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Review Article

Introduction to Hazard Analysis and Critical Control Points (HACCP)

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Abstract

HACCP is a recognized worldwide as the most effective managing system in which food safety is addressed through the analysis and control of biological (microbes & toxins), chemical, and physical hazards in food manufacturing, storage, distribution, and consumers consumption. Although biological contamination of food can lead to health hazard to consumers or even death in addition to financial losses, also chemical and physical contamination of foods are also health hazard to consumers and must be controlled as in the case of food biological contamination.

Implementation of HACCP system in a food organization means control over stages of food manufacturing from raw materials, processing, storage, distribution, to consumers handling in order to ensure food safety for consumption.

This proactive system of HACCP as a mean of controlling all aspects of food safety, has made this system desirable to food manufacturing, retails, food service and to worldwide food regulation agencies. HACCP systems are currently implemented internationally in all food operations to build food safety for agricultural production, food manufacturing, retail, and food service.

Keywords: *HACCP; Hazard Analysis; Critical Control Point; Good Manufacturing Practice (GMP); Sanitation Standard Operation Procedures (SSOPs); Critical Control Point (CCP); CCP Decision Tree; Food Process Flow Charts; Food Safety; Microbial Contamination; Toxins; Heavy Metals; Foreign Objects in Foods*

Introduction

HACCP was developed in the early 1960 when the National Aerospace Agency (NASA) asked Pillsbury a United States food company to produce food that could be used under zero gravity [1]. The problem of unknown behavior of food product under zero gravity was solved quickly, but Pillsbury company recognized that the existing destructive quality control techniques for food safety are not reliable for such special food products to assure complete eliminating potential contamination in such special foods from biological, chemical or physical hazards that could cause illness or injury to astronauts in space flight. The cooperation of Pillsbury food scientists with researchers from Natick Research Laboratories, and National Aerospace Agency (NASA) resulted in developing a non-destructive quality assurance system for food safety relied on preventive action by control and record keeping over complete food process steps from raw materials to the end product distribution [2]. This developed non-destructive quality assurance system for space program food safety project was the initiation for the current HACCP plan system.

The initial developed HACCP system was presented in the year 1971 by Pillsbury food company at the Conference on Food Protection (CFP) sponsored by Food and Drug Administration (FDA). This presented HACCP system consists of three HACCP plan principles [3]. These three HACCP principles are:

- Identification and assessment of hazards associated with food from farm to fork.
- Determination of the Critical Control Points (CCPs) to control any identified health hazard in food process.
- Establishment of a system or systems to monitor the critical control points.

The outcome from this 1971 conference is a training program managed by Pillsbury Food company scientist to FDA inspectors for the inspection of canned foods. The title for this training program was "Food Safety through the Hazard Analysis and Critical Control Point System" and this was the first time HACCP plan was used as subject for education. Toward the end of 1980s training for developing and implementing HACCP plan for food safety management systems are offered by several food safety companies. These training programs, and, scientific journals publications on HACCP concept for food safety were instrumental in making HACCP the predominant non-destructive food safety system. Finally, In the year 1998, it became a requirement for all food businesses to obtain a food safety certification under HACCP guidelines with the exception of smaller food business that do not have the financial capacity to implement HACCP plan [4]. In the year 1993, The National Advisory Committee of Microbiological Criteria for Foods (NACMCF) revised HACCP guidance standard, adding five preliminary steps to the developed seven principles of HACCP system [5]. This revised HACCP guidance provided significant input to the hazard analysis process. Currently, HACCP is an internationally recognized system for reducing the risk of safety hazards in foods for both domestic and international food production [6].

Current seven HACCP principles and application guidelines

HACCP is a preventative food safety system in wish every step-in food manufacturing process, plus food products storage, and distribution is scientifically analyzed and controlled for biological, chemical, and physical hazards. The current seven basic HACCP principles (Figure 1) that are developed and implemented internationally are:

- Identify hazard analysis accessing les risk.
- Identifying Critical Control Points (CCPs).
- Establishing Critical Limits (CL).
- Implementing continuous Monitoring.
- Implementing Corrective Measures.
- Verification and Validation.
- Documentations and Records keeping.

