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RESEARCH ARTICLE

FOOD SAFETY KNOWLEDGE ON PROCESSING AND CATERING AMONG FOOD SCIENCE UNDERGRADUATES: A SURVEY

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ABSTRACT

Trained human resources are needed to prevent food safety hazards along the food chain. A survey of food science undergraduate teams from six universities in Sri Lanka was conducted to assess food safety knowledge at two points in the food chain, food processing and catering. The questions on food processing assessed exposures of the undergraduates in classes and outside. A second assessment addressed the application of food safety knowledge in food preparation and catering management. Six teams of 5 undergraduates each answered the food processing questions. Forty-two undergraduates answered questions on food safety at food catering as individuals. The answers of undergraduates to questions related to the classroom knowledge were satisfactory, but not to knowledge on emerging hazards related to food processing. The ability of students to arrive at management decisions to avoid food safety hazards in food preparation and catering was 50%. Comparison of the responses with results from 4 countries to equivalent questions indicated notable influence of food habits over food safety knowledge. Weaknesses in the application of food refrigeration knowledge were observed. Exposing undergraduates to individual assignments in class and in industries as learning experiences may enhance their capacity to choose consumer-oriented food safety options.

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INTRODUCTION

Addressing food safety along the food processing chain leads to increased consumer health protection. Food processing and catering industries are major employers in many countries. It is vital to get the future employees in the food processing and catering industries upgraded to keep up with changing global food safety standards. In implementing food safety, the words management, handling, practices, procedures, manufacturing are cited frequently, indicating the importance of skilled human resources operating the links in the food chain (Oyarzabal and Van Renterghem 2020). Poor practices in food processing and food handling affect food safety leading to health implications, especially with expanding global food trade. Manpower with modern knowledge on food safety is required for consumer protection avoiding unsafe and unhygienic foods. Surveys assessing food safety knowledge and food preparation habits among undergraduate students and other community groups were conducted in several countries, to identify future strategies to improve the focus on food safety education. Surveys on food safety knowledge gaps and perceptions in undergraduates in Kansas State University (Yarrow *et al.* 2009), in 4 universities in Japan (Takeda *et al.* 2011), in Aristotle University of Thessaloniki in Greece (Lazou *et al.* 2012), in Lebanese University (Hassan and Dimassi 2014), in University of Medical Sciences in Iran (Eslami *et al.* 2015), in high school students of Ontario, Canada (Majowicz *et al.* 2015), among undergraduates in Waterloo University, Canada (Courtney *et al.* 2016), among undergraduates of 21 universities and colleges in USA, conducted by the University of Maine (Ferk *et al.* 2016), in nutrition students of Saint Benedict and Saint John University focusing on undergraduate knowledge and kitchen inspection (Xiong and Olson 2017), among undergraduates from different food related departments in the

University of Agriculture, Peshawar, Pakistan (Zeeshan *et al.* 2017), among undergraduates in the University of Purdue, Indiana (Chuang *et al.* 2021), in food science undergraduates of Glyndwr University, Iraq (Muhyaddin and Sabir 2022), and undergraduates in several universities in Bangladesh (Islam *et al.* 2022), are among studies focusing student groups. The undergraduates assessed varied in their background from those with no exposure to food science knowledge to those having different degrees of exposure to food science, nutrition, or health sciences. The common focus in the surveys was on consumer level food safety knowledge at domestic food preparation and consumption. Surveys assessing knowledge on food handling and food safety are reported in participants of food and nutrition programs (Meer and Misner 2000), street food vendors (Lues *et al.* 2006), food handlers in military hospitals (Sharif *et al.* 2013), consumers (Da Costa *et al.* 2016), food service staff in hospitals (Alquarashi *et al.* 2019), food service establishments (Labovic *et al.* 2023) and several other community groups. The activities of the groups studied directly affect consumer health arising from exposure to unsafe foods. The study on food service establishments where swabs from work benches and palms of food handlers were tested for microbial contaminants, has shown a notable reduction in microbial counts after the employees were trained on food safety (Labovic *et al.* 2023). The publications identified in the category of employees and consumers report the outcomes of surveys addressing persons trained for the job, and those undergoing on-the-job training with situations not comparable with each other. The observations on the distinct groups associated with food handling suggest the importance on training them. There is the need to intensely expose food science and technology undergraduates to food safety as they accept management responsibilities in the food industry after graduation.

