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Measures for controlling safety of crushed ice and tube ice in developing country

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ABSTRACT

Contamination of pathogens in crushed and tube ice is a public health concern in many developing countries, calling for the development of practical preventive measures to reduce microbial and chemical contamination. By applying principles of hazard analysis and critical control points (HACCP), data on production and distribution processes in 11 ice-making plants in different provinces of Thailand were obtained. Results showed that producers of both ice forms lacked knowledge on water treatment and disinfection that could cause microbial contamination. Other sources of microbial contamination were from condensate in tube ice production and from dirty sacks used in ice transportation. A chemical hazard also was found in crushed ice due to chromium contamination in an anti-rusting agent.

1. Introduction

Crushed ice is prepared from traditional blocked ice, while tube ice is a new generation of ice-making that is produced using more specific and sanitary machines. However, microbial contamination of both ice forms is common in many developing countries including Thailand, which is a main exporter of ice-making technology to her neighboring countries. Studies by the Department of Medical Sciences, Ministry of Public Health, Thailand have indicated that crushed ice in the market were contaminated with *Escherichia coli, Salmonella* spp. *Vibrio cholerae* non O1/non O139 and *Staphylococcus aureus* (Bangtrakulnont, Deeaum, & Kumkaew, 2000). Outbreaks of gastroenteritis due to contaminated ice have been reported in the many provinces of Thailand and other parts of the world (Falcão, Dias, Correa, & Falcão, 2002; Malasao, 1995; Nongharnpitak, 2000; Pawsey & Howard, 2001). Usually, *E. coli*, coliforms and a variety of microorganisms in ice are indicators of poor water quality of water, a lack of hygiene in production or handling, or both (Food Safety Authority of Ireland, 2002; Lateef, Oloke, Gueguim Kana, & Pacheco, 2006; Nichols, Gillespie, & de Louvois, 2000; Wilson, Hogg, & Barr, 1997). In addition, a Thailand Food and Drug Administration (Thai FDA) survey showed that at least 67% of tube ice was contaminated with coliforms and *E. coli* (Rojjanawanicharkorn, Srithongderm, Thunyacharoen, & Duangjai, 2007). In addition, chemicals used in water treatment, ice processing and sanitizing ice bags can pollute crushed ice. Consumption of contaminated ice not only causes consumer health problems; it also has an adverse economic impact and damages a country's reputation.

By applying only the concept of general Good Manufacturing Practices (GMP) standard, ice producers are not always able to improve the quality of their products, since it was designed for the general control of various food types (Falcão et al., 2002; FEHD, 2005; Makkaew, 2005; Thai FDA, 2006). In addition, greater infrastructure investment will not guarantee product safety. To efficiently solve the hazard problems of both ice forms, a specific GMP for each ice form should be developed by combining the general GMP with the concept of Hazard Analysis and Critical Control Points (HACCP). Moreover, the specifically developed GMP should be more practical and efficient for ice producers, especially in developing countries where infrastructures are not yet perfect.

2. Materials and methods

2.1. Common practices for production and distribution of ice

A survey of 11 ice-making plants in Thailand, as well as the ice machine builder and supplier, Patkol Public Co., Ltd., Samutprakan, Thailand, revealed that their main production and distribution processes were quite similar, especially in machine design and packaging.

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2.1.1. Block and crushed ice

Raw water from different sources (i.e., underground, surface, pipe) was treated and stored. Thereafter, this water then poured into an ice can, which was then lifted and submerged into a cold brine pond. The ice can was normally made from zinc galvanized iron. The brine pond contained 18–22° Baume brine of −12 °C and the anti- rusting agent, sodium dichromate dihydrate. The brine pond was made of cement, and the area around it was laid with wood. As cold brine was being circulated in the pond, ice gradually formed in the ice can. During ice formation, filtered air was blown onto unformed ice (ice center) through a stainless steel tube in order to make the ice clear. Meanwhile, impurities were also sucked out from the ice center. The freezing process normally took about 24–28 h. Formed ice was removed from the can after it was lifted up from the brine pond and submerged in a thawing pond that was filled with water. Thereafter, the block ice was slid on the floor to the platform. Before being crushed, the block ice was cut into smaller chunks. The ice crushing machine was made either from iron or stainless steel. Crushed ice was normally packed by hand in woven polypropylene sacks for distribution. For excess production, block ice was stored at −3 to −5 °C in a freezing room before being crushed and distributed. The size of the sack used for packing 20 kg of crushed ice was 48 × 81 cm^2. This sack belonged to either the factory or customer and was reusable. It was usually cleaned with water before use. The ice-filled sack was manually tied with a string and loaded onto either an open truck or a closed-insulated truck for distribution.

