


Article

A Multimethod Study on Kitchen Hygiene, Consumer Knowledge and Food Handling Practices at Home

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Abstract: The aim of the study was to identify consumers' food safety knowledge, practices, and hygiene status in the observed home kitchens. The results provide the starting point for evaluating progress or regression in this area compared to the past statewide study. Food safety knowledge was analyzed among 380 consumers with an online questionnaire. Additionally, 16 consumers were observed during their preparation of specified foods. The hygiene conditions in the kitchens were microbiologically examined using contact agar plates, while the cleaning adequacy was determined by measuring the ATP bioluminescence. A lack of knowledge on certain topics regarding food safety was established; the consumers aged from 36 to 55 in general and women demonstrated the highest level of knowledge. In some cases, the observed consumers did not take proper action when preparing the food. Increased total bacteria, coliform bacteria, and *Escherichia coli* counts were detected in 12.7% of the consumers' kitchens observed here. Eighty-three (74.1%) out of 112 surfaces examined with either hygiene test sheets or ATP swabs met the standards and were adequately or acceptably cleaned. The kitchen surfaces exceeded the recommended limits for 25% of consumers. Statistical differences in RLU and TCC levels on surfaces between older and younger consumers were not observed, although all (25%) inadequately cleaned kitchens belonged to older consumers. The greatest emphasis has to be put on the cleaning of home kitchens and personal hygiene. Even though consumers have some knowledge on food safety, they often fail to put that knowledge into daily practice.

Keywords: consumers; food safety; knowledge; practice; observation



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1. Introduction

Many consumers are unaware of the fact that their home environment poses a risk of foodborne disease outbreaks [1–3]. According to the EFSA and ECDC [4] report, the category “domestic setting” was the most commonly reported setting (N = 97; 39.1% of strong-evidence outbreaks) where foodborne outbreaks occurred. The research findings show that consumers most often associate foodborne disease (FBD) with the catering industry [5,6]. The recent Eurobarometer report [7] revealed that food hygiene is fifth place out of 15 topics that most concern European consumers (32%) when it comes to food and is at 10th place among Slovenian consumers (18%). Most food is prepared by consumers at home [2], so knowledge about food preparation in their home kitchens is all the more important, as it reduces the likelihood of FBD [8,9]. Proper consumer behavior in food preparation is—in addition to the knowledge of food hygiene—a key element in ensuring consumer safety [6,10–13]. The lack of knowledge and mishandling of food during preparation is more common in consumer groups of young adults (18 to 29 years of age), men, and people older than 60 years [5,14]. Irregularities in food handling at home are related to improper hand washing, the improper separation of equipment

and utensils, inadequate cold food storage, cross-contamination, and the inadequate heat treatment of food [3,5,15–17]. Against such a background, there is a constant and still urgent need for improved domestic food hygiene knowledge and practice [2,17–19]. However, consumer education activities are expensive to organize, maintain, and evaluate. Thus, it is particularly important to correctly identify, target, and reach higher risk consumer groups [20–22].

The main purpose of our research was to assess and determine the level of food safety knowledge and food handling practices by consumers in the domestic milieu, including their behavior during the preparation of selected foods and the hygiene conditions in their home kitchens. The outcomes of this study also serve for a comparison with the data collected among Slovenian consumers in a nationwide study in 2008 [5] in order to evaluate the progress or regression of the results.

2. Materials and Methods

2.1. Consumer Food Safety Knowledge

To assess consumer food safety knowledge, we used a validated questionnaire, based on a questionnaire from the Food and Drug Administration (FDA) [23]. Some additional questions were added in order to compare the data with the previous Slovenian survey on consumer knowledge of food safety, carried out in 2008 [5]. The questionnaire was translated into the Slovenian language and tested among five experts in the food safety field and 20 consumers of different age groups and genders, resulting in minor modifications with the wording of questions.

The questionnaire was entered into an online survey application and a web link to the questionnaire was sent to consumers via e-mail and social networks. The questionnaire responses were analyzed using SPSS version 20.0 software (New York, NY, USA). To examine the relationships among and between the variables, a chi-square test for independence (χ^2 test) for categorical variables (nominal and dichotomous types) and an independent sample *t*-test or ANOVA for ordinal variables (5-point Likert-type measurement scale) treated as a continuous variable were used. Gender, age and educational level were used as independent variables. The significance level of $p < 0.05$ was used.

2.2. Observing Consumers' Food Handling Practices at Home

The sample for this qualitative research consisted of 16 people, selected based on the snowball principle [24]. Out of these, 8 consumers were more than 65 years of age and 8 were younger than 35 years with small children. We decided on such a sample because the elderly and children belong to a population group vulnerable to FBD. The responsible household member was informed about the general aim of the research. When a responsible household member agreed to participate, the date and hour were determined via the phone. During the home visit, the consumers' task was to prepare the raw food delivered to them into a roast chicken leg, rice with carrots and peas, and cabbage salad. Individual steps of their food handling were recorded in the observation checklist, which was prepared on the basis of a review of other similar studies [2,6]. We observed the frequency and method of hand washing; cleaning of equipment, utensils, and kitchen surfaces; prevention of cross-contamination; method of food preparation; and heat treatment of food. A Testo 106 food thermometer (measuring range -50 to $+275$ °C, ± 0.5 °C accuracy at the range -30 to $+99.9$ °C) was used to measure the temperature of the air in the refrigerators. The air temperature was measured in the middle shelf in the refrigerator after the thermometer had been in the refrigerator for 15 min.

