https://doi.org/10.3389/fmicb.2020.631736>
- Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology*, *88*(5), 879–903. <https://doi.org/10.1037/0021-9010.88.5.879>
- Poorolajal, J. (2021). The global pandemics are getting more frequent and severe. *Journal of Research in Health Sciences*, *21*(1), Article e00502. [10.34172/jrhs.2021.40](https://doi.org/10.34172/jrhs.2021.40)
- Ruan, J., Cai, Q., & Jin, S. (2021). Impact of COVID-19 and nationwide lockdowns on vegetable prices: Evidence from wholesale markets in China. *American Journal of Agricultural Economics*, *103*(5), 1574–1594. <https://doi.org/10.1111/ajae.12211>
- Sanlier, N. (2009). The knowledge and practice of food safety by young and adult consumers. *Food Control*, *20*(6), 538–542. <https://doi.org/10.1016/j.foodcont.2008.08.006>
- Schmidt, S., Benke, C., & Pané-Farré, C. A. (2021). Purchasing under threat: Changes in shopping patterns during the COVID-19 pandemic. *PLoS One*, *16*(6), Article e0253231. <https://doi.org/10.1371/journal.pone.0253231>
- Shrestha, N. (2021). Factor analysis as a tool for survey analysis. *American Journal of Applied Mathematics and Statistics*, *9*(1), 4–11.
- Song, Y., Li, C., & Pancras, J. (2015). The demonstration effect of consumption across cities in China: Evidence from the automobile market. In *Emerging markets and the future of the BRIC nations* (pp. 143–169). Edward Elgar Publishing.
- Taber, K. S. (2018). The use of Cronbach's Alpha when developing and reporting research instruments in science education. *Research in Science Education*, *48*(6), 1273–1296. <https://doi.org/10.1007/s11165-016-9602-2>
- The National Administration of Disease Control and Prevention. (2021). *Overview of the national epidemic situation of notifiable infectious diseases in 2020*. Retrieved from <http://www.nhc.gov.cn/jkj/s3578/202103/fla448b7df7d4760976fea6d55834966.shtml>. Accessed May, 30, 2024.
- Thomas, M. S., & Feng, Y. (2021). Food handling practices in the era of COVID-19: A mixed-method longitudinal needs assessment of consumers in the United States. *Journal of Food Protection*, *84*(7), 1176–1187. <https://doi.org/10.4315/JFP-21-006>
- Wang, M., Bai, L., Gong, S., & Huang, L. (2020). Determinants of consumer food safety self-protection behaviour – An analysis using grounded theory. *Food Control*, *113*, Article 107198. <https://doi.org/10.1016/j.foodcont.2020.107198>
- Wang, H. H., & Hao, N. (2020). Panic buying? Food hoarding during the pandemic period with city lockdown. *Journal of Integrative Agriculture*, *19*(12), 2916–2925. [https://doi.org/10.1016/S2095-3119\(20\)63448-7](https://doi.org/10.1016/S2095-3119(20)63448-7)
- Wang, M., Huang, L., Liang, X., & Bai, L. (2021). Consumer knowledge, risk perception and food-handling behaviors – A national survey in China. *Food Control*, *122*, Article 107789. <https://doi.org/10.1016/j.foodcont.2020.107789>
- Wang, J., Li, F., Liu, Z., & Li, N. (2022). COVID-19 outbreaks linked to imported frozen food in China: Status and challenges. *China CDC Weekly*, *4*(22), 483–487. [10.46234/ccdcw2022.072](https://doi.org/10.46234/ccdcw2022.072)
- Wang, K., Miroso, M., Hou, Y., & Bremer, P. (2022). Chinese consumers' acceptance of novel technologies designed to control foodborne bacteria. *Journal of Food Protection*, *85*(7), 1017–1026. <https://doi.org/10.4315/JFP-22-006>
- Wang, S., Shan, L., Wang, X., & Wu, L. (2019). Consumer's risk perception of foodborne diseases and high-risk food safety practices in domestic kitchens. *International Food and Agribusiness Management Review*, *22*(5), 707–716. [10.22434/ifafr2019.0009](https://doi.org/10.22434/ifafr2019.0009)
- Wang, W.-C., Yao, G., Tsai, Y.-J., Wang, J.-D., & Hsieh, C.-L. (2006). Validating, improving reliability, and estimating correlation of the four subscales in the WHOQOL-BREF using multidimensional Rasch analysis. *Quality of Life Research*, *15*(4), 607–620. <https://doi.org/10.1007/s11136-005-4365-7>
- Wang, X., Zhao, F., Tian, X., Min, S., von Cramon-Taubadel, S., Huang, J., & Fan, S. (2022). How online food delivery platforms contributed to the resilience of the urban food system in China during the COVID-19 pandemic. *Global Food Security*, *35*, Article 100658. <https://doi.org/10.1016/j.gfs.2022.100658>
- Wilcock, A., Pun, M., Khanona, J., & Aung, M. (2004). Consumer attitudes, knowledge and behaviour: A review of food safety issues. *Trends in Food Science & Technology*, *15*(2), 56–66. <https://doi.org/10.1016/j.tifs.2003.08.004>
- World Health Organization. (2020a). *COVID-19 and food safety: Guidance for food businesses: Interim guidance*. <https://apps.who.int/iris/bitstream/handle/10665/331705/WHO-2019-nCoV-Food-Safety-2020.1-eng.pdf>
- World Health Organization. (2020b). *Handwashing an effective tool to prevent COVID-19, other diseases*. Retrieved from <https://www.who.int/southeastasia/news/detail/15-10-2020-handwashing-an-effective-tool-to-prevent-COVID-19-other-diseases>. Accessed December 19, 2023.
- World Health Organization. (2023). *WHO coronavirus (COVID-19) dashboard*. Retrieved from <https://covid19.who.int/>. Accessed December 15, 2023.
- Xinhua. (2023). *Explainer: China's COVID policy shift saves lives, spurs economic recovery*. Retrieved from http://www.china.org.cn/china/Off_the_Wire/2023-03/24/content_85189429.htm. Accessed December 15, 2023.
- Yue, W., Liu, N., Zheng, Q., & Wang, H. H. (2021). Does the COVID-19 pandemic change consumers' food consumption and Willingness-to-Pay? The case of China. *Foods*, *10*(9), Article 2156. <https://doi.org/10.3390/foods10092156>