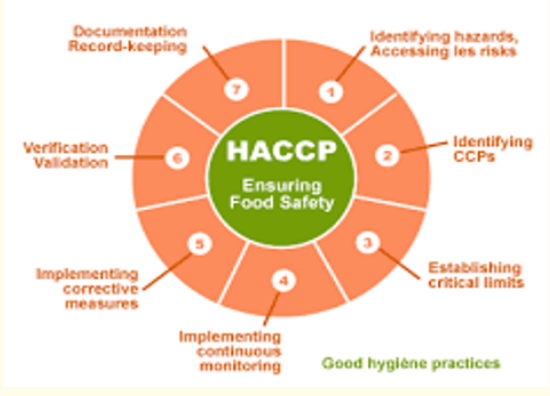

Figure 1: *The Seven Principles of HACCP plan to ensure food safety.*

Principle (1): Identify hazard analysis accessing les risk

HACCP team listing steps in the food process, identify significant hazard or hazards that might occur in each step-in food process, and develop method or methods that must be used in their HACCP plan to prevent, eliminate, or control these identified hazards in food production process.

Principle (2): Identifying critical control points (CCPs)

Identify a control procedure that can be applied in each food process step to eliminate food safety hazard or reduce the hazard to acceptable limit in the end product. Identify CCPs that might be required in food process steps are by using a CCP decision tree method (Figure 2). In some cases, one CCP may control more than one step in food process, or control more than one food safety hazard. In other cases, more than one CCP is needed to control a single hazard in a single food process step. Having said that, the number of CCPs for food process depend on the nature of food and the type of the control needed to assure the food safety of the end product.

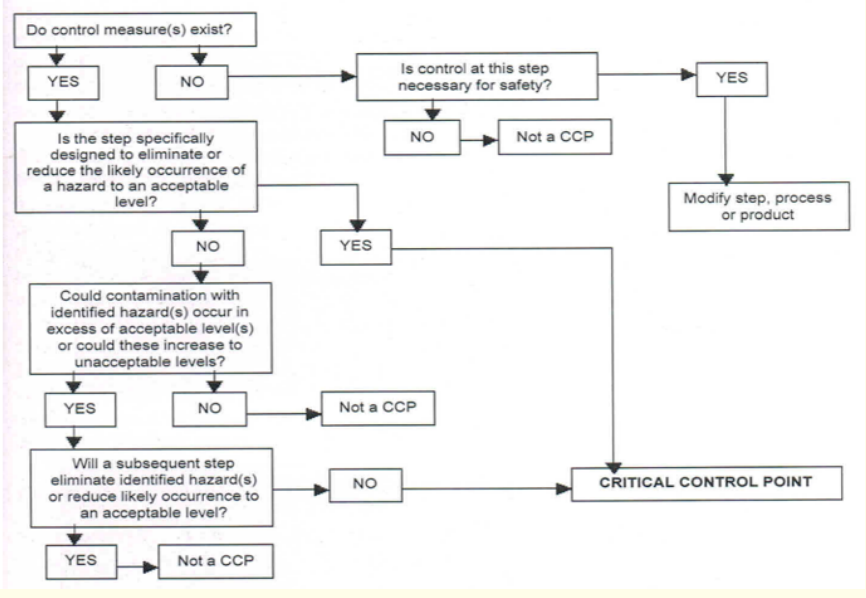

Figure 2: *Example of CCPs decision tree for one food process step. The diagram shows hazard concern questions for one step in the process with answers yes or no that assist in making a CCP decision.*

Principle (3): Establishing critical limits (CL)

Critical Limit (CL) is the limit to which biological, chemical, or physical hazard that must be controlled to prevent, eliminate or reduce the hazard into an acceptable limit at the identified CCPs in a in food process steps. Critical limit measurement methods can be time, temperature, moisture, pH, water activity (Aw) or any other methods that are acceptable by regulatory standards.

Principle (4): Implementing continuous monitoring

Monitoring food process steps by the measurement of the critical limit (CL) at each designated critical control point (CCP) must be described including how, when, frequently the measurement taken and who is responsible for taking these measurements during production process.

Principle (5): Implementing corrective measures

Corrective actions are the procedure that must be taken when monitoring indicate that there is a divination from the established critical limit (CL) in a critical control point (CCP). Taking appropriate corrective action in the event of a divination at CCP is essential for producing safe food. Corrective measures are usually including identification of the problem and steps taken to assure that such problem will never occur again.

Principle (6): Verification and validation

The validity of a HACCP system is to determine that the process is operating according to the plan. Verification involves taking suffusion steps such as auditing of CCPs, calibration of instruments used for CCPs measurements, in process food product testing, record

review, and prior food shipment review to ensure that the validity of the HACCP system is operating according to the plan. It is important that the individual doing verification have appropriate technical expertise to perform this function and sometimes it is prefer to be carried by third party or by regulatory agencies.