Moreover, participants were informed about the possibility to refuse their participation or to change their mind at any time during the home visit without any consequences. All the data were collected with consent.

2.3. Imprint and Swab Sampling to Establish the Microbiological Quality and Hygiene of Kitchen Surfaces

The microbiological conditions of work surfaces (Table 1) and utensils were established with RIDA[®]COUNT Total test hygiene sheets to determine the total aerobic mesophilic microorganism counts (total colony count—TCC), and RIDA[®]COUNT *E. coli*/Coliform test hygiene sheets to determine the number of coliform bacteria, including *E. coli* (R-Biopharm AG, Darmstadt, Germany). One sample per consumer was taken on a clean cutting board and service plate (Table 1). The sampling procedure was applied in accordance with ISO 18593 [25] and the manufacturer's instructions. The obtained results were compared to the guidelines for the microbiological safety of food intended for the final consumer [26] that define the criteria used to evaluate the cleanliness of surface samples.

Table 1. A table of the sample sites of test sheets for establishing the total number of aerobic mesophilic microorganisms and the number of coliform bacteria, including *E. coli*, and the sample sites of swabs taken to measure the ATP bioluminescence.

Method	Sample Sites
Test sheets RIDA [®] COUNT	Cutting board Service plate
Swabs taken to measure the ATP bioluminescence	Knife for cutting meat Work counter Refrigerator wall (shelf for delicacies) Dishwasher wall (rubber pad next to the filter) Salad servers

The cleanliness of the selected surfaces (Table 1) was evaluated by swabbing in order to measure the ATP bioluminescence (Hygiena, CA, USA). The swabs were taken according to the manufacturer's instructions from a 100 cm² surface area and from the whole surfaces of the cutlery and the knife used for cutting meat. The results were interpreted in relative light units (RLU). The limit values recommended by the swab and luminometer producer were used [27].

3. Results

3.1. Results of the Questionnaire

The online survey started in November 2018 and was completed in April 2019. Only the relevant units that were fully ($n = 260$) or partially completed ($n = 80$) were used for the analysis. The key results of the survey are presented separately according to content areas.

3.1.1. Demographic Data

Table 2 shows the demographic data for the surveyed consumers ($n = 340$), i.e., age group, level of education, and gender.

Table 2. Demographic data for the surveyed consumers ($n = 340$).

Variable		<i>n</i>	%
Gender	Men	63	19
	Women	277	81
Age group	1st age group (18 to 35 years)	171	50
	2nd age group (36 to 55 years)	107	31
	3rd age group (over 56 years)	62	19
Education level	Primary, secondary, and post-secondary *	185	55
	University education, master's degree, doctorate	155	45

Legend: * Post-secondary education includes a two-year post-secondary program of study.

3.1.2. Risk Perceptions

In our study, more than half (65%) of the consumers believed that FBD were rare in domestic households, and 62% of them claimed that people were more often infected or poisoned by food consumed in restaurants. The majority agreed that food contaminated with microorganisms posed a serious (50.5%) or very serious (38.6%) risk to consumers. However, some specific responses in this category were mainly influenced by age (Table 3).

Table 3. Overall results of the questionnaire analysis and statistical significance ($p < 0.05$) by gender, age, and education level.

Categories and Variables Studied	Overall Agreement Correctness/Rate	<i>p</i> -Values			Subgroup with Statistically Significant Higher Rate *
		Gender	Age	Education	
Risk perception					
Certain groups of people are more susceptible to infections and/or food poisoning.	71%	0.352	0.015	0.003	Highly educated older consumers
Risk for infection and/or food poisoning is higher among the elderly.	71%	0.053	0.033	0.362	Younger consumers
Risk for infection and/or food poisoning is higher among people with poor hygiene habits.	57%	0.687	0.041	0.474	Middle-aged consumers
Eating hygienically prepared food cannot lead to infection or poisoning.	48%	0.923	0.006	0.291	Older consumers
Awareness of microorganisms existing on food and surfaces					
Prevention of infections from foods containing bacteria of the <i>Salmonella</i> genus by thorough heat treatment.	69%	0.892	0.001	0.112	Younger consumers
Agreeing with the fact that raw chicken contains pathogenic microorganisms.	63%	0.030	0.138	0.204	Women
Agreeing with the fact that that raw seafood contains pathogenic microorganisms.	52%	0.140	0.008	0.827	Middle-aged consumers
Washing hands					
Appropriate hand drying method (a paper towel or a kitchen towel only for wiping the hands).	63%	0.719	0.036	0.100	Middle-aged consumers
Appropriate hand washing technique (warm water and soap) before preparing food.	60%	0.632	0.024	0.885	Middle-aged consumers
Appropriate hand washing time (more than 20 s) before preparing food?	10%	0.008	0.415	0.678	Women
Handling utensils after contact with raw meat					
Washing the cutting board with detergent and warm water.	83%	0.000	0.095	0.167	Women
Using another knife or washing the knife with detergent and warm water.	78%	0.019	0.080	0.033	Highly educated consumers
Using another cutting board.	55%	0.064	0.27	0.060	Middle-aged consumers
Cold chain maintenance					
Control thermometer in the refrigerator.	30%	0.014	0.416	0.574	Women
Use of insulating bag after purchase of perishable food.	23%	0.137	0.023	0.176	Older consumers
Food thawing					
Appropriate thawing technique of frozen meat (in the refrigerator).	52%	0.509	0.105	0.015	Highly educated consumers
Food handling after heat treatment					
Appropriate reheating leftovers (until boiling and boil for a few minutes).	62%	0.906	0.039	0.115	Middle-aged consumers
Appropriate cooling method for heat-treated dishes (in less than two hours after heat treatment).	50%	0.622	0.011	0.071	Middle-aged consumers

Note: * Detailed information on the results of the subcategories can be found in Sections 3.1.2–3.1.8. Younger consumers (1st age group): 18–35 years; middle-aged consumers (2nd age group): 36–55 years; older consumers (3rd age group): over 56 years; higher level of education: university education, MSc., PhD.

