Hazard Analysis and Risk-Based Preventive Controls for Human Food: Guidance for Industry

Draft Guidance

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For questions regarding this draft document contact FDA's Technical Assistance Network by submitting the form available at http://www.fda.gov/Food/GuidanceRegulation/FSMA/ucm459719.htm.

U.S. Department of Health and Human Services
Food and Drug Administration
Center for Food Safety and Applied Nutrition

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Hazard Analysis and Risk-Based Preventive Controls for Human Food: Draft Guidance for Industry[1]

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Introduction and Purpose

I. Introduction

In 21 Code of Federal Regulations (CFR) part 117 (part 117), we have established our regulation entitled "*Current Good Manufacturing Practice, Hazard Analysis, and Risk Based Preventive Controls for Human Food*." We published the final rule establishing part 117 in the *Federal Register* of September 17, 2015 (80 FR 55908). Part 117 establishes requirements for current good manufacturing practice for human food (CGMPs), for hazard analysis and risk-based preventive controls for human food (PCHF), and related requirements as shown in Table 1.

Table 1. Subparts Established in 21 CFR Part 117

Subpart	Title
A	General Provisions
B	Current Good Manufacturing Practice
C	Hazard Analysis and Risk-Based Preventive Controls
D	Modified Requirements
E	Withdrawal of a Qualified Facility Exemption
F	Requirements Applying to Records That Must be Established and Maintained
G	Supply-Chain Program

The PCHF requirements implement the provisions of the FDA Food Safety Modernization Act (FSMA), established in section 418 of the Federal Food, Drug, and Cosmetic Act (FD&C Act) (21 U.S.C. 350g). Part 117 includes several complete or partial exemptions from the PCHF requirements. See 21 CFR 117.5 for a list and description of these exemptions.

This document is directed to those persons (you) who are subject to the PCHF requirements of part 117). Establishing risk-based preventive controls enables you to apply a proactive and

[1] This guidance has been prepared by the Office of Food Safety in the Center for Food Safety and Applied Nutrition at the U.S. Food and Drug Administration.

systematic approach to your food safety program through the establishment of preventive controls designed to protect your food, and the consumer, from biological, chemical (including radiological), and physical hazards. Risk-based preventive controls will not give you a "zero-risk" system for manufacturing, processing, packing, and holding food; rather, risk-based preventive controls are designed to minimize the risk of known or reasonably foreseeable food safety hazards that may cause illness or injury if they are present in the products you produce.

This guidance is intended to help you comply with the following specific PCHF requirements established in subparts C and G of part 117:

- A written food safety plan (FSP);
- Hazard analysis;
- Preventive controls;
- Monitoring;
- Corrective actions;
- Verification; and
- Associated records.

You only need to apply preventive controls if, after conducting a hazard analysis of the products and processes conducted at your facilities, you identify known or reasonably foreseeable biological, chemical, or physical hazards that require a preventive control. (Known or reasonably foreseeable hazards are the potential hazards to be evaluated by the facility to determine whether any require a preventive control in that facility.) We do not expect that known or reasonably foreseeable hazards for a food require a preventive control in all facilities. We also do not expect that all possible preventive measures and verification procedures apply to all foods produced in your facility. For example, we would not expect you to have sanitation controls to prevent food allergen cross-contact for a processing line that is dedicated to foods containing only that food allergen.

It is important for you to be aware of the potential hazards that may be associated with your food process and products. When you understand the potential hazards, it is easier to design and implement an FSP designed to control all identified food safety hazards that may cause illness or injury if they are present in the products you produce.

This guidance is not directed to persons who are exempt under 21 CFR 117.5. However, such persons may find some of the principles and recommendations in this guidance helpful in manufacturing, processing, packing, and holding human food.

We intend this draft guidance to include the 14 chapters listed in the Table of Contents. We will announce the availability of each draft chapter for public comment as the chapter becomes available, rather than delaying release of individual draft chapters until all the draft chapters are available. Those chapters that you see listed in the Table of Contents as “coming soon” are not yet available.

FDA's guidance documents, including this guidance, do not establish legally enforceable responsibilities. Instead, guidance describes the Agency's current thinking on a topic and should be viewed only as recommendations, unless specific regulatory or statutory requirements are cited. The use of the word *should* in Agency guidance means that something is suggested or recommended, but not required.

II. Purpose of this Guidance

The purpose of this guidance is to help you develop an FSP in accordance with the PCHF requirements. Specifically, this document provides guidance on:

- Understanding the biological, chemical (including radiological) and physical hazards that are commonly of concern in manufacturing, processing, packing, and holding of FDA-regulated food products;
- Understanding the components of an FSP and the importance of each component;
- Understanding how to conduct a hazard analysis and develop an FSP for the products that you process;
- Understanding how to identify control measures for common biological (specifically bacterial pathogens), chemical, and physical hazards associated with many processed foods so you can apply those controls to the hazards identified in your hazard analysis;
- Understanding how to identify and apply the preventive control management components (i.e., monitoring, corrective actions and corrections, and verification); and
- Understanding the recordkeeping requirements associated with the FSP and implementation of the FSP.

