Hindawi
Journal of Food Quality
Volume 2022, Article ID 5321333, 12 pages
https://doi.org/10.1155/2022/5321333

Research Article

Implementation of HACCP Management System in a Cake Manufacturing Company in Dhaka, Bangladesh: A Case Study

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Received 22 November 2021; Revised 12 February 2022; Accepted 18 February 2022; Published 9 March 2022

Academic Editor: Vicente M. G mez L pez

The study aims to provide technical information on the development and application of hazard analysis and critical control points (HACCP) in one of the popular cake manufacturing companies in Dhaka, Bangladesh. A generic HACCP plan in accordance with legal requirements was created after a detailed analysis of data collected from the company. Every step of the production process was examined for biological, chemical, and physical hazards. The prerequisite program was designed to address some hazards prior to production, thereby simplifying the HACCP plan. The critical control points were determined by answering the questions in the decision trees. Finally, the HACCP control chart was created to include critical limits, monitoring, and corrective actions as the components of several HACCP principles. One critical control point (CCP) and two operational prerequisite programs (oPRPs) were identified throughout the manufacturing process. This is the first HACCP study aimed at a cake manufacturing company, and it is expected that it would assist process engineers and quality control specialists in designing and implementing control measures.

1. Introduction

Cakes are popular sweet bakery products all over the world. Globally, the cake market is expected to grow at a rate of 3.3% per year from 2018 to 2023, reaching a value of $75 billion by 2023 [1, 2]. Cakes are available in an enormous variety of forms and recipes, making them popular among people of all ages and demographics around the world. The primary raw materials of cake include flour, sugar, egg, shortening [3], color, flavor, salt, and emulsifier, which are then processed into finished goods via various processing steps such as mixing, baking, cooling, and packaging [4]. Foodborne illnesses are usually associated with this kind of processed products. *Escherichia coli* O157 : H7 has been found in cheese and pizza, *Listeria monocytogenes* in cheese and ice cream, and *Salmonella typhimurium* in peanut butter [5]. Between 2004 and 2013, there were 142 cases of foodborne disease outbreaks and 2822 illnesses associated with bakery products in the United States [6]. Numerous food safety hazards associated with cake raw materials have been discovered, including aflatoxin B1 [7], mycotoxins [8], *E. coli*, *Salmonella* spp., *Bacillus cereus*, and several pathogenic microorganisms in flour [9]. Besides, presence of *Salmonella* [10], *Campylobacter* [11], and *Listeria* [12] is very common in the raw eggshell. Various types of hazards can be introduced during the cake manufacturing process through different processing steps such as food raw materials, processing equipment, processing environment, and food handlers.

The food industry is responsible not only for producing safe foods, but also for demonstrating how food safety issues are designed and implemented. Developing a food safety management system contributes to this goal in an open and transparent manner [13]. The HACCP system is a powerful

and efficient tool for producing safe food. In the food production system, the HACCP tool application is a systematic science-based system that specifies specific food safety hazards. It determines the food safety control measure [14]. At the moment, many countries, including the United States, Japan, the United Kingdom, and European Union member states as well as international organizations such as the WHO, FAO, and Codex Alimentarius Commission (CAC), have adopted the HACCP system and have stringent criteria regarding food imports [13]. Every HACCP system is capable of addressing and accommodating changes in technological advancement, advancement in equipment design, adjustments in processing procedures, and so on. Principles of the HACCP system have been adopted by the Codex Alimentarius Commission (CAC), and application guidelines are presented in an annex to the general principles of food hygiene [14]. HACCP implementation is based on seven principles that are used to identify and control hazards to an acceptable level [15, 16]. Before implementing a HACCP plan, a strong prerequisite program should be in place. Prerequisite programs (for example, sanitation, pest control, personnel practices, GHP, ingredient and product specifications, staff training, cleaning and disinfectant regimes, and hygienically designed facilities) are used to ensure that employees, equipment, premises, and transportation do not contribute to or become food safety hazards [14, 17]. Subsequently, HACCP is a globally recognized, effective, and preventive food safety management system for measuring hazards, estimating risks, and establishing precise control measures that emphasize prevention and control rather than reliance on end-product testing and traditional inspection methods. Implementing HACCP is more effective than traditional quality assurance methods in gaining consumer trust and establishing a good corporate image [13].

Food contamination and adulteration have lately arisen as serious public health concerns in Bangladesh, and unsanitary food handling practices have become a prevalent phenomenon in the Bangladesh food industries [18]. As a result, an independent food safety body named BFSA was formed in 2015. According to the BABBMA, there are approximately 60 large factories registered in Bangladesh that manufacture bakery products [19]. Pesticide residues and postprocessing contamination with pathogenic microbes such as *Salmonella* and *E. coli* are the most prevalent food safety risks in this sector [20]. Bangladesh has a moderate level of food safety inspection, though the leading private food industries have the internal capacity to ensure food safety compliance with US and European standards [20]. Adopting HACCP is beneficial for building the trust of customers and developing a positive corporate image. The use of HACCP enables Bangladeshi food companies to break down trade barriers and participate in worldwide business, thus expanding their markets and generating revenues. Furthermore, a rational and appropriate HACCP plan can assist food companies in improving their management level and raising the safety consciousness of their employees [13]. Hence, this current study aimed to implement the HACCP system in a cake manufacturing plant in order to identify CCPs, thereby establishing an effective preventive system that will lead to safer and more efficient cake production. To the best of our knowledge, this is the first study to show HACCP implementation in a cake manufacturing company in Bangladesh. This will be helpful for the process engineers and quality control specialists to design and implement control measures in the baking industries. The method is intended for use in cake manufacture when higher control is sought for broader applicability. The implementation of the HACCP system can effectively ensure the quality and safety of the final product.