Consumers in the 3rd age group were much more likely to agree (72.2%) that certain populations are more susceptible to food poisoning compared to the 2nd (62.8%) and 1st (47.9%) age groups. In contrast, elderly consumers (3rd age group) least agreed (56.4%) that elderly are at higher risk of foodborne infections compared to the 2nd and 1st age groups, with 73.4% and 75.0% agreement, respectively (Table 3). Elderly consumers (3rd age group) least agreed (43.6%) that people with poor hygienic habits are at higher risk of foodborne infections, while the 1st and 2nd age groups agreed at 56.0% and 64.9%, respectively.

3.1.3. Awareness of Microorganisms on Food and Surfaces

The awareness of microorganisms was highest among younger consumers in the first age group and lowest among older consumers in the third age group. When asked about specific microorganisms, the bacteria *Yersinia enterocolitica* (21%), *Bacillus cereus* (25%), and *Clostridium perfringens* (29%) were the least known, while *Salmonella* (96%), *E. coli* O157 (56%), and *Staphylococcus aureus* were among the best known. The respondents overall considered chicken to be riskier compared to seafood (Table 3). Women associated raw chicken meat with pathogenic microorganisms more than men, with 66.7% and 48.1% selecting the “very likely” option, respectively. On the other hand, the knowledge of how to prevent infections from food containing *Salmonella* was age-dependent (Table 3). Younger consumers were most likely (75.9% and 72.8% in the 1st and 2nd age groups, respectively) to see thorough cooking as the best course of action, while older consumers (3rd age group) saw this as an option only in 46.3%, while 44.4% no longer considered this type of food to be safe at all.

3.1.4. Washing Hands

The questionnaire revealed that 60% of consumers reported washing their hands always with warm water and soap before preparing food, while the rest reported washing their hands almost always (31%) or sometimes (9%). The technique of hand washing (with warm water and soap) was found to be age-dependent (Table 3), as in the 1st and 2nd age groups 67.7% and 65.5%, respectively, reported always washing their hands in this manner, while only 51.9% ($p = 0.024$) reported this in the 3rd age group. The handwashing time turned out to be the most critical element of hand hygiene. Among the 290 consumers, 26% reported washing their hands for 10 s or less, 46% for 11 to 20 s, and 10% for 20 s or more, while the others gave no consideration to the washing time. Significantly more males (43%) than females (23%) washed their hands for only 10 s or less. The statistical analysis (Table 3) revealed that women reported washing their hands for longer than men ($p = 0.008$). After washing their hands, 37% of the consumers reported using a kitchen towel that was only for drying hands, followed by those who used paper towels (26%) and those who used a kitchen towel that was also used for drying dishes (22%). The proper technique of hand drying was reported (Table 3) significantly more frequently by older (78.3% and 77.1% in the 2nd and 3rd age groups, respectively) consumers than by the 1st age group, who reported a proper technique of hand drying in 63.2% of respondents.

3.1.5. Handling Utensils after Contact with Raw Meat

Overall, 17% of the consumers (Table 3) reported risky practices with potential for cross-contamination, while washing the cutting board after use (cutting raw meat) with water only was more frequent in males (35.3%) than females (13.5%) ($p < 0.001$). Similarly, after using the knife (cutting raw meat), males were more likely (35.3%) than females (19.1%) to wash it with water only. After cutting red meat or poultry, 61.2% of consumers in the 2nd age group and 56.8% in the 1st age group used a second cutting board for vegetables, while only 39.7% of consumers in the 3rd age group reported this practice ($p = 0.027$).

On the other hand, after cutting raw meat, a large share (44%) of the consumers reported to washing the cutting board with detergent and warm water (38% of all female and 27% of all male consumers).

3.1.6. Cold Chain Maintenance

Of all the categories studied, the lowest food safety performance was found in maintaining the cold chain (Table 3). Thirty percent of respondents reported having a thermometer in their refrigerator at home, with females reporting this more often (33%) than males (18.5%) (Table 3). More than half of the respondents (51%) did not know the temperature in their refrigerator. Of those who said they had a thermometer, slightly more than half (54%) knew the temperature. As many as 40% of consumers reported never checking the temperature or only checking it when food felt too hot or too cold (32%), while the rest checked the temperature daily, once a month, or weekly (28%). The consumers were asked to indicate the temperature in their home refrigerator. The mean value of the temperatures reported was 5.4 °C. Most consumers (31%) indicated that the temperature was 5 °C. After a purchase, the use of an insulated bag to maintain the cold chain was found to be age-specific (Table 3), and was most commonly used by the third age group, who reported always using it (33.3%), followed by the second (21.7%) and first (19.3%) age groups.

3.1.7. Food Thawing

Frozen meat was reported to be properly defrosted by 52% of the consumers (34% in the refrigerator, 11% under cold running water, and 7% in the microwave), while 42% and 6% of the consumers defrosted meat on the kitchen counter and never defrosted frozen meat, respectively. The defrosting of frozen meat was related to the level of education (Table 3), with those with low education most likely (47.3%) to defrost frozen meat on the kitchen counter, while 36.8% of those with higher education reported this practice ($p = 0.015$).