In all above studies with undergraduates, the focus was exclusively on food safety knowledge from a hygiene and health perspective at the end of the farm-to-fork food chain. The studies attempted to seek links on food safety knowledge with domestic food preparation habits. The importance of understanding food safety knowledge in food technology undergraduates destined to serve as managers in industries along the food chain is highlighted by Muhyaddin and Sabir (2023). The focus on food safety has expanded from the previous interactions with end-products, to in-process interactions recently. Food control authorities in many countries take a preventive food control approach to ensure consumer protection, requiring interference at early stages of food processing, concentrating on food safety management along the food chain. Food safety management requires trained manpower and interactions in food processing. This is the first study examining food safety knowledge, at processing, of food science and technology undergraduates to understand their capacity to take preventive food safety measures, as potential food safety managers in food processing industries and food catering organizations. The focus was on two points of the food chain, namely at food processing where presence and entry of hazards could be controlled, and at food preparation and catering, where proliferation of new hazards could be minimized. The objective of this study differs from previous studies in targeting identified food science undergraduate groups and assessing their knowledge towards practices leading to consumer health protection at domestic level.

MATERIALS AND METHODS

Food science and industry relationship: The study was carried out by the Institute of Food Science and Technology Sri Lanka (IFSTSL) in July 2023. The questions were designed to assess the food science and technology capacity beyond classroom learning, focusing specifically the knowledge on practical food safety, applied to specific products and processes, in processing and in operating a food catering organization.

Questionnaires: Two questionnaires to assess food science and technology knowledge on product safety in processing, and practical food safety catering applications at management level respectively were prepared after perusal of questionnaires validated and published in other surveys (Byrd-Bredbenner *et al.* 2007; Lazou *et al.* 2012; Hassan and Dimassi 2014; Courtney *et al.* 2016; Ferk *et al.* 2016; Islam *et al.* 2022). The validated questions were modified to suit the local food practices, retaining the context. Additional questions were included to address local food processing and catering practices. The new questions were prepared by an academic with 30 years of experience in teaching and curriculum development in food science in several countries and having experience in preparing similar questionnaires for several years. The questions were validated by a food regulations-oriented food safety professional for face and content. The questionnaires are submitted as supplemental material.

Selection of undergraduates: On request of the IFSTSL, six universities offering food science modules in undergraduate programs sent a team of 5 undergraduates to respond to the questions on food safety in food processing. The results were analyzed for each team. Seven undergraduates were sent by the same universities to respond individually to the questions on food safety in catering. The results for food catering questions were analyzed by pooling all responses as a single group. The students recommended by each university were expected to be the best among each lot. The participants represented a population of approximately 300 following food science modules in the six universities in their third and fourth years. The undergraduates answered the questions in a written examination. Of the six universities, undergraduates from three universities were following 4-year food science and technology degree programs, undergraduates in two universities were following food science modules in their final year, and in one university undergraduates were following food science modules for 2 years with strong exposure to food and nutrition modules.

Questions on food safety in food processing: Twenty-five questions on food processing with emphasis on food safety problems were presented to students in a multi-select, multiple-choice format. Of the 25 questions, 10 (40%) were designed to recognize the processing related knowledge gained by students in the classroom, and 15 (60%) to recognize the knowledge gained outside the classroom through self-learning activities. Each question carried 4 answers, of which 1 or more are true answers. The undergraduates were required to identify each answer as true or false. Zero marks were allocated when the participants did not identify answers as true or false. The responses of members in each team to each question were totaled to recognize the overall food processing knowledge of the team. Since a team of five members provides their responses to four possible answers as true or false, a maximum score of 20 could be obtained by the team for each question. The total scores of the team for each question were clustered into 4 categories as 0-5 (<25%), 6-10 (25-50%), 11-15 (50-75%) and 16-20 (>75%). A total of 30 students answered the questions.

Questions on food safety at food catering: Seven undergraduates nominated from each participating university were assessed for their food safety knowledge related to food catering activities, assigning each student to play the role of a quality manager. The 40 questions used in the assessment were of single-select multiple-choice format with each question carrying 5 possible answers. The students were expected to identify the best answer. Of the 40 questions in the survey, 16 were equivalent to those used in the surveys in Greece (Lazou *et al.* 2012) 17 in Lebanon (Hassan and Dimassi 2014) and 25 in Bangladesh (Islam *et al.* 2022). There were 16 questions equivalent to those used in University of Maine (Ferk *et al.* 2016). The rest of the questions were designed to address food safety violations affecting consumer protection commonly observed in the catering industry. The anticipated best answers to questions are abbreviated along with questions, under results and discussion. The objective was to assess the behavior of each undergraduate facing practical operational problems as a quality manager in a food preparation and catering organization. Score of +1 was given to the correct response. The percentage marks gained for each question by the 42 undergraduates were compared with similar data from the four countries. The scores obtained by each undergraduate for the question paper were used to estimate the mean and standard deviation for the group.