2. Materials and Methods

2.1. Company Description. This study was conducted in a cake manufacturing company located in the Dhaka division of Bangladesh, which was a joint venture manufacturing company between Denmark and Bangladesh. Dhaka, Bangladesh's capital city, is home to a plethora of food businesses. For this study, we chose a freshly formed company that intends to fully implement food safety regulations. Moreover, it was the first specialized cake manufacturing company in Bangladesh. The research was carried out from January to August of 2019. It was classified as a medium-scale plant, with a monthly production capacity of 500 tons and a workforce of around 200 people during the study period. Muffins, plain cakes, fruit cakes, Swiss rolls, and sponge cakes were among the products produced by the company. In addition to the domestic market, the products had begun to be exported directly to international markets. The restructuring was intended to expand the company's market. As a result, the company planned to implement an effective FSMS to ensure consumer food safety and high-quality products. This study explains the PRPs, OPRPs, and HACCP principles in accordance with the standard requirements for the cake manufacturing line. The company layout (Figure 1) shown below is adopted from the corresponding authors' previous work [21].

2.2. HACCP Implementation Steps. HACCP is a scientific and systematic approach to food safety that identifies and controls specific food safety hazards. Implementing HACCP is a symbol of product quality and safety that ensures consumer satisfaction. According to Codex Alimentarius, the HACCP system is based on seven scientific principles [22].

Principle 1. Perform hazard analysis (HA) for the identification of physical, chemical, and biological hazards.

Principle 2. Identification of critical control points (CCPs) according to the decision tree.

Principle 3. Establishing critical limits (CL) to ensure uniformity in the safety analyses of the processes involved.

Principle 4. Monitoring each CCP.

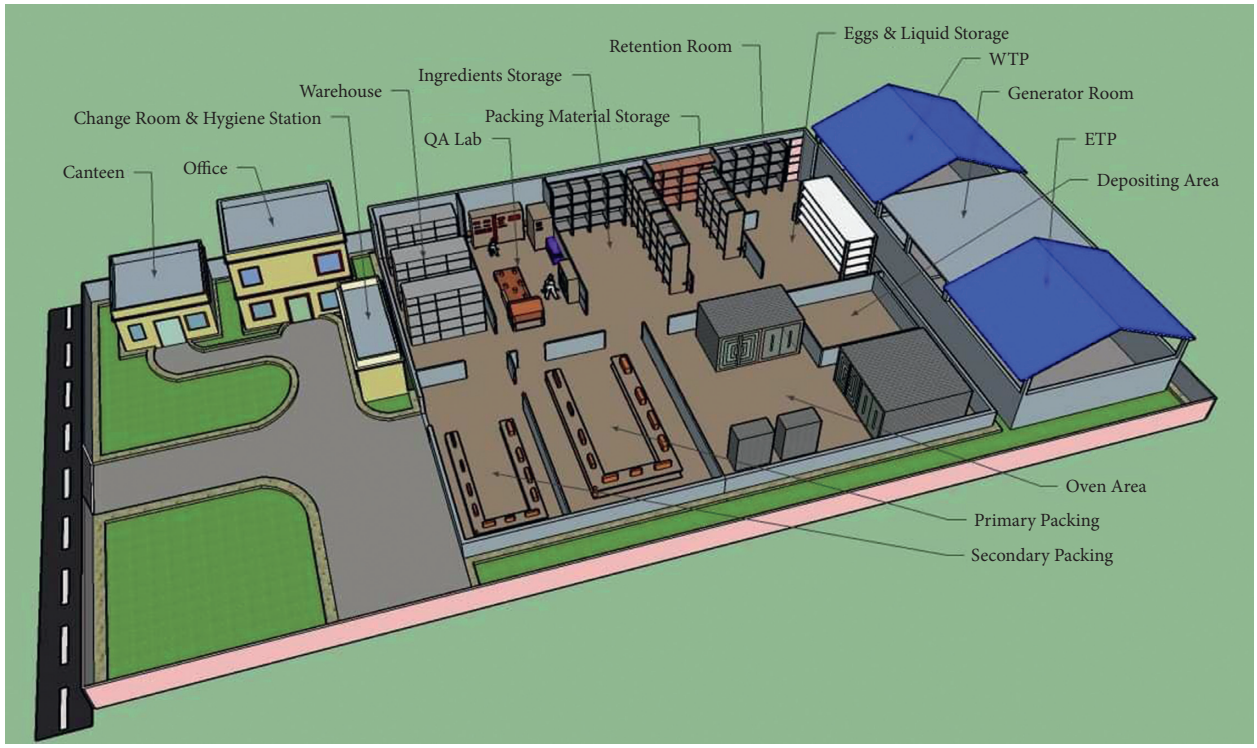

Figure 1: Layout of the plant [21].