3.1.8. Food Handling after Heat Treatment

Half of the 250 consumers reported allowing the prepared dish to cool at room temperature for less than two hours, 28% of them for more than two hours, and 21% did not pay attention. The majority (88%) handled the roasted meat correctly after heat treatment, as they did not place it in the container where the raw meat had been stored. Reheating (heating food quickly to 75 °C or hotter by stirring to distribute the heat over the entire surface) was reported by 62% to be done until the food is boiling, followed by 26.1% who reheated only until the food is warm enough and suitable for immediate consumption. The rest indicated that reheating was not necessary as leftovers were thrown away or given to animals.

The methods of cooling heat-treated dishes (cooling to a temperature of about 20 °C within a maximum of two hours, then refrigerating up to 5 °C or freezing −18 °C immediately afterwards) and reheating leftovers were age-dependent (Table 3). The proper cooling method was applied in 25.8%, 18.8%, and 10.3% of age groups 2, 3, and 1, respectively. Similarly, the method of reheating was applied in 71.4%, 65.5%, and 53.2% in age groups 2, 3, and 1, respectively.

3.2. The Results of Observing Consumers and Their Food Handling Practices

Observations of the preparation of the selected foods were carried out with prior arrangements at the consumers' homes. We observed 16 consumers, 8 of whom were over 65 years old and 8 under 35 years old with children aged 5 years or younger. We observed 8 women, 4 being under 35 years of age, and 8 men, 4 being over 65 years of age, preparing selected foods.

3.2.1. Hand Washing

Through the observations of consumers' food handling, it was found out that 8 of 16 washed their hands properly with soap and warm water, out of which 2 were over 65 years and 6 were younger than 35 years. Four consumers did not wash their hands and another 4 did not wash them correctly. The latter were over 65 years old (2 men and 2 women); they did not use soap or used cold water when washing their hands.

The differences between genders were not obvious. After contact with raw poultry meat, 8 consumers washed their hands correctly, with half of them being younger than 35 years and half of them being older than 65 years. Women demonstrated much better conduct after handling raw poultry meat, since 5 women washed their hands correctly (out of which 4 were over 65 years and 1 was younger than 35 years), while 3 men did so (2 younger and 1 older).

After washing, 3 consumers correctly wiped their hands, namely 1 older and 1 younger consumer, who both used paper towels, as well as 1 younger consumer who used a kitchen towel for this purpose. The others did not wipe their hands or wiped them incorrectly with a kitchen towel that was used for wiping hands, surfaces, and dishes.

The duration of washing hands for the surveyed consumers before starting to prepare food and after handling raw poultry meat and raw vegetables was too short, since none of the surveyed consumers washed their hands for more than 12 s.

3.2.2. Cleaning the Cutting Board after Its Use

Nine out of 16 consumers, of which 6 were younger and 3 were older consumers, correctly cleaned the board used for cutting raw poultry meat. The consumers cleaned the board with warm water and detergent and rinsed it with warm water ($n = 6$) or they put the board in the dishwasher ($n = 3$). Two male consumers over 65 years only washed the board with cold water and without detergent, and five consumers did not clean the cutting board (4 of them did not use the board, while 1 younger consumer subsequently used the same board without washing it to cut vegetables). No significant differences between genders were detected.

3.2.3. Measurements of Air Temperature in Refrigerators

At the time of measurement, only 2 of 16 refrigerators were operating below the recommended temperature ($5\text{ }^{\circ}\text{C}$) for consumer refrigerators [28]. Nine out of 16 refrigerators operated above $7.0\text{ }^{\circ}\text{C}$, while the rest operated within the tolerance range ($5 \pm 2\text{ }^{\circ}\text{C}$). The highest measured temperature in a refrigerator was $12.9\text{ }^{\circ}\text{C}$, while the lowest $4.1\text{ }^{\circ}\text{C}$. The average temperature in the refrigerators of consumers younger than 35 years was $7.1\text{ }^{\circ}\text{C}$ (max $9.2\text{ }^{\circ}\text{C}$; min $4.1\text{ }^{\circ}\text{C}$), while for consumers over 65 years it was somewhat higher, namely $7.6\text{ }^{\circ}\text{C}$ (max $12.9\text{ }^{\circ}\text{C}$; min $4.5\text{ }^{\circ}\text{C}$).

3.2.4. The Risks of Cross-Contamination during Food Preparation

Fourteen consumers did not use separate boards and knives to prepare meat and vegetables. Only 2 male consumers separated items correctly. Ten consumers correctly separated raw poultry meat from other food types, 5 of whom were over 65 years. The others did not separate them consistently. We also paid attention to the separation of raw foods from ready-made foods, which was respected by the majority (14) of consumers. Two younger male consumers separated them inconsistently. The majority of the observed consumers (14 out of 16 observed) did not wash poultry meat before preparation, which is in line with the recommendations (28). Before using it, the meat was washed by 3 women, namely 2 younger than 35 years (out of 8) and 1 older than 65 years (out of 8).

Seven consumers washed carrots before cutting them. Nine consumers did not wash carrots, out of these 5 were younger and 4 were older consumers. Only one younger consumer peeled the carrots before cutting and washed the cabbage before preparation, while the other 15 consumers did not wash them but instead only removed the outer leaves.