2.1.2. Tube ice

Treated and stored raw water was also used for producing tube ice. Tube ice was produced in a stainless steel machine with similar designs (Fig. 1). The process began by pumping treated water up to the top water tank (Fig. 1-a) of the machine. Due to gravity, water passed through nozzles (Fig. 1-b) and flowed onto the surfaces of cold metal pipes (Fig. 1-c) that were filled with the refrigerant, ammonia gas (Fig. 1-d), inside the machine. The flowing water was gradually frozen into a large ice column. When frozen this way, the water formed into clear ice, since air and dissolved solids (impurities) present in the water were discharged down to the bottom tank (Fig. 1-g). The water temperature in the bottom tank was close to 0 °C; however it may stand in the tank at room temperature for at least 12–24 h after each production batch. During production, the condensate that formed on the outside surface of the bottom tank was collected in a well (Fig. 1-h), which was later used in many factories for ice production again. As the ice was completely formed, the supplied refrigerant was terminated and a hot refrigerant was then trapped in the machine chamber in order to heat the metal pipe surface and remove ice columns from the pipes. Thereafter, the ice columns were laid down and cut by an ice cutter (Fig. 1-f) below. Finally, the tube ice was removed and sent to a collecting bin. The overall process took about 30–40 min for one batch of tube ice. The inner temperature of the tube ice production machine was about −15 to −17 °C. Two sizes of tube ice were available, namely, small and large (22 and 32 mm in length, respectively). For commercial distribution, tube ice was packed using semi-automatic and automatic machines into 20 kg reusable woven polypropylene sacks and 1.5 kg polyethylene bags, respectively. The packed woven polypropylene sack was closed manually by tying with a string, while the polyethylene bag was heat-sealed. The packed ice was stored at −5 to −10 °C before distribution. Based on a customer's need, tube ice was sometimes crushed as well. The sack cleaning process and ice distribution condition for tube ice were similar to the crushed ice.

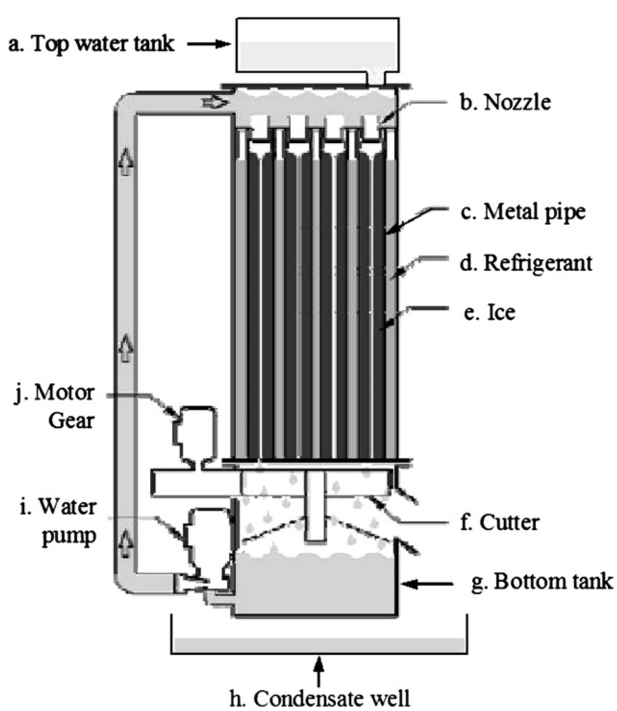

Fig. 1. Tube ice-making machine (modified from Patkol Public Co., Ltd.).

