CHAPTER 3

An Introduction to the Hazard Analysis and Critical Control Point (HACCP) System and Its Application to Fermented Foods

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INTRODUCTION

The Hazard Analysis and Critical Control Point system, often known under its acronym HACCP, is a system that was conceived in the 1960s by the Pillsbury Company, National Aeronautics and Space Administration (NASA), and the U.S. Army Laboratories at Natick to ensure the safety of foods for astronauts. Originally developed to ensure the microbiological safety of foodstuffs, it is now recognized that the system can be equally applied to control and prevent chemical and physical hazards.[11]

In the 30 years since its conception, the HACCP system has grown to become the universally recognized and accepted method for food safety assurance. In appreciation of the importance of the HACCP system for enhancing food safety, and in view of the importance of globalization of the food supply and the need for harmonization of food safety requirements, the Codex Alimentarius Commission (CAC) adopted in 1993 the Guidelines for the Application of HACCP, which have received international recognition. In 1997, on the recommendation of the World Health Organization (WHO), the CAC guidelines were revised and improved.[5]

For more than 20 years, WHO has recognized the importance of the HACCP system for the prevention of food-borne diseases and has played an important role in its development, promotion, and harmonization. One of the most important initiatives of the organization has been the promotion of the HACCP system in small industries and cottage industries and the use of the HACCP system for health education activities.

Before explaining the HACCP system and its application to the preparation of fermented foods, it is essential to understand why the system has received such recognition by the food industry and has been promoted by public health authorities, in particular WHO. For this purpose, the historical development of food safety needs to be reviewed.*

HISTORICAL DEVELOPMENT

Food safety has been of concern to humankind since the dawn of history, and many of the problems encountered in our food supply go back to the earliest recorded years. Many rules and recommendations advocated in religious or historical texts are evidence of the concern to protect people against food-borne hazards and food adulteration. Although advances in science and technology in the last few centuries have increased scientists' understanding of chemical and biological hazards, up until the early 1980s, the food hygiene† systems in many countries were based on empirical knowledge acquired through the surveillance of food-borne diseases

*Food safety is the assurance that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use.

†Food hygiene is defined as all conditions and measures necessary to ensure the safety and suitability of food at all stages of the food chain.

and, in some instances, on the perception of what is considered a hazard. Often, this perception led to the fact that food hygiene was interpreted simply as cleanliness.

Because of the prevalence of diseases transmitted by the fecal–oral route, such as typhoid fever and cholera, the emphasis of food safety programs for a long time was on the improvement of water supply and sanitation infrastructures and the protection of food from fecal contamination. As a result, regulatory authorities focused their inspection activities on the cleaning and sanitation of food businesses and on the personal hygiene of food handlers. A similar approach was adopted in health education activities, and the focus of food hygiene education programs was based mainly on hand washing, boiling of water, and the protection of food from flies. These measures, where implemented, have been effective in reducing the incidence of fecal-orally transmitted food-borne and waterborne diseases, such as typhoid fever and cholera. However, they have been insufficient to prevent other types of food-borne diseases, such as salmonellosis and campylobacteriosis. With the recent drastic changes in food production and lifestyles, some of these diseases have even increased in incidence. In addition, other types of problems have emerged.[6]

THE NEED FOR CHANGE

The end of the twentieth century was marked by significant changes in the food safety assurance system and food control. Traditionally, the method of food safety assurance was based on two types of measure: (1) actions undertaken during the procurement of raw materials, processing, manufacturing, transport, and distribution, including design, layout, and cleaning of premises to prevent contamination; and (2) actions undertaken to ensure that food, which was produced, was indeed safe. The former were usually prescribed in the Codes of Good Manufacturing Practice (GMP) and/or the Codes of Hygienic Practice (GHP). For the purpose of the latter, industries tested the end product for confirmation of safety. Food control and public health authorities also inspected premises for compliance with GMP/GHP and other regulatory requirements. As mentioned above, these inspections often focused on the cleanliness of premises, food handlers, and the immediate environment and failed to identify shortcomings related to the production and preparation procedure itself. Authorities also carried out independent testing of end products. These methods of food safety assurance and food control showed certain weaknesses: The control of premises was based on random inspection and not on what happened during longer periods of time before or after the inspection. End-product testing performed by industry or food inspectors also proved to be costly and time consuming and provided insufficient assurance of food safety (see the following section on the benefits of the HACCP system).

Concomitant with the recognition of the limitations of traditional approaches to food safety control, the concern for food safety grew. There were many reasons for these concerns.[3]