We recommend that you consider how this guidance relates to each of your operations and tailor your control strategies to the specific circumstances for the foods you process.

III. Glossary of Terms Used in This Guidance

A. Definitions Established in 21 CFR 117.3

Acid foods or **Acidified foods:** Foods that have an equilibrium pH of 4.6 or below.

Adequate: That which is needed to accomplish the intended purpose in keeping with good public health practice.

Allergen cross-contact: The unintentional incorporation of a food allergen into a food.

Correction: An action to identify and correct a problem that occurred during the production of food, without other actions associated with a corrective action procedure (such as actions to reduce the likelihood that the problem will recur, evaluate all affected food for safety, and prevent affected food from entering commerce).

Critical control point (CCP): A point, step, or procedure in a food process at which control can be applied and is essential to prevent or eliminate a food safety hazard or reduce such hazard to an acceptable level.

Environmental pathogen: A pathogen capable of surviving and persisting with the manufacturing processing, packing, or holding environment such that food may be contaminated and may result in foodborne illness if that food is consumed without treatment to significantly minimize the environmental pathogen. Examples of environmental pathogens

include *Listeria monocytogenes* and *Salmonella* spp. but do not include the spores of pathogenic sporeforming bacteria.

Facility: A domestic facility or foreign facility that is required to register under section 415 of the Federal Food, Drug, and Cosmetic Act, in accordance with the requirements of 21 CFR part 1, subpart H.

Food: Includes (1) articles used for food or drink for man or other animals, (2) chewing gum, and (3) articles used for components of any such article and includes raw materials and ingredients.

Food allergen: A major food allergen as defined in section 201(qq) of the Federal Food, Drug, and Cosmetic Act (e.g., any of the following: (1) Milk, egg, fish (e.g., bass, flounder, or cod), Crustacean shellfish (e.g., crab, lobster, or shrimp), tree nuts (e.g., almonds, pecans, or walnuts), wheat, peanuts, and soybeans. (2) A food ingredient that contains protein derived from a food specified in paragraph (1), except any highly refined oil derived from a food specified in paragraph (1) and any ingredient derived from such highly refined oil.)

Food-contact surfaces: Those surfaces that contact human food and those surfaces from which drainage, or other transfer, onto the food or onto surfaces that contact the food ordinarily occurs during the normal course of operation. “Food contact surfaces” includes utensils and food-contact surfaces of equipment.

Hazard: Any biological, chemical (including radiological), or physical agent that has the potential to cause illness or injury.

Hazard requiring a preventive control: A known or reasonably foreseeable hazard for which a person knowledgeable about the safe manufacturing, processing, packing, or holding of food would, based on the outcome of a hazard analysis (which includes the severity of the illness or injury if the hazard were to occur and the probability that the hazard will occur in the absence of preventive controls) establish one or more preventive controls to significantly minimize or prevent the hazard in a food and components to manage those controls (such as monitoring, corrections or corrective actions, verification and records) as appropriate to the food, the facility and the nature of the preventive control and its role in the facility’s food safety system.

Known or reasonably foreseeable hazard: A potential biological, chemical (including radiological), or physical hazard that is known to be, or has the potential to be, associated with the facility or the food.

Microorganisms: Yeast, molds, bacteria, viruses, protozoa, and microscopic parasites and includes species that are pathogens. The term “undesirable microorganisms” includes those microorganisms that are pathogens, that subject food to decomposition, that indicate that food is contaminated with filth, or that otherwise may cause food to be adulterated.

Monitor: To conduct a planned sequence of observations or measurements to assess whether a process, point, or procedure is under control and to produce an accurate record for use in verification.

Pathogen: A microorganism of public health significance.

Pest: Any objectionable animals or insects including birds, rodents, flies, and larvae.

Preventive controls: Those risk-based, reasonably appropriate procedures, practices, and processes that a person knowledgeable about the safe manufacturing, processing, packing, or holding of food would employ to significantly minimize or prevent the hazards identified under the hazard analysis that are consistent with the current scientific understanding of safe food manufacturing, processing, packaging, or holding at the time of the analysis.

Preventive controls qualified individual (PCQI): A qualified individual who has successfully completed training in the development and application of risk-based preventive controls at least equivalent to that received under a standardized curriculum recognized as adequate by FDA or is otherwise qualified through job experience to develop and apply a food safety system.

Qualified individual: A person who has the education, training, or experience (or a combination thereof) necessary to manufacture, process, pack, or hold clean and safe food as appropriate to the individual's assigned duties. A qualified individual may be, but is not required to be, an employee of the establishment.

