Food Safety knowledge and Handling Practices among Jordanian University Students

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Abstract

This study assessed food safety knowledge and practices (KP) among 461 university students in Jordan, comparing health-related and non-health-related students. A cross-sectional survey using a questionnaire evaluated demographics, food safety knowledge, and handling practices. Health-related students scored higher in food safety knowledge with significant differences between them (mean: 4.95 ± 2.32) compared to non-health-related students (mean: 3.73 ± 1.92, $p < 0.001$).

Health-related female students also demonstrated better knowledge (mean: 6.70 ± 1.95) than males (mean: 6.03 ± 2.38, $p = 0.008$). Significant differences were found, especially among non-health-related students.

Common issues included inadequate food storage knowledge and reliance on feel-touch tests instead of thermometers, leading to undercooking and foodborne infections. Additionally, the COVID-19 pandemic temporarily improved practices, though post-pandemic declines were noted in handwashing and thermometer use.

This study highlights the need for targeted interventions, particularly for male students not enrolled in health-related fields. Targeted educational programs and practical training focusing on food safety can significantly improve both knowledge and practice, reducing health risks. Including food safety modules in non-health disciplines can help bridge the gap between academic knowledge and practical application.

Keywords: Food Safety, University Students, Knowledge and Practices (KP), Educational Interventions, Jordan.

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المعرفة بسلامة الغذاء وممارسات التعامل مع الطعام بين طلبة الجامعات في الأردن

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ملخص

قامت هذه الدراسة بتقييم المعرفة والممارسات المتعلقة بسلامة الغذاء بين 461 من طلبة الجامعات في الأردن، مع المقارنة بين الطلبة من التخصصات الصحية والطلبة من غير التخصصات الصحية. تم إجراء دراسة مقطعية باستخدام استبيان لتقييم المعلومات الديموغرافية ومعرفة سلامة الغذاء وممارسات التعامل مع الطعام.

حصل الطلاب من التخصصات الصحية على درجات أعلى في معرفة سلامة الغذاء (المتوسط: 2.32 ±4.95) مع وجود فروقا معنوية مقارنة بالطلاب من غير التخصصات الصحية (المتوسط: 3.73± 1.92، P <0.001).

كما أظهرت الدراسة أن الطالبات من التخصصات الصحية حققن معرفة أفضل مع وجود فروقا معنوية (المتوسط: 6.70±1.95) مقارنة بالطلاب الذكور (المتوسط: 6.03± 2.38، P =0.008).

تضمنت المشاكل الشائعة نقص المعرفة بتخزين الأغذية بشكل صحيح والاعتماد على اختبارات اللمس بدلا من استخدام موازين الحرارة، مما أدى إلى عدم الطهي الكافي للطعام وانتشار العدوى المنقولة عن طريق الطعام. بالإضافة إلى ذلك، فإن كوفيد-19 كان السبب في حدوث تحسن مؤقت في الممارسات المتعلقة بالطعام مثل غسل اليدين واستخدام موازين الحرارة والتي تراجعت بعد الجائحة. يمكن للبرامج التعليمية والتدريبات العملية التي تركز على سلامة الغذاء أن تحسن المعرفة والممارسات الصحية، وتقلل من المخاطر الصحية. كما أن إدماج وحدات تعليمية عن سلامة الغذاء في التخصصات الغير صحية يسد الفجوة بين المعرفة الأكاديمية والتطبيق العملي.

الكلمات المفتاحية: سلامة الغذاء، طلبة الجامعات، المعرفة والممارسات، التداخلات العلمية، الأردن.

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Introduction:

Food safety is a major global concern, with contaminated food causing illness in one out of every ten people, and 420,000 deaths annually (World Health Organization [WHO], 2022). Foodborne diseases have significant public health repercussions, making it important to address them immediately. The WHO Foodborne Disease Burden Epidemiology Reference Group (FERG) estimates that foodborne diseases have a global burden comparable to major infectious diseases including malaria, HIV/AIDS, and tuberculosis. Diarrheal disease agents, including norovirus and *Campylobacter* spp., are among the leading causes of foodborne illness. Children under the age of five bear 40% of the load from these illnesses (Havelaar et al., 2015).

Food safety has become an issue due to environmental factors that have contributed to the reemergence of harmful diseases (Singh & Monal, 2019). Antibiotic-resistant bacteria such as *Listeria monocytogenes*, *Clostridium perfringens*, and *Salmonella spp*. are causing foodborne illnesses, leading to substantial financial burdens on healthcare systems and industries worldwide. (Almaary, 2023). In the light of global food trade, food safety has far-reaching economic implications. Microbiological food safety incidents are increasing due to vast manufacturing and complex supply chains, putting pressure on stakeholders to maintain stringent control measures. Recent research has highlighted how food supply chains are becoming increasingly complex and vulnerable, leading to increased risks of contamination and food safety incidents (Vantarakis & Dimitrakopoulou, 2022). These factors highlight the necessity of international cooperation and new approaches to food safety. Consumer behavior is also an important consideration in food safety. Ongoing safety education is critical to raising awareness and lowering the incidence of foodborne infections. Effective use of media platforms can result in behavioral changes that can promote food safety (Bolek, 2020). These findings emphasize the significance of treating foodborne diseases in order to promote public health and mitigate their harmful consequences.

Food handlers' Knowledge and practice (KP) are critical factors influencing food safety. According to studies, poor practices and a lack of food safety expertise among food handlers are the main causes of foodborne diseases. For example, Food handlers in Malaysia demonstrated reasonable knowledge of hygiene, but insufficient procedures still led to contamination risks. A study found that while 91% adhered to basic hygiene practices, gaps in contamination prevention remained, indicating the need for stricter

oversight (Elexson et al., 2023). Similar issues were reported in China, where food handlers lacked essential knowledge about foodborne pathogens, contributing to contamination risks (Tokan et al., 2023). In Ghana, due to the unfavorable attitudes of the foodservice providers, high levels of food contamination were caused, highlighting the need for improved education (Ernawati et al., 2021). In Qatar, fast-food handlers lacked the basic understanding despite training (Elobeid et al., 2019). Enhancing KP via ongoing instruction is essential for effective food safety interventions.