2.2. Evaluation of potential hazard from ice-making machines

2.2.1. Contamination of chromium in block ice

Chromium from the anti-rusting agent could cause a chemical hazard. Ice portions that were stained with a yellow color were collected and analyzed for residual chromium, as compared with normal ice at the same production site.

2.2.2. Remaining water in the bottom water tank increased microbial risk in tube ice

A water sample that was prepared by diluting ditch water at dilution factors of 1:100 and 1:5000 and packed in polyethylene bags was put in a stainless steel tray, which was cooled at −10 °C for overnight. The tray was then covered and cooled at −10 °C for 35 min. Thereafter, the water sample was removed from the freezer and then checked for aerobic bacteria and coliforms. To simulate the condition of remaining water held in the bottom water tank during no production, water was left at room temperature for 12 h. Thereafter, the water was again checked for microbial quality. The experiment was conducted in three sets of samples of each dilution.

2.2.3. Condensate around bottom tank increased microbial risk in tube ice

Condensate from around the bottom tank was sometimes reused for making ice. This reuse might increase microbial risk, since its basin was located outside of the tube-ice-making machine and was open to the environment. A sample was collected from Paitoon Ice Factory Co., Ltd., Nakhonpathom, Thailand, and evaluated for aerobic plate count as well as total coliforms.

2.3. Development of preventive measures

2.3.1. Water treatment

Interviews with staff at the Paitoon Ice Factory Co., Ltd., were conducted to determine the statuses of water used for crushed and tube ice. Water samples were then taken in order to analyze residual chlorine and microbial quality. Factory staff members were

Table 1
Microbial qualities of water at the factory before and after implementing proper chlorination.

Parameter	Before chlorination	After chlorination implementation		
	1st survey	2nd survey	3rd survey	4th survey
APC (cfu/ml)	1.2×10^3	<25	5.2×10^1	3.0×10^1
Total coliforms (MPN/100 ml)	130	<1.8	<1.8	1.8

advised to add chlorine based on the Thai FDA's recommendation for treating raw water in bottled water production. After implementation, the water was sampled again and tested for the same qualities.

2.3.2. *Sack cleaning*

The factory's normal cleaning process was determined based on observations at the study plants. The process was developed in the laboratory, and simulated sacks were made from the factory's sack fabric at much smaller size (16×24 cm^2). In each experiment, all of the sack samples were first soaked in ditch water for 1 h ("dirty sacks"), and then swab-tested for aerobic plate count and total coliforms. Thereafter, certain processes were verified including: (i) pre-washing in water before soaking in chlorinated water, (ii) appropriate chlorine concentration for sack soaking, (iii) appropriate sack soaking period in chlorinated water, and (iv) appropriate drying and storage conditions.

2.3.2.1. Effect of washing sacks with water before soaking in chlorinated water on microbial quality of sack. In each experiment, after soaking sacks in dirty water, all of them were divided into 2 parts. For the first part, sacks were washed with tap water before being fully soaked in chlorinated water at 10 ppm chlorine for 20 min. The second part was soaked in chlorinated water without pre-washing. Dirty sack, washed sack and disinfected sack of both groups were analyzed for aerobic plate count and total coliforms.

2.3.2.2. Appropriate chlorine concentrations and soaking period for reducing microbial risk in sacks. Dirty sacks were first pre-washed, if needed, based on the result from 3.2a, and soaked in chlorinated water of concentrations 0.25, 1, 4, 7, and 10 ppm of residual chlorine for 20 min. The efficient chlorine concentration was determined by considering results of microbial analyses. This value would be used as the minimum chlorine concentration that should be maintained for sack disinfection. Thereafter, the study on minimum soaking period was performed with the optimum concentration of chlorine by varying soaking periods at 0, 5, 10, and 15 min.

At the factory, chlorinated water for cleaning sacks must be used continuously for about 12 h, which could normally cover up to 2000 sacks. Therefore, an appropriate initial concentration of chlorine in chlorinated water must be high enough to retain a minimum effective concentration after 12 h or being used for cleaning 2000 sacks. The initial chlorine concentration used in this experiment was approximately 100 ppm. Certain numbers of sack were then soaked in the prepared chlorinated water at a ratio of 200 sacks per 350 l for a certain period of time (evaluated from appropriate soaking period); the soaking cycle continued until the concentration of chlorine reached the minimum effective concentration.

