Hygienic Practices and Structural Conditions of the Food Processing Premises Were the Main Drivers of Microbiological Quality of Edible Ice Products in Binh Phuoc Province, Vietnam 2019

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Source: Environmental Health Insights, 14(1)

Published By: SAGE Publishing

URL: https://doi.org/10.1177/1178630220929722

Hygienic Practices and Structural Conditions of the Food Processing Premises Were the Main Drivers of Microbiological Quality of Edible Ice Products in Binh Phuoc Province, Vietnam 2019

Environmental Health Insights
Volume 14: 1–9

DOI: 10.1177/1178630220929722

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ABSTRACT

BACKGROUND: Ice is used in large quantities as refreshment in alcoholic and nonalcoholic beverages, especially in summer time. Contamination of edible ice products with pathogens is a public health concern in various countries, including Vietnam. This study aimed to assess the food safety conditions, the quality of edible ice products and related factors at manufacturing premises in Binh Phuoc Province, Vietnam in 2019.

METHODS: A cross-sectional study was conducted in 2019 using both quantitative and qualitative methods. Food safety assessment was carried out in all 45 ice producing premises in the province and 79 ice samples were collected and analyzed microbiologically. In-depth interviews were conducted with 2 food safety management staff, 4 owners of premises, and 4 workers.

RESULTS: Only 22.4% (18/79) and 37.8% (30/79) of the premises met requirement for food safety conditions and microbiological food safety requirements, respectively. Half of the ice samples, 51.9% (41/79), were contaminated, 49.4% (39/79) with *Escherichia coli* and 12.7% (10/79) with total coliforms. *Streptococci, Pseudomonas aeruginosa* were not detected. The major risks were material, odds ratio (OR) = 4.2 (95% confidence interval [CI]: 1.002-17.6), structural challenges in the facilities, OR = 4.3 (95% CI: 1.13-16.7), broken floors or difficulty in cleaning, OR = 5.4 (95% CI: 1.26-22.9), and poor staff hygiene practices, OR = 19.5 (95% CI: 4.2-91.1). Workers lacked knowledge and appropriate practices to prevent microbial contamination of ice products.

CONCLUSIONS: The food safety conditions and the quality of ice cubes at manufacturing premises in Binh Phuoc Province were not acceptable. Hygiene deficiencies in ice producing and handling processes, inadequate knowledge of staff, inadequate food safety management practices, and hygiene conditions of the premises were important factors in producing contaminated ice products. We recommend more staff training and crediting the staff when performing adequate practices, paying attention to broken floors or difficulty in cleaning, structural deficiency, and ensuring regular monitoring of premises. This study adds a special interest to ensure food safety conditions at ice producing premises to prevent microbial contamination of the products.

KEYWORDS: Ice cubes, ice tubes, food safety conditions, microbial contamination, Binh Phuoc Province, Vietnam

RECEIVED: May 3, 2020. **ACCEPTED:** May 4, 2020.

TYPE: Original Research

FUNDING: The author(s) received no financial support for the research, authorship, and/or publication of this article.

DECLARATION OF CONFLICTING INTERESTS: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Introduction

Consumable ice presents a potential hazard due to pathogenic microbial contamination, where a contaminated water source is used in its production or where there are lapses in hygiene in their handling. Outbreaks of gastroenteritis due to contaminated ice have been reported in other parts of the world.[1-3] For example, a major outbreak of hepatitis A in Lampang and Chiang Rai, Thailand, affecting 906 people, was reportedly due to contaminated ice cubes.[4] Initial investigations pointed to an ice factory in Chiang Rai Province where water is drawn from artesian wells that were contaminated with coliforms.[4] Another gastrointestinal outbreak was reported among 154 diners who attended a Christmas buffet on December 9 and 10, 2016, in City of Tampere, southern Finland. The outbreak was also reported to be linked with ice cubes from 3 vending machines with high levels of heterotrophic bacteria.[3] Studies from various countries have shown that the microbiological quality of ice manufactured for use in foods and drinks could be a cause for concern.[1,5-7] These studies showed that *Escherichia coli*, coliforms, and a variety of microorganisms could be present in ice products demonstrating either the poor quality of source water used or a lack of hygiene in the production process or handling or both.[1,5-7] If source water is contaminated with harmful microorganisms, the process of freezing cannot destroy them because many microorganisms can survive in ice despite reduced numbers over time. If pathogens are present in the source water from which the ice is made, they may also be viable in the ice when it is used, thus present a risk of infections for the customer. In addition, pathogens can contaminate ice cubes through poor hygiene practices. Thus, contaminated water supply, poor hygiene, and poor handling practices can impact microbial quality of ice cubes.