- increasing incidence of food-borne diseases in many parts of the world
- recognition that one of the major health problems of developing countries, infant diarrhea, is to a large extent food-borne
- emergence of new or newly recognized food-borne pathogens such as verocytotoxin-producing *Escherichia coli*, *Campylobacter* spp., food-borne trematodes, and *Salmonella enteritidis*
- increased knowledge and awareness of the serious and chronic health effects of food-borne hazards
- increased number of vulnerable people, such as the elderly, children, pregnant women, immunocompromised individuals, the undernourished, and individuals with other underlying health problems
- increased awareness of the economic consequences of food-borne diseases
- the possibility of detecting minute amounts of contaminants in food, due to advances in scientific and analytical methods
- industrialization and mass production leading to (1) increased risks of large-scale food

contamination and (2) the considerably larger numbers of people affected in food-borne disease outbreaks as a result
- urbanization, leading to a longer and more complex food chain, and thus greater possibilities for food contamination
- new food technologies and processing methods, causing concern either about the safety of the products themselves or about the eventual consequences due to inappropriate handling in households or food service and catering establishments
- changing lifestyles, depicted by an increasing number of meals eaten out of the home, either in food service and catering establishments or at street food stalls
- increased tourism worldwide and international trade in foodstuffs, both leading to a greater exposure to foreign and unfamiliar food-borne hazards
- increased contamination of the environment
- increased consumer awareness of food safety
- lack of or decreasing resources for food safety

As a result of the above, but also recognizing the limitations of the traditional approaches, public health authorities and the food industry have both recognized the need to move to a more preventive, scientific, and cost-effective food safety assurance approach, namely, the HACCP system.

WHAT IS THE HACCP SYSTEM?

The HACCP system is defined by the CAC as a *system which identifies, evaluates, and controls hazards which are significant for food safety.* The value of the HACCP system lies in the fact that it is a scientific, rational, and systematic approach to the identification, assessment, and control of hazards during production, processing, manufacturing, preparation, and use of food to ensure that food is safe when consumed. The HACCP system is based on seven principles, as introduced in Appendix 3–A.[2]

Through the application of these principles, industries or food establishments that apply the system will be led to review their process of food production or preparation critically, to identify hazards and control measures, to establish objective criteria for ensuring safety, and to monitor that control measures have been properly implemented, in particular at those steps during the food production that are critical for food safety. They will also foresee the necessary corrective actions when monitoring procedures indicate failures in the control of hazards. Through verification and documentation, they can also, at all times, verify the adequacy of their measures. Guidance for the application of these principles has also been provided by the CAC text on HACCP Principles and Guidelines for its Application (Appendix 3–A). It is, however, recognized that for the application of the HACCP system to be successful, some additional measures need to be considered.

1. *Management commitment.* The successful implementation of the HACCP system requires a change in attitude of policy and decision makers in all sectors concerned as well as management commitment. Although implementation of the HACCP system brings many benefits, and in the long term may reduce financial costs, its implementation in the initial stages requires additional resources encompassing qualified personnel, technical support facilities, equipment, training, and so forth. Such conditions can be met only where there is a management commitment.
2. *Prerequisites for HACCP.* Prior to applying the HACCP system to any sector of the food chain, that sector should be operating according to the CAC General Principles of Food Hygiene, the appropriate CAC Codes of Practice, and appropriate food safety legislation.
3. *Training.* Adequate training of personnel is a key to effective implementation of the HACCP system. Such training should include an explanation of the HACCP system, the reasons for and the objectives of its application, as well as the responsibilities of each person involved in the imple-

mentation of the HACCP plan. The tasks of operators working at each critical control point (CCP) should also be clearly defined and the operators should be trained in performing them.[2,11]

BENEFITS OF THE HACCP SYSTEM

The benefits of the HACCP system are summarized in the following paragraphs.[11]

- The HACCP system overcomes many of the limitations of the traditional approaches to food safety control (generally based on "snap-shot" inspection and end-product testing), including
  a. limitations of "snap-shot" inspection techniques in predicting potential food safety problems
  b. the difficulty of collecting and examining sufficient samples to obtain meaningful, representative information in a timely manner and without the high cost of end-product analysis
  c. reduction of the potential for product recall
  d. identification of problems without understanding the causes
- The HACCP system allows for the identification of all conceivable, reasonably expected hazards, even where failures have not previously been experienced. It is therefore particularly useful for new operations.
- The HACCP system is sufficiently flexible to accommodate any changes that might be introduced, such as progress in equipment design, improvements in processing procedures, and technological developments related to the product.
- The HACCP system will help target/direct resources to the most critical part of the food operation.
- With the HACCP system, one can expect an improvement in the relationship between (1) food processors and food inspectors and (2) food processors and consumers. The HACCP system provides a scientifically sound basis for demonstrating that all reasonable precautions have been taken to prevent a hazard from reaching the consumer. In this way, it encourages confidence in the safety of food products and thus promotes both confidence in the food industry and stability of food businesses.
- Data collected facilitate the work of food inspectors for auditing purposes.
- The HACCP system is applicable to the whole food chain, from the raw material to the end product (i.e., growing, harvesting, processing or manufacturing, transport and distribution, preparation, and consumption).
- The application of the HACCP system can promote international trade by increasing confidence in food safety.
- The HACCP system can be readily integrated into quality management systems such as total quality management, ISO 9000, and so forth.

AREAS OF APPLICATION

The HACCP principles can be applied in a variety of ways.

- The HACCP system is a system that is used as a method of food safety assurance in food production, processing, manufacturing, and preparation. The CAC guidelines for the application of the HACCP system provide guidance on how the seven principles of HACCP can be implemented in food industries in order to have the greatest chance of success (Appendix 3–A).
- The HACCP system is amenable to effective food control. It allows for more efficient inspection of food operations because the role of food inspectors is centered on the assessment of the HACCP plan and confirmation that it is designed properly and operating effectively.
- The HACCP principles, in particular principles 1 to 5, can be used to study food preparation practices and to identify and assess hazardous behavior, which should be the focus of health education interventions.