2.3.2.3. Appropriate drying and storage condition of washed sacks. By using the evaluated appropriate chlorine concentration and soaking period, dirty sacks were washed and stacked in a way that was practiced at the factory. The stacked sacks were left in air for 0, 1 and 4 h and then kept in new plastic bags at room temperature for 0, 12 and 24 h. This design simulated the factory practice of normally either leaving the sacks to dry outside or storing the wet ones inside a truck for about one day.

2.4. *Analysis*

2.4.1. *Microbial*

Pipe or tap water was sampled after the valve or faucet had been flame sterilized. A water sample of 150 ml was aseptically collected in 250 ml sterile Duran™ bottle. The collected ice samples were stored frozen in insulated containers until being analyzed at the laboratory. Water and ice samples were analyzed for aerobic plate count (BAM, 2001a) and total coliforms by 5-tube MPN technique (BAM, 2001b). The swab test was performed within the designated area of 5×10 cm^2 in both horizontal and vertical directions. The cotton swab was then put into a buffer solution and rinsed briefly.

Table 2
Microbial qualities of water kept under the simulated condition of water in the bottom tank of tube-ice-making machine (cooled at −10 °C for 35 min and kept at room temperature for 12 h).

Test	Aerobic plate count (cfu/ml)			Total coliforms (MPN/100 ml)		
	At 0 h	At 12 h	% reduction	At 0 h	At 12 h	% reduction
1.	8.7×10^3	5.6×10^3	35.6	920	350	92.0
2.	1.3×10^3	6.9×10^2	46.9	540	240	55.6
3.	1.9×10^3	1.3×10^3	31.6	350	240	31.4
4.	<25	<25	*	4.5	4.5	0
5.	<25	<25	*	4	3.6	10
6.	<25	<25	*	3.6	3.6	0

* Data could not be calculated.

Table 3
Total coliforms of equipment surface and workers' hands as assessed by a swab test.

Sample	Total coliforms[a b] (MPN/10.16 cm^2)
Operator's hand (gloved)	6.1[c]
Block ice	
Platform (low usage)	15.0
Platform (high usage)	188.9
Ice crusher (inlet)	<6.1
Ice crusher (outlet)	<6.1
Tube ice	
Collecting bin	7.3
Manual packaging machine (outlet)	56.9
Conveyed trail	7.3

[a] Transformed from per 50 cm^2 into 10.16 cm^2.
[b] Standard of Department of Medical Science = 500 MPN/10.16 cm^2.
[c] Total coliforms reported as MPN/hand.

Table 4
Microbial qualities of sacks soaked in chlorinated water with and without pre-washing with water.

Test	Parameter	Dirty sack	No pre-washing	Pre-washing with water	
			Cl-cleaned sack	Washed sack	Cl-cleaned sack
1.	APC[a]	1.7×10^4	6.6×10^3	1.1×10^4	3.4×10^1
	TC[b]	920	17	49	2
2.	APC[a]	1.8×10^4	4.6×10^3	2.2×10^4	<25
	TC[b]	>1600	1600	>1600	<1.8
3.	APC[a]	1.8×10^4	2.3×10^3	1.4×10^4	3.6×10^1
	TC[b]	>1600	920	1600	<1.8
4.	APC[a]	3.8×10^4	3.4×10^4	1.5×10^4	<25
	TC[b]	>1600	69	1600	1.8

[a] Aerobic plate count reported as cfu/ml.
[b] Total coliforms reported as MPN/100 ml.

Table 5
Microbial qualities of sacks soaked in chlorinated water at various concentrations.

Test	Parameter	Dirty sack	Residual chlorine concentration (ppm)				
			0.25	1	4	7	10
1	APC[a]	2.1×10^4	3.8×10^3	6.4×10^3	3.4×10^1	5.2×10^1	<25
	TC[b]	>1600	920	350	23	<1.8	<1.8
2	APC[a]	1.4×10^4	2.0×10^3	5.8×10^3	7.9×10^1	<25	3.6×10^1
	TC[b]	>1600	920	350	4.5	<1.8	<1.8
3	APC[a]	3.8×10^4	2.4×10^4	1.2×10^3	8.5×10^1	<25	7.5×10^1
	TC[b]	>1600	1600	350	23	<1.8	<1.8
4	APC[a]	2.4×10^4	2.4×10^3	5.6×10^3	3.2×10^2	<25	<25
	TC[b]	>1600	920	540	23	<1.8	<1.8

[a] Aerobic plate count reported as cfu/ml.
[b] Total coliforms reported as MPN/100 ml.