RTE (Ready-to-eat) food: Any food that is normally eaten in its raw state or any other food, including a processed food, for which it is reasonably foreseeable that the food will be eaten without further processing that would significantly minimize biological hazards.

Sanitize: To adequately treat cleaned surfaces by a process that is effective in destroying vegetative cells of pathogens, and in substantially reducing numbers of other undesirable microorganisms, but without adversely affecting the product or its safety for the consumer.

Significantly minimize: To reduce to an acceptable level, including to eliminate.

Validation: Obtaining and evaluating scientific and technical evidence that a control measure, combination of control measures, or the food safety plan as a whole, when properly implemented, is capable of effectively controlling the identified hazards.

Verification: The application of methods, procedures, tests and other evaluations, in addition to monitoring, to determine whether a control measure or combination of control measures is or has been operating as intended and to establish the validity of the food safety plan.

B. Other Terms that FDA Uses in this Guidance

Clean in place (CIP): A system used to clean process piping, bins, tanks, mixing equipment, or larger pieces of equipment without disassembly, where interior

product zones are fully exposed and soil can be readily washed away by the flow of the cleaning solution.

Clean out of place (COP): A system (*e.g*. cleaning tanks) used to clean equipment parts, piping, etc. after disassembly.

Control point (CP): Any step at which biological, physical, or chemical factors can be controlled.

Cleaning: The removal of soil, food residue, dirt, grease or other objectionable matter.

Control, Control measure: See Preventive controls.

Corrective action: An action to identify and correct a problem that occurred during the production of food, including actions associated with a corrective action procedure (such as actions to reduce the likelihood that the problem will recur, evaluate all affected food for safety, and prevent affected food from entering commerce).

Critical limit (CL): A maximum and/or minimum value to which a biological, chemical, or physical parameter must be controlled to prevent, eliminate or reduce to an acceptable level the occurrence of a food-safety hazard.

Deviation: Failure to meet a critical limit.

End-Point Internal Product Temperature (EPIPT): A measurement of the internal temperature of the product at the end of the heat process.

Environmental sample: A sample that is collected from a surface or area of the plant for the purpose of testing the surface or area for the presence of microorganisms, usually environmental pathogens.

Food safety plan: A set of written documents that is based upon food safety principles and incorporates hazard analysis, preventive controls, and delineates monitoring, corrective action, and verification procedures to be followed, including a recall plan.

Food Safety System: The result of the implementation of the Food Safety Plan.

HACCP (Hazard Analysis and Critical Control Point): A system which identifies, evaluates, and controls hazards that are significant for food safety.

Hazard analysis: The process of collecting and evaluating information on hazards and conditions leading to their presence to decide which should be addressed through a preventive control.

Operating limits: Criteria that may be more stringent than critical limits and are established for reasons other than food safety.

Prerequisite programs: Procedures, including Current Good Manufacturing Practices (CGMPs), that provide the basic environmental and operating conditions necessary to support the Food Safety Plan.

Severity: The seriousness of the effects of a hazard.

IV. Table of Abbreviations Used in This Guidance

Abbreviation	What It Means
ABC	Almond Board of California
a_w	Water activity
CCP	Critical control point
CDC	Centers for Disease Control and Prevention
CIP	Clean in place
CFR	Code of Federal Regulations
CGMP	Current good manufacturing practice
CL	Critical limit
Codex	Codex Alimentarius Commission
COP	Clean out of place
CP	Control point
D-value	Decimal reduction time
EPIPT	End-Point Internal Product Temperature
EPA	U.S. Environmental Protection Agency
FALCPA	Food Allergen Labeling and Consumer Protection Act
FDA	U.S. Food and Drug Administration
FSIS	Food Safety and Inspection Service of the U.S. Department of Agriculture
FSMA	FDA Food Safety Modernization Act
FSP	Food safety plan

Abbreviation	What It Means
FSPCA	Food Safety Preventive Controls Alliance
HACCP	Hazard Analysis and Critical Control Point
HPP	High Pressure Processing
LACF	Low-acid canned food
NRTE food	Not ready-to-eat food
Part 117	Current Good Manufacturing Practice, Hazard Analysis, and Risk-Based Preventive Controls for Human Food (21 CFR part 117)
PCHF	"Preventive Controls for Human Food" (requirements in 21 CFR part 117 for hazard analysis and risk-based preventive controls for human food in accordance with section 418 of the FD&C Act)
PCQI	Preventive controls qualified individual
PPO	Propylene oxide
ROP	Reduced oxygen packaging
RTE food	Ready-to-eat food
TDT	Thermal Death Time
USDA	U.S. Department of Agriculture
WIP	Work-in-process
z-value	The degrees in Fahrenheit required for the thermal destruction curve to cross one log cycle (i.e., for reducing the D value by a factor of 10)

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Chapter 1: The Food Safety Plan

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[2] This guidance has been prepared by the Office of Food Safety in the Center for Food Safety and Applied Nutrition at the U.S. Food and Drug Administration.