In Vietnam, using ice cubes in food and drinks is very common, especially in hot days. Studies from different countries available showed that pathogens in ice cubes are quite common and outbreaks of gastroenteritis due to contaminated ices have occurred.[1,2,4] However, data on microbiological quality of edible ice cubes and ice tubes from ice manufacturing premises in Vietnam were quite limited. Therefore, we conducted this study to assess the food safety conditions, to determine the microbiological quality of edible ice from ice manufacturing plants, and to identify factors associated with the quality of ice products. The results will provide scientific information to assess the risk of edible ice to public health and to assist the risk management decisions to control the production and handling of edible ice. Data on microbiological quality of ice from Binh Phuoc Province, Vietnam, can yield useful insights for developing appropriate programs and actions on microbiological risk management for ice products both in Vietnam and other countries with similar settings.

Methods

Study design

A cross-sectional study was implemented from January to September 2019 using both quantitative and qualitative methods.

Study participant and setting

Study participants and objects of this study included ice manufacturing premises, owners and employees of these premises, finished ice products, and authorities responsible for food safety at provincial and district levels in Binh Phuoc Province. Binh Phuoc is a poor rural province located in the Southeast region of Viet Nam, to the north of Ho Chi Minh City and shares a border with Cambodia. Binh Phuoc Province covers an area of 6881 km^2, including lowland and mountain, and had a population of 994 679 people in 2019.

Sample size and sampling

Food safety conditions at all 45 ice producing premises in Binh Phuoc Province were assessed. All owners and employees of the 45 premises (105 people) were invited to participate in survey. Among 45 premises, 6 premises only producing tube ice, 5 premises only producing ice cube (1 sample per premise was taken), and 34 premises producing both ice tube an ice cube (1 sample of each type per premise were taken). In total, 79 ice samples (including 39 ice cube and 40 tube ice samples) were collected and analyzed for pathogens. Participants for in-depth interviews were purposely selected based on their relevance to the research questions and their roles in ensuring ice quality. A total of 2 food safety management staff, 4 owners of premises, and 4 workers (2 from urban areas and 2 from rural areas) were invited to participate in in-depth interviews.

Measurements

The food safety conditions at ice producing premises were assessed based on general conditions (6 criteria), following administrative and reporting regulations (5 criteria), facilities' conditions (13 criteria), equipment's conditions (11 criteria), and 10 criteria related to employees (Table 1). These criteria were specified in the Decree No. 15/2018/NĐ–CP, Decree No. 155/2018/NĐ–CP of the Vietnamese Government and National technical regulation for edible ice (Regulation No. QCVN 10:2011/BYT).[7–9]

Data on the microbiological quality of edible ice samples were analyzed by Binh Phuoc Department of Food Safety and Hygiene. The quality of ice samples was assessed according to 5 criteria specified in Vietnamese regulation No. QCVN 10:2011/BYT (Table 2).[8]

Possible factors affecting the ice quality were explored, including factors related to the maintenance of food safety during the production and factors related to the food safety management of authorities at the premises.

Data collection

During sampling, food inspectors observed to assess the food safety conditions of the ice producing premises, handling practices of workers that might compromise the microbiological quality the ice and taking ice samples. All ice samples were kept at 2°C to 5°C during transport, and within 24 hours the samples were delivered to Viet Tin Analysis Testing Company Limited, which was certified by the Ministry of Health in assessing the quality of ice. The analyses included quantitative analysis of total coliform, *E. coli, Streptococci faecal, Pseudomonas aeruginosa*, and spores of sulfite-reducing anaerobes. Data quality were controlled in the field by supervisor as well as by the investigator of this study. The principle investigator of this study conducted all in-depth interviews, which were recorded.