RESULTS AND DISCUSSION

This study assessed the knowledge of the potential quality controllers in food processing and catering systems, with a view to recognize problematic areas and improvements needed in food safety education. Previous studies examined food safety due to microbiological hazards at the end of food chain; this study focused on a wide problem area addressing chemical hazards in food processing and microbiological hazards in food catering. Results of the assessments based on the two questionnaires are discussed separately below.

Responses to questions on food safety at food processing: This part of the survey assessed the strength of industrial knowledge gained in classrooms and outside by undergraduates. A brief phrase from each question and the scores obtained by the six teams for the questions are summarized in Table 1. The scores are converted to color code for easy comparative visualization as percentages. As indicated by the colors in the Table, the overall achievement scores (out of 20) are mostly below 75%. The first three columns (A, B & C) represent the scores obtained by the undergraduates following 4-year food science and technology degree programs. The fourth column (D) represents scores obtained by undergraduates following a degree program where food science is offered for 2 years. The last two columns (E & F) represent undergraduates following food science modules for 1 year in the agriculture curricula. The distribution of colors reflects the gaps in knowledge requiring longer exposure to food science and technology modules to achieve recognizable food safety knowledge in food processing. The colors in the first column indicate a high

degree of consistency in performance by one team. The scores and color distribution for question 2 on blanching of vegetables indicate a good knowledge for the purpose of blanching and its outcome. Contrarily, the scores obtained to question 23 on packaging materials are poor for all teams. In identifying the properties of cellophane as a packaging material, 77% of participants failed to recognize cellophane is compostable, produced from biodegradable materials. They probably identified cello phane as synthetic polyethylene. The poor performance probably indicates the need to strengthen the depth of content in food packaging modules, in all food science degree programs. A higher level of knowledge on packaging materials to ensure food safety and environmental concerns is expected from the undergraduates aiming to manage food processing activities.

A low overall group average of less than 50% marks is observed for 21 out of 40 questions in this study. The level of achievement cannot be considered satisfactory for food science undergraduates. The results suggest the need to strengthen the practical food safety component in training, through exposures to real life situations. Of the 40 questions in this study, 25 were equivalent to the questions in the Bangladesh study, 17 were equivalent to those in the study in Lebanon, 16 were equivalent to the study in Greece and 15 were equivalent to the study in USA. Table 2 compares similarities in the results from the 5 countries as percentages. Although the application of food safety principles cannot vary in the 5 situations, the overall pattern of responses indicates strong associations of practices linked to food cultures, especially food habits.

Table 1. Responses of the food science undergraduate teams to the multiple-choice questions

Questions	A	B	C	D	E	F
1 Biochemistry of fish fermentation	12	13	13	15	16	15
2 Vegetable blanching	18	19	20	20	17	16
3 Safe marine fish availability	14	8	12	9	13	8
4 Slow freezing of meat to -4 °C	12	12	11	12	9	6
5 Chemistry of tea processing	11	13	13	10	11	8
6 Cadmium in rice	14	8	15	10	14	6
7 Moisture in foods	17	10	13	11	11	13
8 Carcinogenic mycotoxins in food	11	10	8	8	6	3
9 Polycyclic aromatic hydrocarbons	11	11	12	9	10	7
10 Antibiotics in raising food-animals	12	10	12	11	11	11
11 Food import controls in Sri Lanka	12	13	9	9	10	8
12 Nutritional value of coconut oil	12	13	14	9	10	10
13 Safety of boiled eggs	12	7	11	8	12	11
14 Dicyanamide and milk industry	12	10	7	11	7	8
15 Cordial preservative regulations	12	13	9	14	11	11
16 Meat fermenting microorganisms	11	13	9	8	11	12
17 Food colors from <i>Serratia</i>	12	9	11	7	8	9
18 ISO standards for lab accreditation	15	11	6	6	5	12
19 Cocoa fermentation	12	10	9	18	17	12
20 Food testing by ELISA	12	9	12	13	13	15
21 <i>Listeria</i> in processed foods	12	10	10	16	12	8
22 Location of rat traps in factories	17	14	16	16	13	16
23 Cellophane as a packaging material	9	9	8	6	8	8
24 Land selection for food crops	18	17	11	11	13	11
25 Food allergen declaration in labels	17	15	13	16	11	8