3.3. The Microbiological Quality Results and the Cleanliness of Surfaces

3.3.1. Hygiene Test Sheets

The presence of presumptive coliform bacteria, including *E. coli*, on the cutting boards was detected in one surveyed consumer. According to the manufacturer's instructions (R-Biopharm, Germany), the lowest detection limit for the total colony count and coliform bacteria (*E. coli*) is 1 CFU/20 cm², while the maximum number of colonies per sheet is

250 CFU/20 cm². Since only two characteristic colonies grew on the medium and were not further identified in this sample, this result cannot be used to interpret the adequacy of the surfaces examined here. In the other 15 consumers, *E. coli* and other coliform bacteria were not detected, which means that the samples from the mentioned surfaces complied with the parameters from the guidelines for the microbiological safety of food intended for the final consumer [26], stipulating that no *E. coli* bacteria are found in a swab.

Based on the TCC values, we classified each surface into one of three groups: adequately cleaned, acceptable, and inadequately cleaned. The acceptable level for the TCC on kitchen utensils is 100 CFU/20 cm² or 2.0 log CFU/20 cm² according to the guidelines [26]; thus, we assessed surface contamination above these levels as inadequate. Surfaces with TCC levels below log 1.0 CFU/20 cm² were defined as adequately cleaned. Surfaces were classified as acceptably cleaned when the TCC values were between log 1.1 and log 2.0 CFU/20 cm². The TCCs were above log 2.0 CFU/20 cm² on two cutting boards (12.5%), while the plates of all consumers were adequately ($n = 12$, 75%) or acceptably (4, 25%) cleaned.

According to the TCC limits of the two tested utensils as a whole, we divided the individual consumers into four classes as follows: 1st class: cutting board and plate were adequately cleaned; 2nd class: one of the tested surfaces was adequate and the other was acceptable; 3rd class: both surfaces were acceptable; 4th class: one or both tested surfaces were inadequately cleaned (Table 4).

3.3.2. ATP Swabs

The measurements of ATP bioluminescence were used to evaluate the cleanliness of the selected surfaces (knife for cutting meat, work counter, refrigerator walls, dishwasher wall, and salad servers). The manufacturer's recommended limits were used to interpret the results obtained as adequately cleaned (pass, 0 to 10 RLU), acceptably cleaned (caution, 11 to 30 RLU), and inadequately cleaned (fail, 31 RLU and above)/100 cm² of surface [29]. No less than 26 (40.6%) of the surfaces tested were inadequately cleaned according to these criteria. The average RLU values were the highest on knives used for cutting meat (163.68 ± 266.28). These utensils were inadequately cleaned by half ($n = 8$) of the 16 consumers surveyed, while only 31% ($n = 5$) were rated as adequately clean. The highest RLU value/total area of the knife was exceeded by more than 100 times (Table 4, Figure 1).

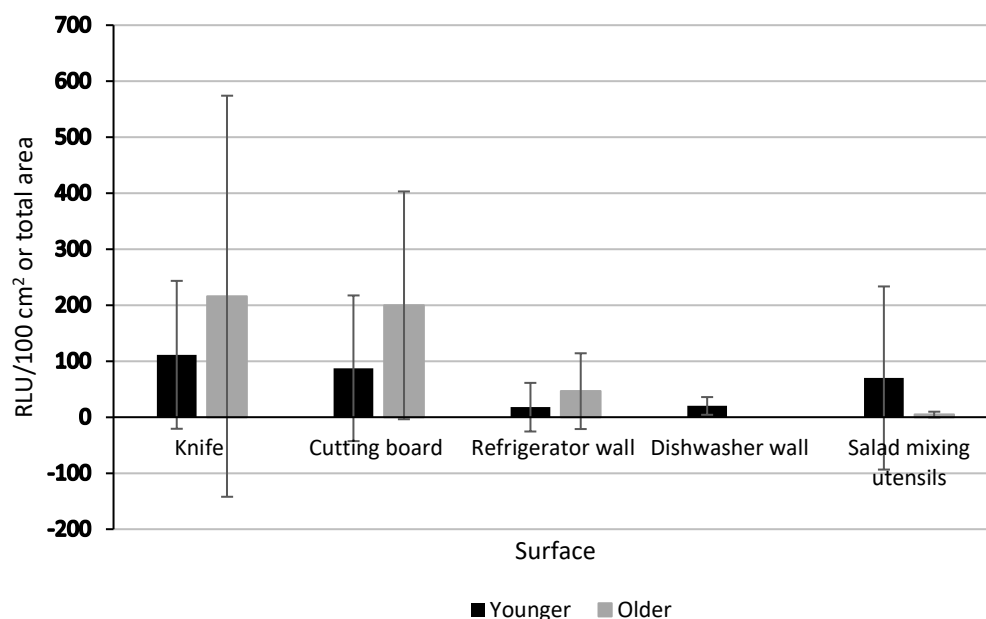


Figure 1. Average RLU values of the kitchen surfaces referring to older and younger consumers, measured via ATP bioluminescence ($n = 16$). Note: The measurements of dishwasher walls referring to older consumers were not included because most of them did not have this appliance.

Table 4. Cleanliness of surfaces and utensils used by the observed consumers based on the ATP bioluminescence and total colony count results.