Young adults and university students are an important group for food safety research because they are at a transitional stage of life where they are developing independent living skills, and have diverse food consumption habits. Studies have consistently revealed that this demographic frequently lacks enough food safety information exposing them to foodborne infections. There are significant gaps in food safety knowledge and practices among university students (Chuang et al., 2021). Furthermore, students who do not study in health-related fields in some cases lack knowledge of food safety (Courtney et al., 2016). There is a noticeable gap between knowledge and actual food safety practices, stressing on the importance of practical training (Stratev et al., 2017). Variations in food safety behaviors have also been identified on the basis of gender with female students showing better attitudes and practices than their male counterparts (Hussien et al., 2022).

Despite the global emphasis on food safety, research has shown insufficient KP regarding food safety across various populations in Jordan. These insufficient KPs are influenced by demographic characteristics, and are likely to be reflected among students as well (Okour et al., 2018). As evident from the studies by (Osaili et al., 2018; 2021) these shortcomings particularly affect university students, whose food safety knowledge and practices have been found to be inadequate, highlighting the need for more focused educational efforts. While earlier studies in Jordan have focused on foodservice staff and the general student population, our study fills a critical gap by specifically comparing food safety knowledge and practices between health-related and non-health-related university students. This comparison is necessary because students in health-related fields are often exposed to formal education about food safety as part of their curriculum, whereas non-health-related students may lack this exposure, potentially leading to significant differences in their food safety knowledge and behaviors. Understanding these differences helps ensure that interventions are

appropriately targeted based on the students' academic background. Furthermore, our research uniquely examines the influence of gender which is not adequately explored in previous studies. Addressing these demographic influences is crucial because factors like gender and prior exposure can significantly shape food safety behaviors. Understanding these variations enables the development of more personalized and effective educational programs. By addressing these factors, our study contributes to a deeper understanding of the specific gaps in food safety practices and helps inform more targeted and effective interventions across different student groups.

The main objective of this study is to analyze and compare food safety KP among health-related and non-health-related university students in Jordan and to explore the influence of demographic factors on these elements.

The rationale for this study stems from the increased global focus on hygiene and food safety due to the COVID-19 pandemic, though its long-term effects on students' food safety knowledge and practices in Jordan remain uncertain. A recent study explored university students' food safety knowledge during the pandemic, focusing on areas such as cross-contamination prevention, personal hygiene, and food storage practices (Osaili et al., 2021). Investigating how COVID-19 has shaped food safety behaviors among students will provide essential insights for developing effective post-pandemic educational interventions, ensuring better food safety practices and minimizing the risk of foodborne illnesses.

Materials and Methods:

Study design and population

The targeted population in this cross-sectional study includes 461 undergraduate students enrolled at Jordanian Universities. About 36.2% of students were enrolled in health-related and 63.8% of students were enrolled in non-health-related courses.

The sample size calculation was based on Krejcie and Morgan's (1970) formula for determining sample size for a finite population. Given the total number of university students in Jordan, which is 399,923 (as reported by the ’Ministry of Higher Education and Scientific Research, 2022/2023- https://www.mohe.gov.jo/), and using a confidence level of 95% and a margin of error of 5%, the required sample size was calculated as follows:

$$S = \frac{X^2 * N * P * (1 - P)}{d^2 * (N - 1) + X^2 * P * (1 - P)}$$

Where:

S = required sample size

X^2= the table value of chi-square for 1 degree of freedom at the desired confidence level (3.841 for 95%)

N = population size (399,923)

P = population proportion (assumed to be 0.5 for maximum variability)

d = degree of accuracy expressed as a proportion (0.05)

By applying this formula, the minimum required sample size was found to be 384. A total of 461 participants were included in this study, exceeding the required sample size to ensure sufficient statistical power for detecting significant differences between groups. Convenience sampling method was used to gather participants.

Questionnaire development and Validation:

The questionnaire was developed by adopting and revising tested tools from previous studies (Byrd-Bredbenner et al., 2007; Osaili et al., 2011; Lazou et al., 2012). Modifications were made to reflect Jordanian dietary patterns. The questionnaire was prepared in both Arabic and English. The English version was adapted from the study by Lazou et al. (2012), and the translation into Arabic was conducted by an official expert in translation. The Arabic version was reviewed and validated by four nutrition experts from different universities to ensure accuracy and cultural relevance. The questionnaire consisted of four sections: demographic information, food safety knowledge, food handling practices, and an introductory section. It included a total of 30 questions: 14 on food safety knowledge, 16 on food handling practices, and demographic information. A pilot study with 30 students assessed the clarity and suitability of the questions. Adjustments were made based on the pilot study results.

Data Collection and Analysis:

Data was collected from October to December 2023 using an online survey via Google Forms. Participation was voluntary and anonymous, with efforts to ensure genuine responses. To ensure that only students filled out the questionnaire, obligatory questions were included to confirm their

eligibility (such as age, university enrollment, and field of study), which had to be answered before moving to other questions or submitting the form. The platforms used to distribute the questionnaire included WhatsApp and emails, targeting university students directly. Inappropriately filled questionnaires were excluded. Ethical approval was obtained from the Committee on Human Subjects in Research at Balqa Applied University, and informed consent was obtained from all participants. Data were managed using Microsoft Excel and analyzed with IBM SPSS version 28.

To summarize the demographic variables, descriptive statistics were employed. These variables included gender, academic field of study, and cooking habits. The mean was used to represent the central tendency of the data, while the standard deviation (SD) was used to measure the variability or spread of the scores around the mean. This provided insight into the average food safety knowledge and handling practices among different groups of participants, while also indicating how much the scores varied within those groups.

To assess whether there were significant differences in food safety knowledge and handling practices between students in health-related fields and those in non-health-related fields, an independent sample t-test was used. This statistical test is designed to compare the mean scores of two independent groups to determine if any observed differences are statistically significant. A p-value of ≤ 0.050 was set as the threshold for statistical significance. If the p-value was below 0.05, it indicated that the differences observed between the groups were unlikely to be due to chance, and therefore statistically significant.

In addition to the t-test, Fisher's exact chi-squared test was employed to analyze the relationship between categorical variables, such as gender and academic field, and specific responses related to food safety knowledge and practices. This test was chosen because it is particularly effective when dealing with small sample sizes or when the expected frequencies in the data are low.