Code: ■ 75-100% ■ 50-75% ■ 25-50% ■ <25%

The response to the balance 23 questions varied among the six teams. The response to each question by each team indicates the potential areas for improvement in the food science modules of the respective teaching programs. The yellow and red colors in Table 1 suggest areas requiring increased attention in undergraduate training. Food safety interactions at processing need deep understanding of the problems associated with potential chemical and microbiological hazards. It would be of interest to assess the responses of student groups in other countries to similar food processing situations.

Responses to questions on food safety in catering: The objective of this assessment was to understand the ability of the undergraduates to make decisions individually, to avoid food safety problems in a food catering unit. Higher levels of food safety knowledge have been reported with undergraduates following health related courses compared to general undergraduate populations in similar assessments (Hassan and Dimass, 2014; Eslami *et al.*, 2015; Courtney *et al.*, 2016; Smigic *et al.*, 2020).

General trends: The number of participants identifying the best solution to each situation is given in Table 2. The anticipated best solution to each question is given with the question in square brackets, in abbreviated form. The best solutions identified by undergraduates in this study are compared as percentages with that of Bangladesh (Islam *et al.*, 2022), Lebanon (Hasan and Dimassi 2014), Greece (Lazou *et al.*, 2012) and in University of Maine, USA (Ferk *et al.*, 2016).

Beliefs, which take the form of food habits in practice, are recognized as important factors driving food safety decisions (Byrd-Bred Benner *et al.*, 2007). In the 15 common questions, there were notable differences among the 5 countries in the percentage best responses of undergraduates to questions on refrigeration of foods.

Responses on refrigeration of foods: Prepared foods are refrigerated to minimize microbial growth pending consumption as a consumer health protection measure. The best response to question 3, on the shelf of the refrigerator for storing raw meat for 4 h, by the study population was very poor (2%). The low scoring may be arising from the common local practices of purchasing meat and fish sold at ambient temperatures and cooking immediately, rather than cold storage at purchase or at home. Poor response (14%) to overnight thawing of frozen meat in question 10, and the very poor response (2%) to the use of refrigerator to keep the prepared meal packets for a few hours in question 13, appears to originate from similar cultural habits, standing above the concerns on microbiological food safety. Contrarily, 58% of the USA undergraduates and 84% of the Canadian undergraduates believed in refrigerated storage of foods pending consumption. In the study sample 84% undergraduates identified keeping the takeaway food in hot oven or reheating before delivery as the best option in question 13. This response is perhaps linked to the cultural practice of consuming warm food soon after cooking. Receiving a cold packet of food is not considered ethical culturally. The situation observed with the responses of the undergraduates of some countries indicate a problem needing attention during education aiming increased consumer health protection.

Table 2. Percent students selecting the best (correct) answers to catering food safety questions