- The HACCP concept can be used in the management of overall food safety programs to identify those problems all along the food chain that are of greatest risk to public health, and to prioritize interventions.

THE HACCP SYSTEM IN FOOD HYGIENE

Today, to achieve food safety, it is recognized that there is a need to apply measures of increased specificity (Figure 3–1). At a more general level, the CAC outlines the general principles of food hygiene. These principles lay the foundation for food hygiene. Second, more product-specific hygienic measures may be applied to focus better on issues that are relevant to specific commodities. These measures, also prescribed by the CAC, are described in specific codes of manufacturing or hygienic practices. The CAC has developed codes for a number of products, such as smoked or salted fish, cured ham, and so forth. Finally, application of the HACCP system can further enhance food safety by providing a mechanism for analyzing the hazards for each food or process, developing a tailor-made plan for ensuring food safety with emphasis on CCPs, and ensuring that the critical limits at these points are met. With each layer of the above measures, the degree of assurance of food safety increases.[4]

To harmonize and promote the application of the HACCP system in food industries, the CAC outlined the principles and elaborated the guidelines for the application of the system. The principles of the HACCP system, as defined by the CAC, set the basis for the minimum requirements for mandatory application of the HACCP system. The guidelines are, on the other hand, a general guidance, and adherence to them is voluntary. The CAC text on the HACCP Principles and Guidelines for its Application are presently annexed to the CAC General Principles of Food Hygiene, and their application is consequently recommended. However, due to the status of the CAC in international trade in food, the application of the HACCP system to the production, processing, or manufacturing of food may in some countries become compulsory for food export. The reason is that since the conclusion of the GATT Uruguay Round of Multilateral Trade Negotiations in April 1994 and the coming into force of the World Trade Organization (WTO) Agreement on Sanitary and Phytosanitary Measures, the work of CAC is recognized as the reference or "yardstick" for national food safety requirements. As a result, members of the WTO need to take the work of CAC into consideration

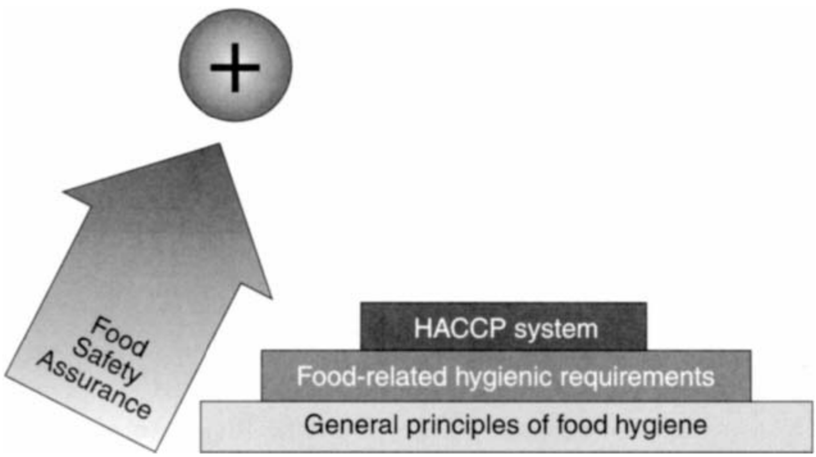

Figure 3–1 HACCP in food hygiene: Each additional measure of food hygiene will increase the degree of food safety assurance.[14]

and adapt their legislation to the provisions provided by CAC. In recent years, some countries such as the United States and the European Union have made application of the HACCP system compulsory in the production and processing of certain foodstuffs such as seafood, including those that are imported.

The implementation of the HACCP system in all food industries is an established goal in many countries. However, most progress made in implementing the HACCP system so far has been achieved in medium- and large-scale food industries, particularly in industrialized countries. Worldwide, analyses of food-borne disease outbreaks show that the greatest majority of food-borne disease outbreaks result from malpractices during food preparation in small businesses, canteens, and homes. In small businesses and homes in both developed and developing countries, the application of the HACCP system meets with greater difficulties.

In recognition of the need for improving the safety of foods that are prepared or processed in homes, food service establishments, street food vendors, and "cottage" industries, WHO proposed the use of HACCP systems to small operations and for health education purposes.[1,7,10]

APPLICATION OF THE HACCP APPROACH TO FOOD PREPARATION

The CAC General Principles of Food Hygiene provide guidance on the basic general requirements that are essential to ensuring food safety as well as food suitability. WHO has adapted these principles to different settings (e.g., food service establishments, street food vendors, and households) and recommended specific hygienic measures for the preparation of food under such conditions.[9,12,13] Although these food hygiene principles are fundamental to achieving food safety, their application for ensuring safety nevertheless has certain limitations.[10]

- They do not provide a mechanism for prioritizing control measures, even though some measures may prove to be more critical than others.
- The guidance is nonspecific to foods, operations, special socioeconomic conditions where the food is prepared, or the cultural factors leading to high-risk practices.