Data analysis and statistical method

Descriptive statistics were carried out using Epi data 3.1 and SPSS 16 to assess the food safety conditions of premises and microbial quality of ice samples. Proportions of variables of interest, and a significance level of $P < .05$ was used. Qualitative data were analyzed according to identified themes.

Ethical considerations

The protocol of this study was approved by the Scientific and Ethical Committee in Biomedical Research, Hanoi University of Public Health, under Decision number 48/2019/YTCC–HD3 dated March 18, 2019. All human subjects in the study were asked for their consent before collecting data, and all had complete rights to withdraw from the study at any time without any threats or disadvantages.

Table 1. Criteria used to assess food safety conditions at ice producing premises.

NO.	CRITERIA	MEET REQUIREMENTS	
		YES	NO
A	Administrative and reporting requirements (5 criteria)		
A1	Business license appropriate with products that promise is producing		
A2	Have food safety condition certificate		
A3	Have product self-declaration		
A4	Have health examination certificates for premise's owner and employees who directly involved in the production process		
A5	Have food safety knowledge training certificates for premise's owner and employees who directly involved in the production		
B	Facilities' conditions (13 criteria)		
B1	Premises are located far from contamination sources		
B2	Production process follows the one way principle		
B3	Facility structural features		
B3a	*Walls: waterproof, no cracking, no musty**		
B3b	*Ceiling: water proof, no cracking, no musty*		
B3c	*Floor: smooth, easy to clean and well drainable*		
B4	Ice product storage area: separated and clean		
B5	Water supply system: enough clean water for production that meet the drinking water standard issued by Ministry of Health (QCVN 01:2009/BYT)		
B6	Waste management system: adequate rubbish bins with lids		
B7	Adequate drainage system, no stagnant		
B8	Personal protective clothes changing room		
B9	Toilets		
B9a	*Located far away from production sites*		
B9b	*Have wash hand basins*		
B9c	*Have adequate soap, disinfectants, hand towels*		
C	Equipment's conditions (11 criteria)		
C1	Production line		
C1a	*Self-contained production line*		
C1b	*Do not contaminate ice products*		
C1c	*Easily to be cleaned*		
C2	Production equipment		
C2a	*Do not contaminate ice products*		
C2b	*Easily to be cleaned*		
C3	Equipment directly come into contact with ice products		
C3a	*Do not contaminate ice products*		
C3b	*Easily to be cleaned*		
C4	Personal protective equipment used in the production area (booths, shoes, footwear)		

(Continued)

Table 1. (Continued)

NO.	CRITERIA	MEET REQUIREMENTS	
		YES	NO
C5	Pest control equipment at production sites and storage areas		
C6	Equipment cleaning procedure		
C6a	*Equipment directly come into contact with ice products are cleaned at the end of each production day*		
C6b	*Equipment directly come into contact with ice products are cleaned with a clean water source that used to make ice*		
D	Employees		
D1	Meet requirements to be involved in production process		
D1a	*Have health examination certificates provided by designated clinical/health centers*		
D1b	*Have food safety knowledge training certificates for employees who directly involved in the production process*		
D2	Personal hygiene practices		
D2a	*Have clean and protective/working clothes used in production*		
D2b	*Wear hair caps*		
D2c	*Wear clean face masks*		
D2d	*Wear hand gloves*		
D2e	*Hand nails are clean and kept short*		
D2f	*Do not wear jewelry*		
D2g	*Do not eat and/or drink in the production areas*		
D2h	*Do not smoking and spitting in the production areas*		

*Those written in italics were sub-criteria.

Table 2. Five criteria to assess quality of ice samples according to Vietnamese regulation No. QCVN 10:2011/BYT.[6]

FIRST TESTING ROUND				
CRITERIA	NUMBER OF SAMPLE AND QUANTITY		REQUIREMENT	
1. *Escherichia coli* or heat resistance coliforms	1 × 250 g		Not detected in any sample	
2. Total coliforms	1 × 250 g		If number of bacteria (or spores) ⩾1 and ⩽2, then need to test for the second round. If number of bacteria (or spores) >2 then discarded.	
3. *Streptococci faecal*	1 × 250 g			
4. *Pseudomonas aeruginosa*	1 × 250 g			
5. The spores of sulfite-reducing anaerobes	1 × 50 g			
SECOND TESTING ROUND	MAXIMUM PERMITTED LIMITS (IN 1 G OF ICE)			
CRITERIA	N[a]	C[b]	M[c]	M[d]
1. Total coliforms	4	1	0	2
2. *Streptococci faecal*	4	1	0	2
3. *Pseudomonas aeruginosa*	4	1	0	2
4. The spores of sulfite-reducing anaerobes	4	1	0	2