Principle 5. Establishing corrective actions to be executed when monitoring indicates a deviation from a predefined critical limit.

Principle 6. Establishing effective record-keeping procedures.

Principle 7. Establishing procedures for verification that the HACCP system is working correctly.

In this study, PRPs and OPRPs are applied along with HACCP plan throughout the whole production process.

3. Results and Discussion

3.1. Implementation of HACCP Plan. According to an analysis of the HACCP system applied in the company, there was no reduction in end-product quality during the manufacturing process, with notably strong application of prerequisites and entire commitment and sense of responsibility on the part of all employees. However, numerous external factors can be a potential barrier in all stages of the HACCP implementation process, including (a) the illusion of control in the absence of adequate staff training; (b) company size as a potential factor due to a lack of resources, technical knowledge, and experience; (c) major industries that find it easier to implement the HACCP system than small businesses; (d) lack of HACCP program leadership; (e) lack of cooperation between industry and law enforcement authorities; (f) insufficient equipment; (g) poorly designed equipment and an incorrect plan layout; (h) employee lackness of time to accomplish HACCP; (i) lack of equivalence of different types of HACCP programs [23].

3.1.1. Listing the Prerequisite (PRP). Prior to the HACCP system, PRPs are systematically applied in the food processing sector to support and improve the system's effectiveness and efficiency. PRP application is considered as the foundation of HACCP system. PRP represents the formalization of GMP and GHP elements [24]. The PRPs were PRP environmental hygiene, PRP establishment-design and facilities, PRP premises and rooms, PRP equipment, PRP water supply, PRP drainage and waste disposal, PRP cleaning and sanitation, PRP personnel hygiene facilities and toilets, PRP temperature and air quality control, PRP lighting, PRP handling, storage, and transportation, PRP control of operation, PRP pest control, PRP waste management, PRP traceability, and PRP training.

3.1.2. Preliminary Steps to Enable Hazard Analysis. The implementation of a food safety system (HACCP) is a continuous process that is based on the management concepts of an iterative four-step management method known as the PDCA cycle (plan, do, check, and act).

(1) The HACCP team. A team was formed to implement an efficient HACCP system. While assembling the HACCP team for the company, the following factors were taken into account. The team was supposed to have six members.

(a) In terms of qualifications and experience, the members must be competent in their particular fields of activity

(b) The team should be led by a team leader who will direct the activities

(c) The team coordinator will be in charge of developing, implementing, and maintaining the HACCP system

(d) All team members are expected to receive proper training

(e) The team must develop and maintain all documents in accordance with the HACCP system

(f) Furthermore, if there is a change or modification in the process, the team must examine the adequacy of the HACCP system on a yearly basis

Thus, the formation of the HACCP team was as follows:

HACCP Team Leader
Plant Manager
HACCP Team Coordinator
Manufacturing Manager
HACCP Team Members
Quality Assurance Manager
Manager-HRM and Compliance
Ware House Manager
Maintenance Manager (Electrical)
Maintenance Manager (Mechanical)
Supply Chain Manager

The team leader, as the highest authority, maintains the smooth operation of the company and ensures that all legal criteria for its proper operation are met. It is also his obligation to supervise all phases of the plan, as well as the responsibilities and coordination of all internal and external corporate operations [25]. The team members are responsible for keeping and regulating the records related to their area of operation.

(2) Product characteristics and intended use. The HACCP team needs to start with a thorough description of the produces, defining their composition and chemical, biological, and physical properties.

Table 1 shows the generic framework for the description of cake.

(3) Construction of flow diagram. A flowchart showing the whole manufacturing process of cake was constructed (Figure 2). The HACCP team checked the flow diagrams on site. It is critical that the flowchart be properly prepared and thoroughly analyzed on the ground and contain as much information as feasible. Only a well-planned, informative, and well-analyzed flowchart helps to facilitate overall production process, making it much easier to detect potential deviations [25].

3.1.3. Hazard Analysis and Identification of CCPs and oPRPs. The hazard analysis assists in identifying potential hazards associated with the entire process, from raw material receipt to product delivery to consumers. During the hazard analysis, hazards were further categorized into three categories: (a) biological, (b) physical, and (c) chemical [26]. Hazard analysis or identification is generally aimed to identify potential threats to human health that may be introduced into baked goods during the manufacturing process. Based on the hazard analysis, further risk assessments were accomplished. In the process of risk assessment, customer complaints, shipment returns, and laboratory test results were typically taken into account [27]. Hazards as identified for each step of the process flow diagram were entered in the format. Following the completion of the subsequent process steps, values for the likelihood of the hazard's presence and the consequences of the hazards were entered into the assessment column. The values were determined as in Table 2 and Table 3.

