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The management of the domestic refrigeration: microbiological status and temperature

The domestic refrigeration

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Abstract

Purpose – The purpose of this paper is to provide information on the consumer management of refrigerated food, establish the level and the incidence of bacterial contamination and operating temperatures in domestic refrigerators from north and centre Italy.

Design/methodology/approach – A questionnaire was designed involving 24 questions which covered three topics: the socio-demographic data, the domestic management of refrigerated food and general information about the refrigerator. The questionnaire responses were subjected to descriptive statistical analysis and further processed with the multiple correspondence analysis (MCA) and cluster analysis (CA). Based on MCA and CA, 84 refrigerators were selected to assess the temperature and the microbiological status (total viable counts (TVC); Enterobacteriaceae total counts (ETC); *Salmonella* spp. and *Listeria* spp.).

Findings – Totally, 660 interviews were carried out. The majority of respondents were female (81.4 per cent) and were married (71.4 per cent). Almost an half of them were between 31 and 50 years old (48.2 per cent) and had a secondary school degree (47 per cent). Regarding domestic management of refrigerated food, the majority of respondents (87.2 per cent) were aware of the correct temperature range (1–5°C) for retail refrigerator units, but only 18 per cent of them check the temperature. *Listeria monocytogenes* and *Salmonella* spp. were not recovered; *Listeria innocua* was recovered (2.4 per cent). Regarding the TVC values, the 21.5 per cent of the tested refrigerators were classified as insufficient (from 100 to 104 cfu/cm²) or inadequate (> 104 cfu/cm²). Consumer education should be focused in order to reduce foodborne disease. Only safety-conscious consumers can become active partners within the food safety chain.

Originality/value – Result obtained from the present survey revealed that consumers are not familiar with their role in the food safety chain and that they allow numerous opportunities for microbiological contamination of food. The study clearly indicates the need for greater consumer education regarding proper domestic refrigerator management. Indeed, appropriate behaviours could make the refrigerator less likely to act as a significant niche for persistence and dissemination of food pathogens.

Keywords Food-contact surfaces, Foodborne pathogens, Refrigeration, TVCs and ETCs

Paper type Research paper

1. Introduction

There is considerable evidence that the incidence of foodborne diseases is increasing, even though it is also a significant underestimation of the true magnitude of the



problem, with as little as 2 per cent of cases of foodborne acute gastroenteritis in the community being detected by current surveillance schemes (Sharma *et al.*, 2009).

Several reasons may explain the increasing incidence of gastro-intestinal infections, including evolution in commercial food production (minimal processing) and demographic changes. It was estimated that approximately 20 per cent of the population (the very young, old, pregnant and immuno-compromised people) may be classified within “at-risk” groups. Moreover, the spread of infection involving new or more virulent pathogens represent a serious global concern (Beumer and Kusumaningrum, 2003). Although consumers tend to associate foodborne illness with eating outside the home (Anonymous, 2006) research suggests that food-poisoning cases are initiated in private home three times more frequently than in commercial operations (Kilonzo-Nthenge *et al.*, 2008). It was estimated that up to 87 per cent of foodborne disease outbreaks that occurred in Europe, Australia, New Zealand, US and Canada originated from food prepared or consumed at homes (15).

Many of these are associated with the most common fault in domestic food hygiene practices, such as poor cleanliness, inappropriate storage and refrigerator management. Failure to follow correct practices in the adjustment, maintenance, use or cleaning of domestic refrigerators poses a number of risks to consumer. Kilonzo-Nthenge *et al.* (2008) highlighted that refrigerator form an important link in the wider chain of cross-contamination, and a significant factor in 28 per cent of outbreaks of domestic foodborne diseases. Bacterial contaminating raw food, packages, etc. introduced to domestic refrigerators may directly contaminate other stored foods or attach to and persist on the interior surfaces of the refrigerators.

