Original Article

The implementation of a Hazard Analysis and Critical Control Point management system in a peanut butter ice cream plant

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A B S T R A C T

To ensure the safety of the peanut butter ice cream manufacture, a Hazard Analysis and Critical Control Point (HACCP) plan has been designed and applied to the production process. Potential biological, chemical, and physical hazards in each manufacturing procedure were identified. Critical control points for the peanut butter ice cream were then determined as the pasteurization and freezing process. The establishment of a monitoring system, corrective actions, verification procedures, and documentation and record keeping were followed to complete the HACCP program. The results of this study indicate that implementing the HACCP system in food industries can effectively enhance food safety and quality while improving the production management.

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1. Introduction

Peanut butter ice cream is a food that is made from a mix of dairy products and peanut butter with the addition of sugar, stabilizers, and emulsifiers, and then processed to produce the frozen dessert. Ice cream products are very popular in Taiwan, accounting for a market share of approximately 1400 million New Taiwan Dollars, which is about 17,000 tons of ice cream according to the economic statistics of 2013 [1]. Likewise, peanut products are well liked and widely consumed by Taiwanese people of all ages, making peanut butter ice cream a favorable choice among the many ice cream flavors. However, peanut butter is easily subjected to aflatoxin...
Hazard Analysis and Critical Control Point (HACCP) is a systematic and scientific approach applied in the food industry for the identification and control of specific hazards. The HACCP program covers the input of the materials, production process, final products, facilities, and personnel at the critical control points (CCPs). It consists of two major components: hazard analysis and the control measure of the critical limit. Hazard analysis is the process of identifying and evaluating the potential hazard factors that may negatively affect food safety, while the control measure is to prevent or eliminate the hazards to a minimized and acceptable level [4]. The HACCP system has been widely adopted by countries all over the world as well as international organizations, including the World Health Organization and the Food and Agriculture Organization, and is currently a world-recognized preventive management system to maintain food hygiene.

In Taiwan, HACCP is defined as the Food Safety Control System in the regulations of the Department of Health (now upgraded to the Ministry of Health and Welfare) [5]. It is an extended food safety supervision that is based on the present standard operating procedures, Good Manufacturing Practice, and Good Hygiene Practice [6]. Although the HACCP system has been proven to be effective in controlling and preventing food hazards, it is still a voluntary procedure for most food industries in Taiwan. To expand the application of HACCP in Taiwanese food industry, the government has been promoting this control system stage by stage, from encouraging spontaneous employment to mandatory implementation in certain food sectors [7]. With the occurrence of many food safety issues in recent years, HACCP could be a possible alternative to avoid these problems and ensure food safety.

Various studies have been conducted to assess the ice cream production after the application of a HACCP program, and this has proven to have positive effects on both the microbiological quality and the overall quality of the final product [8–10]. In this case study, information on the peanut butter ice cream production was collected and evaluated, and a HACCP plan (Table 1) was implemented to this production process. The quality and safety of the peanut butter ice cream product can be effectively guaranteed through this HACCP implementation (Table 2).

2. Materials and methods

2.1. Study object

The entire production process of peanut butter ice cream was evaluated including the plant layout, facility structure, technical standards, cleansing method, staff assignment, safety control, storage conditions, and distribution (Fig. 1). The potential biological, chemical, and physical hazards that may exist in the peanut butter ice cream production process were identified and CCPs were selected.

2.2. Methods

Based on the 2008 revised form of the Food Safety Control System of the Department of Health, Executive Yuan, and the HACCP and guidelines for its application of the United Nations Codex Alimentarius Commission, the overall technical process of peanut butter ice cream production was drawn and a hazard analysis was performed. CCPs were subsequently identified and selected. Critical limits, as well as a monitoring system, corrective actions, verifications, and documentation and records were then established according to government regulations and industry standards. The decision tree method, a visual and easy-to-understand analysis, was applied to determine the CCPs.

3. Results and discussion

The flow diagram of the peanut butter ice cream production is summarized in Fig. 2, including the receiving of raw material, weighing and blending, pasteurization, homogenization, cooling and ageing, freezing (followed by peanut butter addition), packaging, hardening, and storage and distribution.

