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Research Article

Validating a HACCP System for the Production of Vegetable *Shito*

Nina Bernice Ackah, Elvis Alfred Baidoo, and Alexander Henry Kwadwo Appiah

CSIR-Food Research Institute (FRI), Accra, Ghana

Correspondence should be addressed to Nina Bernice Ackah; fromnina2u@gmail.com

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Vegetable *shito* is a novel pepper sauce product developed to cater for the needs of vegetarians. Due to its increasing popularity, it is prudent to assure its safety through the implementation of a quality management system for its production. This work was aimed at developing and validating a HACCP system for the production of vegetable *shito*. The HACCP system was successfully developed and validated to ensure that critical limits established for the critical control points were adequate to eliminate identified hazards. Validation was done through microbial challenge testing, and results obtained indicated that the HACCP plan developed will be effective in controlling and eliminating microbial hazards related to the vegetable *shito*. With such a quality management system in place, vegetable *shito* producers would be able to produce *shito* products which are safe and have a stable shelf life.

1. Introduction

Convenience foods are becoming increasingly popular among food processors and consumers alike due to current changes in lifestyle. As food processors seek to market foods that satisfy the convenience requirements of consumers, it is imperative that the safety and shelf life of those foods are also considered to prevent food-borne illnesses as well as economic losses due to food spoilage. *Shito* is one of such convenience foods and is very popular among the Ghanaian populace. It is also exported for more economic gains. It is a sauce which accompanies several Ghanaian dishes like *kenkey* and *waakye*. Vegetable *shito* is a novel product which has been developed to meet the dietary requirements of vegetarians. It is a product which is gaining popularity among vegetarian and nonvegetarians as well as export markets. In order to meet export requirements on quality, mandatory food safety and quality assurance standards need to be implemented. Hazard Analysis and Critical Control Points (HACCP) is one of these guidelines which are being adopted globally to ensure that all foods offered for sale are safe. In the 30 years since its conception, the HACCP system has grown to become the universally recognized and accepted method for food safety assurance. The major determinant for the utilization of HACCP as a food safety management tool has been the growing global concerns on food safety by various stakeholders like consumers, food processors, governments, and public health officials. However, due to lack of technical expertise and adequate scientific information, some companies are unable to develop and implement HACCP [1–3] especially in the developing world [4]. Taylor [5] has asserted that some of the barriers to HACCP implementation by SMEs include availability of appropriate training in HACCP methodology, access to technical expertise, and the general resource problems of time and money. It has been reported by Panisselo and Quantick [3] that difficulties in validation and verification of HACCP plans are potential barriers for the implementation of HACCP plans. However, economic benefits from international trading have been promoting food quality assurance programs in domestic manufacturing companies [6]. Because producers of vegetable *shito* are currently targeting international markets, they need to have a validated HACCP-based quality management system in place to guarantee the safety of the product. Validation is very important to check whether the HACCP-based quality management system will make the products safe when put in practice. More specifically, validation is to ensure that the control measures put in place are effective to eliminate, reduce, or prevent any potential hazards in the food product. Scientific and technical information can be available either through personal communication with scientists or assessing scientific literature and publications [7]. This work was therefore aimed supporting vegetable *shito* processors through the development and validation of a HACCP-based quality assurance system for the production of vegetable *shito*. It is anticipated that this HACCP system will be modified to suit each *shito* producing companies' peculiar characteristics.

2. Methodology

In order to establish a HACCP-based quality assurance program for the production of vegetable *shito*, five different *shito* producing companies located in Accra or Tema in the Greater Accra Region of Ghana were randomly visited. Information related to the production processes was collected from these companies. However, only one company was chosen for this HACCP study because it exports some of its products. Moreover, the HACCP process is company specific, production process specific, and product specific, implying that a generic HACCP system cannot be developed for two different companies who produce the same products. The selected *shito* producing company is a privately owned food processing company located at Tema and has been in operation since 1993. It targets the local open market as well as export with USA as the main export destination for its products. The number of employees is twelve, putting it in the medium scale category of companies [8]. The company has a quality assurance department but no quality manager and therefore the chief operating officer is in charge of quality matters at the company. The company uses prerequisite programs/good manufacturing practices as its main quality guidelines during processing to meet customer and stakeholder requirements. It has well-documented procedures and documents covering the fourteen pillars of PRPs.