Therefore, it is recommended that HACCP studies be conducted in these settings to identify the measures that are critical for ensuring the safety of foods in the given sociocultural and economic conditions of preparation. The identified measures should be considered CCPs and, depending on the circumstances, they should be the subject either of enforcement and/or of training and education.

In general, small food businesses or street food vendors do not have the expertise necessary for conducting such HACCP studies. The same is also true for domestic food handlers. It is the role of trade associations, food inspectors or, in the case of domestic food handlers, health authorities to conduct such studies and train or educate the food businesses and households in implementing and monitoring control measures at the CCP in an adequate manner. Such an approach provides a mechanism for prioritizing key behavior or practices that should be enforced or promoted in a given professional group or population.

In most cases, a complete HACCP study cannot be conducted for every type of food and preparation method, and priorities must, therefore, be set. Whenever possible, epidemiological data should be used in establishing priorities. High priority should be given to foods that are commonly implicated as vehicles of food-borne diseases and to the type of food operations where outbreaks of food-borne diseases have been reported. Data on food-borne diseases are, however, not always available. In the absence of such data, priorities can be set based on the factors described in the following paragraphs.

Intrinsic Properties of the Food Involved

Some foods may contain toxic chemicals or microbial pathogens or their toxins because of the practices involved in the production of the raw materials. For example, raw meats may be contaminated with microbial pathogens at the slaughtering stage, and raw vegetables may be contaminated with microbial pathogens or toxic chemicals from fertilizers, pesticides, and so forth. Food properties also relate primarily to characteristics of the food that may support the survival and/or growth of microorganisms based on knowledge of microbial ecology and epidemiological history. The characteristics that are most useful are pH, water activity (A_w), and redox potential (Eh). These factors influence the growth of infectious or toxigenic microorganisms. Foods that are possibly hazardous because they readily support rapid and progressive growth of microorganisms should be given high priority. Next, priority should be given to foods that can support the growth of pathogens during prolonged storage periods. Foods that are "relatively stable," in particular with regard to pathogenic organisms, can be assigned lower priority.

Preparation and Handling

Food operations that commonly contribute to the cause of food-borne illnesses are those that (1) prepare hazardous foods in advance of serving, (2) store foods in a manner that might allow microbial growth, and (3) inadequately reheat food to inactivate pathogens or toxins. On the other hand, food that is thoroughly cooked just before consumption is safe from biological hazards although chemicals and certain toxins may not be affected. Food that has been processed, even in a simple form such as fermentation, may be safe when held at ambient temperatures. Similarly, commercially processed foods, especially those that are well packaged, may pose little hazard to the consumer when they are sold by street vendors.

Volume of Food Prepared

The concern about volume of food prepared relates primarily to the amount of food prepared in advance of sale and/or consumption. For instance, in street-vending operations, this amount can be indirectly measured by the average daily sales, the amount of prepared foods on display, and the duration of holding cooked foods on display.

Susceptibility of Consumers

Infants and children, pregnant women, the hospitalized, immunocompromised persons, and the elderly are more susceptible to food-borne diseases than the general population. Foods which are intended for these groups of consumers should receive a higher priority.

Many of the fermented foods, particularly those that are prepared as complementary foods for infants and young children in Africa, fall into one or more of the above categories. In view of this, WHO joined with the Food and Agricultural Organization (FAO) in December 1995 to conduct a workshop on the assessment of fermentation as a household technology to improve food safety, during which the HACCP system was applied to several African fermented foods.[8] CCPs for the preparation of each of these foods were determined and it was recommended that control measures at these points should be included in the health education of food handlers. As an example, the application of the HACCP system to the preparation of *gari* is presented below. HACCP studies have shown that in general, the following measures during the preparation of African fermented foods should be the focus of training and health education.

- rapid and adequate acidification
- sufficient cooking for rendering food safe
- sufficient size reduction of cassava to enable enzymatic degradation of toxic cyanogenic glycosides
- avoidance of moldy raw material in view of possible mycotoxin contamination
- use of safe water

Through these studies, it could also be clearly demonstrated that some preparation practices presented a high food safety risk. For instance, the preparation of *togwa* (see Chapter 12) involves the addition of "power flour" after the food has been cooked. Thus, there is a risk of postcooking contamination, particularly with acid-resistant pathogens. In addition, if the lactic acid fermentation fails, the addition of power flour may lead to the proliferation of bacterial pathogens. To minimize food safety risks, it was recommended to accelerate the fermentation by back-slopping or use of starter cultures, or using power flour of high quality and avoiding postcooking contamination. In addition, the HACCP study showed that the original procedure for power flour preparation needs to be modified. In order to avoid postcooking contamination, it was recommended to boil the water that was used for the purpose of soaking and germination.