A Scoring system was used to evaluate participants' food safety knowledge and handling practices. The questionnaire's food safety knowledge section included 14 questions, with participants receiving one point for each correct answer. Incorrect or unanswered questions were given a score of zero, leading to a maximum possible score of 14 points. Similarly, the food-handling practices section included 16 questions, with each correct answer earning one point, resulting in a maximum score of 16 points. No partial points were awarded. The total score for each respondent

was calculated by summing their points from the correct answers in both the knowledge and handling practices sections. Higher scores indicated greater proficiency in food safety knowledge and better food-handling practices.

The use of these statistical methods allowed for a detailed comparison of food safety knowledge and practices between health-related and non-health-related students, highlighting significant differences between the two groups.

Results and Discussion:

Demographics

The demographic characteristics of the study population presented in Table:1 provide a foundational understanding of the sample involved in the study, offering insights into the diversity and background of participants. The study population consists predominantly of female participants, accounting for 76.79% (354 individuals) of the total sample, while male participants make up 23.21% (107 individuals). This significant disparity in gender distribution could influence the study's findings, particularly in areas related to food safety practices and knowledge, as previous research often indicates gender differences in these areas (Byrd-Bredbenner et al., 2007; Osaili et al., 2011; Lazou et al., 2012).

Table (1) Demographic characteristics of the study population (N= 461)

Demographic Variables		**Frequency**
		N (%)
Gender	Female	354 (76.79)
	Male	107 (23.21)
Age (Mean ± SD)		22.70 ± 5.83
Residential status	Alone	12 (2.60)
	With family	427 (92.62)
	Dorm	13 (2.82)
	Roommate	9 (1.95)
Major field of the study	Health related	294 (63.77)
	Non-health related	167 (36.23)
Year	First	58 (12.58)
	Second	82 (17.79)
	Third	133 (28.85)
	Fourth	103 (22.34)

Demographic Variables		Frequency
	Fifth	38 (8.24)
	Sixth	47 (10.20)
Personal food purchase for home	No	228 (49.46)
	Yes	233 (50.54)
Personal cooking habits	Yes, almost always	172 (37.31)
	Sometimes	289 (62.69)
Frequency of meals consumed away from home	Never	27 (5.86)
	Everyday	26 (5.64)
	More than 2 times per week	85 (18.44)
	1-2 times per week	168 (36.44)
	1-3 times per month	155 (33.62)
Personal food poisoning experience	No	335 (72.67)
	Yes	126 (27.33)
Major source of food safety information	University studies	196 (42.52)
	Family/ friends	58 (12.58)
	Personal doctor	31 (6.72)
	Mass media	43(9.33)
	Internet	112 (24.30)
	Others	21 (4.56)

The average age of the participants is 22.70 years, with a standard deviation of 5.83. Which might reflect a population primarily composed of young adults, potentially affecting their food safety knowledge and practices. The majority of participants (92.62%) live with their families, while a smaller fraction lives alone (2.60%), in dormitories (2.82%), or with roommates (1.95%). Living arrangements can significantly impact food safety behaviors, with those living with family potentially benefiting from shared household responsibilities and experiences.

Participants are categorized into health-related and non-health-related fields of study. A considerable majority (63.77%) are from health-related fields, such as medicine, nursing, or public health, while 36.23% are from non-health-related fields. This distinction is crucial as it may correlate with differing levels of food safety knowledge and practices, given that health-related fields typically emphasize these topics more in their curricula. The study sample is distributed across various academic years, with the largest groups being third-year (28.85%) and fourth-year students (22.34%). First-

year students constitute 12.58%, second-year students 17.79%, fifth-year students 8.24%, and sixth-year students 10.20%. The distribution across academic years allows for an examination of how food safety knowledge and practices evolve throughout one's academic career.

Regarding personal food purchase for home consumption, the participants are nearly evenly split, with 50.54% reporting they purchase food for their home and 49.46% indicating they do not. In terms of cooking habits, 37.31% of participants reported that they cook always, while 62.69% cook sometimes. These habits are pivotal in understanding how often participants are directly involved in food preparation and handling, which directly affects their food safety practices.

A variety of eating habits outside the home are noted, with 5.86% of participants never eating meals away from home, 5.64% eating out every day, 18.44% more than twice a week, 36.44% one to two times per week, and 33.62% one to three times per month. The number of meals not take at home can influence exposure to foodborne pathogens and the reliance on personal food safety knowledge. A majority of participants (72.67%) reported never having experienced food poisoning, whereas 27.33% had experienced it at least once. Personal experience with food poisoning could potentially heighten an individual's awareness and knowledge of food safety practices.

The key sources of food safety information vary among participants, with 42.52% citing university studies as their main source, 12.58% relying on family and friends, 6.72% consulting personal doctors, 9.33% using mass media, 24.30% turning to the internet, and 4.56% using other sources. The diversity in sources highlights the range of influences on participants' food safety knowledge and underscores the importance of accurate and accessible food safety education across different mediums. These demographic characteristics provide a comprehensive overview of the study population, offering critical context for interpreting the subsequent findings related to food safety knowledge and practices. Understanding these demographics is crucial for tailoring educational interventions and public health strategies to enhance food safety awareness and behaviors among different groups.

Food Safety Knowledge

The study highlights significant differences in food safety knowledge between participants from health-related and non-health-related fields. According to Table 2, the cumulative food safety knowledge score for health-related students was considerably higher, with a mean of 4.95 ± 2.32, compared to 3.73 ± 1.92 for non-health-related students ($p < 0.001$). This aligns with findings from a study conducted in Sudan, where health-related students demonstrated significantly higher scores in food safety knowledge compared to non-health-related students ($p < 0.05$) (Mohammed et al., 2023). The trend is consistent across various categories of food safety knowledge, indicating the more comprehensive understanding and training that students in health-related fields receive.

For instance, in food microbiology and cross-contamination (Table 3), health-related field students had a higher mean score (1.00 ± 0.95) compared to their non-health-related counterparts (0.55 ± 0.80); however, this difference was not statistically significant ($p = 0.446$). Similar observations were made by Smigic et al. (2020), who found that Serbian students from food/health-related faculties exhibited better food safety understanding compared to those in non-health-related disciplines.

In the knowledge of food preparation and cooking (Table 4), health-related students outperformed non-health-related students, with scores of 1.14 ± 0.95 and 0.67 ± 0.77, respectively ($p < 0.001$). This mirrors findings by Vuksanović et al. (2022), where students outside of health-related fields lacked sufficient food safety knowledge, particularly in food preparation.