A number of surveys of consumers handling of refrigerated foods have been carried out over the last 30 years and air temperatures in domestic refrigerators have been measured in a sub-set of these (James *et al.*, 2008).

In some of those, it is very clear how the temperatures were measured, where the sensors were positioned and for how long the measurements were carried out. In others far less data are provided in the publications so results may not be strictly comparable.

In an UK study, Evans *et al.* (1991) showed that the overall mean air temperature for all the refrigerators in the survey was 6°C with 70 per cent of refrigerators operating at average temperatures above 5°C. Sergelidis *et al.* (1997) reported that 25 per cent of the 136 domestic refrigerators investigated in Greece had temperatures above 10°C. A 2004 survey of New Zealand Food Safety Authority (Anonymous, 2007) found one-third of the 53 refrigerators surveyed operating above the recommended temperature range of between 1 and 5°C. In analysing the data from most of the various surveys reported over the last 30 years Peck *et al.* (2006) concluded that 61.2 per cent of refrigerators throughout the world run at temperatures above 5°C.

An analysis carried out in the Evans *et al.* (1991) UK study, showed that in 69.9 per cent of refrigerators the warmest place was in the top and in 45.1 per cent the coolest place was in the middle. However, the top of the refrigerator was not always the warmest and the bottom the coldest place. Backalis *et al.* (2003) found the warmest place in the door with the lowest temperature being in the middle position of some refrigerators and the upper tray in other. While Laguerre *et al.* (2002) found the highest temperature could something be in the top and at other times in the middle of the same refrigerator.

Refrigerator can support the growing of psychotropic pathogens such as *Listeria monocytogenes* and *Yersinia enterocolitica*, which can increase to significant numbers in food stored for extended periods. Moreover, many domestic refrigerators are

incorrectly adjusted, operating above the recommended temperature and are capable of supporting sub-optimum growth of mesophilic organisms such as *Staphylococcus aureus* and *Salmonella* spp. (Jackson *et al.*, 2007).

Consumers represent one of the most important components in the food safety chain when considering a “farm to table” approach. It is essential to understand consumers’ awareness concerning home food safety in order to plan proper education programmes.

To our knowledge, this is the first survey into domestic practices that may affect the safety of food products in Italy, although similar studies have been conducted in other countries.

Therefore, the objectives of this study were: to evaluate consumers behaviour with regard to refrigeration practices and to determinate the incidence of significant foodborne pathogens (*L. monocytogenes*, *Salmonella* spp.) and the general hygienic status of domestic fridges (total viable count (TVC); Enterobacteriaceae total count (ETC)).

2. Materials and methods

2.1 Questionnaire

The survey was conducted from March to July 2009 in different Italian provinces located in northern and central Italy. A questionnaire was designed involving 24 questions divided into three sections: demographic characteristics (gender, age, residence area, education, employment status and household size), domestic management of refrigerated food (placing, packaging and temperature), and general information about the refrigerator (type, refrigeration system and cleaning practices). Interviewers were trained final-year students who conducted interviews in their home cities. Interviewers briefly explained the purpose and the nature of the study to the respondents, and sought permission for inclusion of their views in the survey. Administration of the interviews took the form of the face-to-face interviews in the respondents’ homes or workplaces. Each questionnaire took approximately 10 min to complete.

2.2 Data analysis

Following the survey, three kinds of data sets were obtained: raw data, coded data and synthetic data. Raw data set corresponds to a direct transcription of the responses of the survey. Coded data set corresponds to a codification of the data in order to obtain continuous and nominal data. The synthetic data set corresponds to a conversion of all the continuous data into classes (modalities) in order to get nominal data. Over those data, multiple correspondence analysis (MCA) and Spearman rank correlation test were performed. Moreover, data obtained from MCA were used to perform the cluster analysis (CA) using Ward’s method. All statistical analysis was made up using SPSS (Chicago, IL) ver. 16.0. Based on MCA and CA, 84 refrigerators were selected for microbiological analysis.