2.1. HACCP Development. The HACCP process recommended by Luning and Marcelis [9] was used for this work.

2.1.1. Obtaining Management Commitment. Management and owners of the *shito* producing company provided evidence that they were actually committed to the implementation of the HACCP system in all aspects, from the purchasing of the raw materials through the production process to the final dispatch of the end-product. Management commitment is crucial for the successful implementation of any quality assurance program [9] and therefore, management of the *shito* producing company indicated its readiness to commit to the implementation of the HACCP-based quality assurance system. Management demonstrated their commitment to the use of high quality raw materials and ensuring good manufacturing practices at the production site. In addition, Management exhibited its readiness for keeping and maintaining a standard production building with respect to facilities and resources available to workers at the plant. Management also invested in training sessions for personnel at the production site to upgrade their knowledge, skills, and expertise levels regarding HACCP and GMPs. Management expressed its commitment to ensure that the HACCP system is reviewed twice a year and all documents pertaining to the HACCP system is kept up-to-date and under specific conditions. Management also committed to organise quality review meetings at least twice a year to assess the current status of the HACCP system and possible revision of the HACCP plan where necessary.

2.1.2. Formation of HACCP Team. The HACCP team was made up of 2 research scientists from the Council for Scientific and Industrial Research–Food Research Institute, the Chief Executive Officer, Chief Operations Officer, and the production manager of the selected *shito* processing company. The Chief Operating Officer was appointed as the Food Safety Team Leader with the following responsibilities:

(i) Managing production personnel and organizing their work
(ii) Ensuring relevant training and education of production personnel
(iii) Ensuring that the HACCP system is established, implemented, maintained, and updated
(iv) Reporting to top management on the effectiveness and suitability of the HACCP system
(v) Liaising with external parties on matters relating to the HACCP system.

2.1.3. Description of the Product. Vegetable *shito* was described as a spicy smooth dark brown sauce. The principal ingredients are soya bean oil, onions, ginger, tomato paste, pepper, soya bean flour, iodised salt, seasoning, herbs, and spices. It is hermetically packed in sachets with a shelf life of 12 months, and it is stored under cool, dry, and ambient conditions ($25 \pm 3°C$).

2.1.4. Identification of Intended Use and Consumers. Vegetable *shito* is intended to be used as a ready-to-eat sauce which is best consumed with rice, meats, yam, and so on. It is suitable for vegetarians, ovo-lacto vegetarians, and vegans. Eating vegetable *shito* alone in excessive quantities can cause diarrhoea due to the amount of pepper it contains. It is not recommended for infants below 1 year.

2.1.5. Construction of Flow Diagram and Confirmation. A flow diagram was prepared according to the unit processes which take place during *shito* production and modified to reflect actual processes after the whole process was observed (Figure 1).

2.1.6. Identification of Potential Hazards and Consideration of Potential Control Measures. Potential hazards were identified through the use of existing scientific information in literature. *Bacillus cereus* and *Clostridium* spp. in canned