No	Questions [Best response]	Best of 40	% giving the best response				
			SL	Ban	Leb	Gre	US
1.	On the very first day you observe the employees wearing the aprons taking meals in the restaurant. Which action would you take immediately? [Restrict aprons to work bench areas]	18	43	neq	neq	neq	neq
2.	After cutting meat on the chopping board, the employee wants to cut vegetables. Of the following, which would you permit as food safety manager? [Another clean chopping board]	38	90	27	39	61	81
3.	The kitchen refrigerator contains three shelves. Which shelf would you recommend for raw meat storage for 4 hours? [Bottom shelf]	1	2	62	16	23	40
4.	After cutting fresh fish, the knife is required to cut pineapple. What is your recommendation? [Wash with soap and hot water]	20	48	46	74	67	neq
5.	One of the employees has a wound on the back of his /her palm covered with a plaster. What action would you take? [Allow if gloves are worn]	11	26	26	27	20	63
6.	There is milk left in a pot after serving the customers. What do you do with the leftover milk? [Boil and reuse]	35	83	40	38	22	35
7.	In examining the raw material storage section, the peanuts purchased recently in bulk were found to be mouldy. What action would you take? [Discard all peanuts]	22	52	neq	neq	neq	neq
8.	On instructions displayed near the hand washing sink, employees are guided to rub the palms with soap for a minimum required duration. What is the minimum duration? [20 seconds]	18	43	51	39	97	72
9.	You would observe that some of the employees working in the food processing are wearing jewelry including their wedding rings. What would you recommend as immediate action? [Remove all including wedding ring]	26	62	18	76	neq	neq
10.	The frozen meat is taken out for cooking. What is the best recommendation for thawing of meat? [Overnight in refrigerator]	14	33	7	28	25	neq
11.	Due to interruption of electricity supply, the meat, chicken, and seafood in the freezer are already at room temperature with juices oozing out. What would you do with them? [Throw them]	12	29	10	neq	32	64
12.	After a party in the hotel where liquor and prawns were served, several persons reported faintish and got hospitalized. The diagnosis indicates over consumption of prawns and red wine leading to release of traces of arsenic from prawns. How would you prevent such events at the future parties? [Serve limited quantities of prawn and wine]	37	88	neq	neq	neq	neq
13.	Three packets of take away dinner was ordered, and the purchaser later informed that he would come only after 2 hours to collect them. What guidance would you provide to the kitchen staff? [Store in refrigerator]	1	2	32	29	28	58
14.	Which one of the following would you recommended during training of the staff on washing their hands before entering the food preparing area for work? [Soap and water and drying]	42	100	84	87	97	60
15.	Fruits and vegetables may have contact with soil and other unclean surfaces, requiring further cleaning. What would you advise the employees to do? [Wash with running cold water]	36	86	36	neq	73	52
16.	In offering a tender to buy eggs from a farm, which of the following conditions would you lay down for the supplier to adhere to? [Brush eggs before packing]	15	36	neq	neq	neq	neq
17.	Microorganisms get transferred from various sources to palms. After touching which of the following do you wash your palms prior to preparing food? [Face]	32	76	50	34	39	neq
18.	Which food would you recommend testing for <i>Campylobacter</i> if concerns are raised by the health authorities of an epidemic in the country? [Undercooked duck meat]	20	48	44	neq	6	10
19.	Which of the following food is most likely to become contaminated with <i>Listeria monocytogenes</i> ? [Raw or undercooked meat/fish]	35	83	41	neq	15	13.5
20.	If the purchasing officer travels with a vehicle to purchase fish and other raw food from the open market, which order of purchase would you recommend to the officer? [End of purchase]	24	57	63	60	55	65
21.	Chicken is prepared in different ways to meet consumer preferences. What is the temperature you would recommend being achieved at the centre of chicken, on checking using a penetration thermometer? [75 °C]	10	24	11	38	21	66
22.	Of the different ways the eggs are served, which one would ensure lowest possibility of bacterial presence? [Hard albumin and hard yolk]	18	43	43	52	32	neq
23.	The supervisor of the food preparation section is expected to ensure food contaminations do not occur through employees. As a precautionary measure which groups of persons should be kept out of food preparation work by the supervisor? [Having sore throat]	16	62	58	neq	neq	neq
24.	On examining the automated temperature records of the refrigerator, which temperature would compel you to take corrective actions to ensure safety & quality of refrigerated food? [6 °C]	10	24	32	53	44	neq
25.	What temperature would you expect to see in automatic temperature records of the freezer used to store chicken? [-18 °C]	25	60	46	49	neq	20
26.	In relation to ensuring food safety among different foods served to customers which one would you consider the most hazardous? [Fried eggs with shiny yellow semi-solid yolk]	4	10	60	neq	neq	neq
27.	Tasty fried foods carry a marketing advantage in restaurant business. With the current concern on food safety hazards linked to trans-fatty acid formation during frying, which cooking oil would you recommend for purchase? [Coconut oil]	17	40	neq	neq	neq	neq
28.	In the food preparation business, many practices are recommended to ensure food safety. As the food safety manager, which of the following would you consider as topmost priority to avoid food poisoning? [Keeping food refrigerated until serving time]	9	21	6	neq	51	neq
29.	Of the following, which method would you recommend as the most suitable to wash dishes? [Immediately after meal with detergent and wipe with clean towel]	18	43	27	neq	45	61
30.	The use of coconut oil in food preparation has become a food safety concern due to complains on aflatoxins. What type of coconut oil would you recommend being purchased for the restaurant? [Chemically refined coconut oil]	26	62	neq	neq	neq	neq
31.	Which of the following practices would you recommend to the person supervising cleaning of kitchen counters and stoves as the best? [Dry clean and brush & and water followed by sanitizer]	16	62	61	79	32	35
32.	Restaurants are using plastics cans to store fruit juices and plastic basins for food preparation. As a food safety manager, what measures would you adopt to ensure that the foods in the restaurant are safe? [Use food grade plastics]	32	76	neq	neq	neq	neq