Consumer Group	ATP Bioluminescence				TCC (log CFU/20 cm ²)			
	Knife (RLU/Total Area)	Working Counter (RLU/100 cm ²)	Refrigerator Wall (RLU/100 cm ²)	Salad Mixing Utensils (RLU/Total Area)	*	Cutting Board	Plate	**
Y1	8	64	1	3	3	1.90	0.60	2
Y2	116	401	8	58	4	1.25	0.30	2
Y3	317	25	0	1	3	1.51	0	2
Y4	306	101	1	9	4	0.90	0	1
Y5	0	43	0	3	3	1.30	0.30	2
Y6	115	5	2	7	3	1.51	1.23	3
Y7	11	38	125	472	4	1.25	0	2
Y8	18	22	6	7	2	0	0	1
O1	51	104	6	3	4	2.31	0.84	4
O2	12	81	9	15	3	0	0	1
O3	7	251	37	9	4	0.30	1.04	1
O4	4	96	2	1	3	0.60	1.45	2
O5	0	11	80	0	3	0.48	0	1
O6	484	359	5	1	4	1.71	1.88	3
O7	1003	620	201	6	4	1.30	1.53	3
O8	167	76	32	3	4	2.60 ^{en}	0.85	4
Average	163.68	143.56	23.19	37.38		1.18	0.63	
SD	266.28	174.84	56.86	116.17		0.77	0.65	

Note: Y: group of younger consumers; O: group of older consumers; RLU: relative light units—the bold black values mean that the cleanliness of the sampled surface is inadequate; TCC: total colony count. * Degree of surface cleanliness was estimated according to the producer' instructions (Hygiena, 2021) as a pass (adequate, 0 to 10 RLU), caution (acceptable, 11 to 30 RLU), and fail (inadequate, 31 and more) per 100 cm², and four classes were formed: 1st class: three or four surfaces belong according to the RLU values to pass, none to fail; 2nd class: two surfaces belong to pass according to the RLU values and two surfaces belong to caution; 3rd class: three surfaces belong to pass or caution according to the RLU values and only one belongs to fail; 4th class: two or more surfaces belong to fail according to the RLU values. ** Degree of surface contamination was estimated according to Guidelines (2019) with the compliant limit values of the TCC on kitchen utensils under 2.0 log CFU/20cm² and four classes were formed: 1st class: the TCC on the cutting desk and plate was below log 1.0 CFU/20cm²; 2nd class: TCC of one surface was below log 1.0 CFU/20cm² and the TCC of the other was between 1.1 log CFU and 2.0 log CFU/20cm²; 3rd class: TCC of both surfaces was between 1.1 log CFU and 2.0 log CFU/20cm²; 4th class: TCC of one or both tested surfaces was above 2.0 log CFU/20cm²; en: estimated number.

According to the ATP bioluminescence measurements, the work counter was rated as inadequately clean for the majority (75%, $n = 12$) of the consumers surveyed, while only one (young) consumer (6.3%) had an adequately clean working counter (Table 4).

The refrigerator walls were found to be inadequately clean for 5 (31.3%) consumers, although the average RLU values were the lowest compared to the other surfaces tested (32.19 ± 56.86 RLU/100 cm²) (Table 4, Figure 1).

The samples taken from the walls of the dishwasher (rubber pad on the filter) were less numerous because 44% of the consumers surveyed (7 elderly) did not have a dishwasher at home, so they were not included in further calculations. About 55.6% ($n = 6$) of 9 samples showed acceptable cleanliness for the dishwasher walls, while 22.2% ($n = 2$) each were adequate and inadequate, respectively.

The ATP bioluminescence results for salad utensils (forks, spoons, stirring spoons) were encouraging, as 81.2% ($n = 13$) of the samples could be rated as adequately cleaned, while one sample was acceptably cleaned and 12.6% ($n = 2$) were inadequately cleaned. The RLU levels were highest on the surfaces in kitchens mainly belonging to the older consumers, except for the salad mixing utensils (Figure 1).

Following the same principle of classifying consumers based on TCC limits, we did the same based on RLU limits, as follows: 1st class: three or four surfaces were adequate according to the RLU values, none were inadequate; 2nd class: two surfaces were adequate

according to the RLU values and two surfaces were acceptable, none were inadequate; 3rd class: three surfaces were adequate or acceptable according to the RLU values, only one was inadequate; 4th class: two or more surfaces were inadequate.

After classifying the hygienic adequacy of the surfaces based on the RLU and TCC values, we calculated the sum of the classes for each individual consumer and defined the overall hygienic conditions in their kitchen. In 4 (25%) kitchens, the surfaces were inadequately cleaned, and all of them belonged to the older consumers. The hygiene levels of the observed kitchen surfaces and utensils were acceptable and adequate in 9 (56.3%) and 3 (18.8%) of the observed consumers, respectively. Statistical differences in RLU and TCC values on the surfaces when using the t-test for independent samples between older and younger consumers were not observed ($p = 0.33$).

4. Discussion

It was assumed that consumers with a higher level of education would have more food safety knowledge, but was not fully confirmed, as it was found that there were only certain areas where consumers with a higher level of education showed better performances than those with a lower level of education. However, this is not a surprising result, since food safety is part of regular education only in primary schools and in professional education in the field of food science. The Food Safety Survey by the FDA [23] found that food was handled the least safely by the youngest American consumers, by the oldest, and by those with the highest level of education. In studies that gathered data through questionnaires and by observing consumers during food preparation, it was established that many consumers correctly answered questions about food safety and good hygiene practices, but they often acted contrary to what they stated in the questionnaires [1,18,19,22]; the chances of FBD are, thus, much higher than shown in the epidemiological data [2,10,21].