The likelihood, i.e., probability, and consequences of a specified hazardous event occurring are combined to form risk. Thus, it can be defined as follows: risk index (RI) = likelihood × consequences.

Significant hazards were identified using a numerical scale of one (1) to four (4) of likelihood and consequence. When rating likelihood and consequences, previous experiences, records, and data were considered (Table 3).

According to Table 3, the IR for this current study varies between 1 and 12. The calculated risk index shows that if the RI is higher than 8, then it should be managed by the HACCP plan. HACCP plan is a document prepared in accordance with the seven principles of HACCP [25]. On the other hand, when the IR is less than 4, the results should be maintained by the oPRPs [25]. The RI for the production of cake is shown in Table 4.

After completing the hazard assessment, relative control measures are selected with the help of the CCP decision tree as shown in Figure 3. CCP is a step in which a specific control measure must be implemented in order to prevent or eliminate a food safety hazard or reduce the risk to an acceptable level [16] (Section 3.1).

An oPRP's components are the same as those of a CCP, with the exception that no critical limit is required for control measure(s) [15], and failure in the manufacturing process has no direct effect on the process [25]. The hazard analysis of the cake manufacturing process is shown in Table 5.

3.1.4. Establishing the oPRP and HACCP Plan. The HACCP plan was established for each oPRP and CCP by specifying the hazards, control measures, CL, corrective action, verification, and records management. The potential control points for the hazards appeared in both the raw material and the manufacturing process. Table 6 and Table 7 show the oPRP and HACCP plan in the cake manufacturing process. The HACCP control chart (Table 7) showed all the potential critical hazards that can occur during the processing steps. Gandhi [28] included hazard description, critical limit, observation procedure, responsible person, monitoring procedure, and corrective action in his HACCP control chart for soy milk production, whereas Burson [29] reported processing steps, records, and verification procedures in his meat product control chart. The HACCP control chart in the current study is similar to some previous studies [15, 25, 30]. One CCP, metal detection, and two oPRPs, baking and

Table 1: Product description and intended use.

Product	Cake is a bakery product	
Product composition	Wheat flour, sugar, eggs, salt, vegetable fat, glycerol, starch, wheat starch, skim milk powder, raising agents (E 500), preservative (E 202), and flavor	
Product characteristics	Physicochemical characteristics:	
	Moisture	18–22% wb
	Water activity (a_w)	0.76–0.81
	Acid value of extracted fat, (as oleic acid), percent by mass, max.	1.0
	Protein	5–7 g/100g
	Microbiological characteristics:	
	Total viable count, cfu/g, max.	20000
	Enterobacteriaceae spp.	$\leq 10^2$ UFC/g
	Staphylococcus aureus	$\leq 10^2$ UFC/g
	Salmonella spp.	Absent
	Listeria monocytogenes	Absent
	Coliform	Absent
	Mold, maximum	50 CFU/g
	Sensory characteristics:	
	Physical condition	Solid
	Color	Characteristics
	Flavor	Typical
	Texture	Typical
Labeling requirements	Product's name, composition, allergen information, origin, manufactures date, expiry date, destination, net weight, storage temperature, and destination	
Storage and transport conditions	Primary packages should be packaged further in a secondary packing procedure (gift boxes). Secondary boxed must packed in tertiary packaging (cartons). Final storage and transportation should make at ambient temperature	
Shelf life	4 months	
Intended use	Direct consumption. The product mentioned is for the general population, except for gluten-sensitive groups	
Applicable laws	BDS 1574, specifications for cakes; BDS 1240, specifications for drinking water; BDS 381, specifications for maida; BDS 1567, specifications for refined oil; BDS 79, specifications for jams and jellies; BDS 1615, specifications for cocoa powder; BDS 138, specifications for refined sugar; BDS 207, specifications for milk powder and cream powder; BDS 822, code of hygienic conditions for food processing units, etc.	

packaging, were discovered during the cake manufacturing process. The center temperature of the bakery product crumb needs to be above 100 °C for few minutes. During baking, all vegetative pathogenic bacteria should be destroyed [31, 32]. The main ingredients of cake dough include fats and oils, eggs, flour, and sugar. Among these, sugar is comparatively safe in regard to any foodborne illness. Fats and oils can be a potential source of *Listeria* [9]. Flour, on the other hand, can pose both chemical and microbial risks. However, the most dangerous and common thing that can happen is mycotoxin, such as aflatoxin. Despite the fact that the physicochemical properties of flour (i.e., low a_w) do not allow bacteria to grow, microorganisms can survive for extended periods of time during storage [9]. As for the egg shells, they are considered as a major source of *Salmonella* enteritidis [33, 34]. However, cake dough is not considered a high-risk food because it has a low a_w and requires baking prior to packaging and consumption [9, 35].