Similarly, in food storage and chilling knowledge (Table 5), health-related students had a higher mean score (1.67 ± 1.06) than non-health-related students (1.46 ± 1.01), with a significant p-value of 0.037. This is consistent with Ashkanani et al. (2021), who observed that Kuwaiti students from non-health-related fields also exhibited knowledge deficits in food storage practices.

During and post-COVID, notable shifts in food safety knowledge were observed across various categories. The overall knowledge of food safety significantly improved post-pandemic, as seen in the increase from 41.3% during the pandemic (Osaili et al., 2021) to 49.5% in 2023. This reflects a heightened awareness, likely driven by the health concerns during the pandemic. Specifically, knowledge of cross-contamination nearly doubled from 28.4% to 58.1%, indicating a major post-pandemic improvement, possibly influenced by the increased public discourse on hygiene during the

pandemic. Awareness of appropriate cooking temperatures and safe food storage also rose by 5.19% and 16.9%, respectively. These findings suggest that the pandemic may have contributed to a sustained increase in food safety awareness, as individuals became more vigilant about health risks associated with food handling and storage. However, it also highlights that gaps remain, as seen in less pronounced improvements in specific areas like the knowledge of cooking temperatures, which only increased by 5.19%, from 33.2% during the pandemic to 38.39% post-pandemic.

Our findings align with previous research indicating the need for ongoing educational interventions to reinforce food safety behaviors among non-health-related students. Studies like (Muhyaddin & Sabir, 2022) and Lazou et al. (2012) identified consistent gaps in knowledge about proper refrigerator temperatures and the use of food thermometers. Cufaoglu et al. (2022) and Jones et al. (2018) also emphasized that practical training and the integration of food safety education into university curricula are essential to ensure long-term behavioral changes.

Table (2) Mean scores per food safety section and field of study

Score Category	Field of Study	Food Handling Score		Food Safety Knowledge Score	
		Mean ± SD	P-value	Mean ± SD	P-value
Overall score	Health-related	6.79 ± 2.08	0.001	4.95 ± 2.32	<0.001
	Non-health related	6.12 ± 2.00		3.73 ± 1.92	
Food microbiology/cross-contamination	Health-related	2.05 ± 1.13	0.003	1.00 ± 0.95	0.446
	Non-health related	1.75 ± 0.98		0.55 ± 0.80	
Food preparation/cooking	Health-related	0.61 ± 0.66	0.241	1.14 ± 0.95	<0.001
	Non-health related	0.53 ± 0.619		0.67 ± 0.77	
Food storage/chilling	Health-related	1.65 ± 0.95	0.043	1.67 ± 1.06	0.037
	Non-health related	1.46 ± 1.03		1.46 ± 1.01	
Cleaning/ hygiene	Health-related	2.48 ± 0.94	0.317	1.15 ± 0.95	0.264
	Non-health related	2.38 ± 1.01		1.05 ± 0.93	

Table (3) Responses to food microbiology/cross-contamination knowledge questions per field of study

Responses to food microbiology/cross-contamination knowledge questions per field of study/ Subsection: food microbiology/cross-contamination knowledge	**Multiple-Choice Responses (Correct Responses in Bold)**	**Total N (%)**	**Field of Studies**		***P-value***
			Health-Related	**Non-Health Related**	
			N (%)	**N (%)**	
(Q17) Staphylococcus bacteria that cause food poisoning are most likely associated with which food?	Contaminated water from unfiltered mountain streams and lakes	106 (22.99)	72 (15.62)	34 (7.38)	0.009
	Food prepared by cooks with their bare hands and then left at room temperature	90 (19.52)	66 (14.32)	24 (5.21)	
	Undercooked fish	49 (10.63)	27 (5.86)	22 (4.77)	
	Raw or undercooked eggs and poultry	64 (13.88)	49 (10.63)	15 (3.25)	
	Don't know	152 (32.97)	80 (17.35)	72 (15.62)	
(Q18) Campylobacter bacteria are most likely associated with which food?	Canned food	67 (14.53)	48 (10.41)	19 (4.12)	0.068
	Raw or undercooked fish	75 (16.27)	41 (8.89)	34 (7.38)	
	Raw or undercooked poultry	104 (22.56)	78 (16.92)	26 (5.64)	
	Raw or undercooked beef	54 (11.71)	38 (8.24)	16 (3.47)	
	Don't know	161 (34.92)	89 (19.31)	72 (15.62)	
(Q19) You may contaminate the next food you touch with Salmonella bacteria if you don't wash your hands after touching:	Raw meat	53 (11.50)	25 (5.42)	28 (6.07)	*0.605*
	Raw vegetables	40 (8.68)	27 (5.86)	13 (2.82)	
	Raw beef	74 (16.05)	47 (10.20)	27 (5.86)	
	Raw chicken	155 (33.62)	123 (26.68)	32 (6.94)	
	Don't know	139 (30.15)	72 (15.62)	67 (14.53)	
(Q20) Listeria bacteria are most likely associated with which food?	Home canned foods	79 (17.14)	55 (11.93)	24 (5.21)	*0.057*
	Raw or undercooked beef	89 (19.31)	58 (12.58)	31 (6.72)	
	Deli meats	*37 (8.03)*	*27 (5.86)*	*10 (2.17)*	
	Raw eggs and poultry	*61 (13.23)*	*41 (8.89)*	*20 (4.34)*	
	Don't know	*195 (42.30)*	*113 (24.51)*	*82 (17.79)*	

Table (4) Responses to food preparation/cooking knowledge questions per field of study