1.1 Purpose of this Chapter

The guidance provided in this chapter is intended to help you understand what a food safety plan is and how it differs from a HACCP plan. The PCHF requirements specify that a facility must prepare, or have prepared, and implement a written food safety plan. See 21 CFR 117.126.

1.2 What is a Food Safety Plan?

A Food Safety Plan (FSP) consists of the primary documents in a preventive controls food safety system that provides a systematic approach to the identification of food safety hazards that must be controlled to prevent or minimize the likelihood of foodborne illness or injury. It contains a collection of written documents that describes activities that ensure the safety of food during manufacturing, processing, packing, and holding. See 21 CFR 117.126.

Below, we describe the written documents that make up the FSP (see 21 CFR 117.126(b)).

- Hazard analysis to identify whether there are hazards requiring a preventive control. This hazard analysis must be written, regardless of whether any hazards requiring a preventive control are identified. (Some facilities may not identify any hazards requiring a preventive control.)
- When the hazard analysis identifies hazards requiring a preventive control, the FSP also includes the following written documents:
    - Preventive controls (see 21 CFR 117.135), as appropriate to the facility and the food, to ensure safe food is produced, including:
        - Process controls
        - Food allergen controls
        - Sanitation controls
        - Supply-chain controls
        - Recall plan
        - Other controls
    - Procedures for monitoring the implementation of the preventive controls, as appropriate to the nature of the preventive control and its role in the facility's food safety system
    - Corrective action procedures, as appropriate to the nature of the hazard and the nature of the preventive control
    - Verification procedures, as appropriate to the nature of the preventive control and its role in the facility's food safety system

This written FSP is a record that you must maintain. See 21 CFR 170.126(c) and 21 CFR part 117, subpart F, particularly 21 CFR 117.310. In addition, you must maintain records to document that you are implementing the FSP. (See 21 CFR 117.190.)

The FSP starts with a hazard analysis of all ingredients and process or manufacturing steps (see Chapter 2 of this guidance). A "hazard" is any biological, chemical (including radiological), or physical agent that has the potential to cause illness or injury. It is important to understand that for the purposes of food safety, the term "hazard" refers only to the conditions or contaminants in food that are capable of causing illness or injury to people. These include hazards that occur naturally, that are unintentionally added or that may be intentionally added to a food for purposes of economic gain (i.e., economic adulteration). Many conditions are highly undesirable in food, such as the presence of insects, hair, filth or spoilage, and violations of regulatory food standards. All of these defects should be controlled in food processing; often, however, these defects do not directly affect the safety of the product. Unless these conditions directly affect food safety, documents addressing these issues are not included in an FSP. If the hazard analysis does not identify any hazards requiring a preventive control, the only document in the FSP would be the hazard analysis.

1.3 Who Develops the Food Safety Plan for a Facility?

A "preventive controls qualified individual" (PCQI) must develop (or oversee the development of) the FSP. A PCQI is a person with the education, training, or experience (or a combination of these) to develop and apply a food safety system. A PCQI can be qualified through job experience or by completing training equivalent to the standardized curriculum recognized as adequate by FDA (e.g., the Food Safety Preventive Controls Alliance (FSPCA) training). The PCQI does not need to be an employee of the facility. See 21 CFR 117.126(a) and the definition of PCQI in 21 CFR 117.3.

The FSP must be signed and dated by the owner, operator or agent in charge of the facility when it is first completed and whenever the plan is modified (See 21 CFR 117.310.). See section 1.6 of this document for information on signing an FSP that consists of multiple components such as HACCP plans, prerequisite programs, a recall plan and a variety of procedures.

1.4 What are the Differences Between a HACCP Plan and a Food Safety Plan?

Hazard Analysis and Critical Control Points (HACCP) is a preventive food safety strategy that is a systematic approach to the identification and assessment of the risk of hazards from a particular food or food production process or practice and the control of those hazards that are reasonably likely to occur. HACCP systems have been mandated by U.S. Federal regulations issued by the Food and Drug Administration (FDA) for seafood and juice and by the Food Safety and Inspection Service (FSIS) for meat and poultry.

The preventive controls approach to controlling hazards used in an FSP incorporates the use of risk-based HACCP principles in its development. (See the HACCP principles and their application as described by the National Advisory Committee on Microbiological Criteria for Foods.) Although an FSP and a HACCP plan are similar, they are not identical. Table 1-1 compares what is required for the elements of each type of plan. In the following paragraphs, we briefly discuss each of these elements.