[a]n: minimum number of samples need to be tested.
[b]c: maximum number of samples accepted when detected bacteria/spores at level greater than m and smaller than M values.
[c]m: maximum accepted number of bacteria/spore in 1 sampling unit.
[d]M: maximum number of bacteria/spore that no sample is allowed to exceed this level.

Table 3. General characteristics of the study sample.

CHARACTERISTICS		NUMBER OF PREMISES (N=45)	%
Production capacity	Less than 2 tons/day	11	24.4
	2-5 tons/day	22	48.9
	Over 5 tons/day	12	26.7
Production area	Less than 100 m^2	6	13.3
	100-500 m^2	31	68.9
	Above 500 m^2	8	17.8
Number of employees	⩽2 employees/premise	28	62.2
	3-4 employees/premise	15	33.3
	⩾5 employees/premise	2	4.4
Main products	Ice tube	16	35.6
	Both ice tube and ice cube	9	20
	Ice cube	20	44.4
Water sources for production	Pipe water	4	8.9
	Drill well	41	91.1

Results

General characteristics of the study sample

Table 3 shows the general characteristics of the study sample. Most of premises had production capacity of 2 to 5 tons/day (accounted for 48.9%, 1 ton equals 1000 kg), followed by over 5 tons/day (accounted for 26.7%) and 24.4% of the premises had the production capacity of less than 2 tons/day. About 68.9% of the premises had production areas from 100 m^2 to 500 m^2, 17.8% had areas above 500 m^2, and 13.3% had production areas less than 100 m^2.

About 62.2% of premises had 1 or 2 employees, 33.3% of premises had 3 to 4 employees, and 4.4% of premises had 5 or more employees. The main products of these premises were ice cubes (accounted for 44.4%), ice tubes (35.6%; an ice tube is a large and long piece of ice that is then crushed in the restaurants), and the remaining 20% of the premises produced both ice cubes and ice tubes. Most of premises still used water from drill well (the quality is usually not adequate and may be contaminated) for ice production (91.1%) and only a small proportion of premises (8.9%) used pipe water source.

Food safety condition of ice production premises

The results showed that most of premises met administrative requirements (93.3%). About one third of premises (37.8%) met requirements on equipment and hygiene practices of employees during ice production and less than one fourth (24.4%) of premises met requirements on infrastructure. Overall, only 24.4% premises met all 39 food safety requirements (Figure 1).

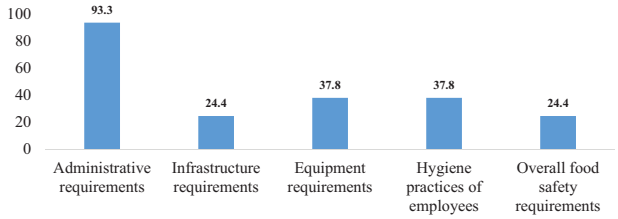

Figure 1. Proportion of premises met requirement according to 4 aspects of assessment.

Microbiological quality of edible ice cubes and ice tubes

Laboratory analysis of ice samples showed that among 79 ice samples taken from 45 premises, only 38 samples (48.1%) met microbiological criteria and 41 samples (accounted for 51.9%) did not meet the requirement (Table 4). About 100% of tested ice samples met safety standard for *Streptococci faecal*, *Pseudomonas aeruginosa*, and spores of sulfite-reducing anaerobes. However, only 87.3% of ice samples met standard for total coliforms and 50.6% of samples met *E coli* criteria. Among 45 premises, only 17 premises had ice samples met microbiological requirements, which accounted for 37.8%. Figure 2 shows that 24 ice tube samples (60%) and 18 ice cube samples (46.1%) violated microbiological standard. Overall, only 37 ice samples (46.8%) met the microbiological standard.