The physical hazard of metal in cake is the most serious, and it is harmful to the consumer. Metal detectors can now be used to detect and remove metallic components during food processing. The presence of metallic components can significantly reduce food safety, resulting in perforation of human gastrointestinal tissues and surgical resection. The presence of metallic particles can cause damage to various valuable machine parts, resulting in a sudden production line shutdown and economic loss. Metal detectors are installed by food processing industrialists for product quality and safety, equipment protection, consumer satisfaction, and regulatory body requirements, among other things. Metal detectors are extremely important and effective for metal hazard control in solid seasoning powder and liquid sauces through the implementation of a HACCP plan [36]. In the current study, there was no additional step in the manufacturing process that could detect or eliminate this problem, according to the process flowchart. According to a study conducted by [13], packaging and cartooning are the most important parts of the production process, with no other steps left out to assure process safety. The authors in [13] conducted their study on a biscuit manufacturing plant

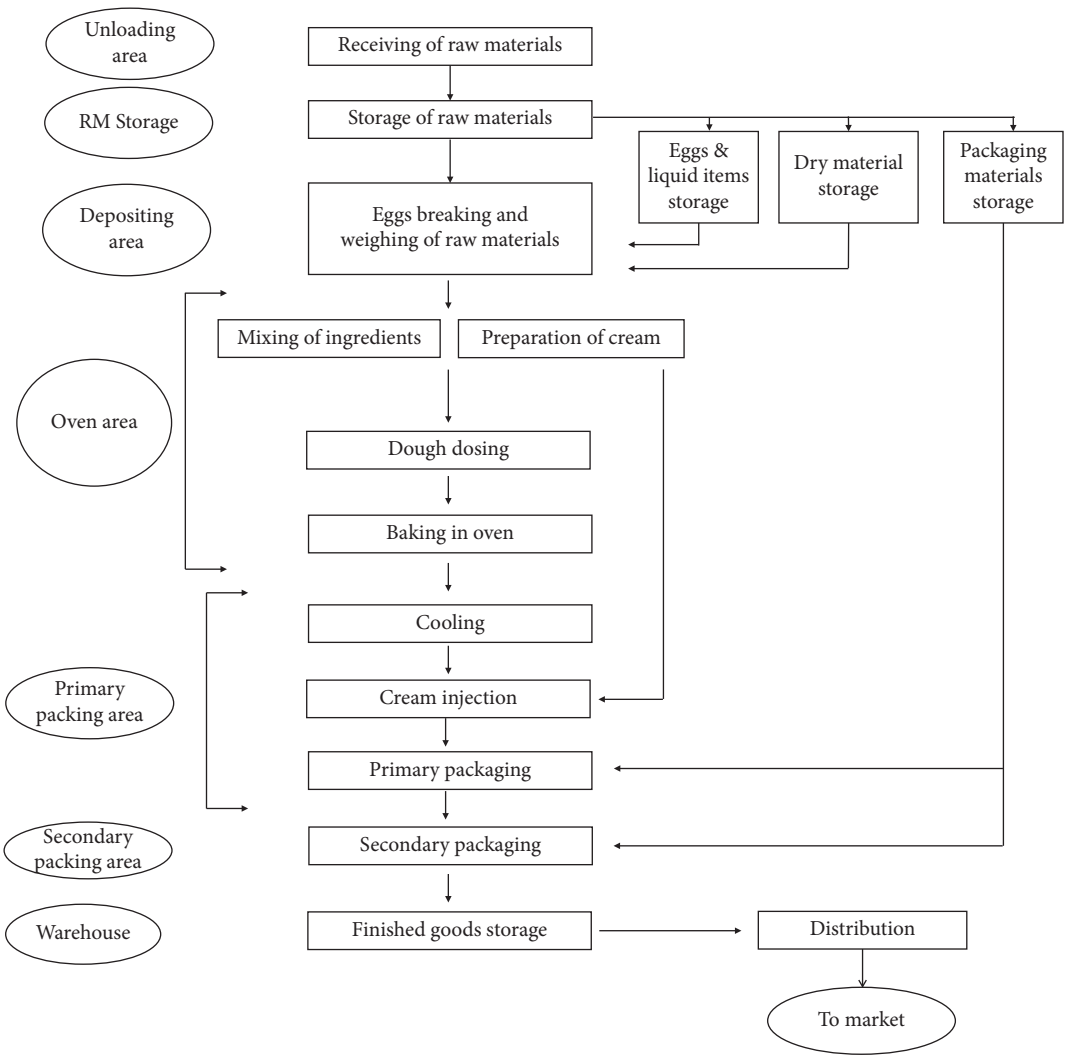

Figure 2: Complete flowchart of the cake manufacturing process.

Table 2: Likelihood and consequence criteria to specify potential hazard in cake manufacturing process.

Likelihood (probability)	Consequences (severity)
4. Frequent, e.g., daily	4. Very high (catastrophe), e.g., death
3. Likely, e.g., weekly	3. High (critical), e.g., illness
2. Occasional, e.g., monthly	2. Medium, e.g., injury
1. Unlikely, e.g., yearly	1. Minor, e.g., no injuries

Table 3: Analysis of likelihood vs. consequences.

Hazard types	Likelihood (probability)	Consequences (severity)	RI
Physical (stones, sand, husks, and plastic)	X	y	Xy
Chemical (mercury (hg), chromium (cr), aflatoxin, melamine)	X	y	Xy
Biological: total plate count (TPC), coli form, molds, and pests	X	y	Xy

Table 4: Risk index and its management [25].