The rinsed solution was assessed for total coliforms by using the 3-tube Most Probable Number (MPN) technique (Speck, 1984).

2.4.2. Chemical

Residual chlorine in the water samples was determined by the spectrometry method using CHLORINE SERIES 200′. The range of the test was 0.0–6.0 mg/l. Chromium content was determined by using flame atomic absorption spectrophotometry (APHA, 2005).

3. Results and discussion

3.1. Water treatment

From the survey, various sources of water were treated using different methods. Surface water from different sources — river water, man-made soiled pond water, ditch water from mining canals as well as ground water — were either treated by the factories or by the municipality as tap water. Since most factories did not analyze raw water before setting up their water treatment systems, microbial and chemical contamination could lead to improper water-treatment processes. Moreover, water-treatment processes, especially disinfection through chlorination, were not consistently practiced. In addition, contamination due to improper handling and storage of treated water could be other causes of microbial and chemical contamination, since both raw and treated water in many plants was not properly stored and well-protected. Water quality has a direct impact on the quality of ice, which could be clearly observed in tube ice that is produced under a close system.

By following a process for disinfection with 0.2–0.5 ppm residual chlorine, the total coliform problem could be solved (Table 1). Water used for ice-making must be treated and stored similar to the processes used for producing drinking water, since they are both controlled by the same standard. In addition, this study found that freezing did not significantly reduce microbial load, especially in terms of total coliform (unreported data). Similar to drinking water producers, ice producers should be trained on specific GMP for bottled drinking water production, as well.

Table 6
Microbial qualities of sacks soaked in 10 ppm of chlorinated water at different soaking periods.

Test	Parameters	Soaking time (min)			
		0	5	10	15
1.	APC[a]	2.6×10^3	<25	<25	<25
	TC[b]	>1600	<1.8	<1.8	<1.8
2.	APC[a]	3.6×10^3	<25	<25	<25
	TC[b]	1600	2	<1.8	<1.8
3.	APC[a]	5.4×10^3	<25	<25	<25
	TC[b]	>1600	<1.8	<1.8	1.8
4.	APC[a]	1.2×10^4	<25	<25	<25
	TC[b]	>1600	<1.8	<1.8	<1.8

[a] Aerobic plate count reported as cfu/ml.
[b] Total coliforms reported as MPN/100 ml.

3.2. Block ice

Block ice-making involved several types of equipment that require regular maintenance based on general GMP requirement. However, there still were certain equipment and processes that required special monitoring.

3.2.1. Block ice can

A sample obtained from a leaked ice can appear yellow in color inside the block ice. The yellow color was due to contamination from an anti-rusting agent, sodium dichromate dihydrate, in the salt brine. The yellow part contained 0.237 mg chromium/kg of ice, which was not found in normal block ice. Such contamination could lead to chemical hazards since the World Health Organization allows only 0.05 mg chromium/liter of drinking water (WHO, 2006). Regular maintenance should be conducted for ice cans.

3.2.2. Water in the thawing tank

A sample of water used in the thawing tank was contaminated with total coliforms at 110 cfu/100 ml, which could affect the microbial quality of block ice. Normally, the water is not properly treated and reused. The thawing water must be treated as cooling water in the canning line, which must be changed regularly and maintain a level of residual chlorine at 2.0 ppm (Mookajornphan, 1997).

3.3. Tube ice

Since for the most part, tube ice-making systems are well-protected from the environment, regular maintenance of the machines could prevent physical and chemical hazards. However, bottom and condensate tanks might be at risk of microbial growth and contamination.