APPLICATION OF THE HACCP SYSTEM TO GARI*

1. **Product description**—Gari is a granular starchy food that is made from cassava roots. The processing starts with peeling, washing, and grating the tubers. The grated pulp is then put into bags (often jute or woven polypropylene bags) and left to ferment for several days under weight (pressure), during which time water is also removed. Fermentation is followed by fragmentation, drying, and roasting. During the roasting stage, the core temperature reaches 80–85 °C and the starch is gelatinized. Palm oil is sometimes added during roasting. After the roasting process, the gari, as it is now called, is cooled and stored. The final moisture content will determine its shelf life. When a final moisture content of less than 10% is reached, *gari* may be stored for several months. At higher moisture contents, the shelf life of gari is reduced to a few weeks because of potential mold growth.
2. **Intended use**—Gari is an important part of the staple diet in Nigeria and many other African countries. It is also given to children over one year of age. Gari can be prepared in many different ways. In the following example, soaking in cold water is used.
3. **Flow diagram**—The flow diagram of gari is presented in Figure 3–2.
4. **Hazards of concern**—Hazards considered in this context include biological (e.g., bacteria, viruses, parasites), chemical (e.g., contaminants, mycotoxins), and physical agents.
5. **Identification of hazards, control measures, and CCPs**—Table 3–1 shows the hazards that are associated with each step in the preparation of gari and some possible measures for their control.
   a. *Raw material:* Major hazards of cassava are cyanogenic glucosides (i.e., linamarin and lotaustralin) and contamination by agrochemicals. Cyanogenic glucosides will be hydrolyzed and removed during later stages in the processing and preparation of gari (i.e., grating, fermenting, and roasting). However, in regard to chemical contaminants and agrochemicals, households should obtain assurance from the suppliers regarding the safety of raw products.

      Depending on its source, water may be contaminated. Although the microbiological safety of water is of lesser importance when washing cassava because it will be fermented and heat treated, it is critical that safe water is used in the final preparatory stages before consumption.
   b. *Peeling:* Some foreign matter and pathogens may be introduced at this step. However, because the cassava will be washed and heat treated, the control of hazards, other than peeling in hygienic conditions, is not critical at this stage.
   c. *Washing:* Microbiological hazards may be introduced if the water is not clean. Therefore, as part of a good hy-

*Application of the HACCP system has been simplified and adapted to household conditions. Although the same approach can be used for production on a cottage and industrial scale, the requirements in terms of CCPs, critical limits, and monitoring procedures may be different and more severe. Model HACCP plans are not appropriate for use until they are validated for a specific food and food process.

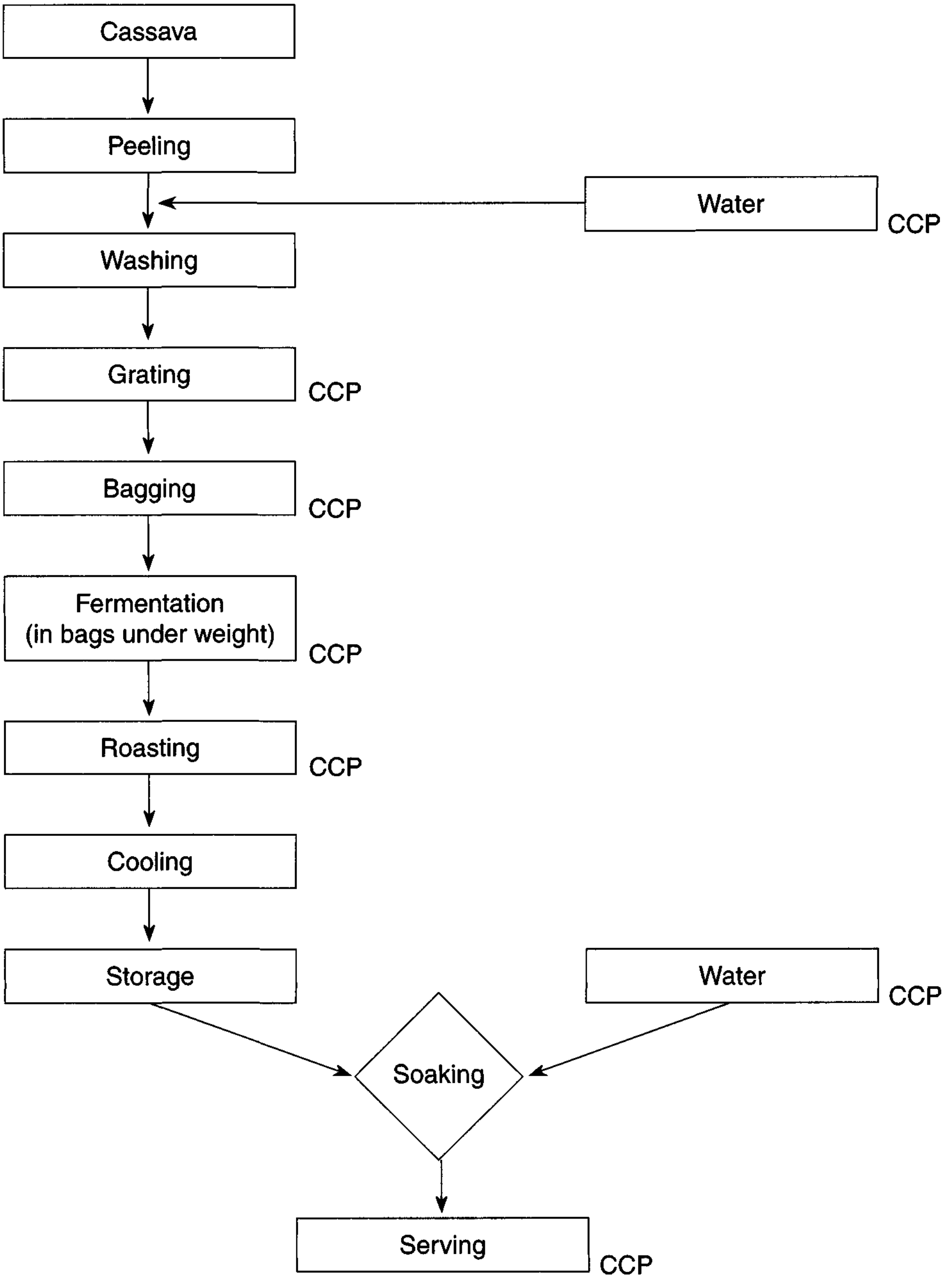

Figure 3–2 Application of the HACCP system to the preparation of *gari* in households[8]