2.3 Collection of samples from home refrigerators

Before microbiological sampling, the temperature of each refrigerator was measured and recorded by using a portable digital thermometer (DT 97, TFA, Germany) placed on the middle shelves of the domestic refrigerator and adjusted to recorded the internal temperature over a 24-h period. Before microbiological sampling, the temperature of each refrigerator was measured and recorded by using a portable digital thermometer DT 97 (TFA Germany) (temperature range: -10 - $+60^{\circ}\text{C}$, $\pm 1^{\circ}\text{C}$). The thermometers were adjusted to record the maximum, minimum and average internal air temperature.

According to Kennedy *et al.* (2005), participants were asked to place the thermometer on the middle shelves of the domestic refrigerator and to keep them over a 24-h period. From each refrigerator two samples were then collected. To evaluate the general hygienic parameters (TVC and ETC) a sample was collected by swab technique by using sterile cotton swabs moistened in sterile normal saline solution (NSS). An area of 100 cm² was marked with a sterile frame of 10×10 cm. Swabs were then placed into a tube containing 10 ml of NSS.

To determine the incidence of *Listeria* spp. and *Salmonella* spp. the inner surface (base, shelves and sides) of each fridge was swabbed using a sterile sponge moistened with 10 ml of NSS by the inverted bag technique (Lasta *et al.*, 1992).

All samples were transported to the laboratory in a cool box at approximately 4°C and microbiological examined within 2 h. Samples were investigated, using the methods described by the International Standardization Organization (ISO).

2.4 Enumeration of Enterobacteriaceae and aerobic counts

Tubes containing swabs were shaken on a vortex mixer for 30 s for uniform distribution of microorganisms. For the enumeration of TVC and ETC, tenfold serial dilution up to 10⁻³ were prepared for subsequent plating on plate count agar (PCA, Oxoid) and violet red bile glucose agar (VRBGA, Oxoid), according to EN ISO 4833 and EN ISO 21528-2, respectively. PCA were incubated for 72 h at 30°C and VRBGA for 24 h at 37°C. TVC and ETC were expressed as cfu/cm².

2.5 Isolation and identification of *Listeria* spp. and *Salmonella* spp.

For *Listeria* spp., each sponge was homogenised for 1 min with 90 ml of buffered peptone water (Oxoid). According to EN ISO 12290-1, a volume of 10 ml of the homogenate was transferred into 90 ml of Half-Fraser broth (Oxoid) and incubated for 48 h at 30°C. Half-Fraser broth culture tubes showing blackening were streaked to Agar *Listeria* Ottaviani and Agosti (ALOA, bioMérieux) plates with subsequent incubation for 24 h at 37°C and, if necessary, for an additional 24 h at 37°C. Following incubation, five typical colonies were transferred on tryptone soy agar (Oxoid) and incubated for 24 h at 37°C. Pure cultures were confirmed by Gram staining, oxidase test, catalase reaction and finally identified by biochemical test strips (API *Listeria*, bioMérieux).

Isolation of *Salmonella* spp. was carried out according to EN ISO 6579. Sponges previously homogenised were incubated for 24 h at 37°C. Afterwards, 0.1 ml of the pre-enrichment sample was transferred in 10 ml of Rappaport-Vassiliadis medium (Oxoid) for another 24 h at 42°C. Enrichment samples were then plated into xylose lysine deoxycholate agar (Oxoid) and incubated at 37°C for 24 h. Presumptive isolates were subcultured, confirmed by Gram staining and agglutination test, and finally identified using biochemical test (API 20E, bioMérieux).