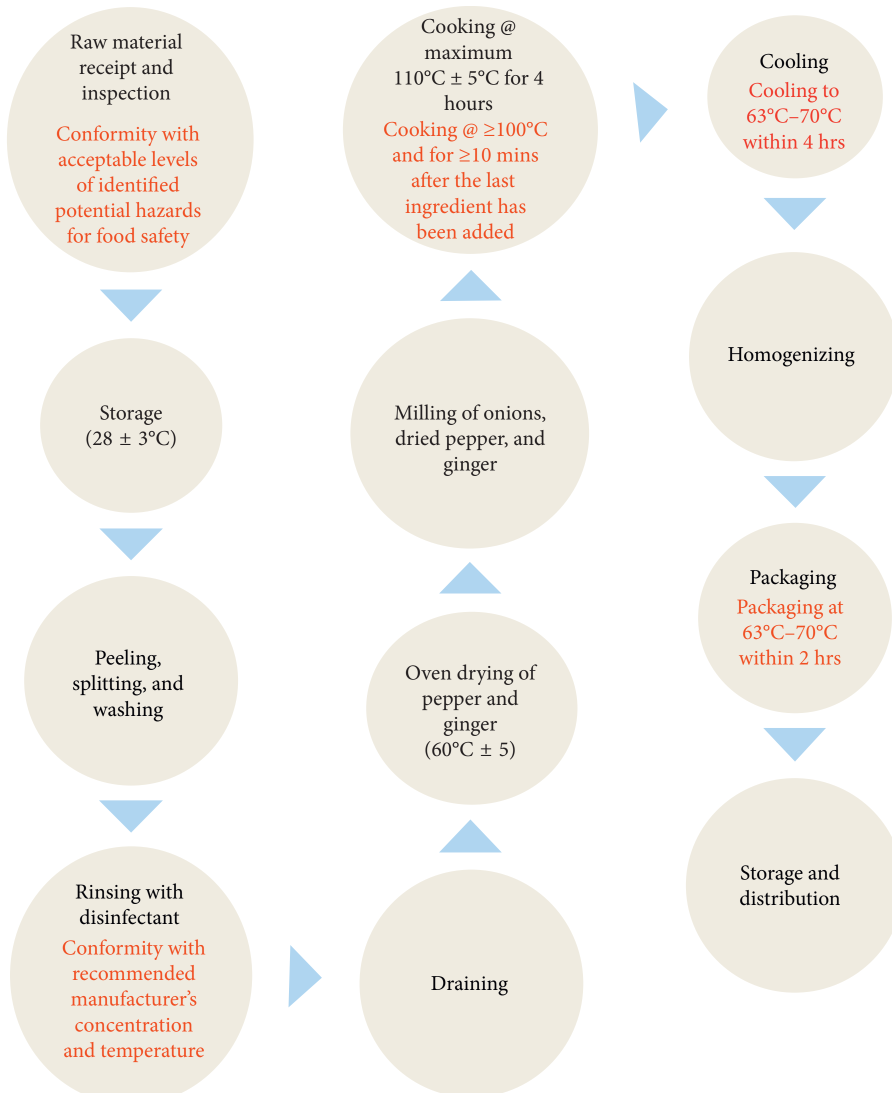

Figure 1: Flow diagram for vegetable *shito* production.

vegetables and fruits have been identified as a cause of food poisoning [10]. This implies their possible presence in canned tomatoes paste. *Bacillus cereus, Clostridium perfringens*, as well as non-spore-forming vegetative cells such as *Escherichia coli* and *Salmonella* have been isolated from soya powder, milled dried pepper, seasoning, herbs, and spices which have all been causes of food poisoning [11, 12]. Growth of mould prior to and after drying may also result in mycotoxin production, particularly aflatoxins in spices including pepper [12, 13]. *E. coli* and *Salmonella* spp. are some of the hazards which have been associated with process water [13]. Subsequently, in a product such as vegetable *shito*, aflatoxins, *Staphylococcus aureus, Clostridium perfringens, Escherichia coli*, *Salmonella* spp., and *Bacillus cereus* are the potential hazards which could be present. Based on the information obtained, raw materials were analysed to determine the presence and levels of potential hazards using standard methods. Samples were prepared [14] and analysed for *Escherichia coli* [15], *Bacillus cereus* [16], *Staphylococcus aureus* [17], *Salmonella* [18], *Clostridium perfringens* [19], and aflatoxins [20]. The detection limits for the aflatoxin tests were 0.15 μg/kg for aflatoxins B1 and B2 and 0.13 μg/kg for aflatoxins G1 and G2.