gienic practice, safe water should be used. Hazards introduced at this step can nevertheless be controlled during subsequent steps of gari production. Washing can, though, decrease the amount of foreign matter.

d. *Grating:* This is the most important step with regard to detoxification when the cellular disruption results in the release of linamarase enzymes and greater contact of the enzymes with its substrate linamarin. Therefore, grating

Table 3–1 Application of the HACCP System to the Preparation of *Gari* in Households

Step	*Hazards*	*Control Measures*	*Critical Control Points*	*Critical Limit*	*Monitoring Procedure*	*Corrective Actions*
1. Raw material i) Cassava	a. Agrochemicals	a. Obtain assurance from supplier of adequate preharvest and postharvest handling of roots	a. No			
	b. Cyanogenic glucosides	b. Grating, fermentation, and roasting	b. No			
	c. Pathogens	c. Heat treatment	c. No			
1. Raw material ii) Water	a. Chemical contaminants, depending on the source	a. Obtain assurance of the source of water; use only safe water	a. Yes	a. Clear, free of odor and off-taste	a. Observation, smelling, and tasting	a. Use another source of water
	b. Pathogens (e.g., pathogenic *E.coli, Campylobacter, V. cholerae, Salmonella, Cryptosporidium, Giardia lamblia, Entamoeba histolytica*), Rotavirus	b. i) Use safe water (i.e., filtered and disinfected) or ii) Boil the water	b. Yes for step 10	b. i) Indication of contamination ii) Bubbles	b. i) Inquiry from health authorities ii) Observation	b. i) Boil the water ii) Reboil
2. Peeling	a. Foreign matter	a. Washing	a. No			
	b. Pathogens	b. Heat treatment	b. No			
3. Washing	a. Introduction of pathogens through water	a. Use safe water	a. No			
	b. Residual foreign matter	b. Thorough washing	b. Yes	b. As clean as possible	b. Observation	b. Reclean

continues

Table 3–1 continued

Step	*Hazards*	*Control Measures*	*Critical Control Points*	*Critical Limit*	*Monitoring Procedure*	*Corrective Actions*
4. Grating	a. Residual cyanide	a. Complete grating	a. Yes	a. Absence of coarse particles	a. Observation	a. Regrate
	b. Pathogens	b. Clean the equipment	b. No			
	c. Foreign matter	c. Use well-maintained equipment	c. Yes	c. Free of visible foreign matter	c. Observation	c. Remove foreign material
5. Bagging	Chemical contamination	Use clean bags; obtain assurance from supplier about no previous and hazardous use of the bags	Yes	Absence of chemical contaminants	Monitor the source and other uses of bags	Use other bags
6. Fermentation under weight	Growth of pathogens and production of toxin (e.g., *Staphylococcus aureus*)	Rapid fermentation	Yes	Acid taste and characteristic odors within 24 hours	Observation, smelling, and tasting	Discard
7. Roasting	a. Residual cyanide	a. i) Thorough roasting ii) Breaking up lumps	a. Yes	a. i) Sufficient time for roasting ii) Small size particles	a. i)Time keeping ii) Observation	a. i) Continue roasting ii) Breaking up lumps
	b. Mold growth during storage if high moisture content	b. Same as above	b. Yes	b. Same as above	b. Same as above	b. Same as above

continues

Table 3–1 continued

Step	*Hazards*	*Control Measures*	*Critical Control Points*	*Critical Limit*	*Monitoring Procedure*	*Corrective Actions*
8. Cooling	Contamination through environment	Cool under hygienic conditions (e.g., put in clean container and clean environment)	No			
9. Storing	Mold growth during storage if high moisture content	Thorough roasting (see step 7: roasting); keep in dry conditions	No, see step 7			
10. Soaking and serving	a. Recontamination with water	a. Use safe water	a. Yes see step 1	a. See step 1 (water)	a. See step 1 (water)	a. See step 1(water)
	b. Recontamination by dirty hands, utensils, environ-ment	b. Wash hands and use clean utensils	b. Yes	b. Washing with soap and thorough rinsing with clean water	b. Observation	b. Thorough heating
	c. Growth of pathogens and spores of *Bacillus cereus*, if consumption is delayed for more than four hours	c. Consumption without delay	c. Yes	c. Use within four hours	c. Time keeping	c. Thorough heating

must be thorough to ensure a fast degradation of linamarin.

