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Design and application of hazard analysis critical control point principles for typical frozen vegetables

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ABSTRACT

Frozen food industry must be concerned with food safety. Food safety of most of frozen food industry can be accrued by hazard analysis and critical control point (HACCP). HACCP is prerequisite program for transactions of food products. This study aimed to set up a specific HACCP plan for frozen vegetable processing plant in Bangladesh. A specific HACCP model has been developed for this plant for improvement of safety, sanitation and quality issue for frozen vegetables processing plant. HACCP model was set up based on the actual conditions in the plant. HACCP plan, verification procedures and recordkeeping system were initiated by three-member HACCP team. Three critical control point (CCPs) were identified with one operational prerequisite program (OPRP) in the processing plant. The most important identified CCPs were blanching, individually quick frozen (IQF freezing), and metal detector. Cold storage was identified as OPRP in this process. Based on this research and findings, the authors recommend for implementation of HACCP system in frozen food processing industries.

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1. Introduction

The cold chain industry worldwide is growing at a rapid pace. The world is becoming more and more urbanized which supports the convenience food culture. The global frozen food industry recorded approximately 4% growth in 2010 exceeding $192 billion. The market is expected to see 19% expansion over next 5 years exceeding $228 billion by the end of 2015. Frozen meat represents the leading segment, accounting for more than 41% of the overall market in terms of value. Europe accounts for 37.6% of the global frozen food market value. For Bangladesh, plausible lucrative export destinations are USA, Canada, Australia, Middle-East, and Europe. The domestic frozen foods market is also growing at a rapid pace with the expansion being almost 30% in 2011-2012 over the preceding fiscal year (1). At present, the market is projected to be at over BDT 2680 million. The frozen foods domestic market in Bangladesh can be broadly divided into four broad segments: (i) frozen ready to cook snacks – this includes both meat and fish based snacks such as chicken nuggets, meatball, strips, fish ball, fish cakes, and vegetable-based snacks; (ii) frozen ready-to-cook meat – this includes frosted whole chickens, lambs, mutton, and beef; (iii) frozen ready-to-cook vegetables – this includes frosted vegetables such as bean seeds, kakrol, patol, okra, and Jackfruit seeds; and (iv) frozen ready-to-cook fishes – finally ready-to-cook fishes has also become popular. To maintain the international standard of the frozen food industry, it is necessary to explore and follow the principles of hazard analysis critical control points (HACCP) systems (1). HACCP is a scientific and very effective rational means of assuring food safety from raw materials to final consumption, using "farm to table" methodology. HACCP was originally developed as a microbiological safety system to

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ensure food safety for astronauts. Around 1960's HACCP was used for food safety and quality control systems, but based on end product testing, which was an inefficient method due to product waste. As a result, it is necessary to develop a preventive system to give a high level of food safety (2,3,4). Nowadays, the introduction of food quality and safety HACCP has become synonymous with food safety (5).

HACCP is a useful preventative food safety system, including modern quality control inspection system. Although HACCP is not "zero risk" and does not eliminate the possibility of a hazard getting into the food product. However, HACCP is the most effective way to active food safety issue to prevent the possible hazards and to improve the process. It is a recognized systematic and preventive approach to physical, chemical, and microbial hazards through anticipation and prevention, rather than through end-product inspection and testing and thereby reducing the foodborne illness (6). HACCP system is designed to prevent the occurrence of foodborne hazards from production through manufacturing, storage and distribution of a food product by applying controls at points in a food production process where hazards could be controlled, reduced or eliminated (7). Food industry aims to assurance of safe production, the supply of adequately safe and healthy food products. Nonetheless, these aims can be achieved only by adopting a systematic and organizational structure, controlling activities, procedures and resources according to the standards of total quality systems such as ISO 9000 series and the HACCP (8). HACCP program maintains safety and wholesomeness of frozen food products such as frozen meat, chicken, and vegetables because potential hazards that may occur during processing are anticipated, evaluated, controlled, and prevented. Processing plants are required to have a HACCP plan for each product (9).