Responses to food preparation/cooking knowledge questions per field of study. Subsection: food preparation/cooking knowledge	Multiple-Choice Responses (Correct Responses in Bold)	Total N (%)	Field of Studies		P-value
			Health-Related	Non-Health Related	
			N (%)	N (%)	
(Q21) All foods are considered safe when cooked to an internal temperature of:	54°C	47 (10.20)	31 (6.72)	16 (3.47)	0.081
	60 °C	78 (16.92)	50 (10.85)	28 (6.07)	
	66 °C	60 (13.02)	41 (8.89)	19 (4.12)	
	74 °C	99 (21.48)	78 (16.92)	21 (4.56)	
	Don't know	177 (38.39)	94 (20.39)	83 (18.00)	
(Q22) Salmonella bacteria can cause food poisoning. How can a food be made safe if it has Salmonella in it?	**Cook it thoroughly**	181 (39.26)	414 (89.80)	40 (8.68)	<0.001
	Wash it under extremely hot running water	55 (11.93)	33 (7.16)	22 (4.77)	
	Freeze it for at least three days	56 (12.15)	34 (7.38)	22 (4.77)	
	The food cannot be made safe	41 (8.89)	31 (6.72)	10 (2.17)	
	Don't know	128 (27.77)	55 (11.93)	73 (15.84)	
(Q23) In order fried eggs to be safe to eat, how should their texture be after cooking?	Semi-solid albumen and yolk	96 (20.82)	65 (14.10)	31 (6.72)	0.002
	Solid albumen and semi-solid yolk	105 (22.78)	70 (15.18)	35 (7.59)	
	Solid albumen and yolk	166 (36.01)	115 (24.95)	51 (11.06)	
	Solid albumen and liquid yolk	30 (6.51)	17 (3.69)	13 (2.82)	
	Don't know	64 (13.88)	27 (5.86)	37 (8.03)	

Table (5)Responses to food storage/chilling knowledge questions per field of study

Subsection: food storage/chilling knowledge Field of studies	Multiple-Choice Responses (Correct Responses in Bold)	Total N (%)	Field of Studies		P-value
			Health-Related	Non-Health Related	
			N (%)	N (%)	
(Q 24) Which food is least likely to cause food poisoning?	Slices of pizza left on the counter overnight	49 (10.63)	34 (7.38)	15 (3.25)	0.008
	Baked potato that was left on the counter	108 (23.43)	73 (15.84)	35 (7.59)	
	Leftover chicken eaten cold	74 (16.05)	49 (10.63)	25 (5.42)	
	Chocolate cake that was left on the kitchen counter overnight	149 (32.32)	103 (22.34)	46 (9.98)	
	Don't know	81 (17.57)	35 (7.59)	46 (9.98)	
(Q 25) What is the maximum temperature refrigerators should be to preserve the safety of foods?	18 °C	91 (19.74)	61 (13.23)	30 (9.98)	<0.001
	-4 °C	83 (18.00)	64 (13.88)	19 (4.12)	
	4 °C	85 (18.44)	65 (14.10)	20 (4.34)	
	7 °C	70 (15.18)	44 (9.54)	26 (5.64)	
	12 °C	22 (4.77)	14 (3.04)	8 (1.74)	
	Don't know	110 (23.86)	46 (9.98)	64 (13.88)	
(Q 26) Freezing eliminates harmful germs in food:	True	282 (61.17)	170 (36.88)	112 (24.30)	0.031
	False	179 (38.83)	124 (26.90)	55 (11.93)	
(Q 27) What is the least safe method for thawing a frozen roast?	Leave it in the refrigerator until it is thawed	96 (20.82)	61 (13.23)	35 (7.59)	0.001
	Leave it on the kitchen counter until it is thawed	134 (29.07)	96 (20.82)	38 (8.24)	
	Put it in a microwave oven set to automatic defrost	117 (25.38)	81 (17.57)	36 (7.81)	
	Put it under running water for 1 h	44 (9.54)	28 (6.07)	16 (3.47)	
	Don't know	70 (15.18)	28 (6.07)	42 (9.11)	
(Q 28) Which should not be done when storing raw meat, fish, or poultry in the refrigerator?	Place it in the coldest part of the refrigerator	92 (19.96)	59 (12.80)	33 (7.16)	0.229
	Set it in a larger container before refrigerating	44 (9.54)	31 (6.72)	13 (2.82)	
	Place it on the lowest shelf in the refrigerator	78 (16.92)	52 (11.28)	26 (5.64)	
	Leave it in the package they came in	78 (16.92)	49 (10.63)	29 (6.29)	
	All should be done when storing raw meat, fish, or poultry	86 (18.66)	58 (12.58)	28 (6.07)	
	Don't know	83 (18.00)	45 (9.76)	38 (8.24)	

Table (6) Responses to cleaning/hygiene knowledge questions per field of study

Subsection: cleaning/hygiene knowledge	Multiple-Choice Responses (Correct Responses in Bold)	Total N (%)	Field of Studies		P-value
			Health-Related	Non-Health Related	
			N (%)	N (%)	
(Q 29) Which of the following is considered the most important way to prevent food poisoning?	Spray for pests in the kitchen area at least every week	78 (16.92)	47 (10.20)	31 (6.72)	0.890
	Rarely or never serve leftovers	74 (16.05)	53 (11.50)	21 (4.56)	
	Keep foods refrigerated until it's time to cool or serve them	144 (31.24)	90 (19.52)	54 (11.71)	
	Clean kitchen counters with sanitizing solutions weekly	165 (35.79)	104 (22.56)	61 (13.23)	
(Q30) The wash of dishes may include:(e). To prevent food poisoning, which of the aforementioned choices do you regard as the best?	1 or 2	75 (16.27)	40 (8.68)	35 (7.59)	0.627
	1 or 3	101 (21.91)	68 (14.75)	33 (7.16)	
	2 or 4	62 (13.45)	43 (9.33)	19 (4.12)	
	3 or 4	89 (19.31)	63 (14.75)	26 (5.64)	
	All of the above	134 (29.07)	80 (17.35)	54 (11.71)	
(Q 31) Which procedure for cleaning kitchen counters is most likely to prevent food poisoning?	Spray with a strong sanitizing solution	39 (8.46)	23 (4.99)	16 (3.47)	0.063
	Wash with a detergent, rinse, then wipe with a sanitizing solution	121 (26.25)	86 (18.66)	35 (7.59)	
	Wipe with a sanitizing solution, then rinse with clean water and wipe dry	125 (27.11)	79 (17.14)	46 (9.98)	
	Brush off any dirt or food pieces, then wipe with sanitizing solution	118 (25.60)	80 (17.35)	38 (8.24)	
	Don't know	58 (12.58)	26 (5.64)	32 (6.94)	
(Q32) When should kitchen counters be washed, rinsed, and sanitized?	After each use	159 (34.49)	109 (23.64)	50 (10.85)	0.034
	When you begin working with another type of food	54 (11.71)	36 (7.81)	18 (3.90)	
	at 4-h intervals if the counter is in constant use	46 (9.98)	28 (6.07)	18 (3.90)	
	All of the above	147 (31.89)	94 (20.39)	53 (11.50)	
	Don't know	55 (11.93)	27 (5.86)	28 (6.07)	

Gender differences were also notable in food safety knowledge. Highlighted in Table 7, females had higher overall food safety knowledge scores (4.64 ± 2.24) compared to males (4.07 ± 2.29), with a p-value of 0.026. This pattern was particularly evident in the knowledge of food preparation and cooking, where females scored 1.01 ± 0.94, significantly higher than males who scored 0.81 ± 0.84 (p = 0.037). The gender differences in food safety knowledge observed in our study, with previous research. Studies by (Roy et al., 2020) and (Chuang et al., 2021) also found that females tend to demonstrate better food safety practices than males. This suggests that females may be more diligent in learning and applying food safety knowledge, which is necessary for minimizing the risk of foodborne diseases.