3.3.1. Bottom tank

The results shown in Table 2 indicate that the number of bacteria tended to reduce during storage but not at consistent rate. In the case of low-level contamination, changes in total coliforms were not observable. Changes in both aerobic plate count and total coliforms, however, were less than 1 log cycle. Due to a very low initial temperature (close to 0 °C), temperature fluctuation in the tank did not promote microbial growth and should not be a microbial hazard as long as properly-treated water is used for the production. However, regular drainage of water from the tank was also a good strategy for preventing the accumulation of microorganisms and hardness.

Table 7
Microbial quality of sacks after being dried and stored at different periods.

Dry 4 h (complete dried)		Dry 1 h (Partially dried)	Dry 0 h (no dry)			Dirty sack			Test		
			Store 0 h	Store 12 h	Store 24 h	Store 0 h	Store 12 h	Store 24 h	Store 0 h	Store 12 h	Store 24 h
1	APC[a]	1.5×10^5	4.6×10^1	1.5×10^2	4.5×10^2	<25	5.1×10^2	1.3×10^4	4.6×10^1	9.8×10^1	<25
	TC[b]	>1600	<1.8	<1.8	<1.8	<1.8	<1.8	13	<1.8	<1.8	<1.8
2	APC[a]	8.0×10^4	<25	7.5×10^1	1.6×10^2	<25	3.8×10^2	2.6×10^4	<25	3.2×10^1	5.2×10^1
	TC[b]	>1600	<1.8	<1.8	<1.8	<1.8	2	43	<1.8	<1.8	<1.8
3	APC[a]	5.0×10^3	<25	2.8×10^2	4.9×10^3	2.7×10^1	4.3×10^3	1.4×10^4	3.9×10^1	6.4×10^1	<25
	TC[b]	>1600	<1.8	1.8	<1.8	1.8	2	7.8	<1.8	<1.8	<1.8
4	APC[a]	1.2×10^4	<25	3.1×10^1	2.3×10^2	9.6×10^1	5.7×10^1	2.5×10^3	3.3×10^1	8.5×10^1	<25
	TC[b]	920	<1.8	<1.8	<1.8	1.8	<1.8	23	<1.8	2	<1.8

[a] Aerobic plate count reported as cfu/ml.
[b] Total coliforms reported as MPN/100 ml.

3.3.2. Condensate well

Samples collected from the condensate well under tube ice-making machine show that coliform bacteria were found at least 23 MPN/100 ml. This level arose because the well is not protected and is prone to environmental contamination. Hence, the condensate should not be allowed for use in ice production.

3.4. Ice handling

Food-contacting surfaces, such as platforms for block ice removal, ice bin and ice trails as well as operators' hands, could be sources of microorganisms if they are not cleaned properly, as presented in Table 3. Platforms for block ice removal should be treated as a restricted area, where only authorized personnel with good personal hygiene are allowed. Instead of wood, the floor surface should be made of a durable, cleanable and disinfectable material, such as stainless steel, in order to prevent microbial accumulation and physical hazard (Mcswane, Rue, & Linton, 2000; Troller, 1983). Before entering the area, one should wear provided clean shoes, which should be disinfected in chlorinated water. In this study, ice-crushing machines did not cause change in microbial quality of ice (unreported data), since residual ice in the machine melted and drained out without accumulation. Personal hygiene of workers must be enforced, especially for persons who are in direct contact with ice.

3.5. Sack cleaning

Reused sacks need to be cleaned properly using practical methods for industry.

3.5.1. Pre-washing with water before soaking in chlorinated water

Table 4 indicates that washing sacks with water before soaking in chlorinated water could improve microbial quality. The numbers of both aerobic plate count and coliform bacteria considerably decreased after a sack was washed with water before soaking in the chlorinated water. Therefore, pre-washing with water is a necessary complimentary process with chlorination in order to remove dirt, which could reduce the disinfection efficiency of chlorine.