3.1. Hazard analysis and prevention measures establishment

Hazard analysis was conducted at every technical procedure starting from the receipt of materials to the delivery of the final product. All biological, chemical, and physical agents with the potential to cause adverse health effects were identified and evaluated. The significance of each hazard factor will be determined by the severity of the risk.

3.1.1. Receiving of raw material

As a major ingredient, milk and milk products provide ice cream with milk fat and nonfat solids, which contributes to its unique mouth feel and rich flavor. The fresh cream from milk offers a fine combination of lipids that produces the smooth texture and the melting properties of the ice cream [11]. All dairy products must meet the requirement of the Ministry of Health and Welfare: Sanitation Standard for Milk and Milk Products, and each one should also conform to the Chinese National Standards according to its distinctive type. Egg yolk normally serves as an emulsifier in ice cream products. It is a source of lecithin, which provides emulsifying properties to develop the creamy characteristic desired in ice cream [12]. As regulated by the Taiwanese government, egg products are required to meet the conditions set by the Ministry of Health and Welfare: Sanitation Standard for Eggs and Egg Products. In addition, suppliers are strongly encouraged to submit self-inspection reports to ensure food safety, especially in regards to Salmonella contamination. Being the main flavoring of the peanut butter ice cream, peanut butter is subjected to the law of the Ministry of Health and Welfare: Sanitation Standard for the Tolerance of Mycotoxins in Foods to regulate the amount of aflatoxin (no more than 15 ppb) in peanut products.
| Technical process         | Hazard factors                                                                 | Significant or not | Criteria for judgment                                                                 | Prevention & control measures                                                                                                                                 |
|--------------------------|---------------------------------------------------------------------------------|--------------------|---------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Receiving of raw material | B Escherichia coli, Listeria spp., Salmonella spp., Staphylococcus aureus, Aspergillus spp. | No                 | Inappropriate processing, storage, & distribution of the supplier may cause microbial contamination | Confirm certified business license & demand product inspection reports from the suppliers; evaluate suppliers periodically & select the optimal ones; sample every batch of material; self-evaluation documents should also be provided to ensure material quality |
|                          | C Antibiotics, aflatoxin, nitrate, nitrite                                       | Yes                | Inappropriate production may cause harmful chemicals to pollute the material, such as remaining antibiotics in dairy products; improper treatment of peanut may produce aflatoxin-contaminated products |                                                                                                                                                                |
|                          | P Stone, metal                                                                  | No                 | Brought in by suppliers during the production chain                                      |                                                                                                                                                                |
| Weighing & blending      | B Microbial contamination & growth during processing                              | No                 | Inappropriate processing temperature & sterilization of mixing vat may result in pollution of microorganisms | Perform feeding quickly at a low temperature, mixing vat should be properly cleaned & sterilized in advance                                                                                                                                 |
|                          | C Excessive food additives                                                      | No                 | Excessive consumption of food additives may have adverse health effects                  | Product formula should strictly follow the requirement of food regulations; weighing facilities should be frequently corrected                                                                                           |
|                          | P Metal residue                                                                 | No                 | Metal may left at weighing & mixing facility                                              | Manufacturing area & facilities must be kept clean; conduct sifting & metal detection in the following procedures                                                                                                       |
| Pasteurization           | B Pathogen remains after pasteurization                                          | Yes                | Inadequate pasteurization                                                               | Strictly control pasteurization time & temperature                                                                                                           |
|                          | C None                                                                          | No                 | N/A                                                                                     | N/A                                                                                                                                                    |
|                          | P None                                                                          | No                 | N/A                                                                                     | N/A                                                                                                                                                    |
| Aging                    | B Microbial contamination & growth                                              | No                 | Improper aging condition & sealing of facility may result in microbial contamination     | Strictly control ageing condition; keep relevant facilities clean & sealed                                                                             |
|                          | C None                                                                          | No                 | N/A                                                                                     | N/A                                                                                                                                                    |
|                          | P None                                                                          | No                 | N/A                                                                                     | N/A                                                                                                                                                    |
| Freezing (plus peanut     | B Microbial contamination & growth                                              | Yes                | Unhygienic container & operation area                                                    | Keep the inlet & its surrounding air clean; filter screen must be sterilized in advance; peanut butter addition should be processed quickly at low temperature |
| butter addition)         | C None                                                                          | No                 | N/A                                                                                     | N/A                                                                                                                                                    |
|                          | P None                                                                          | No                 | N/A                                                                                     | N/A                                                                                                                                                    |