Some identified control measures for the microbiological hazards are the use of good quality raw materials from approved suppliers, temperature control of products during storage, prompt drying of ingredients, separation of ingredients from processed products, and hygienic processing [12, 13, 21]. For the aflatoxins, proper drying and storage to achieve a water activity below 0.6 is adequate to prevent their production [13]. Acceptable levels of identified hazards for food safety were obtained through literature and are provided in Table 1.

2.1.7. Identification of Critical Control Points (CCPs). Critical control points (CCPs) are the steps at which controls can be applied and where those controls are crucial to prevent and/or eliminate and/or reduce to an acceptable level food safety hazards. CCPs were identified using the CCP decision tree recommended by Luning and

Table 1: Acceptable levels of identified potential hazards for food safety.

Potential hazards	Acceptable levels for food safety (raw materials)	Acceptable levels for food safety (finished product)
Bacillus cereus	10^6 cfu/g [13]	<10 cfu/g [13]
Clostridium perfringens	10^2 cfu/g [13]	<10 cfu/g [13]
Escherichia coli	10^2 cfu/g [13]	<10 cfu/g [13]
Salmonella	Absent/25 g [13]	Absent/25 g [13]
Staphylococcus aureus	10^2 cfu/g [13]	<10 cfu/g [13]
Aflatoxins B1	5 μg/kg [22]	5 μg/kg [22]
Total aflatoxins	10 μg/kg [22]	10 μg/kg [22]

Table 2: Critical limits for CCPs.

Number	CCP	Critical limits
1	Raw material receipt	Conforms with specifications as stated in Table 1
2	Washing of ginger and pepper and rinsing with disinfectant	Washing with water 5 times and once with a food grade sanitizer at the recommended manufacturer's concentration and temperature
3	Cooking	Temperatures of 75°C or above are effective in destroying almost all types of bacteria [23, 24]. Time of cooking after last ingredient is added should be at least 2 minutes when the core temperature of the product has reached at least 75°C [24]. It is assumed that the core temperature of the formulation after the last ingredient has been added will take about 5 min to reach the minimum required temperature and therefore, cooking should be done for at least 10 min after the last ingredient has been added and the minimum temperature attained at 100°C
4	Cooling	Temperatures above 63°C will control the multiplication of bacteria in hot food [23]. Rapidly cool to 63°C–70°C within 4 h [25]
5	Packaging	Complete packaging at product temperature 63°C–70°C within 2 h [24]

Table 3: Alternative monitoring systems for the CCPs.

CCP	Monitoring system 1
Raw material receipt	Inspection of certificate of analysis from selected suppliers
Washing of ginger and pepper	Manual inspection of number of washing times Use of thermometer to check temperature of wash water/sanitizing solution Use of chlorine strips to check concentration of sanitizing solution
Cooking	Ensure homogenized product by continuous stirring. Use of fixed calibrated temperature probes or thermometers with manual timing
Cooling	Ensure homogenized product by continuous stirring Use of fixed calibrated temperature probes or thermometers with manual timing
Packaging	Use of fixed calibrated temperature probes or thermometers with manual timing

Marcelis [9]. The CCPs identified were raw material receipt, washing of ginger and pepper, cooking, cooling, and packaging.

2.1.8. Establishment of Critical Limits (CLs) for CCPs. The critical limit is a criterion or value which separates acceptability from unacceptability. CLs were set for the identified CCPs using available literature and legislative requirements. Critical limits for the CCPs are provided in Table 2.

2.1.9. Establishment of Monitoring Systems for the CCPs. Monitoring systems are important to ensure that the production process is running according to plan. In addition, these systems ensure that deviations do not occur without notice and implementation of the proper corrective actions. Alternative monitoring systems were established for the CCPs using available scientific tools and research information (Table 3).