RI	Risk type	Management of risk
$RI \leq 4$	Satisfactory risk	Should be managed by oPRPs
$4 \geq RI \leq 8$	Lower risk	
$8 \geq RI \leq 12$	Increased risk	Should be managed by the HACCP plan
$12 \geq RI \leq 16$	Critical risk	

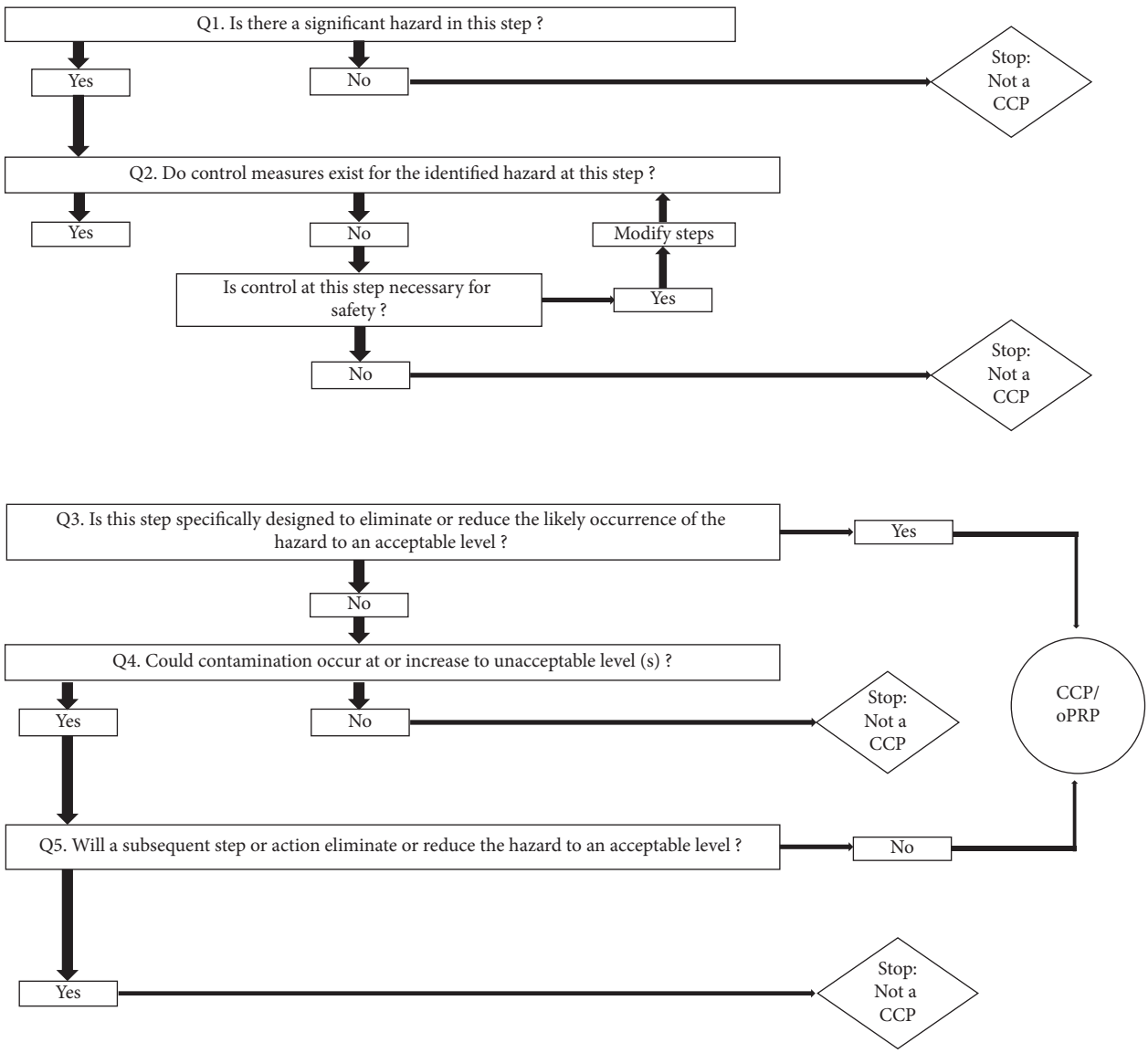

Figure 3: CCP decision tree for HACCP implementation (adopted from [15]).

in Bangladesh. Baking and metal detection were also identified as two of the CCPs in that investigation, which is consistent with the current study.

To ensure that the HACCP plan is working as intended, the food safety team developed a verification strategy that describes the goal, methods, frequency, and responsibilities for the verification activities. Records and documentation are generated to offer evidence of the system's effective execution [37]. Different documentation formats were also employed in our research to monitor specified measure control and ensure suitable corrective actions. Documentation often included deviations, accompanying remedial activities, and verifications. The following aspects for monitoring procedure comprised of HACCP were object, such as additive quantity; method, such as requiring for inspection report; frequency, such as every batch; and persons, such as operators [38].