3.5.2. Effective chlorine concentration and soaking period

Lower chlorine concentrations, i.e. 1–4 ppm (chlorine concentration in municipal tap water), was not high enough to destroy coliforms on the sack. Minimum chlorine concentration that could effectively reduce total coliforms was at 7 ppm (Table 5). Table 6 shows the effect of the soaking period on the microbial quality of sacks. After sacks had been soaked in 10 ppm chlorinated water for more than 5 min, both aerobic plate count and total coliforms were be reduced to < 25 cfu/ml and <1.8 MPN/100 ml, respectively. To develop a practical cleaning method for factory use, approx. 100 ppm Cl – the concentration normally used for cleaning and disinfecting raw materials in the food industry – was used to maintain a minimum effective Cl concentration of 7 ppm after 10 soaking batches (200 sacks/batch), under the condition that all sacks can be completely submerged in the chlorinated water for at least 5 min.

3.5.3. Drying and storage conditions

Methods for drying and storage of the washed sacks were performed differently even in the same factory. Table 7 indicates the difference in microbial qualities of the washed sacks that had been dried and stored under different conditions. Complete drying resulted in the sacks of better microbial quality than the ones that were partially dried, especially as the washed sacks were stored for 24 h. As a consequence, cleaned sacks should be used at once or dried properly. Partially dried sacks (1 h) are not recommended, since loss of chlorine and residual water allowed more growth of microorganism.

Table 8
Microbial qualities of water, ice and sack samples collected at the study site before and after implementation of the developed measures.

Sample	Aerobic plate count (cfu/ml)[a]			Total coliforms (MPN/100 ml)[b]		
	Before	After	% reduction	Before	After	% reduction
Treated water	1.2×10^3	<25	>97.9	130	<1.8	>98.6
Block ice	1.5×10^2	<25	83.3	13	1.8	86.1
Crushed ice	7.1×10^3	5.0×10^2	92.5	240	2	99.2
Small tube ice	5.5×10^2	<25	>95.4	32	1.8	94.4
Large tube ice	3.8×10^2	1.8×10^2	52.6	46	2	95.6
Small tube ice (packed in sack)	1.8×10^4	2.2×10^2	98.8	>1600	2	99.9
Large tube ice (packed in sack)	1.3×10^4	3.0×10^2	97.7	540	1.8	>99.7
Large tube ice (packed in plastic bag)	1.4×10^2	1.3×10^2	7.1	23	2	91.3
Crushed tube ice	1.3×10^3	4.6×10^2	64.6	70	2	97.1
Empty sack (ready to use)	8.8×10^8	1.6×10^5	99.8	>877520	<984	>99.9

[a] Aerobic plate count of sack reported as cfu/sack.
[b] Total coliforms of sack reported as MPN/sack.

3.6. Test for the practicality of the developed measures

After the developed technology had been transferred and implemented at the factory, changes of microbial quality as aerobic plate count and total coliforms are shown in Table 8. Aerobic plate count of all samples decreased and percent reduction ranged from 7.1% to 99.8%. The least percent reduction was aerobic plate count of tube ice packed in plastic bags due to the low initial load. Total coliforms of all samples also decreased at % reductions ranged from 86.1 to 99.9%.

4. Conclusion

Several critical points need to be controlled during the production of block/crushed and tube ice. Water used for ice production must be disinfected, treated and stored similarly to drinking water since water quality and safety cannot be improved via freezing. Reused sack for packing ice must be cleaned with water and disinfected in 100 ppm chlorinated water for at least 5 min, which practically can be used up to 2000 sacks (200 sacks each time). The disinfected sacks should be either immediately used or used after completely dried.

Additional control points for the block/crushed ice were completeness of the ice can, the quality of ice removing water, and restrictions in the ice transferring area. In particular for block ice, the ice removing water should be chlorinated and controlled at 0.5–2.0 ppm free chlorine. The can used for making ice block must be regularly checked for completeness to prevent chemical hazard from anti-rusting agent, while the area for block ice transferring should be restricted. In addition, condensate from the bottom tank of the tube ice-making machine should not be used for ice production. Good Manufacturing Practices must be strictly performed at all production steps, as well as personal hygiene, especially in the ice-contacting area.

Finally, Ice production technology from Thailand has been exported to many countries, especially in Southeast Asia. Consequently, the findings noted herein will be very beneficial to those countries and Thai companies that do machine exportation.

References

American Public Health Association (APHA). (2005). *Standard methods for the examination of water and wastewater* (21th ed).. Washington DC: American Public Health Association.