2.1.10. Establishment of Corrective Actions (CAs) for Deviations from CLs Which May Occur at CCPs. Consideration of the following corrective actions indicated in Table 4 is appropriate when a deviation occurs at a CCP [13].

2.1.11. Establishment Verification Procedures. Verification procedures are essential to ensure that standard operating procedures and requirements of the HACCP plan are being adhered to. Table 5 summarises activities which are deemed important for verification procedures.

Table 4: Corrective actions at the critical control points in case of deviations from the critical limits.

CCP	Corrective action
Raw material receipt	Reject/discard batch
Washing of ginger and pepper	Repeat washing procedure and increase or reduce the concentration of sanitizer if concentration is lower or higher than required, respectively
Cooking	Adjust temperature or heat setting and cook longer until required temperature and time is achieved
Cooling	If required temperature is not achieved within 4 h, reheat product to minimum required temperature after cooking and begin cooling process again. If internal product temperature does not reach 63°C–70°C within an additional 4 h after reheating, product should be frozen and reworked with a new batch
Packaging	If temperature of product falls below required minimum temperature, reheat product to required minimum packaging temperature and continue packaging If temperature has been out of range for more than 2 h, product should be frozen and reworked with a new batch

Table 5: Verification procedures.

CCP	Verification procedures
Raw material receipt	Weekly inspection of raw material receipt documents Weekly inspection of test reports
Washing of ginger and pepper	Weekly inspection of washing records for ginger and pepper (number of times washed and details of type, concentration, and temperature of sanitizing solution used for washing)
Drying of pepper and ginger	Inspection of calibration certificate of temperature probes once every 6 months Inspection of records for drying pepper and ginger once every week (maximum temperature and time of drying) Inspection of moisture records for pepper and ginger once every week
Cooking	Inspection of calibration certificate of temperature probes once every 6 months Inspection of records for cooking once a day at end of production (temperature and time of cooking)
Cooling	Inspection of calibration certificate of temperature probes once every 6 months Inspection of records for cooling once a day at end of production (temperature and time of cooling)
Packaging	Inspection of calibration certificate of temperature probes once every 6 months Inspection of records for packaging once a day at end of production (temperature and duration of packaging) Inspection of test reports of end-products once a month

2.2. Validation of HACCP Plan. The HACCP plan was validated through Challenge testing [26]. For the challenge test, 1 kg each of ginger and pepper, which are the principal ingredients for vegetable *shito* were inoculated with 1 ml of an overnight nutrient broth culture of pathogens (*Escherichia coli*—ATCC 8739, *Bacillus cereus*—ATCC 6633, *Staphylococcus aureus*—ATCC 6538, and *Clostridium perfringens*—ATCC 13124) in 1 L water. After inoculation, the deliberately contaminated raw materials were sampled and analysed using standard methods to get the actual level of contamination with the pathogens. They were then taken through the normal production process according to the HACCP plan for the production of vegetable *shito*. The pepper was washed five times with water in a bowl which submerged the last pepper and once with Vegiwash food sanitizer at the recommended manufacturer's concentration (1 pack in 40 litres of water) and a temperature of 39°C. The ginger was washed ten times with water in a bowl which submerged the last ginger and once with Vegiwash food sanitizer at the recommended manufacturer's concentration (1 pack in 40 litres of water) and a temperature of 39°C. The ginger and pepper were dried in a Weston Stainless Steel Food Dehydrator (SKU: WS-74-1001-W) at 65°C for 6 h. Onions were peeled, cut into two halves, and washed four times with water at 39°C and once with Vegiwash food sanitizer at the recommended manufacturer's concentration (1 pack in 40 litres of water) and a temperature of 39°C. Onions, pepper, and ginger were milled separately with vegetable grinding machine (Gelgoog GG-813). Onions were added to soya bean oil at a temperature of 110°C and cooked in a cooker (Elro DGN2) for 1 hr at a minimum temperature of 102°C. Other ingredients were added and the total cooking time was 4 hours. The time of cooking after the last ingredient was added was 10 min at a minimum temperature

Table 6: Level of hazards in contaminated raw materials.