Table (7) Mean scores per food safety section and gender

Score Category	Field of Study	Food Handling Score		Food Safety Knowledge Score	
		Mean±SD	P-value	Mean±SD	P-value
Overall score	Female	6.70 ± 1.95	0.008	4.64 ± 2.24	0.026
	Male	6.03 ± 2.38		4.07 ± 2.29	
Food microbiology/cross-contamination	Female	2.04 ± 1.06	<0.001	0.86 ± 0.91	0.286
	Male	1.61 ± 1.10		0.75 ± 0.98	
Food preparation/cooking	Female	0.58 ± 0.65	0.996	1.01 ± 0.94	0.037
	Male	0.58 ± 0.64		0.81 ± 0.84	
Food storage/chilling	Female	1±1.00	0.890	1.63 ± 1.06	0.177
	Male	1.57 ± 0.94		1.48 ± 1.01	
Cleaning/ hygiene	Female	2.50 ± 0.93	0.052	1.14 ± 0.94	0.348
	Male	2.27 ± 1.07		1.04 ± 0.95	

Food Handling Practices

The analysis of food handling practices revealed significant differences based on the field of study, similar to previous research. Health-related field participants in our study had higher overall food handling scores, averaging 6.79 ± 2.08 compared to 6.12 ± 2.00 for non-health-related participants, with a significant p-value of 0.001, as shown in Table 2. This finding aligns with a study conducted in Serbian universities, where health-related students demonstrated higher food handling practices scores (48.8%) compared to

their non-health-related peers, who scored significantly lower (Vuksanović et al., 2022). (Similarly, Osaili et al., 2011) found that health-related students in Jordan scored significantly higher in food safety knowledge, with an average score of 7.2, compared to 5.8 among non-health-related students.

In our study, health-related students also scored higher in food microbiology and cross-contamination practices, with averages of 2.05 ± 1.13 compared to 1.75 ± 0.98 for non-health-related students, as illustrated in Table 8, and a p-value of 0.003. This reinforces findings by Smigic et al. (2020), who found that Serbian health-related students scored 25% better in these areas. In food preparation and cooking practices, Table 9 shows that 61.61% of health-related students correctly identified the proper temperature for cooking hamburgers, compared to only 20.61% of non-health-related students. This is consistent with Ashkanani et al. (2021), where health-related students scored 30% higher in proper food cooking methods. Similarly, Vuksanović et al. (2022) found that 65% of health-related students in Serbia had correct cooking knowledge, while only 35% of non-health-related students did.

In terms of specific practices, Table 9 reveals that only 3.69% of participants in our study correctly used food thermometers, a figure consistent with (Hussien et al., 2022), who found that only 4% of Palestinian university students used thermometers properly. A similar study in Ghana reported that only 3.5% of students used food thermometers, highlighting a common gap in food safety practices globally (Lawal et al., 2023).

Cleaning and hygiene practices also showed differences, with 84.82% of health-related students adhering to proper handwashing practices before meal preparation, compared to 55.31% of non-health-related students, as indicated in Table 10. This mirrors findings from (Osaili et al., 2011), where 86% of health-related students reported regular handwashing, compared to 58% of non-health-related students. (Lazou et al., 2012) found similar handwashing compliance among health-related students in Greece, with rates around 85% .

These findings emphasize the consistent gaps in food handling practices among non-health-related students across different regions, highlighting the need for targeted educational interventions. Studies like those by (Cufaoglu et al., 2022) and (Jones et al., 2018) have recommended practical, hands-on

training to bridge the knowledge-practice divide and improve food safety behavior among non-health-related students.

Table (8) Responses to food microbiology/cross-contamination practice questions per field of study

Responses to food microbiology/cross-contamination practice questions per field of study.	Multiple-Choice Responses (Correct Responses in Bold)	Total N (%)	Field of Studies		P-value
			Health-Related	Non-Health Related	
			N (%)	N (%)	
(Q1) After you have used a cutting board to slice raw meat or chicken and need to cut tomatoes, what do you do?	Use the cutting board as it is	26 (5.64)	17 (3.69)	9 (1.96)	0.164
	Wipe the cutting board off with a paper towel	17 (3.69)	12 (2.60)	5 (1.95)	
	Rinse the cutting board under water	73 (15.84)	34 (7.38)	39 (1.08)	
	Turn the board over and use the other side	44 (9.54)	31 (6.72)	13 (8.46)	
	Wash the cutting board with soap and rinse it under hot water	301 (65.29)	200 (43.38)	101 (21.91)	
(Q2) When you cut raw meat and need to use the knife again, what do you do?	Reuse the knife as it is	30 (6.51)	18 (3.90)	12 (2.60)	0.901
	Rinse with cold water	81 (17.57)	52 (11.28)	29 (6.29)	
	Wipe with a cloth	15 (3.25)	11 (2.39)	4 (0.87)	
	Wash with detergent and hot water	335 (72.67)	213 (46.20)	122 (26.46)	
(Q3) In your house, where is raw meat stored in the refrigerator?	Top shelf	262 (56.83)	170 (36.88)	92 (19.96)	0.292
	Middle shelf	47 (10.20)	29 (6.29)	18 (3.90)	
	Lowest shelf	95 (20.61)	66 (14.32)	29 (6.29)	
	Anywhere	57 (12.36)	29 (6.29)	28 (6.07)	