Foreign matter and pathogens may also be introduced at this stage. Although pathogens can be killed at the roasting step, the prevention and elimination of any foreign matter at this step is essential.

e. *Bagging:* Unclean bags may further contaminate the raw material. Chemical contamination is of particular concern at this step. The bags should not have been used previously for purposes that could jeopardize the safety of gari (e.g., for storage of pesticides).
f. *Fermentation:* Rapid fermentation is important to prevent the growth of undesirable microorganisms and the production of toxins. Fermentation is therefore a CCP for the control of pathogens.

   Fermentation also provides the opportunity (contact time) necessary for the action of linamarase on its substrate. During later stages, however, fermentation may have an antagonistic effect on detoxification because the decrease in pH resulting from fermentation may lead to the stability of cyanohydrins. An optimization of the fermentation process with respect to hydrolysis of linamarin and control of microbial growth is therefore important for ensuring the chemical and microbiological safety of gari.
g. *Roasting:* Further detoxification of cassava occurs during roasting when the hydrogen cyanide is evaporated. Thorough drying at this step is also important for the stability of gari and the prevention of mold growth during storage. It is important to prevent lumps from forming because they may limit the drying and evaporation of hydrogen cyanide.
h. *Cooling:* Cooling should take place under hygienic conditions.
i. *Storing:* To prevent mold growth, gari should be kept under dry conditions and protected from animals and rodents.
j. *Serving:* Water used for soaking gari, as well as hands and utensils, may reintroduce pathogens. It is critical that the water used at this step is safe, and that utensils and hands are washed thoroughly.

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HACCP Principles and Guidelines for Its Application

Assemble HACCP team

The food operation should ensure that the appropriate product-specific knowledge and expertise is available for the development of an effective HACCP plan. Optimally, this may be accomplished by assembling a multidisciplinary team. Where such expertise is not available on-site, expert advice should be obtained from other sources. The scope of the HACCP plan should be identified. The scope should describe which segment of the food chain is involved and the general classes of hazards to be addressed (e.g., does it cover all classes of hazards or only selected classes).

Describe product

A full description of the product should be drawn up, including relevant safety information such as composition, physical/chemical structure (including A_w, pH, etc.), microbicidal/static treatments (e.g., heat treatment, freezing, brining, smoking, etc.), packaging, durability, storage conditions, and method of distribution.

Identify intended use

The intended use should be based on the expected uses of the product by the end user or consumer. In specific cases, vulnerable groups of the population such as institutional feeding may have to be considered.

Construct flow diagram

The flow diagram should be constructed by the HACCP team. The flow diagram should cover all steps in the operation. When applying HACCP to a given operation, consideration should be given to steps preceding and following the specified operation.

On-site confirmation of flow diagram

The HACCP team should confirm the processing operation against the flow diagram during all stages and hours of operation and amend the flow diagram where appropriate.

HACCP principles	Guidelines for their application
Principle 1 ***Conduct a hazard analysis***	The HACCP team should list all of the hazards that may be reasonably expected to occur at each step from primary production, processing, manufacture, and distribution until the point of consumption. The HACCP team should next conduct a hazard analysis to identify for the HACCP plan which hazards are of such a nature that their elimination or reduction to acceptable levels is essential to the production of a safe food. In conducting the hazard analysis, wherever possible, the following should be included: • the likely occurrence of hazards and severity of their adverse health effects • the qualitative and/or quantitative evaluation of the presence of hazards • survival or multiplication of microorganisms of concern • production or persistence in foods of toxins, chemicals, or physical agents • conditions leading to the above The team must then consider what control measures, if any, exist that can be applied for each hazard. More than one control measure may be required to control a specific hazard(s) and more than one hazard may be controlled by a specified control measure.
Principle 2 ***Determine the critical control points (CCPs).***	There may be more than one CCP at which control is applied to address the same hazard. The determination of a CCP in the HACCP system can be facilitated by the application of a decision tree (Figure 3–A–1) which indicates a logic reasoning approach. Application of a decision tree should be flexible, given whether the operation is for production, slaughter, processing, storage, distribution, or other. It should be used for guidance when determining CCPs. This example of a decision tree may not be applicable to all situations. Other approaches may be used. Training in the application of the decision tree is recommended. If a hazard has been identified at a step where control is necessary for safety, and no control measure exists at that step, or any other, then the product or process should be modified at that step, or at any earlier or later stage, to include a control measure.
Principle 3 ***Establish critical limit(s).***	Critical limits must be specified and validated if possible for each critical control point. In some cases, more than one critical limit will be elaborated at a particular step. Criteria often used include measurements of temperature, time, moisture level, pH, A_w, and available chlorine, and sensory parameters such as visual appearance and texture.