3. Results

3.1 Questionnaire results

In total, 660 interviews were performed. Socio-demographic characteristics of surveyed participants are listed in Table I. Most of the 660 households surveyed were in rural and suburban areas (53.6 per cent) compared to urban areas (46.4 per cent). The majority of respondents were female (81.4 per cent) and almost an half of them were between 31 and 50 years old (48.2 per cent). Most of the respondents were married (71.4 per cent). It can be observed that the number of members was two or more in the

Number of subjects		660	
<i>Residence area</i> ^a		<i>Number of children at home</i> ^a	
Urban	46.4	0	44.2
Suburban	12.3	1	22.3
Rural	41.3	2	26.8
<i>Gender</i> ^a		>2	6.7
Female	81.4	<i>Education level</i> ^a	
Male	18.6	Primary school	23.8
<i>Age class (year)</i> ^a		Secondary school	47
<30	20	University	29.2
31-50	48.2	<i>Job category</i> ^a	
51-70	28.6	Employee	9.5
>70	3.2	Executive	40.3
<i>Civil status</i> ^a		Manager	7.3
Married/cohabits	71.4	Unemployed	1.5
Single	28.6	Retired	11.4
		Student	13.2
		Housewife	16.8

Note: ^aData are presented as percentages

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Table I.
Socio-demographic
characteristics of the
studied population
samples

majority of households (86.8 per cent). Of respondents, 44.2 per cent had no children at home, 22.3 per cent had one child, 26.8 per cent had two children and the remainders had three or more children. Almost an half of respondents had a secondary school degree (47 per cent), 23.8 per cent had a high school degree and 29.2 per cent had a university degree. Of those interviewed, 54.8 per cent were employed, 13.2 per cent were students, 11.4 per cent were retired, 1.5 per cent were unemployed, 16.8 per cent were full-time housewives and 2.3 per cent refused to answer.

Regarding domestic management of refrigerated food, the majority of respondents (87.2 per cent) were aware of the correct temperature range (1-5°C) for retail refrigerator units, but only 18 per cent of them check the temperature. Almost one-half of them (54 per cent) said they removed the overwrap food packaging (cardboard or plastic around yogurt, juice, etc.). Of the interviewed people 36.9 per cent declared that they clean the refrigerator once per month, or more, 14.2 per cent declare they clean it three times per year and 49.1 per cent declared they clean it only when there was visible dirt. The products used for cleaning fridge were specific detergent in 11.2 per cent cases, multipurpose products in 24.1 per cent and homemade methods in 64.7 per cent (vinegar or bleach and warm water) (Table II). There was no correlation between cleaning frequency and products used.

The respondents' answers indicated that the most often quoted refrigerator age group was between one and five years: 38 per cent of the refrigerators were less than five years old, 32 per cent were between five and ten years old, and 30 per cent were more than ten years old. In all, 93 per cent of refrigerators had static refrigeration system and 7 per cent had ventilated ones.

3.2 MCA and CA

MCA allows to group the data obtained from the consumers. Respondents with similar characteristics are close together and the others are far apart. Moreover, each consumer is as close as possible to the characteristic that describes it. The projection of the individual data on the graphical display did not show a clearly

BFJ 116,6	Number of subjects	660
	<i>How many times a week buying food?</i> ^{2a}	
1052	1	20.3
	2	28.5
	> 3	51.2
	<i>How do you place the foods in the fridge?</i> ^{2a}	
	Casual	16.1
	Manufacturer indication	20.8
	Personal order	63.1
	<i>Do you remove the outer packaging of your foods?</i> ^{2a}	
	Yes	54.2
	No	45.8
	<i>How many times you clean the fridge?</i> ^{2a}	
	Every week	11.8
	Every month	24.8
	Every three months	14.2
When the fridge is dirt	49.2	
<i>What kind of products do you use to clean?</i> ^{2a}		
Specific detergents	11.2	
Aspecific products	24.1	
Homemade methods	64.7	
Note: ^a Data are presented as percentages		

Table II.
Domestic management
characteristics of the
refrigerated foods

visible cluster structure, meaning that there is a great variability in the respondent's behaviour. Instead, based on CA, interviewed people can be subdivided into two main groups.