In Bangladesh, frozen vegetables are relatively new field of study, research and business strategy for domestic uses and export throughout the world. At present, several foods Industry in Bangladesh are processed frozen food products including vegetables, and most of them are exported outside the country. However, sometimes, frozen vegetables were rejected by consumer due to several chemical and microbial hazards. Frozen vegetables might contain a bacterium called *Mycobacterium avium* subspecies *paratuberculosis* which is resistant to extreme cold and hot temperatures. Still, some industry deals with the traditional quality testing and inspection. It is thus difficult to maintain fully product inspection because of lack of trained and skilled manpower, human error in obtaining sufficient samples and so on. HACCP is a science-based system used to ensure that food safety hazards are controlled to prevent unsafe food from reaching the consumer. HACCP system also demands financial resources for staff training, equipment and extra supplies, purchase as well as technical support (10). The purpose of this research study was to investigate the present HACCP system of the frozen vegetables industry and design a HACCP model for possible implementation in an actual situation.

2. Materials and methods

The study was conducted in a Frozen Food processing Industry at Savar, Dhaka, Bangladesh.

This study matched qualitative approach of research due to its depth and careful scrutiny. Events, employee interaction and observed behavior were also recorded. It showed the interacted details of phenomena which are difficult to convey with quantitative methods. Qualitative research is exploratory and open-minded which is applicable to this study (11).

A brief HACCP plan was designed based on the setting and processing in this plant to improve the quality of frozen product. Based on the principle and several existing generic model of HACCP, the recordkeeping forms of the model in this study were designed in the following manner. They included; prerequisite program, product description, list of product ingredients and incoming materials, process flow diagram, hazard identification, critical control points (CCPs) determination, and HACCP control chart. HACCP was studied in different sections of frozen vegetables processing such as receiving of raw materials (raw vegetables), washing, sorting and grading, rewashing, cutting and slicing, blanching, cooling, weighing and packaging, passing metal detector, individually quick frozen (IQF) (freezing), cartooning, and cold storage and dispatch. Figure 1 showed the process flow diagram for frozen vegetables.

3. Results

3.1. Prerequisite programs

All existing prerequisite programs were brought under the umbrella of HACCP. Ensure the zero defects with the final product by giving a common direction. Final product should be free from health hazard. Several programs have been used in the plant based on good manufacturing practices. Risk analyses of the different processing steps of frozen vegetables were listed in table 1 with control measures.

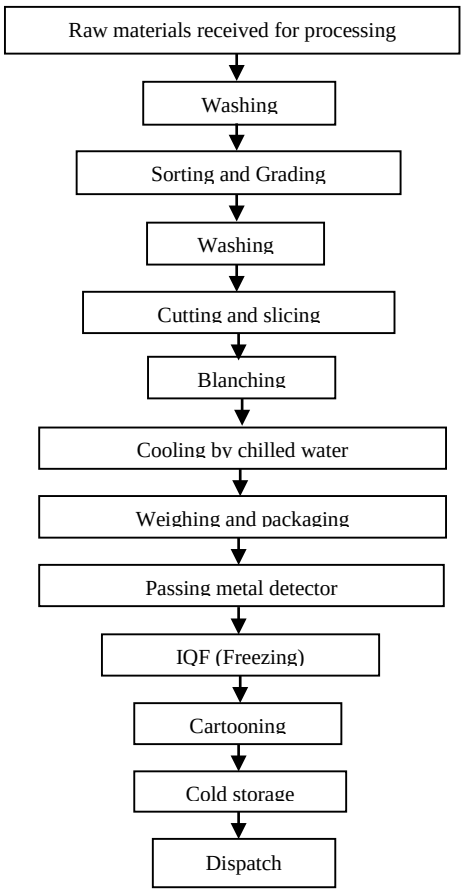

Figure 1. Frozen vegetables processing flow diagram

3.2. Design and layout of plant

The ground floor of the plant or store is not sloped or drained to prevent stagnant water and also not free of waste and debris. This floor design could expose the products to dust and sources of contamination or pest infestation. The corners and joints in all structure lead to accumulation of contaminants make it difficult to clean. Additional shortcomings were presence of cracks and openings. The surface of the floors was not properly design for drainage of waste water and other liquids.

Nonetheless, the plant has good lighting and ventilation. Large windows opening with wire mesh allow air into building. It also provides good natural lighting. Hand washing stations were at inappropriate locations, but without soap or other sanitizing materials. Toilet room was not separated from the plant building. It was in fact near the food store, handling and process areas, which was a big source of contamination. Only one quality control laboratory was available in the plant. In this laboratory, only few experiments were carried out such as inspection test of the raw materials. The tests included gelation of flour and moisture of flour, moisture of oil, and peroxide value.