Principle (7): Documentations and records keeping

Recording the information that can be used to prove the safety of food produced for consumption is the key component of HACCP plan. Documentation should include information on the HACCP team, product description, flow diagrams, hazard analysis, CCPs identification, critical limits, monitoring systems, record keeping procedures, and verification procedures.

Finally, it important to highlight that the application of HACCP plan in food manufacturing is not suffusion for food safety if standalone in food operation [5]. The HACCP plan must be built with other food safety programs of Good Manufacturing Practice (GMP), and Sanitation Standard Operation Procedures (SSOPs).

Good manufacturing practice (GMP)

GMP is a set of operational requirements address both food safety and quality issues that are not critical for the reduction of food safety hazards [7]. Also, it is guidelines that are essential foundation for the development of successful HACCP plans. These guidelines provide guidance for food manufacturing, sanitation protocols, testing methods, and quality assurance in order to assist in reducing the risk of foodborne illness and to secure the production and distribution of safe foods with acceptable quality for human consumption. Many countries follow GMP procedures and have created their own GMP guidelines which corresponded to their own legislations [8].

In summary, GMP practices follow the following standard principles:

- Maintain a clean and hygienic manufacturing areas.
- Control environmental conditions to prevent cross contamination between food products.
- Develop manufacturing process that are clearly defined and controlled.
- Validate all critical control points (CCPs) to ensure the end product safety and consistency.
- Control manufacturing process, and evaluate/validate any process change.
- Write production instructions (production sheet) clearly and record each process step data during manufacturing (good documentation practice).
- Minimize the risk of contamination during distribution and shipping of food products.
- Establish a system for quick recall in the case of any unsafe food product distributed for sale.

Sanitation standard operation procedures (SSOPs)

SSOPs must be followed to ensure adequate cleaning of both product contact and non-product contact surfaces. SSOPs cover raw materials, equipment's, personnel, personal hygiene, and food products handler practice [9]. Food HACCP plans require SSOPs to be documented and periodically reviewed. This periodically review of SSOPs must be done by professional and responsible management.

In summary standard SSOPs guidelines are:

- Food raw materials must be obtained from approved sources and with acceptable standard specifications.
- Hazardous or sensitive raw materials for contamination must be stored separately from other raw materials at proper temperature to avoid cross contamination.
- Gloves and hair restraints must available for food operators and handlers.
- Food operators and handlers must have permit available for inspection at any time.
- Food operators or handlers suspected of being ill should not allow to work in food contact facilities.
- Proper hand washing facilities are available in food production sites and must be used.
- Selection of proper sanitizer and developing effective sanitation protocol for operators to follow.
- Equipment's, utensils, and work surfaces must be cleaned and sanitized periodically.
- Conduct verification of sanitation effectiveness periodically.

Steps necessary for developing a solid HACCP plan

Developing a solid HACCP plan for food process required upfront five tasks before the implementation of the known seven HACCP principles. This bringing total tasks for developing solid HACCP plan into 12 steps.

These necessary upfront six steps are:

1. **Assemble the HACCP team:** Select individuals have specific knowledge and expertise about product and process
2. **Describe the product:** Provides the selected team with general description of the product, ingredients, process methods, and distribution method (refrigerated, frozen, or ambient temperature).
3. **Identify the intended use and consumers:** Describe normal expected use of the end product and target consumers (general public or particular segment of population).
4. **Construct flow diagram to describe the process:** The flow diagram can be block type design and should be clear and simple outline of all food process steps.
5. **Confirmation of designed flow diagram:** HACCP team should perform an on-set review of flow diagram and made any modification that are needed.
6. **HACCP plan**: After these five preliminary tasks are successfully completed, the seven principles of HACCP system are implemented.

Discussion

Foodborne illnesses are usually infectious or toxic in nature and caused by microbial pathogens (bacteria, mold, viruses, and parasites), secreted microbial toxins, chemicals substances, or heavy metals entering the body through contaminated food or water. Microbial pathogens or its toxins in contaminated food can cause severe diarrhea or debilitating microbial infections including meningitis [10]. Chemicals [11] and heavy metals [12] in contaminated food can lead to poisoning and long-term diseases such as cancer. It is estimated that about 600 million food consumers worldwide fall ill after eating contaminated food [13]. This resulted in about 420,000 death per year. It is important to highlight that children under 5 years of age are more susceptible to foodborne illness and death than adults.