Table 1-1 Comparison of Elements of a HACCP Plan and a Food Safety Plan

Element	HACCP Plan	Different in Food Safety Plan
Hazard Analysis	Biological, chemical, physical hazards	Chemical hazards include radiological hazards, consideration of economically motivated adulteration (21 CFR 117.130(b)(1)(ii))
Preventive Controls	CCPs for processes	Process CCPs + controls at other points that are not CCPs (21 CFR 117.135(a)(2))
Parameters and values	Critical limits at CCPs	Parameters and minimum/maximum values (equivalent to critical limits for process controls) (21 CFR 117.135(c)(1))
Monitoring	Required for CCPs	Required as appropriate for preventive controls (21 CFR 117.145)
Corrective actions and Corrections	Corrective actions	Corrective actions or corrections as appropriate (21 CFR 117.150(a))
Verification (including validation)	For process controls	Verification as appropriate for all preventive controls; validation for process controls; supplier verification required when supplier controls a hazard (21 CFR 117.155, 117.160)
Records	For process controls	As appropriate for all preventive controls (21 CFR 117.190)
Recall plan	Not required in the plan	Required when a hazard requiring a preventive control is identified (21 CFR 117.139)

1.4.1 Hazard Analysis and Controls to Address the Hazards

In developing a HACCP plan, the hazard analysis leads to the identification of critical control points (CCPs) where essential process controls are needed to prevent a foodborne hazard from causing illness or injury. Once CCPs are identified, critical limits are established that define the operating conditions in the process that must be effectively managed and monitored to control the hazard. When critical limits are not met, predefined corrective actions are taken. All of the steps in a HACCP plan are recorded and verified to ensure the system is operating as intended.

The FSP also begins with a hazard analysis, which includes consideration of radiological hazards as chemical hazards, as well as hazards due to economically motivated adulteration, such as addition of dyes containing lead to spices to enhance color. The outcome of the hazard

analysis is the facility's determination of whether there are any known or reasonably foreseeable hazards that require a preventive control. In an FSP, preventive controls may be applied at CCPs, but also at points other than at CCPs. The FSP includes control measures that, under the HACCP approach, may have been included in prerequisite programs or CGMPs. For example, supplier controls and food allergen controls have often been addressed through prerequisite programs, and sanitation controls have often been addressed through CGMPs. Process controls in an FSP will have parameters with minimum or maximum values, which are equivalent to the critical limits for HACCP CCPs. The use of preventive controls in an FSP may expand beyond CCPs by identifying and providing controls that may not be process-related, but are still important in the control of a hazard. Critical limits (minimum or maximum values) may not be practical or needed for non-process-related preventive controls, such as using hygienic zoning controls to prevent cross-contact and cross-contamination or ensuring that suppliers have adequately controlled hazards in the foods they are providing a manufacturer/processor.

1.4.2 Monitoring

In a HACCP plan, the CCPs are always monitored. In an FSP, preventive controls are only monitored as appropriate to the nature of the preventive control and its role in the facility's food safety system, and some preventive controls that are not applied at CCPs may not be monitored.

1.4.3 Corrective Actions and Corrections

In a HACCP plan, corrective actions are taken for deviations from a critical limit at a CCP. An FSP also provides for facilities to take corrective actions. However, immediate corrections (e.g., re-cleaning and sanitizing a line before start-up of production when food residue remains after cleaning) may be more appropriate for some preventive controls than a specific corrective action involving product risk evaluations of product safety for some preventive controls. The requirements for an FSP provide this flexibility.

1.4.4 Verification

In a HACCP plan, verification activities take place for process controls to ensure the process can control the hazards and the HACCP plan is being followed. In an FSP, verification activities will also be applied to preventive controls, but because preventive controls are not just process controls, there is flexibility to conduct verification activities as appropriate to the food, the facility and the nature of the preventive control and its role in the food safety system.

1.4.5 Validation

Some HACCP systems (e.g., for juice, and for meat and poultry products) require validation of the HACCP plan as a whole. In an FSP, validation means obtaining and evaluating scientific and technical evidence that a control measure, combination of control measures, or the food safety plan as a whole, when properly implemented, is capable of effectively controlling the identified hazards. The extent of validation activities may be less rigorous for some preventive controls than others, or may not be required (e.g., sanitation controls).

1.4.6 Recall plan

In a HACCP plan, recall plans have not been included. In an FSP, a Recall Plan must be prepared for each product for which a hazard requiring a preventive control has been identified.

1.5 What if a Facility Already Has a HACCP Plan?

If you have an existing HACCP plan, you should determine if it satisfies all the PCHF requirements in part 117. You can use existing programs, procedures, and records and supplement these with any additional information required, such as a supply-chain program.

1.6 What Format Is Required for a Food Safety Plan?

There is no standardized or required format for an FSP. This guidance provides flexibility in its approach to guide you in identifying and establishing preventive controls for different types of hazards identified in your hazard analysis. You can use whatever format works best for your facility, provided that the FSP includes all the required information. The formats shown in this guidance are for illustrative purposes only and may not be complete. The FSPCA training materials have FSP worksheets and teaching example model FSPs that may be helpful.