Raw material	*Bacillus cereus* (cfu/g)	*Escherichia coli* (cfu/g)	*Clostridium perfringens* (cfu/g)	*Staphylococcus aureus* (cfu/g)	*Salmonella* Spp./25 g
Before washing					
Ginger	2.1×10^6	3.4×10^6	2.8×10^6	3.7×10^6	Not detected
Pepper	1.3×10^6	2.2×10^6	1.9×10^6	1.1×10^6	Not detected
After washing and drying					
Ginger	70	2.8×10^3	40	180	Not detected
Pepper	110	40	<10	110	Not detected

of 102°C. Cooling was done rapidly by transfer of the vegetable *shito* into another cooker (Elro DGN2) which was at room temperature. Cooling to 76°C was achieved within 1 hr. Packaging was done in poly laminated aluminum foil using a Century Star packaging equipment (998E-1) within 2 h at a minimum product temperature of 65°C at a rate of 600 sachets/hr. Each sachet had a weight of 10 g. The finished product was sampled randomly and analysed for potential hazards: aflatoxins—Stroka and Anklam [20]; *Escherichia coli*—NMKL 125 [15]; *Bacillus cereus*—NMKL 67 [16]; *Staphylococcus aureus*—NMKL 66 [17]; and *Clostridium perfringens*—ISO 7937 [19]. In order to test for potential spore formers, some *shito* samples were incubated at different temperatures (25C, 44C, 37°C, and 30°C) for 7 and 14 days and analysed for potential hazards.

3. Results

Results obtained after analysing the contaminated raw materials before and after washing and drying are shown in Table 6. It was observed that after washing and drying, the initial levels of pathogens were significantly reduced in the washed and dried pepper and ginger.

The significant reduction in initial microbial levels in ginger and pepper is attributed to the use of a food grade sanitizer containing chlorine which has been recorded as a very effective means for controlling microbial load in fresh produce [27].

Salmonella spp. was not detected neither were *E. coli, Bacillus cereus, Staphylococcus aureus*, and *Clostridium perfringens* isolated from the freshly prepared *shito* as well as after the *shito* had been stored at various temperatures and time (25°C, 44°C, 37°C, and 30°C for 7 and 14 days). Furthermore, aflatoxins B1, B2, G1, and G2 were not detected in the final *shito* product (0.15 μg/kg detection limit for aflatoxins B1 and B2 and 0.13 μg/kg detection limit for aflatoxins G1 and G2).

4. Discussion

The development of quality assurance systems has been documented as a time-consuming activity which also demands a lot of financial commitment [28–30]. However, the benefits of a food safety management system override the burdens which are associated with such systems. This is evident in the validation results obtained, indicating that a HACCP plan, if well-developed and implemented will be sufficient for the elimination of potential hazards and the protection of public health. However, Arpanutud et al. (2009) have concluded that the proper implementation of food safety management systems is influenced by the extent of management commitment. This has been corroborated by several other authors [3, 31, 32]. Management commitment is essential for the provision of all needed resources including training of personnel.

5. Conclusion

Based on the results obtained, it will be concluded that the HACCP system when applied correctly according to plan is effective for the elimination of hazards when they are present in the raw material at levels up to 10^6 cfu/g. Again, the current production process is sufficient to prevent the formation of aflatoxins in the final *shito* product. Even though most food companies face barriers such as infrastructure and technical expertise, such companies need to make use of information available to promote their food safety assurance in order to be sustainable in the international food market. It is therefore recommended that *shito* processing companies should adopt and modify this HACCP-based quality assurance program to guarantee the consistent safety of their products.

Data Availability

Data will be available upon request.

Disclosure

This work was first presented as an oral presentation at the South African Association for Food Science and Technology Congress in 2015.

Conflicts of Interest

The authors declare no conflicts of interest.

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