The premises shall design in such a manner that permits good food hygiene practices and protect cross-contamination. The walls were water, insect, and rodent proof. Wall angles, corners and junctions of walls and floors were sealed and rounded to facilitate cleaning. The floor of the production area was established with the covered drain for liquid to drain and the netted doors were inside auto-closing. There were also floor drains 15 cm deep and directly connected to the effluent treatment plant.

3.3. Personal hygiene and safety

Employee did not follow the personal hygiene instructions. They did not use any gloves and did not cover their hair. However, employees wear the uniform only. Nonetheless, it provides a source of contamination of the products.

Table 1. Risk analysis of the processing steps

Processing steps	Potential hazard	Assessment				Control measures
		Likelihood	Consequences	Risk	Risk level	
Raw materials	Biological	1	1	1	Low	Reject high levels MRL, supply control and certification, transportation, GHP, GMP
	Physical	1	1	1	Low	
Washing	Biological	1	3	3	Low	Control by SSOP
	Chemical	1	1	1	Low	
Sorting and grading	Biological	1	1	1	Low	Control by SOP
Washing	Biological	1	1	1	Low	Control by SSOP
	Chemical	1	2	2	Low	
Cutting and slicing	Physical	1	1	1	Low	Control by SOP
Blanching	Biological	3	2	6	Medium	Control proper time and temperature, personnel training, calibration of thermometer
	Chemical	3	3	9	High	
Cooling	Biological	1	1	1	Low	Control proper time and temperature
Weighing and packaging	Biological	1	3	3	Low	Control by SOP
Passing metal detector	Physical	3	3	9	High	Personnel training and calibration
IQF (freezing)	Biological	3	2	6	Medium	Control proper time and temperature
Cartooning	Biological	1	3	1	Low	Control by SOP
Cold storage	Biological	2	3	6	Medium	Control proper temperature (−18°C minimum)
	Physical	1	3	3	Low	
Dispatch	Biological	1	1	1	Low	Control proper temperature by following the SOP
	Physical	1	1	1	Low	

SSOP: Sanitary standard operating procedure; SOP: Standard operating procedure; MRL: Maximum residue level; GHP: Good hygienic practices; GMP: Good manufacturing practice

The employees must refrain from placing fingers in mouth, nose, and ears and from eating, chewing, spitting, and smoking during handling operation. The employees must wash hand before start of work and when re-entering their work area finish their personal work such as eating and using fresh rooms.

3.4. Water supply

Good quality potable water was supplied at the desired temperature for use in processing operations and cleaning.

3.5. Equipment

All the equipment and processing zones were checked routinely to ensure a smooth running system and free from any hazards. The equipment has been operating properly and was found to be free of cracks, rust, and dents.

3.6. Storage and transportation

The raw materials storeroom did not ensure appropriate temperature and humidity. However, the final product stored room maintains proper temperature and humidity. The storage rooms were to be cleaned, temperature and humidity controlled and to be monitored by hygrometer and data logger. Daily inspection of the conditions ensured a consistent environment to prevent the hazards and produce quality products. Proper transportation equipment's were used where cleanliness, temperature and separation of food items and nonfood items were considered and monitored.

3.7. Sanitation system

The sanitation program should be maintained for a sanitary environment. Sanitation is very essential for the warehouse, distribution of safe and legal products. There were several components of a sanitation program that must be in place to meet the goal (12).

3.8. Waste management

The company has its own waste treatment plant along with proper drainage and storage system which is a combination of activated sludge method and aerobic treatment that contains equalization tank, gravity settle unit, flocculation unit, coagulation unit, tube settler, effluent discharge system, and sand bath. The physical, chemical and biological specification based on national standard of entering waste and discharging waste water was also checked regularly.

3.9. Traceability

Lot No., batch No., incoming date, production date, etc., were properly maintained for proper identification and traceability. First-in-first-out was also maintained for all raw and packaging materials.

3.10. Pest control program

The pest control program was to so good in the frozen vegetables plant to eliminate rodent, insects, and birds. However, pest management programs need more than traditional spraying techniques to eliminate pests. Modern pest management programs were designed to allow pest prevention as well as control. This was practiced in the plant every week. The decision matrix was fulfilled based on the answers given to the question from the CCP decision tree (Tables 2 and 3).