The FSP may consist of one or more existing HACCP plans, one or more prerequisite programs that include food safety controls, a recall plan, a written supply-chain program, written verification procedures such as environmental monitoring, and any other components specified in the PCHF requirements. You have flexibility in how to organize these documents within your FSP. One approach for organizing the FSP to allow for signing and dating it is to collect all these documents in a single location (e.g., a binder or folder) with a cover page containing the signature of the owner, operator, or agent in charge of the facility and the date on which the cover page was signed. However, because the FSP also could be a set of documents kept in different locations within the facility, another approach is for the owner, operator, or agent in charge of the facility to sign and date a list of the relevant documents (e.g., as in a Table of Contents).

1.7 When Are Changes Needed for a Food Safety Plan?

The FSP is a dynamic document that reflects your current hazard analysis, preventive controls, and applicable procedures. The FSP as a whole must be reanalyzed at least every 3 years. The reanalysis may be limited to the applicable portion of the FSP when you make changes to your system or equipment, when you become aware of new information about potential hazards associated with the food or your facility, when there is an unanticipated food safety problem, or when you find that a preventive control, combination of preventive controls, or the FSP itself is ineffective. See 21 CFR 117.170.

1.8 References

National Advisory Committee on Microbiological Criteria for Foods (NACMCF). 1998. “Hazard Analysis and Critical Control Point Principles and Application Guidelines.” *J Food Protect* 61: 1246-1259.

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Chapter 2: Conducting a Hazard Analysis

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[3] This guidance has been prepared by the Office of Food Safety in the Center for Food Safety and Applied Nutrition at the U.S. Food and Drug Administration.

2.1 Purpose of this Chapter

The guidance provided in this chapter is intended to help you conduct a hazard analysis in accordance with the PCHF requirements. The hazard analysis must be written, regardless of the results of the analysis, and must include two elements: (1) a hazard identification and (2) a hazard evaluation. You conduct a hazard analysis to identify and evaluate, based on experience, illness data, scientific reports, and other information, known or reasonably foreseeable hazards for each type of food manufactured, processed, packed, or held at your facility to determine whether there are hazards requiring preventive controls. See 21 CFR 117.130.

2.2 Overview of a Hazard Analysis

Part 117 does not define the term "hazard analysis." See Box 2-1 for a definition of "hazard analysis" that was developed by the Food Safety Preventive Controls Alliance (FSPCA).

Box 2-1. A Definition for "Hazard Analysis"

Hazard Analysis

The process of collecting and evaluating information on hazards and the conditions leading to their presence to determine which hazards are significant for food safety and therefore should be addressed in a HACCP plan or food safety plan (FSP).

Food Safety Preventive Controls Alliance

This section will guide you through the steps involved in conducting a hazard analysis. The PCHF requirements do not specify that you must use a "Hazard Analysis Worksheet" to conduct your hazard analysis. However, you may find it useful to use such a worksheet. See Form 2-B in Appendix 2 of this guidance and Box 2-3 in this chapter.

The PCHF requirements do not specify that you must use a certain format for conducting a hazard analysis. You may use formats other than the Hazard Analysis Worksheet that we provide in this guidance (including the use of a written narrative) as long as your hazard analysis contains the elements of hazard identification and hazard evaluation.

You use the hazard analysis to determine appropriate preventive controls. Your hazard analysis should provide justification for your decisions. You may group products together in a single hazard analysis worksheet if the food safety hazards and controls are essentially the same for all products in the group, but you should clearly identify any product or process differences. Keep in mind that you will need to refer to your written hazard analysis when you reanalyze or modify your FSP and that it can be a resource for you when you are asked by inspectors or auditors to justify why certain hazards were or were not included in your FSP.

The hazard analysis helps you to focus resources on the most important controls applied to provide safe food. If you do not conduct the hazard analysis correctly, and do not identify all hazards warranting preventive controls within the food safety plan, the food safety plan will not be effective in protecting consumers and preventing food safety issues, no matter how well your facility follows the plan. A proper analysis of biological, chemical (including radiological), and physical hazards associated with food ingredients, finished products, and the processes used calls for good judgment, detailed knowledge of the properties of the raw materials/other ingredients and manufacturing processes, and access to appropriate scientific expertise.

2.3 Recommended Activities Prior to Conducting a Hazard Analysis

Although the PCHF requirements do not specify that you must do so, we recommend that you conduct certain preliminary steps, and set up a Hazard Analysis Worksheet, as a useful framework for organizing and documenting your hazard analysis.