B = biological; C = chemical; CCP = critical control point; N/A = not available; P = physical.
Overall, the peanut butter ice cream should contain over 30% of total solids, 8% of milk fat, and 2.6% of milk protein as stated in the CNS [13]. Due to its nutrient contents and neutral pH value, the microbiological quality of ice cream may be low, as it is a good growth medium for microbes [3]. Numerous incidences of pathogen-contaminated ice creams have been reported, including Listeria spp., Salmonella species, Staphylococcus aureus, Bacillus cereus, and Yersinia enterocolitica [14–16]. Therefore, quality inspection reports should be requested from material suppliers, and every batch purchased should be sufficiently sampled and evaluated.

3.1.2. Blending of material

After weighing the selected ingredients based on the peanut butter ice cream formula, the materials are then blended together to produce the ice cream mix. Liquid milk is first added to the mixing vat, dry ingredients including sugar and other additives then follow to undergo a rapid blending for the powders to be fully incorporated. The feeding process must be operated under a sanitary environment with the mixing vat cleaned and sterilized in advance to ensure microbial safety.

The food additives in the ice cream mix consists of stabilizers and emulsifiers. Stabilizers are responsible for adding viscosity to the ice cream. This function as a control of ice crystal formation by reducing the movement of free water, thus preventing the ice cream from obtaining a coarse texture. Emulsifiers aid in developing the appropriate fat structure and air distribution. Each emulsifier contains a hydrophobic and hydrophilic portion, which allows the fat to be evenly distributed in the ice cream and produce a smooth product [11]. According to the Ministry of Health and Welfare, additives must meet the requirements set by the Standards for Specification, Scope, Application and Limitation of Food Additives.

3.1.3. Pasteurization

Pasteurization is one of the key biological control points in the ice cream manufacture designed to destroy all pathogenic microorganisms. The appropriate time and temperature combination is required as excessive pasteurization may demote the product flavor and quality, while insufficient heating is inept at eliminating the pathogens [12]. This heat treatment must be severe enough for the final product to meet the CNS regulations, where the viable bacterial count in every mL of melted water should be < 30,000, and the result negative for the coliform bacterial test [13].

3.1.4. Homogenization

Homogenization of the mix breaks down and reduces the size of fat globules to form a stable and uniform suspension of fat emulsion. By helping to promote the fat structure, the final ice cream product can gain a smoother texture, richer palatability, and better air stability and melting resistance [13]. This process should be conducted under strictly supervised temperature and pressure conditions to ensure the desired efficiency.

3.1.5. Aging

The objective of aging is to improve the body and the texture of the ice cream by providing time for fat crystallization and protein and stabilizer hydration. Following homogenization, the

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**Table 2** HACCP plan for peanut butter ice cream production.

| Object | Critical limits | Significant hazards | Verification | Corrective measures | Records | Monitoring | Frequency | Object Method | Critical Control Point | Significance |
|--------|----------------|---------------------|--------------|---------------------|---------|------------|-----------|--------------|----------------------|--------------|
| Pasteurization (B) | 70–75°C for 15 minutes | Living pathogens remains | Automatic temperature controller | Apply portable thermometer/timer to check; regular check up; contaminated product can be disposed | Temperature; time | Operator | Every vat | Automatic temperature controller | Pasteurization (B) | Biological hazards |
| Freezing (plus peanut butter addition) (B) | -40°C for 15 minutes | Pathogen contamination & growth | Cell culture | Every batch | Operator: hygiene & quality management personnel; Cell culture | Every batch | Operator: hygiene & quality management personnel; peanut butter addition | Cell culture | Freezing (plus peanut butter addition) (B) | Biological hazards |
| HACCP = Hazard Analysis and Critical Control Point; B = biological hazards. | | | | | | | | | | |
Ice cream mix must be immediately cooled to approximately 0–4°C and is held at this temperature for 4–24 hours to complete the aging process. In order to prevent microorganisms and other undesirable contaminants, the aging facilities must be carefully fastened and sealed during this procedure [17].