Responses to food microbiology/cross-contamination practice questions per field of study.	Multiple-Choice Responses (Correct Responses in Bold)	Total N (%)	Field of Studies		P-value
(Q4) If you have a sore on the back of your hand, do you prepare food for other people?	Yes, if it is not infected	44 (9.54)	27 (5.86)	17 (3.69)	0.962
	Yes, if I put a bandage on it	57 (12.36)	28 (6.07)	29 (6.29)	
	Yes, if I bandage the sore and wear a gloved	164 (35.75)	**124 (26.90)**	**40 (8.68)**	
	No, I don't prepare food until the sore heals	196 (42.52)	115 (24.95)	81 (17.57)	

Table (9) Responses to food preparation/cooking practice questions per field of study

Responses to food preparation cooking practice questions per field of study.	Multiple-Choice Responses (Correct Responses in Bold)	Total N (%)	Field of Studies		P-value
			Health-Related	Non-Health Related	
			N (%)	N (%)	
(Q5) How do you check that a hamburger is sufficiently cooked?	When it looks cooked after checking the color of the meat inside (visible inspection)	89 (19.31)	57 (12.36)	32 (6.94)	0.519
	When the juice runs clear (or is not pink)	30 (6.51)	18 (3.90)	12 (2.60)	
	When it has the correct food thermometer reading	17 (3.69)	12 (2.60)	5 (1.08)	
	By the texture or firmness of meat	31 (6.72)	14 (3.04)	17 (3.69)	
	When it has been cooked for a stated time	10 (2.17)	4 (0.87)	6 (1.30)	
	When it has been cooked for a stated time and it looks cooked after checking the color of the meat inside	284 (61.61)	189 (41.00)	95 (20.61)	

Responses to	Multiple-Choice	Total	Field of Studies		P-value
(Q6) How long do you heat leftover foods?	**Until they are boiling hot**	132 (28.63)	95 (20.61)	37 (8.03)	0.041
	Just until they are hot, but not too hot to eat right away	183 (39.70)	111 (24.08)	72 (15.62)	
	Just until they are at least at room temperature	78 (16.92)	50 (10.85)	28 (6.07)	
	Reheating is not necessary	68 (14.75)	38 (8.24)	30 (6.51)	
(Q7) How do you check that poultry is sufficiently cooked?	When the juice runs clear	53 (11.50)	36 (7.81)	17 (3.69)	0.740
	When it tastes cooked	126 (27.33)	79 (17.14)	47 (10.20)	
	When it looks cooked	164 (35.57)	104 (22.56)	60 (13.02)	
	When the meat has the correct thermometer reading	118 (25.60)	75 (16.27)	43 (9.33)	

Table (10) Responses to cleaning/hygiene practice questions per field of study

Responses to cleaning/hygiene practice questions per field of study/Subsection: cleaning/hygiene practices	Multiple-Choice Responses (Correct Responses in Bold)	Total N (%)	Field of Studies		P-value
			Health-Related	Non-Health Related	
			N (%)	N (%)	
(Q13) How do you wash your hands before starting preparing food or eating?	**Ordinary soap and water**	391 (84.82)	255 (55.31)	136 (29.50)	0.045
	Water only	40 (8.68)	24 (5.21)	16 (3.47)	
	Wipe with a towel or dish cloth	16 (3.47)	10 (2.17)	6 (1.30)	
	You don't clean them at all	14 (3.04)	5 (1.08)	9 (1.95)	
(Q14) How often the kitchen sink drain in your home is sanitized?	**Daily**	337 (73.10)	219 (47.51)	118 (25.60)	0.324
	Weekly	56 (12.15)	36 (7.81)	20 (4.34)	
	Monthly	25 (5.42)	15 (3.25)	10 (2.17)	
	Only when food is going to be thawed or washed in the sink	24 (5.12)	11 (2.39)	13 (2.82)	
	Other	19 (4.12)	13 (2.82)	6 (1.30)	

Responses to	Multiple-	Total	Field of Studies		P <
(Q15) You wash fruits and vegetables by using:	Regular soap	27 (5.86)	14 (3.04)	13 (2.82)	0.725
	Hot water	81 (17.57)	55 (11.93)	26 (5.64)	
	Antibacterial soap	53 (11.50)	32 (6.94)	21 (4.56)	
	Antibacterial sponge	12 (2.60)	9 (1.95)	3 (0.65)	
	Cold running water	288 (62.47)	184 (39.91)	104 (22.56)	
(Q16) When preparing food, you wash your hands after touching which one of these?	**Your face**	11 (2.39)	71 (15.40)	40 (8.68)	0.796
	Utensils that are being used	170 (36.88)	113 (24.51)	57 (12.36)	
	to prepare food	87 (18.87)	50 (10.85)	37 (8.03)	
	Clean pots and pans	39 (8.46)	25 (5.42)	14 (3.04)	
	Clean countertop	53 (11.50)	34 (7.38)	19 (4.12)	
	None of the above	1 (0.22)	1 (0.22)	0 (0.00)	

Gender differences in food handling practices were notable in our study, with females scoring higher overall (6.70 ± 1.95) compared to males (6.03 ± 2.38), with a significant p-value of 0.008, as shown in Table 7. This pattern extended to food microbiology and cross-contamination practices, where females had higher scores (2.04 ± 1.06) than males (1.61 ± 1.10), with a p-value of less than 0.001. These findings are consistent with prior research by (Boulos and Abouelzz, 2020) and (Chuang et al., 2021), who found that females generally demonstrate better food handling behaviors.

In food storage and chilling practices, health-related field participants performed better (1.65 ± 0.95) compared to non-health-related participants (1.46 ± 1.03), as noted in Table 11, which aligns with findings by (Kennedy et al., 2005) and (Ashkanani et al., 2021) that also highlighted gaps in food storage practices among non-health-related students.

During and post-COVID, notable changes in food handling practices were observed. While the pandemic initially raised awareness of hygiene and food safety practices, our post-pandemic data reveals a decline in several key areas. For instance, during the pandemic, 91% of participants adhered to handwashing before food preparation (Osaili et al., 2021).

However, post-pandemic, this figure dropped to 84.82% among health-related students (Table 10), indicating a slight decline in adherence to hygiene practices.

Similarly, the use of food thermometers saw a significant drop. During the pandemic, 15.7% of participants used thermometers correctly, but post-pandemic, only 4% in our study reported proper use (Table 9). In contrast, food storage practices in refrigerators showed a modest improvement, increasing from 43.5% during the pandemic (Osaili et al., 2021) to 51.19% post-pandemic (Table 11). Although this is a positive change, it still highlights that nearly half of participants are not following proper food storage protocols, which poses risks for foodborne illnesses.