Table 2. CCP determination by decision-making tree

Steps	Q1	Q2	Q3	Q4	CCP/OPRP	Remarks/justification of decision
Raw materials	Y	N	N	Y	-	Low-risk level
Washing	Y	N	N	Y	-	Special attention to be given
Sorting and grading	Y	N	N	Y	-	Special attention to be given
Washing	Y	N	Y	Y	-	Low risk
Cutting and slicing	Y	N	Y	Y	-	Special attention to be given
Blanching	Y	Y	Y	N	CCP	Improper blanching time and temperature could retain harmful microbes and spoilage due to catalyst enzyme
Cooling	Y	N	N	Y	-	Special attention to be given
Weighing and packaging	Y	N	Y	Y	-	Special attention should be given, defective and unhygienic sealing and packaging also contaminate the product
Metal detector	Y	Y	Y	N	CCP	Fault calibration, maintenance could cause severe risks
IQF (freezing)	Y	Y	Y	N	CCP	Improper temperature and unhygienic condition in IQF could cause germination of harmful microbes
Cartooning	Y	N	N	N	-	Medium risk
Cold storage	Y	N	N	N	OPRP	Improper temperature and unhygienic condition during storage could cause germination of harmful microbes
Dispatch	Y	N	N	N	-	POA is necessary to be considered
Packaging type						
OPP film	Y	N	N	…	-	Low-risk level
BOPP film	Y	N	N	…	-	Low-risk level
HDPE/LDPE	Y	N	N	…	-	Low-risk level
Gum tape	Y	N	N	…	-	Low-risk level
Cartoon	Y	N	N	…	-	Low-risk level
Packaging materials store	Y	N	N	…	-	Low-risk level

OPP: Oriented polypropylene film; BOPP: Biaxially oriented polypropylene; HDPE/LDPE: High-density polyethylene and low-density polyethylene; POA: Point of attention; CCP: Critical control point; OPRP: One operational prerequisite program

Table 3: Critical limit validation

CCP No.	Steps		Critical limit		Validation data reference/verification
	No.	Name	Parameter	Value	
CCP-01	6	Blanching	Blanching temperature	70-80 °C	BDS 822:1984; fruits and vegetables processing (by Adams)
			Holding time	1-2 min	
			Enzyme (catalyst and peroxidase)	Nil	
CCP-02	9	Metal detector	Metal fragment detection	No detectable metal fragments (≥0.5 mm) in finished product	BDS 822:1984; fruits and vegetables processing (by Adams)
CCP-03	10	Blast freezing	Freezing temperature	−40°C	BDS 822:1984; fruits and vegetables processing (by Adams)
			Time	60-80 min	
			Product output temperature	−18 or −20°C	

CCP: Critical control point

Nonetheless, the potential control points of the hazards appeared in the process, and the so important prevention measures were indicated in table 4.

The HACCP plan was developed to include components of several HACCP principles which are critical limits, monitoring, and corrective action. For frozen vegetables product, the most essential part of the whole HACCP plan is the organization analysis and documentation of the CCPs. The column of the HACCP plan was filled in by the operator or the supervisor who is responsible for the control. The CCP steps were emphasized during production. The suitable documentation of HACCP plant will help to prevent and eliminate critical hazards during production. Therefore, safe and quality products could be produced in the plant. The CCPs were determined in the plant by answering the questions in the decision trees. This document can also be used for the improvement of a HACCP plant in the future.

4. Discussion

The raw material was received after the quality assurance personnel inspection, analysis and confirmation. Then, raw materials were stored at clean and dry place. Raw materials must be kept away from direct sunlight and off the ground. Store supervisor should follow first-in first-out schedule. Raw material receiving and storage has been critical for the final product quality to overcome the hazards to the final product.