Bacteriological Analytical Mannual (BAM). (2001a). Aerobic plate count [online] Available from. http://www.cfsan.fda.gov/%7Eebam/bam-3.html (Accessed 02.02.06).

Bacteriological Analytical Mannual (BAM). (2001b). Enumeration of *Escherichia coli* and the coliform bacteria [online] Available from. http://www.cfsan.fda.gov/%7Eebam/bam-4.html (Accessed 02.02.06).

Bangtrakulnont, A., Deeaum, A., & Kumkaew, R. (2000). Study of microbial quality of ice used for cooling food in Dusit and Pranakorn metropolitan [online] Avialable from. http://webdb.dmsc.moph.go.th/ifc_nih/a_nihR_search.asp?info_id=358 (Accessed 10.02.08).

Falcão, J. P., Dias, A. M. G., Correa, E. F., & Falcão, D. P. (2002). Microbiological quality of ice used to refrigerate foods. *Food Microbiology, 19*, 269–276.

Food and Environmental Hygiene Department (FEHD). The Government of the Hong Kong Special Administrative Region. (2005). The Microbiological quality of edible ice from ice manufacturing plants and retail businesses in Hong Kong [online] Available from. www.fedh.gov.hk/safefood/report/edible_ice/edible_ice_ra.html (Accessed 11.02.08).

Food Safety Authority of Ireland. (2002). Microbiological quality of ice for cooling drinks [online]Available from. http://www.fsai.ie/surveillance/food/ice_cooling_drinks.pdf (Accessed 11.02.08).

Lateef, A., Oloke, J. K., Gueguim Kana, E. B., & Pacheco, A. E. (2006). The microbiological quality of ice used to cool drinks and foods in Ogbomoso metropolis, Southwest, Nigeria. *International Journal of Food Safety, 8*, 39–43.

Makkaew, P. (2005). *Sanitary conditions and bacteriological quality of ice in ice plants, Bangkok Metropolitan*. Bangkok: Faculty of Graduate Studies, Mahidol University.

Malasao, S. (1995). *Microbiological quality of bottled water and ice*. Bangkok: Faculty of Medical Technology, Mahidol University.

Mcswane, D., Rue, N., & Linton, R. (2000). *Essential of food safety and sanitation*. U.S.A.: Prentice-Hall Inc.

Mookajornphan, D. (1997). *Guidelines for good manufacturing practices in canned food. food control division*. Thailand Food and Drug Administration, Ministry of Public Health.

Nichols, G., Gillespie, I., & de Louvois, J. (2000). The microbiological quality of ice used to cool drinks and ready-to-eat from retail and catering premises in the United Kingdom. *Journal of Food Protection, 63*, 78–82.

Nongharnpitak, P. (2000). *The quality of cube ice in plastic buggage at Khon Kaen municipality*. Khon Kaen: Faculty of Science, Khon Kaen University.

Pawsey, R. K., & Howard, P. (2001). Drinking ice as a vector for gastrointestinal disease. *British Food Journal, 103*, 253–263.

Rojjanawanicharkorn, A., Srithongderm, N., Thunyacharoen, P., & Duangjai, W. (2007). *Development of quality control in drinking ice manufacturing: Case study: Khon Kaen province*. Food Control Division, Thailand Food and Drug Administration, Ministry of Public Health.

Speck, M. L. (Ed.). (1984). *Compendium of methods for the microbiological examination of foods*. Washington, D.C.: American Public Health Association.

Thailand Food and Drug Administration (Thai FDA). (2006). *Survey on situation of manufacturing and microbial quality of ice*. Ministry of Public Health.

Troller, J. A. (1983). *Sanitation in food processing*. In *Food science and Technology. A series of Monographs*. U.S.A.: Academic Press Inc.

Wilson, I. G., Hogg, G. M., & Barr, J. G. (1997). Microbiological quality of ice in hospital and community. *Journal of Hospital Infection, 36*, 171–180.

World Health Organization (WHO). (2006) [online] Available from (3rd ed.).*Guidelines for drinking-water quality [electronic resource]: Incorporating first addendum. Vol. 1, Recommendations*. http://www.who.int/water_sanitation_health/dwq/gdwq0506.pdf (Accessed 14.10.09).