This data suggests that while food storage practices saw a small improvement, other critical food safety measures like handwashing and thermometer use have declined post-pandemic, pointing to a need for ongoing education and reinforcement of these behaviors to prevent further backsliding in food safety practices.

Table (11) Responses to food storage/chilling practice questions per field of study

Responses to food storage/chilling practice questions per field of study /Subsection: food storage/chilling practices	Multiple-Choice Responses (Correct Responses in Bold)	Total N (%)	Field of Studies		P-value
			Health-Related	Non-Health Related	
			N (%)	N (%)	
(Q8) When do you place a frozen ice cream in your cart when you go for shopping to the supermarket?	Early in the shopping trip	50 (10.85)	32 (6.94)	18 (3.90)	0.648
	About halfway through the shopping trip	21 (4.56)	13 (2.82)	8 (1.74)	
	Near the end of the shopping trip	43 (9.33)	28 (6.08)	15 (3.25)	
	At the very end of the shopping trip	102 (22.13)	66 (14.32)	36 (7.81)	
	Just before checking out	218 (47.29)	143 (31.02)	75 (16.27)	
	It doesn't matter when I place it in the cart	27 (5.86)	12 (2.60)	15 (3.25)	
(Q9) How do you defrost frozen	At room temperature	236 (51.19)	137 (29.72)	99 (21.48)	0.067

Responses to food meat?	Multiple-	Total	Field of Studies		P <
	In the refrigerator	96 (20.82)	72 (15.62)	24 (5.21)	
	Under running water	129 (27.98)	85 (18.44)	44 (9.54)	
(Q10) Do you have a thermometer in your refrigerator?	**Yes**	298 (64.64)	201 (43.60)	97 (21.04)	0.017
	No	163 (35.36)	93 (20.17)	70 (15.18)	
(Q11) In case your electricity went off and the meat, chicken, and/or seafood in your freezer thawed and felt warm, what do you do?	**Throw them away**	66 (14.32)	40 (8.68)	26 (5.64)	0.358
	Cook them right away	80 (17.35)	52 (11.28)	28 (6.07)	
	See how they smell or look before deciding what to do	239 (51.84)	162 (35.14)	77 (16.70)	
	Immediately re-freeze until solidly frozen, then cook them	19 (4.12)	9 (1.95)	10 (2.17)	
	Immediately re-freeze until future consumption	57 (12.36)	31 (6.72)	26 (5.64)	
(Q12) If a family member/roommate is going to be several hours late for hot meal, how do you store the meal to keep it safe until this person is ready to eat it?	**Store it in the refrigerator and reheat it when the person is ready to eat it**	167 (36.23)	107 (23.21)	60 (13.02)	0.905
	Store it in on the kitchen counter until the person is ready to eat it	94 (20.39)	59 (12.80)	35 (7.59)	
	Store it in a cool oven until the person is ready to eat it	52 (11.28)	32 (6.94)	20 (4.34)	
	Store it in a warm oven until the person is ready to eat it	148 (32.10)	96 (20.82)	52 (11.28)	

Strengths and Limitations:

This study's strengths include a comprehensive examination of food safety KP among Jordanian university students from varied backgrounds. The large sample size of 461 participants improves the reliability and applicability of the results. The study's comparative analysis, which differentiates between health-related and non-health-related students, as well as gender differences, offers insights into the unique demands of various demographic groups. Validated questionnaires developed from prior studies ensure accurate and relevant data collection. Adherence to ethical principles, such as voluntary involvement, anonymity, and informed consent, enhances the integrity of the study process.

However, the study had significant drawbacks. The cross-sectional design limits the capacity to track changes in food safety measures over time. The convenience sampling method may lead to selection bias, as respondents may have varying levels of interest or knowledge concerning food safety compared to nonrespondents. Using self-reported data may lead to social desirability bias, as participants supply answers, they believe are anticipated rather than reflecting their real habits and expertise. Although the sample size is considerable, the results are limited to Jordanian university students and may not be applicable to other demographics or cultural contexts. The study's lack of longitudinal data prevents it from tracking changes in food safety knowledge and practices over time, perhaps providing a more dynamic understanding of how education and interventions affect behavior.

Conclusion:

This study aimed to assess the knowledge and practices relating to food safety among university students in Jordan. These results demonstrate a wide gap between their knowledge about food safety and their actual practice of safe food handling, especially for those not taking health courses. Those pursuing health-related courses were able to comprehend and use principles of food safety more than other students, as many are exposed to safe handling and hygienic preparation practices during their coursework.

Identifying these gaps allows for the development of tailored interventions to improve food safety knowledge and minimize the prevalence of foodborne illnesses among vulnerable populations, particularly young adults in Jordan. The study's findings can inform educational and regulatory policies aimed at promoting higher food safety standards among university students. Female students had higher food

safety knowledge and practices than male students. The results emphasize the importance of focused educational programs to strengthen food safety ideas and behaviors among those students who were not subject related, especially males. These results indicate the need for targeted interventions to improve food safety knowledge and handling practices, especially among non-health-related field students and males. Enhanced education and training can bridge the gap and promote safer food handling behaviors across all demographic groups.

Furthermore, the COVID-19 pandemic had a notable impact on food safety knowledge and practices among students. While the pandemic initially heightened awareness of hygiene and safety protocols, some areas saw post-pandemic declines in key practices such as handwashing and the correct use of food thermometers. However, there were improvements in other aspects, such as increased awareness of cross-contamination and proper food storage practices. These mixed results suggest that while the pandemic served as a catalyst for greater food safety consciousness, consistent educational reinforcement is necessary to maintain and further improve safe food handling behaviors post-pandemic. Targeted interventions must also focus on sustaining these positive behaviors over the long term, ensuring that the gains made during the pandemic are not lost.

In light of this, addressing these gaps with a meticulously constructed educational program can greatly enhance food handling behaviors and subsequently lower the rates of foodborne diseases; thus, public health will be promoted nationally. This demonstrates the need for ongoing food safety education, practical experience as well as incorporation of elements of food safety into university curricula in a range to disciplines. Future research should focus on longitudinal studies that track changes in food safety knowledge and practice over time to provide a more dynamic picture of the impact of educational interventions. These research findings may help policymakers and educators to implement interventions for enhancing food safety knowledge, and practices towards decreasing the risks of incidents from food poisoning in the young age group.

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