Three CCPs were identified in the present study using process decision tree. All those CCPs were determined based on the prerequisite programs requirement in this plant which was crucial to determine the CCPs. Frozen vegetables industry should not consider any hazards after following the HACCP principles in the processing plant. These CCPs included: (i) metal detection - all types of metal should be identified and removed from vegetables by metal detector; (ii) blanching - proper temperature and time should be selected to destroy peroxidase and catalase enzymes; and (iii) blast freezing - IQF freezing should be practiced with optimum temperature and time. The finished product was stored at −18 °C. The quality assurance personnel conduct quality tests to permit product release. The product will be distributed during its shelf life. Whereas, Khaliduzzaman (13) found five CCPs in the production of chicken ball plant, or more precisely: (a) supply of raw material and packaging material; (b) proper storage temperature and time for raw meat; (c) proper temperature and time for water boiling; (d) proper inspection during packing for foreign materials; and (e) proper storage and distribution temperature and time of final product. The model was developed step-by-step based on the seven principles of HACCP system. The prerequisite program was provided to deal with all three types of hazards before the production; therefore, to simplify the HACCP plan, by answering the questions in the decision trees, the CCPs were determined and the potential control points of the hazards appeared in both raw material and the process along with the prevention measures (13). Similar procedure was performed in this study to reduce the potential hazards and created a decision tree for frozen vegetables.

Easdani et al. (14) described the HACCP plan for potato chips production based on actual conditions in the plant to reduce the spread of some diseases by unsafe products due to pathogen reported makes it important to pay attention to the potential contamination in potato chips production. Questions in decision tree and answering them as well as the CCPs were determined. Finally, the HACCP control chart was developed to include components of several HACCP principles which are critical limits, monitoring and corrective action. Two CCPs were found in the processing of potato chips. These included frying of chips and packaging of the final products.

Rosas and Reyes (15) studied the HACCP plan for processing line of frozen whole sardine (*Sardinella aurita*). Their methodology was based on the evaluation of accomplishment of the pre-requisite programs, application of the principles of HACCP and the sequence of stages settled down by the COVENIN Venezuelan standard No 3802.

Table 4. HACCP plan for CCP

P.S	Name of the process	CCP/OPRP No.	Hazard	Critical limit		Monitoring				Corrective action			Verification
				Parameters	Value	Procedure	Frequency	Responsibility	Record	Procedure	Responsibility	Record	
6	Blanching	CCP-01		Temperature and time	70-80°C, 1-2 min	As per SOP and visual inspection	Frequently	Production operator and QA person	Production Record	Reject, set and calibrate time, temperature	QAM	QA record	Calibration of blanching temperature, in-house lab report, outside test report
			Chemical	Catalyst and peroxides enzyme	Nil	By enzyme test	Once per batch	QA person	QA record				
9	Metal Detector	CCP-02	Physical	Foreign metal piece	0.5 mm of Fe, N, Fe, and SS	Proper calibration and visual check	Frequently	Maintenance, QA and production person	Maintenance record	Identify the batch and reject	QAM	QA record	Calibration certificate, in house calibration. schedule
10	Blast freezing	CCP-03		Temperature and time	−40°C, 60-80 min	As per SOP and visual inspection	Frequently	Production operator and QA person	Production record	Reject, set and calibrate time, temperature	QAM	QA record	Temperature record, standard calibration, record of thermometer, defrosting record

QAM: Quality Assurance Manager; OA: Quality assurance; SOP: Standard operating procedure; CCP: Critical control point; HACCP: Hazard analysis and critical control point; OPRP: One operational prerequisite program

Their HACCP plan was proposed with the scope, the selection of the team, the description of the product and the intended use, the flow diagram of the process, hazard analysis and identification of CCP, monitoring system, corrective actions and records. The potential hazards were identified as pathogen growth, presence of histamine and physical objects in the sardines. The control measures of PCC were referred as control of time-temperature during transportation and processing, monitoring of ice supplies and sanitary conditions in the process (15). Based on the process decision tree, four CCPs were identified for biscuits product (12). All those four CCPs were determined based on the prerequisite programs requirement in the plant. These programs were crucial to determine the CCPs. Without the programs, the researchers need to consider more hazards that are possible to the product from outside the process. These CCPs included raw material receiving and storage, mixing, packaging, and product storage.

5. Conclusion

Proper design and implementation of HACCP principles resulted in improvements in food industry, international trade, customer safety, and wholesome food products. This study designed a HACCP plan for a frozen vegetables plant to improve the safety and quality of frozen products. The model was developed step-by-step based on the seven principles of HACCP system. The reduction in number of the identified CCPs was necessary since it will lead to a decrease in overall cost and also increases the net outcome of the company.

Conflict of Interests

Authors have no conflict of interest.

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