2.3.1 Conduct Preliminary Steps

Box 1-2. Preliminary Steps

1. Assemble a Food Safety Team
2. Describe the product, its distribution, intended use, and consumer or end user of the product
3. Develop a process flow diagram and verify it on site
4. Describe the process

Your written hazard analysis is part of your food safety plan, which must be prepared, or its preparation overseen, by one or more preventive controls qualified individuals (21 CFR 117.126(a)(2)). Although the PCHF requirements do not specify that you must do so, we recommend that a Food Safety Team of individuals with expertise in the day-to-day operations of your facility conduct your hazard analysis under the oversight of a Preventive Controls Qualified Individual. The individuals may include personnel from production, sanitation, quality control, laboratory, and maintenance. Using people from different functions within the facility can help provide a complete understanding of the process and things that can go wrong. You can supplement the expertise of the Food Safety Team by competent technical experts from other off-site functions within the firm (where applicable), such as research and development (R&D), technical applications groups, and quality management, as well as from outside experts from universities, cooperative extension services, trade associations, private consulting firms, or other sources.

The effectiveness of your Food Safety Team will be impacted by the quality and completeness of the information provided to them about the facility and food product(s) to be evaluated. Therefore, in order for your Food Safety Team to conduct the hazard analysis, we recommend that you define and document the following details for the facility:

- Product description, including its distribution, intended use, and identification of consumer or end user;
- Process flow diagram; and
- Detailed process description to supplement the process flow diagram.

A product description and how the product will be distributed helps team members understand elements of the product that may impact food safety, such as whether temperature controls are needed during distribution. The description should include the full name of the finished product, including descriptors such as ready-to-eat (RTE), frozen; the packaging type and material; and storage and distribution details. Understanding how the product will be used by the consumer (e.g., consumed with or without further processing, such as cooking) and knowing the intended consumer of the product (e.g., whether the food is intended for general public or specifically intended for a more susceptible population such as infants and young children (e.g., infant formula), the elderly (e.g., foods manufactured for nursing homes), or immunocompromised persons (e.g., foods manufactured for hospitals) helps to identify hazards of particular concern and the need for more stringent controls or verification activities.

The purpose of a process flow diagram is to provide a clear, simple description of the steps involved in the processing of your food product and its associated ingredients as they "flow" from receipt to distribution. The process flow diagram should cover all steps in the process that the facility performs, including receiving and storage steps for each raw material or other ingredient, preparation, processing, packaging, storage and distribution of the product. Additionally the process flow diagram should identify the equipment (e.g., pumps, surge tanks, hoppers, fillers) used in the operations. An accurate process flow diagram serves as a useful organizational format for elements of the food safety plan, because it identifies each of the steps that must be evaluated in the hazard analysis. You should verify the process flow diagram on-site in order to ensure no steps have been overlooked.

The purpose of a detailed process description is to explain what happens at each of the process steps. Information such as the maximum length of time a food is exposed to ambient temperature during processing, whether a food is handled manually, and whether rework is incorporated into product can be important for an accurate hazard analysis.

2.3.2 Set Up the Hazard Analysis Worksheet

Once you have assembled the Food Safety Team and started gathering the information you will use in your hazard analysis, we recommend that you set up a document that you will use to organize the hazard analysis. In this guidance, we describe how to set up an adaptation of the "Hazard Analysis Worksheet" used in HACCP systems to organize your hazard analysis. In this section of this chapter, we discuss how to set-up this worksheet (see Box 2-3, which shows a form adapted from a form used by the FSPCA). In the next section of this chapter, we provide details that will help you use the worksheet to conduct your analysis.

- Column 1: Here, you will list (1) receipt of ingredients used in the process as a means of identifying hazards associated with an ingredient (you may group some ingredients, e.g., "spices"); and (2)

processing steps. The process flow diagram recommended as a preliminary step (see Box 2-2) can help you to identify the processing steps that are included in the hazard analysis.

- Column 2: Here, you will list the results of your hazard identification – i.e., the food safety hazards that potentially could be introduced, controlled, or enhanced at this step (known or reasonably foreseeable hazards). Include all ingredient-related hazards, process-related hazards, and hazards that may be introduced from the environment.
- Column 3: Here, you will record the conclusions of your hazard evaluation – i.e., the determinations you make of whether each listed food safety hazard requires a preventive control (Yes or No).
- Column 4: Here, you will record the reasons that led to the conclusions of your hazard evaluation (i.e., the Yes/No conclusions listed in column 3). Explaining your reasons for a "No" conclusion can be just as important as explaining your reasons for a "Yes" conclusion. To be thorough and to have readily available answers to questions about your hazard analysis, you may find it useful to take a conservative approach by listing in Column 2 several potential hazards even though they clearly do not require a preventive control (especially when there has been significant debate over whether something is actually a potential hazard for the facility), and explain the reasons for your "No" conclusion. This can be useful both during your own review of your food safety plan and during review of your food safety plan by others – e.g., if an inspector or auditor questions whether a particular hazard was considered.
- Column 5: Here, you will identify preventive controls that will significantly minimize or prevent the food safety hazard (e.g., process, allergen, sanitation, supply-chain or other) for those hazards you identified as requiring a preventive control (i.e., a "Yes" in column 3).
- Column 6: Because the worksheet breaks your production process into multiple steps, and the preventive control may be applied at a step in the process other than the step where you listed the hazard, you specify whether the preventive control will be applied at this particular step (Yes/No). It is important to note that identifying a hazard at a processing step as one that requires a preventive control does not mean that the hazard must be controlled at that processing step.