The first group was composed by the majority of the respondents and consisted of families with two or more people, aged less than 31 or between 31 and 50 years. These people had a good level of education (college or university) and they were mainly executive or employee in the education or service sectors. They were aware that the temperature into the refrigerator is not homogeneous and place the food items following the manufacturer's instructions or a personal order. Foods were placed in the refrigerator inside specific boxes (vegetable and cheese bins). Regarding the cleaning of the refrigerator, people belonging to this group wipe out every three months, disassembling the mobile parts, when possible and using specific products for cleaning.

The second group was composed mainly by students who lived alone or shared an apartment or by retired people whose job sector was industry or agriculture. Usually they had a medium-low level of education. In contrast to the first group, people of this group did not know that the temperature in the refrigerator is not uniform and the placing of food is random. Foods were placed into the refrigerator packed in paper. The refrigerator was cleaned "when needed", without disassembling it and using general products (not specific for the fridge) or following homemade systems (e.g. using vinegar, lemon juice, etc.).

The analysis of the correlations showed that people with a good level of education are aware that the temperature is different depending on the position into the refrigerator ($p = 0.157$). The high cleaning frequency is related to the use of specific products for cleaning ($p = 0.159$). Finally, people that use proper boxes to place foods into the refrigerator do not set the items randomly into the household appliance ($p = 0.133$).

3.3 Refrigerators temperatures

The observed refrigerator temperature varied between 2.5 and 15.9°C, with an average temperature of 8.1°C. Of the surveyed refrigerators, 42.8 per cent had an average temperature higher than 4°C, and 51.2 per cent had an average temperature higher than 10°C (Table III).

3.4 Enterobacteriaceae and aerobic counts

The TVC contamination levels observed in this study extend across a wide range of values, ranging from <0.1 to 6.8×10^4 cfu/cm² ($<0.1 \log_{10}$ to $4.83 \log_{10}$ cfu/cm²). The ETCs varied between <0.1 to 1.5×10^4 cfu/cm². The average TVC and ETC were 1.7×10^3 and 2×10^2 cfu/cm², respectively. The obtained TVCs' and ETCs' values were classified according to Festino *et al.* (Figures 1 and 2). A high percentage (78.5 per cent) of the sampled refrigerators showed an adequate hygienic conditions (<100 cfu/cm²), 16.7 per cent were considered insufficient (from 100 to 10^4 cfu/cm²) and 4.8 per cent showed an unacceptable status ($>10^4$ cfu/cm²). The ETCs data showed an insufficient hygienic status in 4.8 per cent of the refrigerators. Only one fridge (1.2 per cent) had an unacceptable condition. The highest TVC and ETC values were recorded in the same fridge.

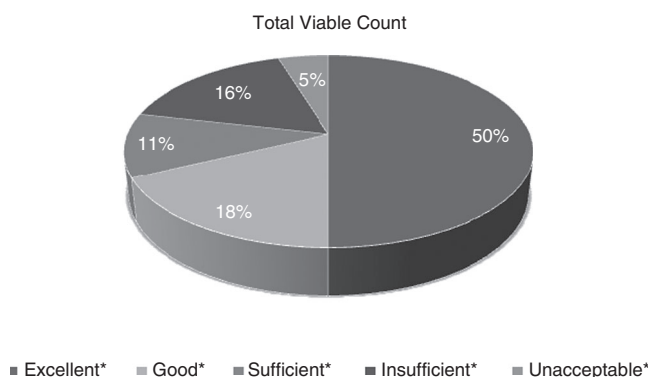
3.5 *Listeria spp.* and *Salmonella spp.*

L. monocytogenes and *Salmonella spp.* were not isolated in any of domestic refrigerators sampled. However, *L. innocua* was detected in two fridges with adequate hygienic status.