Factors associated with the quality of ice products in Binh Phuoc Province in 2019

Results also showed that premises with material facilities that did not meet standard had 4.2 times higher prevalence of

Table 4. Microbiological quality of edible ice products.

MICROBIOLOGICAL CRITERIA	NUMBER OF ICE SAMPLES MET REQUIREMENTS (N = 79)	% OF ICE SAMPLES MET REQUIREMENTS
Total coliforms	69	87.3
Escherichia coli	40	50.6
Streptococci faecal	79	100
Pseudomonas aeruginosa	79	100
Spores of sulfite-reducing anaerobes	79	100
Overall microbiological assessment of ice products	38	48.1

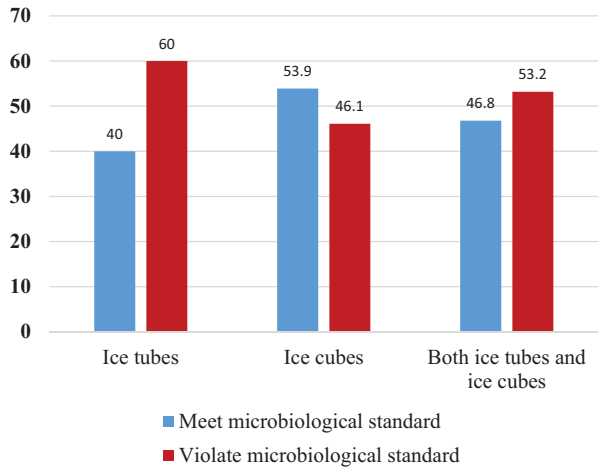

Figure 2. Microbiological quality according to ice products.

samples that did not meet microbiological standard than those with adequate facilities (odds ratio [OR] = 4.2, 95% confidence interval [CI]: 1.002-17.6). Premises with structure facilities that did not meet requirements had 4.3 times higher risk of having samples that did not meet microbiological standard than those with adequate structure facilities (OR = 4.3, 95% CI: 1.13-16.7). Premises with floors inadequate and difficult to be cleaned had 5.4 times higher risk of having ice samples tested positively with pathogens (OR = 5.4, 95% CI: 1.26-22.9). In addition, premises with employees having poor hygiene practices had 19.5 times higher risk of having ice samples tested positive with microorganisms (OR = 19.5, 95% CI: 4.2-91.1).

Qualitative data from in-depth interviews showed that premises' owners and employees were aware of food hygiene and safety requirements, but did not strictly follow them, especially requirements on personal hygiene and equipment cleaning. " . . . I do clean equipment and production floors before producing new ice batch when the boss is here, otherwise I just pump water in and start new batch . . ." (in-depth interview, employee No. 2). Another worker said, ". . . I don't wear personal protective equipments as they are not comfortable, and the boss only provide these equipment sometimes, just few days at the beginning . . ."(in-depth interview, employee No. 1). On the contrary, according to owner of an ice producing premise, "I provide personal protective equipments for the workers and remind them many times about the important of ensuring the hygienic conditions of equipment, facilities, and wearing personal protective equipments, but they often forget" (in-depth interview, owner No. 1). Owners of premises also often did not require workers to have routine annual health checks: "they should have routine health checks and have blood and urine tests, but sometimes I forgot to ask, and only remember when the officer come to inspect our premise" (in-depth interview, owner No. 2). A challenge for these premises was that most workers were casual and seasonal workers so it was difficult for them to train and ensuring safety practices during ice production. Ice being sold at low prices was also another reason that premises' owners did not have sufficient money to invest in adequate equipment and ensuring food safety practices during production. ". . . many premises they sell ice so cheap, so they don't have much revenue to invest on quality assurance . . ." (in-depth interview, employee No. 2). Food safety inspection by local authorities is another challenge due to limited funding, inadequate training of authorities at district level, and lack of essential equipment needed to ensure adequate inspection. As stated by a food safety manager, "The budget for our department is so limited, especially budget for inspection, communication and purchasing equipment. Staff at our department who are recently assigned to the food safety inspection post were not properly trained in inspection skills as well as taking food samples . . ." (in-depth interview, food safety manager No. 1). In addition, in-depth interview with a health manager also showed that communication activities were not specifically on food safety of ice products and were implemented only few times a year due to limited funding. Thus, there were a number of challenges that local authorities and ice production premises were facing to ensure food safety of ice products in Binh Phuoc Province.