One of the reasons for violations of good housekeeping practices according to Redmond and Griffith [30] is optimistic bias related to the perceptions of risk in the context of food safety from the foods people prepare. The unhygienic food handling conditions at home in the current study contradict the lowest ranked risk perceptions according to Redmond and Griffith [30]. In our study, more than half of the consumers believed that FBD were rare in domestic households and claimed that people were more often infected or poisoned by food consumed in restaurants. Although the last Eurobarometer report [7] revealed that food hygiene ranks 5th considering the topics on food that most concern European consumers, food hygiene is rated as last (18%) among Slovenian consumers. Our study also pointed out that the elderly consumers least agreed about the elderly being at higher risk of foodborne infections compared to younger ones and about people with poor hygienic habits being at higher risk of foodborne infections.

Proper hand washing before and during food preparation according to the survey was done more consistently by female consumers than by male ones. When comparing the results with a previous similar study among Slovenian consumers [5], we can see that 86% of consumers always washed their hands before preparing food. Our present research illuminated the fact that the situation is not improving; on the contrary, we found that only 60% of consumers always washed their hands before preparing food. The study by Jevšnik et al. [5] found that more than half of consumers washed their hands for less than 10 s. In our recent study about one-quarter reported a hand washing duration of less than 10 s. Furthermore, 67% of consumers washed their hands with soap and warm water after handling raw red meat, chicken, or fish, which was more than in the study by Jevšnik et al. [5], where the relevant share was 57%.

The questionnaire results showed that slightly less than half of the consumers defrosted food at room temperature, while the rest carried out the procedure correctly in the refrigerator, under running cold water, or in a microwave oven. Lower results were reported by Sterniša et al. [31] and Jevšnik et al. [5], where almost three-quarters (73%) or half (50%) of the consumers thawed frozen meat at room temperature. Studies from abroad found that meat was thawed at room temperature by 44% of Nigerian consumers [32], 47%

of African and Asian consumers [3], and 73% of consulted Belgian consumers [9], as well as more than a half of Turkish consumers [16].

The best knowledge of microorganisms that can cause FBD was shown by younger consumers, which can be attributed to the fact that they have better access to information than older consumers. In general, the knowledge of pathogenic microorganisms was poor. More than half of the surveyed consumers knew only two types of bacteria, namely *Salmonella* and *E. coli*, which was more than noted by Gong et al. [33], as more than half of Chinese consumers had never heard of these bacteria. Borda et al. [34] established that Romanian consumers did not recognize some of the pathogens, especially those that may affect their health in the present day and are categorized as emerging pathogens.

While observing consumers, we found many irregularities that can cause the microbiological contamination of surfaces. A higher risk of microbiological contamination of food was evident in consumers older than 65 years. Raw poultry meat must be kept in the refrigerator, as this prevents the growth of pathogenic microorganisms and cross-contamination during storage. It must be kept at temperatures of up to 5 °C on the lowest shelf in the refrigerator to prevent possible dripping on other foods [1]. We found that most of surveyed consumers (94%) paid no attention to the place in the refrigerator where they stored packed or unpacked foods. Only 1 younger man was attentive in this respect. Incorrect practices with storing foods in refrigerators were found by Janjić et al. [35], who noted that almost half of consumers stored foods incorrectly (raw food above prepared food, inconsistent separation of raw and prepared foods). In the home refrigerators of the surveyed consumers, we measured the cold air temperatures and established that the average temperature amounted to 7.4 °C, which was 1.5 °C higher than recently reported by Ovca et al. [36] after 24 h refrigerator measurements in Slovenian households. A Serbian study of consumers by Janjić et al. [35] demonstrated poorer results, with an average temperature of 9.3 °C, which was above those recommended (5 ± 2 °C) (NIJZ, 2011).

In our recent study, it was found that 30% of the consumers claimed they had a thermometer in their home refrigerator to check the temperature. However, it could also be possible that consumers mistakenly thought their refrigerator's built-in display was a control thermometer. The recent study by Ovca et al. [36] among Slovenian households proved that none of the analyzed refrigerators were equipped with a control thermometer and only few (16%) had a built-in display. Better results were shown in a survey of American consumers, where 42% of consumers had a thermometer in the refrigerator, with an average temperature of 3.6 °C [23].

The question of how the surveyed consumers checked the heat-treated poultry meat was answered by majority that they cut the meat or evaluated its color, and only some of them measured the core temperature [31]. Studies of American [19] and Belgian consumers [1] gave similar results. Visual control is not always a reliable indicator that the meat has received appropriate thermal treatment. Only the core temperature of the meat can attest to this with certainty [16]. In the current study, none of the surveyed consumers used a thermometer during the heat treatment of meat; rather, they evaluated the color of the poultry meat and the baking time, and some cut through the poultry leg.

Most of them (69%) kept leftovers on the kitchen counter, others in the refrigerator (12%), or others gave leftovers to animals to be eaten (19%). Two foreign studies also showed similar results, since 24% of Italian [37] and 17% Chinese [33] consumers let foods cool down at room temperature and then stored them in the refrigerator.

Consumers younger than 35 years and older than 56 years were less informed about the methods of ensuring food safety than consumers aged between 36 and 55 years, meaning they could, thus, more often cause FBD. Due to having weaker immune systems and more diseases, the elderly are more prone to infections or food poisoning [14]. The knowledge of the elderly was acceptable in some areas; however, they often failed to transfer it into practice, since the consumers older than 65 years fared worse when preparing food than the consumers younger than 35 years. We further established that weaker knowledge and

practices regarding ensuring food safety were demonstrated by male consumers, which was also stated in studies performed abroad [16,17,20,22].

Most surfaces (93.8%) sampled with hygiene test sheets used to assess the microbiological quality of surfaces met the guidelines [26] for both standards (total aerobic mesophilic microorganism and coliform bacteria counts, including *E. coli*), indicating that the consumers were adequately cleaning their cutting boards and serving plates. The results of the swabs used for measuring ATP bioluminescence showed poorer hygiene conditions.