Temperature (°C)	Fridge ^a
2-4	6.0
4.1-7.0	20.2
7.1-10.0	22.6
> 10.1	51.2

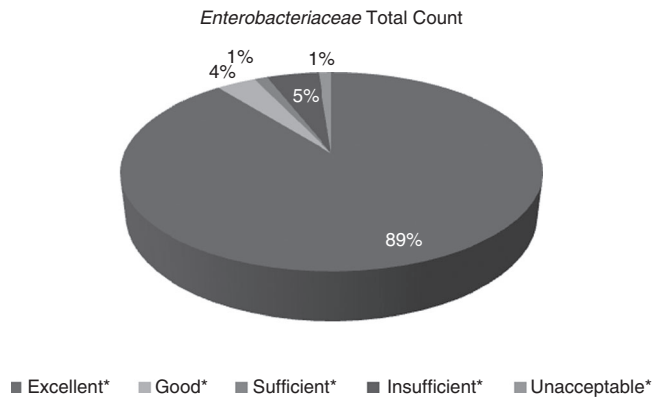
Note: ^aData are presented as percentages

Table III.
Temperature distribution
in sampled fridges



Source: According to Festino *et al.* (2006)

Figure 1.
Classification
of TVCs' values



Source: According to Festino *et al.* (2006)

Figure 2.
Classification
of ETCs' values

However, there was no observable correlation between respondents' socio-demographic status and overall microbial numbers.

4. Discussion

Outbreaks of foodborne illness, especially at the home, occur as a result of improper food hygiene practices in which cross-contamination in combination with inadequate storage or cooking was implicated in many instances (Olsen *et al.*, 2000). The importance of domestic food handling and storage in foodborne illness is supported by epidemiological data. Outbreak investigation in Scotland suggest that most food poisoning occurs in private houses and is associated with mishandling of food (Anonymous, 1992). A sentinel study in the Netherlands (Hoogenboom-Verdegall and Postema, 1990) indicated that 80 per cent of Salmonella and Campylobacter infection were associated with domestic food preparation. Similarly, the domestic kitchen has been implicated as a major source in the high incidence of family-associated food disease in Germany and France (Guiguet *et al.*, 1992).

It is impossible to completely exclude food pathogens from the kitchen; however, their spread, growth and survival can be controlled with correct food storage and regular cleaning and disinfection of food-contact surfaces. Some surveys report the role of refrigerator as a significant niche for persistence and dissemination of foodborne pathogens (Azevedo *et al.*, 2005; Jackson *et al.*, 2007). In our study, 87.2 per cent of people interviewed were aware of the correct temperature inside the fridge, but only 18 per cent of them checked it. This percentage is in agreement with those reported in other studies (James *et al.*, 2008; Kosa *et al.*, 2007; Redmond and Griffith, 2003). Indeed, in a Swedish research, 85 per cent of respondents correctly identified the recommended temperature, although only 25 per cent claimed to know the temperature in their own refrigerator (Marklinder *et al.*, 2004). Temperature abuse is quite frequent in the cold chain, both in commercial and domestic situation. James *et al.* (2008) suggested that domestic refrigerators often operate at temperatures exceeding those recommended. This statement was confirmed by numerous studies. Legendijk *et al.* (2008) reported that 25 per cent of the domestic refrigerators investigated in France, were operating at temperatures higher than 8°C while only 11 per cent were at temperature below 4°C. A Dutch study (James *et al.*, 2008) showed that 70.4 per cent of tested refrigerators were at temperatures higher than 5°C; and 3.2 per cent of them were higher than 9°C.

A study carried out in Portugal (Azevedo *et al.*, 2005) found similar results with only 13 per cent of refrigerators having a mean internal temperature below 4°C. In the present study, 39.3 per cent of the 84 sampled refrigerators had an average temperature higher than 5°C and 51.2 per cent of them had an average temperature higher than 10°C. If food is held over time at temperatures allowing to bacterial growth, there is a potential risk in terms of food safety because a more rapid growth of spoilage microorganisms or food pathogens is allowed, if they are present. *L. monocytogenes* and *Salmonella* spp. were not detected on interior surfaces of domestic refrigerators sampled in this study. However, *L. innocua* was present in two refrigerators (2.4 per cent). In both cases the temperature of the fridge was found higher than 10°C.