.....Continue

33.	Pasteurized milk packs are purchased for use in the restaurant. Which of the following storage methods would you recommend to the kitchen staff to minimize food safety risks in use of milk? [Refrigerate till opening]	20	48	neq	neq	neq	neq
34.	The houseflies transfer germs into prepared foods. Which of the following methods would you recommend to the staff to protect the food preparation area from house flies? [Air curtain in doors and wire mesh in windows]	28	67	neq	neq	neq	neq
35.	Polythene bags for waste disposal are placed in cans adjacent to food cutting tables. How often would you recommend disposal of the sealed bags to bins carrying lids outside the food preparation building? [Once in 2 hours]	9	21	neq	neq	neq	neq
36.	Continued good health of employees is an important part of food safety. Which of the following are important in addressing this aspect? [Annual checks to find whether they are silent carriers of pathogens]	16	38	neq	neq	neq	neq
37.	What is the most important practical food safety message you would give the employees with respect to <i>Escherichia coli</i> ? [Washing hands after toilet]	41	98	neq	neq	neq	neq
38.	There is high consumer concern on safety of sulphur dioxide in foods. If a supervisor working under, you bring a bottle of imported jam indicating a value for 'residual sulphur dioxide' how would you explain it? [Residue from pre freezing treatment of fruits]	14	33	neq	neq	neq	neq
39.	What action would you follow to ensure the supply of beef to the restaurant is safe? [Certification from veterinarian]	19	45	neq	neq	neq	neq
40.	Water could be a source of contaminants affecting safety of prepared food. Which of the following actions would you consider important to provide safe water to the kitchen? [Regular checks on chemical and microbiological quality of water in tank]	27	64	neq	neq	neq	neq

neq = no equivalent question; SL = Sri Lanka; Ban = Bangladesh; Leb = Lebanon; Gre = Greece; US = USA (University of Maine)

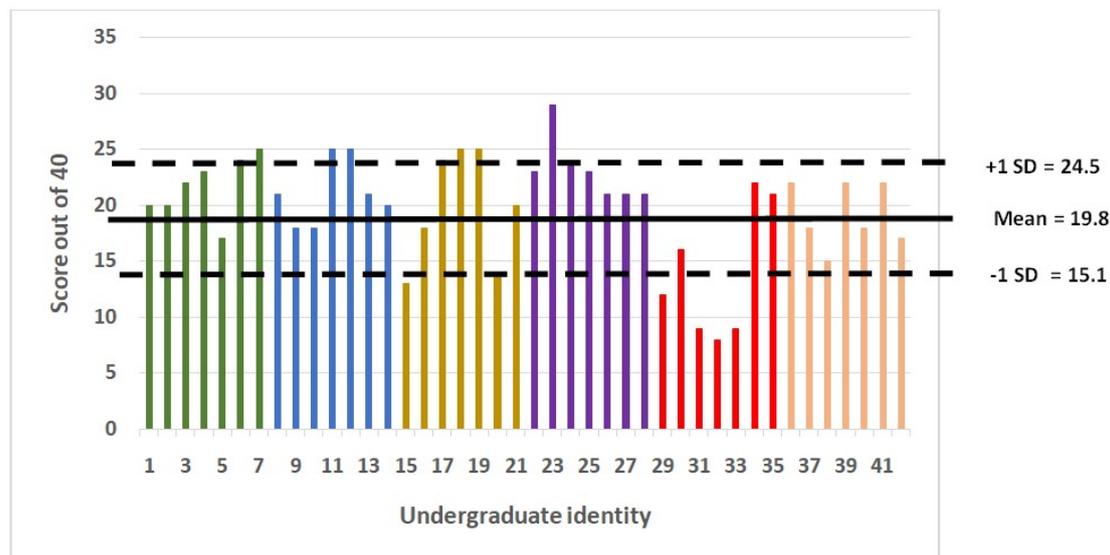


Fig. 1. Scores obtained by individual students answering 40 food safety questions related to catering