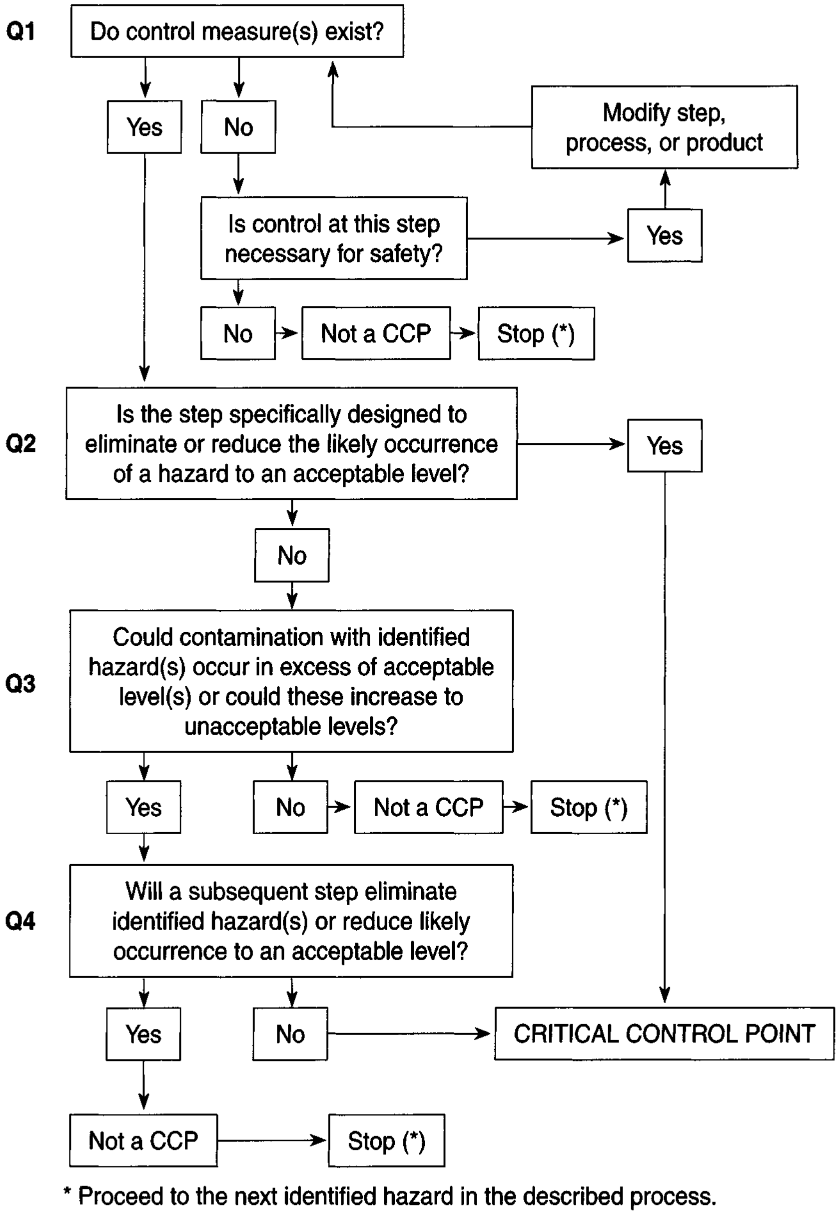

Figure 3–A–1 Example of a decision tree to identify CCPs.[2]

HACCP principles	Guidelines for their application
Principle 4 Establish a system to monitor control of the CCPs.	Monitoring is the scheduled measurement or observation of a CCP relative to its critical limits. The monitoring procedures must be able to detect loss of control at the CCP. Further, monitoring should ideally provide this information in time to make adjustments to ensure control of the process to prevent violating the critical limits. Where possible, process adjustments should be made when

HACCP principles	Guidelines for their application
	monitoring results indicate a trend toward loss of control at a CCP. The adjustments should be taken before a deviation occurs. Data derived from monitoring must be evaluated by a designated person with knowledge and authority to carry out corrective actions when indicated. If monitoring is not continuous, then the amount or frequency of monitoring must be sufficient to guarantee that the CCP is in control. Most monitoring procedures for CCPs will need to be done rapidly because they relate to on-line processes and there will not be time for lengthy analytical testing. Physical and chemical measurements are often preferred to microbiological testing because they may be done rapidly and can often indicate the microbiological control of the product. All records and documents associated with monitoring CCPs must be signed by the person(s) doing the monitoring and by a responsible reviewing official(s) of the company.
Principle 5 ***Establish the corrective action to be taken when monitoring indicates that a particular CCP is not under control.***	Specific corrective actions must be developed for each CCP in the HACCP system in order to deal with deviations when they occur. The actions must ensure that the CCP has been brought under control. Actions taken must also include proper disposition of the affected product. Deviation and product disposition procedures must be documented in the HACCP recordkeeping.
Principle 6 ***Establish procedures for verification to confirm that the HACCP system is working effectively.***	Establish procedures for verification. Verification and auditing methods, procedures, and tests, including random sampling and analysis, can be used to determine if the HACCP system is working correctly. The frequency of verification should be sufficient to confirm that the HACCP system is working effectively. Examples of verification activities include • review of the HACCP system and its records • review of deviations and product dispositions • confirmation that CCPs are kept under control Where possible, validation activities should include actions to confirm the efficacy of all elements of the HACCP plan.
Principle 7 ***Establish documentation concerning all procedures and records appropriate to these principles and their application.***	Efficient and accurate recordkeeping is essential to the application of a HACCP system. HACCP procedures should be documented. Documentation and recordkeeping should be appropriate to the nature and size of the operation. Documentation examples are: • hazard analysis • CCP determination • critical limit determination Record examples are: • CCP monitoring activities • deviations and associated corrective actions • modifications to the HACCP system