Results of this research are in agreement with a previous survey conducted in Portugal which reported low incidence of *Listeria* spp. (3.5 per cent). Colonization of refrigerator by *L. monocytogenes* has already been demonstrated with a prevalence ranging from 0 to 2.9 per cent (Azevedo *et al.*, 2005). Although these surveys suggest that colonization of refrigerator surfaces by this microorganism may not be common, refrigerators cannot be excluded as potential source of contamination for foods. The presence of *L. innocua* suggests favourable conditions for *L. monocytogenes* to growth and persist in domestic refrigerators. Being psychotropic organisms, *L. monocytogenes* and *L. innocua* are capable of growth at refrigeration temperature and become hazardous if present on or transferred to other food. Moreover, their ability to attach to many kinds of surfaces (glass, rubber and stainless steel) and to produce biofilm has been demonstrated (Di Bonaventura *et al.*, 2008).

The average TVC and ETC of the tested refrigerators were 1.7×10^3 and 2×10^2 cfu/cm², respectively. In this survey, the TVC and ETC values showed a direct relationship with the temperature of fridges. Indeed, higher temperatures corresponded to higher microbial loads.

The observation of high TVCs and ETCs in many domestic refrigerators indicates the potential of these domestic appliances as important sources of food contamination during domestic food storage. However, there was no observable correlation between respondents' socio-demographic status and overall microbial numbers. The levels of contamination observed could be influenced by the method of food placing into the fridge. In fact, even against a high level of education, 15 per cent of respondents adopted personal criteria to food placing, disregarding the risk arising from cross-contamination. Raw meat, poultry and fish should be stored separately from other ready to eat foods to avoid cross-contamination. Furthermore, regular cleaning and disinfection of refrigerators decrease or eliminate contamination. A recent study found that visual assessment of the cleanliness of the inside of a home refrigerator may not be a reliable indicator of microbial contamination; thus, responders should regularly clean their refrigerator, regardless of visible soiling (Kosa *et al.*, 2007). Various studies revealed that the cleaning procedures are often incorrect and that their frequency is too low (Azevedo *et al.*, 2005; Kosa *et al.*, 2007). In the current survey, the possibility of cross-contamination following poor hygiene practices was apparent from different data. The majority of respondents stated that they cleaned the refrigerators with multipurpose detergents or homemade methods at least once every four months or when there was visible dirt (63.3 per cent). Only 36.9 per cent of the investigated refrigerators were cleaned monthly or more frequently. To keep the microbial density on a surface low, cleaning and disinfection should be carried out regularly, as they are in food processing premises.

This study highlighted some gaps in food safety knowledge and practices that occur in domestic setting. The most important issues were incorrect refrigerators

temperatures, cleaning practices and control of cross-contamination. Regarding temperature abuse, 6 per cent of tested refrigerators were operating at temperatures less than 4°C. It should be empathized as even a temperature of 4°C would not be appropriated for storing some chilled foods. Indeed, fish, seafood and some meat products reported in the label storage temperatures below 4°C. It follows that these storage conditions may cause adverse effects on their quality and shelf life.

Result obtained from the present survey revealed that consumers are not familiar with their role in the food safety chain and that they allow numerous opportunities for microbiological contamination of food. In conclusion, findings from this study clearly indicate the need for greater consumer education regarding proper domestic refrigerator management. Indeed, appropriate behaviours could make the refrigerator less likely to act as a significant niche for persistence and dissemination of food pathogens.

Food safety agencies around the globe should play an important role in the education of consumers. Education material about good housekeeping educational practice should be available to the general public from many sources. Food safety messages should focus on the younger members of a population with educational programmes, but more importantly, with relevant training. Only safety-conscious consumers can become active partners within food safety circle.

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