### 3.1.6. Freezing

Following the aging procedure, the ice cream mix enters a dynamic freezing process that involves freezing of the mix and air incorporation. Liquid flavors and colors may be added prior to this step to blend with the aged mix. In the freezing
chamber, the mix is subjected to freezing under a continuously agitated environment in order to freeze a portion of water, and whip air into the frozen mix. As a result, the incorporated air will appear as tiny air bubbles in ice cream, which provides the smooth texture, characteristic lightness, and desired overrun in the final product [11,12].

The ice cream mix leaves the freezer with about 50% of its water frozen. Peanut butter is then added to the semi-frozen slurry and evenly mixed and distributed. This addition of peanut butter flavoring should be processed quickly and carefully to prevent microbial contamination. Under the provisions of the Ice Food Factory Good Manufacturing Practice, the freezing procedure should take place at an isolated and clean operation area to avoid bringing in pathogens from the air. The air incorporated into the ice cream mix must be sanitary, hence clean processing facilities and a hygienic environment is mandatory. Additionally, a special unit for preventing dust and insect entry should be installed to ensure personal hygiene for personnel upon entering the working area.

3.1.7. Hardening
After the peanut butter has been added, the ice cream is packaged and undergoes a certain period of low temperature freezing. This step allows most of the remaining water to be frozen and the final ice cream shape to be fixed. Hardening must be performed shortly following the freezing process to promote quick freezing of the water and create small ice crystals. Any delays may result in a temperature rise that causes large ice crystals to occur, limiting the shelf life of the ice cream product. Generally speaking, the hardening process is conducted at −25°C—−18°C for 12–24 hours [12].

3.2. Establishing CCP and critical limit
The HACCP system is implemented in this study as a preventive food safety approach to control potential hazards of the peanut butter ice cream production plants in Taiwan. Based on our hazard analysis, peanut butter ice cream manufacture contains two CCPs, which are mainly referred to improper handling and hygiene during the production. In addition, the lack of correct food hygiene knowledge among factory workers can also be accounted for the proposed CCPs. Critical limits were identified and validated for each corresponding control point to assess the acceptability of the product.

3.2.1. CCP1: Pasteurization
Pasteurization is the first CCP selected in this study. Inadequate pasteurization will not be able to sufficiently destroy the pathogens, whereas a long treatment process or a high temperature pasteurization may cause negative effects to the product quality and flavor. Therefore, in order to kill most pathogenic bacteria, the pasteurization process should be held at 80–85°C for a period of 15 minutes [17].

3.2.2. CCP2: Freezing and peanut butter addition
The second CCP is the procedure of freezing and the addition of peanut butter. This step involves the incorporation of air into the ice cream mix, and is subjected to potential pathogens from the air. Thus, a clean operation area where factory environment, processing equipment, and personal hygiene are strictly controlled is strongly suggested for the freezing step to take place. Facilities and storage containers will need standard cleaning and sanitizing to ensure the hygiene of the incorporated air [17].

3.3. Establishing a monitoring system
To assure that the CCPs are continuously controlled at an acceptable level, a monitoring system is established for scheduled measurements and observations. The monitoring procedure evaluates on the following factors: object, method, frequency, and personnel.

3.4. Establishing corrective actions, verification procedures, and documentation and record keeping
To ensure the safety of food, process adjustments should be made when monitoring results indicate a deviation at an established CCP. Upon losing control of a CCP, specific corrective actions will be applied to bring the CCP back in check. Product disposition procedures will also be enforced on the affected products from the occurred deviation. Following corrective measures, verification procedures including random sampling and analysis is also carried out to determine whether the HACCP plan is working correctly and effectively. Moreover, the implementation of a complete HACCP system requires efficient and accurate record keeping. Documentation including hazard analysis and CCP determination, and record keeping including verifications and modifications should all be well documented. These measures will assist in
verifying that the HACCP controls are in place and properly maintained [4].

4. Conclusion

Application of the HACCP system provides the food industry with an effective measure to enhance food safety and improve management. The hazards of peanut butter ice cream production can mainly be referred to the inappropriate processing conditions and unsanitary environment and facilities. Results of this case study showed the positive effects that the implementation of a HACCP program had on both the microbiological quality of the ice cream product, and the overall quality and hygiene of the manufacturing process. Currently, HACCP has been applied for most of the major ice cream brands, yet implementation in small and medium-sized manufacturers is still difficult. Therefore, this food safety control system requires more of the government's support for its wider application and employment.

Conflicts of interest

All contributing authors declare no conflicts of interest.

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