Hazard Analysis and Critical Control Points (HACCP) was originated in the early 1960's when the U.S. Pillsbury Food Company developed for National Aeronautics and Space Administration (NASA) HACCP plan system for their space program to produce the safest food possible to be consumed by space travelers (astronauts'). The definition of HACCP is a management system in which food safety is addressed through analysis and control of biological, chemical, heavy metals, and physical hazards in raw materials, or interred during manufacturing process, distribution, retails and foods consumption. Physical hazards in foods are foreign objects such as broken glass, or metal fragments that can cause harm to the consumer when food contaminated with these foreign objects is consumed.

The seven principles of HACCP system (Identify hazard analysis accessing les risk, Identifying Critical control points, establishing critical limits, implementing continuous monitoring, Implementing Corrective measures, Verification and Validation, Documentations and records keeping) are currently implemented successfully worldwide in food industries, distribution facilities, retail operations and in food service stores.

Good manufacture practice (GMP) provide guidance for manufacturing, sanitation, testing methods and quality assurance for a food operation in order to assist in reducing the risk of foodborne illness and to secure the production and distribution of safe foods for human consumption. Many countries follow GMP procedures and have created their own GMP guidelines which corresponded to their own legislations. These developed GMP guidelines are the essential foundation for the development of successful HACCP plans.

Currently implementing HACCP plan in small food business specially in developed nations are limited due the cost and it is the subject of extensive discussions by World Health Organization (WHO) and other food organizations [14].

Benefits from implementing effective HACCP pan system includes enhance food safety, increase market access, improve operational activities, reduce costly recall, wastage, and increase consumer confidence.

Consumers are also responsible for their own food safety by following proper storage, cooking of purchased food [15]. In addition, there are regulatory steps that must be taken by consumers to prevent the contamination and growth of foodborne pathogens in purchased foods to ensure their own food safety. Steps that are must be taken by consumers at home are HACCP like practice.

These HACCP like practice are:

- Wash hand and sanitize food-contact surface often.
- Keep raw meat, poultry, eggs, and seafood's away from ready to-eat foods.
- Thaw food in the refrigerator or microwave, not on kitchen counter (the danger zone for microbial growth is at the range of 40°F to145°F).
- Use food thermometer to cook food at 165°F or higher.
- Refrigerate foods properly (cold temperatures slow the growth of foodborne pathogens).

Conclusion

Management awareness and commitment to food safety is necessary for the implementation of an effective HACCP plan (Figure 3). Implemented HACCP system for a food facility should be reviewed on continuous basis as scheduled, and when appropriate amendments made is necessary. It is the responsibility of food processors, retails, and distributors to ensure food produced is safe for human consumption. Also, consumers are responsible for their own food safety by following proper protocols at home to eliminate the contamination of purchase foods.

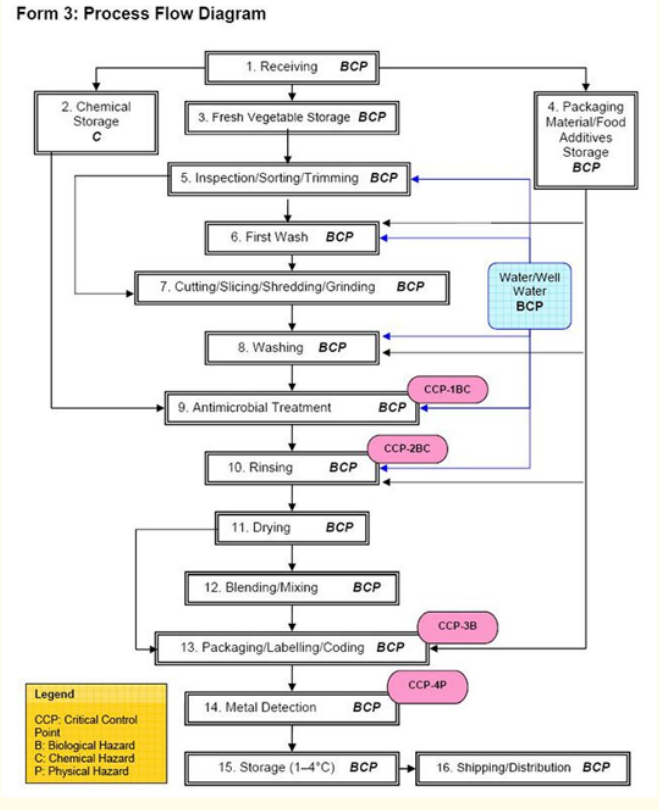

Figure 3: *Example for HACCP plan system for ready-to-eat fresh-cut vegetables. This diagram shows four Critical Control Points (CCPs) in this manufacturing operation process (Saved by Daniel Bagnall).*

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