This present study identifies a significant risk that could have an impact on public health. Nonetheless, the process was controlled by systematic monitoring from primary to final production that was a critical concern for food safety. This system is subject to regular systematic monitoring. CCP was not the only factor. The documentation and data provided by the HACCP system could easily aid in the tracing of the contamination [13]. This approach also aided in the prevention of cross contamination. Finally, it can be declared that this approach delivers greater quality and hygiene standards and ensures superior cake quality.

Table 5: Hazard analysis for the production process of cake.

Processing step	Hazards	Risk effects	Probable causes	Risk evaluation			Control measures (SOP or work instructions)	Decision tree					Record
				P	S	RI		Q1	Q2	Q3	Q4	Q5	
Receiving of raw and packaging materials	Physical: foreign objects, such as hair, insects, broken plastics.	Without consequences	Packaging, hygiene, pest control	3	1	3	Visual inspection	Y	Y	N	Y	Y	PRP
	Chemical: acidity, melamine, heavy metals, residual chemical, etc.	Without consequences	CoA, packaging	1	3	3	Supplier evaluation, CoA, HACCP certificate, personal and transport hygiene status, lab test (QA)	Y	Y	N	Y	Y	PRP
	Biological: microbial contamination (pathogenic)	With consequences	CoA, hygiene	1	4	4	Supplier evaluation, CoA, HACCP certificate, personal and transport hygiene status, lab test (QA)	Y	Y	N	Y	Y	PRP
Storage of raw and packaging materials	Physical: foreign objects, insects	Without consequences	Irregular inspection and improper hygiene	3	1	3	Keep storage environment safe, keep containers closed. Separate areas for raw and packaging materials	Y	Y	N	N		PRP
	Chemical: production of H_2S (eggs)	Without consequences	Storage temperature	2	1	2	Maintaining suitable storage condition, FIFO	N					PRP
	Biological: microbial, pests and insects	With consequences	Transport and storage temperature, pest control, hygiene	1	4	4	FIFO, maintaining suitable storage and transport temperature, pest controlling plan, maintain personal and environmental hygiene during storage and transport	Y	Y	N	Y	Y	PRP
Taking RM and PM from storage to production	Physical: foreign objects Chemical: unidentified Biological: unidentified	Without consequences	Improper handling and personal hygiene	3	1	3	Maintain personal hygiene, wear mask, apron, gloves, head cover and beard cover, maintain SOP, GHP	Y	Y	N	Y	Y	PRP
Batch preparation (weighing and mixing)	Physical: foreign objects, broken egg shells	Without consequences	Improper handling and personal hygiene	2	1	2	Provision of filter in egg broker machine, visual inspection, maintaining personal hygiene, wear mask, apron, gloves, head cover, and beard cover	Y	Y	N	Y	Y	PRP
	Chemical: excess additives, detergents, etc.	Without consequences	Incorrect hygiene and cleaning, faulty recipe	1	1	1	Follow the recipe and recheck, timely calibration of measuring instruments	N					PRP
	Biological: Pathogenic microorganism	With consequences	Improper personal hygiene	1	4	4	Strict personal hygiene, regular hand swab tests by the QA, proper hygiene, food safety, and behavioral training	Y	Y	N	Y	Y	PRP
Mixing	Physical: broken piece of mixing machine, foreign objects	With consequences, without consequences	Maintenance of mixing machine, improper personal hygiene	3	1	3	Checking the status of mixing machine, maintain personal hygiene, wear mask, apron, gloves, head cover, and beard cover	Y	Y	N	Y	Y	PRP
	Chemical: detergents residue	Without consequences	Improper hygiene and cleaning practice	1	1	1	Maintain proper hygiene and cleaning practice	Y	Y	N	Y	Y	PRP
	Biological: pathogenic microorganism	With consequences	Improper personal hygiene	1	4	4	Maintain strict personal hygiene, wear mask, apron, gloves, head cover and beard cover, keep the equipment properly sanitized	Y	Y	N	Y	Y	PRP
Dosing	Physical: broken piece of dosing nozzle Chemical: unidentified Biological: unidentified	With consequences	Maintenance of dosing machine	1	1	1	Checking the status of dosing machine	Y	Y	N	Y	Y	PRP
Baking	Physical: unidentified Chemical: moisture content and water activity	Without consequences	Improper baking time and temperature	3	1	3	Frequent lab test for MC and a_w from each batch, maintenance of baking temperature and time as per SOP	N					PRP
	Biological: microbial contamination	With consequences	Improper baking time and temperature	1	4	4	Maintenance of baking temperature and time as per SOP	Y	Y	N	Y	N	oPRP
Cooling	Physical: unidentified Chemical: moisture content and water activity Biological: unidentified	Without consequences	Improper cooling time and temperature	2	1	2	Check for cooling conveyor speed and cooling temperature	N					PRP
Cream filling	Physical: broken part of cream dosing nozzle Chemical: unidentified Biological: unidentified	With consequences	Maintenance of cream filling machine	1	2	2	Checking the status of cream filling machine	Y	Y	N	Y	Y	PRP
Metal detection	Physical: metal parts Chemical: unidentified Biological: unidentified	With consequences	Inactive sensor of the metal detection machine, machine broken	3	4	12	Frequent checking of the machine status	Y	Y	Y	N	N	CCP
Packaging	Physical: foreign parts from packaging machine surface, damaged pack, leakage in packing	With consequences	Improper cleaning, shortage of nitrogen gas, PLC fault	3	1	3	Proper cleaning of packaging machine, check for nitrogen gas level, regular checking of the PLC system	Y	Y	N	Y	Y	PRP
	Chemical: detergents residue	Without consequences	Improper hygiene and cleaning practice	1	1	1	Maintain proper hygiene and cleaning practice	Y	Y	N	Y	Y	PRP
	Biological: microorganisms	With consequences	Improper personal hygiene, contamination in packing materials	2	4	8	Regular hand and surface swab test, ATP check before packing, strict maintaining of personal hygiene, QA online check for leak package	Y	Y	N	Y	N	oPRP
Filling in box and date coding	No hazard	Without consequences											No risk
Finished goods store	Physical: tertiary package damage by rodents Chemical: unidentified Biological: unidentified	Without consequences	No pest traps and pest control	2	1	2	Put glue trap in proper places, conduct timely pest control action	Y	Y	N	Y	Y	PRP
Delivery transport to market	No hazard												No risk