Discussion

This study assessed the quality of edible ice products and related factors at manufacturing premises in Binh Phuoc Province, Vietnam, in 2019 using a cross-sectional approach with both quantitative and qualitative methods. Food safety

assessment carried out in all of the 45 ice producing premises in the province and 79 ice samples collected revealed that only one fifth of the premises and 40% of the ice samples met the requirements. No pathogens were detected. Poor source water quality was detected in 91.1% (41/79) of the premises, where drill well water was used for ice production. The major risks were poor adherence of staff to hygienic practices and broken floors in the premises. In-depth interviews revealed serious attitudinal challenges within staff and management.

Ice cubes and ice tubes are ready for direct consumption without any further treatment; thus, the microbial quality of ice is critical to prevent foodborne diseases. The relationship between contaminated water source, unhygienic ice equipment, and waterborne diseases highlights the significance of studies on the hygienic quality of ice. A number of studies about the microbiological quality of ice are available in the literature worldwide.[11–13] However, in Vietnam, to our best knowledge, data on the microbiological contamination of ice are still very limited. There are both similarities and differences between the findings from this study and international research evidence. A study conducted in Istanbul in 2017 showed that *E coli* was detected in 6.7% ice and 21.9% ice chest samples. In addition, psychrophilic bacteria were detected in 79.0% of 105 ice chests and in 64.7% of 105 ice samples, whereas Enterococci were detected only in 12.4% ice samples, and coliforms were detected in 67.6% of the ice chests and 51.4% of the ice samples.[11] Chavasit et al investigated the surfaces of ice collecting bins, manual packaging machines, and the conveyor part of the ice machine and determined the total coliform counts as 7.3, 56.9, and 7.3 MPN/10.16 cm^2, respectively.[12] In another study, ice samples were reported to be contaminated with total coliforms (37%), fecal coliforms (25%), and *E. coli* (15%) ranging between 1-95, 1-100, and 1-50 CFU per 100 mL, respectively.[13] Thus, results from studies in different countries demonstrate that ice samples can present public health risks due to the presence of indicator microorganisms such as fecal coliforms and *E. coli*. Ice contaminated with harmful microorganisms, especially multidrug resistant bacteria such as *E. coli, Salmonella*, and *Staphylococci* can cause infections and pose a serious threat to global public health.

The proportion of samples being contaminated with *E. coli* in our study (49.4%) was higher than those reported in Istanbul, Greece, and elsewhere,[11–13] but was lower than that reported in Can Tho City (South of Vietnam).[14] A study by Tong (2019) in Can Tho City showed that total aerobic mesophilic counts ranged from 2.5 to 6.2 log CFU/mL; coliforms and *E. coli* were present on the ice samples of 93.55% and 58.06%, respectively.[14] The proportion of samples that were positive for total coliforms in our study (12.7%) was lower than that in Greece (37%).[13] *E. coli* is commonly found in the gastrointestinal tract and feces of human beings. Its presence provides direct evidence of fecal contamination, probably resulting from the contamination of water storage tanks, production equipment, ice storage areas, as well as improperly handling of the ice productions by workers. Foodborne pathogens including *Streptococci faecal* and *Pseudomonas aeruginosa* were not detected in any ice samples collected in Binh Phuoc Province and this was similar to the study conducted in South Korea where the foodborne pathogens (*Staphylococcus aureus, Listeria monocytogenes*) were not detected from the ice samples collected throughout the country.[15]

The contamination of microorganisms in ice products is possibly due to the contaminated water supply, inadequate production equipment and facilities, and unhygienic practices of workers.[1,4,5] In our study, the personnel involved in ice production were mainly seasonal workers and most of them were not trained enough in matters of food safety and personal hygiene, which could be another important contamination method of ice with enteric bacteria. Workers lacked knowledge and appropriate practices to prevent microbial contamination of ice products. This should be addressed in the future. In addition to training and monitoring of workers' practices, motivation for behavioral changes is needed, either through punishment (less pay if violations) or credit (more pay if the quality is better) may apply. Also a possible fine for the premises is that if an outbreak occurs due to their products, the premises will be named in the press and mass media. This may be an effective option.