Bukhari et al. [38] reported that meat slicers and cutting boards were the most contaminated surfaces in restaurant kitchens (60% and 50%, respectively), whereas washed serving dishes were the least contaminated (18%). The same situation was observed in our study, where more than half of the ATP swabs taken from the surfaces of the knives used to cut meat were inadequately cleaned. Therefore, the surfaces that came into contact with raw food, especially foods of animal origin such as meat, were more contaminated, as the concentrations of faulty microbiota in meat can quickly reach 6.5–7.0 log CFU/g, depending on the handling and storage conditions [39].

Additionally, twelve (75%) working surfaces failed to meet the producer standards [29]. The reasons could be inadequate cleaning, the use of contaminated sponges for cleaning, and the fact that these surfaces were not exposed to higher temperatures or were not rinsed with clean water. Indeed, about 72% of sponges from household kitchens contained more than 7.0 log CFU for the TCC [40]. The lowest average number of RLUs was found on the surfaces of the delicacies drawer in the refrigerator, which can be explained by the inhibition of microorganism growth due to low refrigeration temperatures. Only about 56% of surfaces inside the dishwashers were acceptably clean. The manufacturers recommend regular cleaning of the grates, rubber linings, and filters with a degreaser and additional rinsing with hot water. According to our previous observations in some households, the dishes in the dishwasher were washed only with warm water (only 40 °C to 50 °C), which is not sufficient to kill microorganisms. Therefore, the improper cleaning and maintenance of the dishwasher could pose a risk for the microbiological contamination of kitchen utensils during washing. The poorer results from the ATP swabs in comparison to the results of test sheets could be linked to the fact that the ATP swabs detected all cells (microbial, plant, and animal cells) and also residues of organic origin (e.g., food leftovers), while the test sheets detected only microbial cells [27].

We can conclude that eighty-three (74.1%) of the 112 surfaces examined with either hygiene test sheets or ATP swabs met the standards and were adequately or acceptably cleaned (Table 4). The kitchen surfaces of 4 (25%) consumers exceeded the recommended limits. Statistical differences in RLU and TCC levels on surfaces between older and younger consumers were not observed, although all (25%) inadequately cleaned kitchens belonged to older consumers.

To sum up all of the results obtained with all of the methods used, we found differences between what the consumers mentioned in the survey questionnaire and the way they handled food during its preparation. More than half (60%) of the consumers claimed that they always washed their hands before food handling, i.e., more elderly than younger consumers. Through observing the consumers, we established that half of the consumers washed their hands correctly, but only 25% of the elderly did so. In the survey questionnaire, more than half claimed that they correctly wiped their hands with kitchen or paper towels after washing, while our observations revealed that more than half of the consumers wiped their hands with a kitchen towel that was also used for wiping dishes or the counter. Differences were seen also with handwashing after contact with raw poultry meat, since 67% of the consumers claimed that they always washed their hands with soap and warm water, while through observations we identified a smaller share of correct handwashing after contact with raw poultry meat (50%). We found out that more than half of the surveyed consumers (56%) correctly washed the cutting board after cutting raw poultry meat. The majority of the surveyed consumers (87%) did not separate utensils, such as knives and boards, while the survey results showed a different picture, since 55% of the consumers

claimed that they separated their cutting boards. Differences were observed in washing vegetables before consumption, since 97% of the consumers claimed that they always washed tomatoes before consumption. The results obtained through observation were poor, since less than half of the surveyed consumers washed the carrots before cutting and only 1 consumer washed the cabbage.

5. Conclusions

Deficiencies were found in the consumers' knowledge regarding food defrosting procedures, temperatures in refrigerators, food handling practices, hand hygiene, knowledge about pathogenic microorganisms in food, and the use of thermometers for checking the internal temperature of food during heat treatment. Similar findings were also reported by some other analyzed studies. Moreover, we identified a lack of knowledge in the same content areas as in the previous Slovenian survey [5], which indicates an inadequate emphasis on food safety content.

The biggest drawbacks were identified in the field of cold chain maintenance, where a lack of knowledge identified with the questionnaire was also evident during the observation study. Risky practices (with potential cross-contamination) reported in the questionnaire in reference to the use of cutting boards and knives were evident during the microbiological study, where the highest loads were identified primarily on these surfaces. The highest level of knowledge and skills was shown by consumers aged from 36 to 55; in particular, female consumers performed much better than men, regardless of education. The consumers, especially the older ones, were largely convinced that FBD occurred primarily in restaurants and not at home, which is not in concordance with the actual EFSA statistics.

An increased total bacterial count was detected in 12.5% of the observed consumers' kitchens. The results of the ATP measurements showed that about 40% of the surfaces were cleaned inadequately. An increased emphasis has to be put on the cleaning of home kitchens and on personal hygiene, especially on washing hands more often and more thoroughly. Even though consumers have some knowledge of food safety, they often fail to put that knowledge into daily practice.

It is, therefore, necessary to raise food safety awareness in all consumers with an emphasis on vulnerable groups and to provide formal food safety education about ensuring food safety measures during purchasing and when handling food at home. This very complex field of activities clearly shows that the performance of consumers, as human beings, is constantly under the challenge of traditional beliefs about their skills, which they believe are improving with regular daily practice; this study, however, indicates that human beliefs represent one side of the coin of consumer performance, while the reality is much different and is changing with age and technological advancements in the kitchen.

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