For the question on the temperature expected to be maintained in the refrigerators, correct answers were identified by 24%, 32%, 53% and 44% undergraduates in Sri Lanka, Bangladesh, Lebanon, and Greece respectively. Poor knowledge on refrigeration for food safety appears to be a problem in the study populations from the four countries. A study on undergraduates in Ryerson University, Canada reported that 83.7% students never checked the temperature of their own refrigerators and 43.3 % were not aware of the temperature expected in refrigerators (Obande and Young 2020). Though basic microbiology lessons educate the students on time and temperature relationships on bacterial growth, and temperature danger zone for food storage, the tendency to recognize the role of refrigeration on food safety and consumer health protection appears low.

Food safety scores of individual undergraduates: The scores gained through correct answers by the individual undergraduates to 40 food safety questions on catering are presented in Figure 1. The colors in columns identify the six universities of the participants. The mean value for correct answers is 19.8, which is close to the half point score of 20 out of 40, implying approximately 50% of the study population arrived at positive food safety decisions. The corresponding value for Greek undergraduates was 37% averaged for 32 questions (Lazou et al. 2012). The competency demonstrated in role playing by the undergraduates as quality managers needs further improvements, suggesting rethinking of the student learning approach.

The standard deviation is ± 4.7 for the undergraduate mean score in the study. Of the 42 undergraduates, only 7 reached standard deviation of +1, with one rising above standard deviation of +1 in the score. The number of participants scoring below standard deviations of -1 probably indicates the low effectiveness in delivering catering related food safety messages in particular curricula. The group with all participants scoring above the mean value are from a university with strong nutrition component in their education, which probably reflects higher recognition of nutrients and antinutrients associated with foods. The patterns give an indication of new directions for strengthening food safety learning experiences. In general, results of most of the surveys on food safety perused in this study, the undergraduates scored around 45-55% in the questionnaires. To achieve a higher degree of food safety, the training authorities need to explore new ways to make the students achieve higher scores consistently. It may be pertinent to consider assignments or hypothetical virtual intervention modules, as a mechanism to upgrade food safety problem-solving capacities of undergraduates. While knowledge forms the basis to strengthen the capacity of individuals to address food safety, it is the degree of application of knowledge that matters. The ability to apply is guided by the concepts inculcated through practical training in industry and development of attitudes. Application of knowledge has an element of ownership gained through experience. Persons with tertiary education in Ghana working in the hotel industry having adequate knowledge, were reported to

perform inadequately in application. The low degree of application of knowledge is reported to be due to inadequate understanding of individual hazards and risks (Annor and Baiden 2011). A study with college students in Ethiopia has revealed a statistically significant association between knowledge and practice. However, the food safety practices were linked independently to the attitude of individual students (Azanaw *et al.* 2021). The study also indicates low food safety knowledge among undergraduates. A notable difference in the scores obtained between the undergraduates exposed to food science education and those not exposed to food science education is reported in a survey in Serbia (Smigic *et al.* 2020). In this study the marks lie at $\pm 10\%$ from a median of 50% for the two groups, with group exposed to food science at the higher end. The authors query on the impact of university curricula on the food safety knowledge of students. Observations in the current study on food science graduates and the study in Serbia indicate the need for increased exposure of undergraduates to work situations in the industry. The study on Ontario students (Majowicz *et al.* 2015) concludes the importance of work and volunteer opportunities in improving their food safety attitudes. The relevance of working in an industrial situation, giving opportunities for undergraduates to translate their knowledge into practices, appears an important link to develop the attitudes of the undergraduates. Though it is difficult for universities to find sufficient industrial assignments on food safety to a large population of students, addressing exposure opportunities to students qualifying in food science, food technology and nutrition would develop a strong nucleus to address food safety. The food processing and catering industries have a role to play in working with the universities to strengthen manpower through real life experiences.

CONCLUSIONS

Culture linked food habits appear to play a deciding role in food safety practices of undergraduates resulting in unscientific decisions. This may lead to weak actions on consumer health protection when the graduates are employed by the food industries. It may be necessary to consider food habit specific guidelines for each country, while adhering to basic concepts in food safety to arrive at equivalent levels of food safety globally. With global emphasis on food safety management along the food chain, assessment of undergraduate knowledge at several points in the food chain is becoming more relevant. Voluntary engagement of undergraduates for food handling and preparation work would help to strengthen their food safety practical knowledge and attitudes.

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