Table 6: oPRPs in the cake manufacturing process.

Processing step	Hazard	Control measure(s)	Critical limit	Monitoring procedures				Records	Corrective action	Verification
				What?	How?	Who?	Frequency (when?)			
Baking	Biological: microbial contamination	Maintenance of baking temperature and time as per SOP	Baking temperature between 150 and 250 °C for 5–50 minutes	Oven temperature	Physical inspection	QA officer, production officer	Every one hour interval	QA and production (plan oPRP)	Reset the temperature and time, reject or reuse the product	Physical observation, calibration
Packaging	Biological: microbial contamination	Regular hand and surface swab test, ATP check before packing, strict maintaining of personal hygiene, QA online check for leak package	Surface ATP = <50 RLU; Hand swab for coliform = nil; Hand swab for mold = <50 cfu/ml	Machine surface, workers hands	Swab test, microbiological test in the QA lab	QA executive	ATP test every day, hand swab test twice in a week	QA and production (plan oPRP)	Reclean the surface, observation (hygiene status) of infected hands (person) for a month, reject the leak pack and products	Recheck

Table 7: HACCP control chart.

Processing step	Hazard	Control measure(s)	Critical limit	Monitoring procedures				Records	Corrective action	Verification
				What?	How?	Who?	Frequency (when?)			
Metal detection	Physical: metallic component	Detection of metallic component by metal detector	Absence of metallic component	Sensor of the metal detector, PLC, alarm	Physical inspection and check for alarm (by passing a metal under the metal detector)	Maintenance dept., QA and production dept.	Every 1 hr interval during the production time	QA, production, and maintenance register (plan CCP)	Rejection of the whole lot of nonconformed products	In-house checking by metal pieces, maintenance records, calibration of metal detector, and auditing

4. Conclusion

The HACCP system provides food manufacturers with effective preventive methods for ensuring food safety and improving the quality. Furthermore, the documentation and records generated by the HACCP system can easily assist in tracing the source of contamination, preventing further production of substandard products and reducing the consumption of manpower, material, and financial resources. The current study developed a HACCP plan for a cake manufacturing plant in Bangladesh in order to improve product safety and quality. The hazards in cake manufacturing are primarily due to the use of improper processing conditions, an unsanitary manufacturing environment, and a lack of legislative implementation. We found a CCP and two oPRPs in the entire cake manufacturing process. Further linking of the HACCP system introduced in the factory for quality management systems, such as International Organization for Standardization regulation, can potentially provide higher quality/hygiene standards, as well as increasing customer awareness. However, rather than establishing the HACCP system, management teams of food corporations should ensure the application of the HACCP system in their entire production system.

Abbreviations

HACCP: Hazard analysis and critical control point
GHP: Good hygiene practice
GMP: Good manufacturing practice
BABBMA: Bangladesh Auto Biscuit and Bread Manufacturers' Association
CCP: Critical control point
PRPs: Prerequisites programs
oPRPs: Operational prerequisites programs
BDS: Bangladesh standards
CL: Critical limit
HA: Hazard analysis
HRM: Human resource management
RI: Risk index
CoA: Certificate of assurance
QA: Quality assurance
FIFO: First in first out
SOP: Standard operating procedure
MC: Moisture content
a_w: Water activity
PLC: Programmable logic control.

Data Availability

Data will be available upon reasonable request.

Disclosure

A preprint has also been published in the "Preprints" having doi "10.20944/preprints202107.0577.v1" [39].

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

MFJ and MSH conceptualized the study, conducted additional research works, and engaged in writing, reviewing, and editing. MAE and MNU conducted the research work and collected the data. All the authors gave final approval for publication and agree to be held accountable for the work performed therein. FJ and SH are contributed equally to this paper.

Acknowledgments

The authors gratefully acknowledge the management team of this baking (cake) company for their assistance throughout the research period.

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