In addition, only 22.4% of the premises met requirement on food safety conditions. Thus, it is important to note that although these premises received food safety certificates, the maintenance of food safety conditions at nearly 80% of the premises was poor, ice production equipment were not upgraded, and workers did not follow food safety regulations and did not apply personal and production hygiene practices. This is in line with the findings from a previous research conducted in Ho Chi Minh City in 2014 where 43% (n = 193) of ice manufactures did not comply with the regulations due to neglect or insufficient hygiene.[16]

The strengths and limitations of this study

To the best of our knowledge, this was the first study to assess the food safety conditions, the quality of edible ice cubes at manufacturing premises and related factors in Binh Phuoc Province and among very few studies ever conducted in Vietnam to assess microbiological quality of ice products. Our study contributes to the existing knowledge showing the public health risks that might be associated with microorganisms in ice cubes and ice tubes. This article complements existing literature describing the contamination of pathogens in ice products in developing countries. Evidence from this study can yield useful insights for developing appropriate food safety policy and programs responses both in Vietnam and other similar settings in the world to reduce the health risks for ice consumers.

Although this study reported certain important results, some methodological limitations of this study must be taken into consideration. First, due to the cross-sectional nature of the data collected, the causal relationship between food safety conditions of premises and quality of ice products could not be determined. Second, the quantitative component of this study seemed to have a relatively small sample size of 79 ice samples (including 39 ice cube and 40 tube ice samples) being collected from 45 ice production premises. However, this was the total number of premises operating in 2019 in Binh Phuoc Province. Third, due to limited in funding, this study only conducted microbiological testings for ice samples, but did not test production equipment and workers' hands to assess the risks associated with different stages of the ice production process. Last but not least, although consuming microbial contaminated ice products was associated with various health impacts, it was not possible for this study to assess health impacts among local people due to consuming contaminated ice cubes. Therefore, we recommend that future studies should have more focus on this aspect to fully assess health risks related to microorganisms in ice products.

Conclusions

This study found that 51.9% the ice samples taken from the manufacturing plants did not satisfy the criteria for microorganisms, in which 49.4% of samples were contaminated with *E. coli* and 12.7% of samples were contaminated with total coliforms. About 37.8% of ice production premises met requirements for laboratory testing. Potable clean water supply, adequate hygiene conditions of equipment and production sites, as well as good handling and good hygiene practices of workers were prerequisites to the production of good quality ice. However, only 24.4% of premises met food safety requirements. The presence of *E. coli*, total coliforms, and the lack of proper ice handling practices among approximately three fourth of ice manufacturing premises suggest that consumable ice served in Binh Phuoc Province may present potential hazards. Material and structural faults in facilities, broken floors, difficulty cleaning, and poor staff hygiene were major challenges facing by many ice producing premises in Binh Phuoc Province. This was a quite comprehensive study that investigated not only the microbiological quality of ice, but also the hygienic conditions of ice making machines, workers' personal hygiene, food safety conditions at all ice producing premises in Binh Phuoc Province, and related factors. The results of the current research provided significant data that demonstrate the possible factors causing ice contaminations.

Recommendations

This study suggests that the hygienic management of the ice products at the manufacturing premises is critical and urgently needed. To ensure the hygienic management of ice products, not only the ice-making equipment and production areas should be cleaned on a regular basis but also thorough individual hygiene is required from ice manufacturing workers. Regular monitoring of the hygienic conditions of premises and quality of ice products should be enforced in Binh Phuoc Province as well as other areas of Vietnam. The health sector needs to track these factors and associated policies to promote action on the social determinants of health.

Acknowledgements

We thank the Provincial Food Safety Division, owners, and workers at 45 ice production premises in Binh Phuoc Province for supporting this study and contributing to the data collection in the field. We also thank Ms. Amanda Stephanie Farrell who is a medical student at Duke University for her support in English editing of this article.

Author Contributions

Both authors conceived and designed the study, agreed with the results, conclusions, and came up with arguments for this manuscript. M.H.H. analyzed the data. T.T.T.H wrote the first draft of the paper. Both authors made critical revision, agreed on the final version of the manuscript, and approved it for submission, which was done by T.T.T.H.

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