Box 2-3. Example Hazard Analysis Work Sheet (Also see Form 2-B, Appendix 2)[4]

(1) Ingredient / Processing Step	(2) Identify potential food safety hazards introduced, controlled or enhanced at this step B = biological C = chemical, including radiological P = physical	(3) Are any potential food safety hazards requiring preventive control? (Yes/No)	(4) Justify your decision for column 3	(5) What preventive control measure(s) can be applied to significantly minimize or prevent the food safety hazard? *Process including CCPs, Allergen, Sanitation, Supplier, other preventive control*	(6) Is the preventive control applied at this step? (Yes/No)

2.4 Conducting a Hazard Analysis

2.4.1 Identify Potential Hazards (Ingredient-Related Hazards, Process-Related Hazards, and Hazards that May Be Introduced from the Environment (Hazard Identification)

See 21 CFR 117.130(b).

We recommend that you start your identification of hazards potentially associated with a food or process (the "known or reasonably foreseeable hazards") with a brainstorming session to generate a list of biological, chemical, and physical hazards. Consider the following as you work through this process:

- Information about the product description, intended use, and distribution.
- In-plant experience regarding the likelihood of hazards being associated with the finished products. This may include information from product testing results, consumer complaints, or knowledge of

[4] Adapted from a form available from the FSPCA in "FSPCA Preventive Controls for Human Food Training Curriculum, First Edition – 2016." The 2016 FSPCA form includes some additional features, such as a separate column for "Yes" and "No" responses and a separate row at each step for biological, chemical, and physical hazards (labeled B, C, and P, respectively). You can obtain the FSPCA form, including any later version if the form changes, from the FSPCA website (http://www.iit.edu/ifsh/alliance/resources/fspca_materials).

facility personnel about the condition, function, and design of the facility that may be relevant to contamination.

- Raw materials and ingredients used in the product. Hazards, such as food allergen hazards or pathogens known to be associated with specific types of foods, may be introduced during product formulation. For example, mayonnaise is formulated with egg, which is a food allergen; "egg" must be included on the label and the mayonnaise may be a source of allergen cross-contact in your facility.
- Activities conducted at each step in the manufacturing process. Some processes may introduce hazards (e.g., a broken chopping blade can introduce metal fragments; a broken glass container can introduce glass fragments; improper cooling can allow low numbers of microbial pathogens to increase).
- Equipment used to make the product. Some types of equipment are more difficult to clean than others or are more prone to damage, which may increase the risk of hazards (e.g., biological or physical) being introduced into the product.
- Types of packaging and packaging materials. Reduced oxygen packaging, used to increase shelf life (e.g., potato salad packaged in a plastic container with a snap lid), may create an environment that supports the growth of *Clostridium botulinum (C. botulinum)*.
- Sanitary practices. You should consider the sanitary conditions within the processing facility (e.g., cleanliness of equipment and processing environment) and employee hygiene when identifying hazards. Hard-to-clean equipment may result in pathogen harborage sites. Producing foods with different food allergens on the same line may result in allergen cross-contact.
- External information. Sources may include scientific papers, epidemiological studies (e.g., data from previous outbreaks associated with ingredients or processes relevant to a product), information from applicable government or industry food safety guidance documents, and historical data for similar products, if available.

After reviewing all the relevant information, the Food Safety Team can then develop a list of biological, chemical, and physical hazards that may be introduced, increased (e.g., due to pathogen growth), or controlled at each step described on the flow diagram. Enter those in column 2 of the Hazard Analysis Worksheet.

We recommend that you consult Chapter 3 and Appendix 1 of this guidance to help you identify potential hazards. Chapter 3 of this guidance provides a review of biological, chemical, and physical hazards and Appendix 1 of this guidance provides tables describing potential ingredient-related hazards and process-related hazards. The hazards identified in Chapter 3 and in Appendix 1 do not represent an exhaustive list of hazards potentially associated with a food facility or food. You are responsible for identifying any hazard that may be associated with your process or product, even if it is not listed in Chapter 3.

You may find the following list of questions helpful during the hazard identification process. We adapted this list from Hazard Analysis and Critical Control Point Principles and Application Guidelines published by the National Advisory Committee on Microbiological Criteria for Foods.

<u>Examples of questions to be considered when identifying potential hazards</u>

1. Ingredients

    a. Does the food contain any ingredients that may present microbiological hazards, chemical hazards, or physical hazards?

   b. Is all the water used at any point in the manufacturing process of the appropriate quality standard?

   c. What are the sources of the ingredients (geographical regions, specific supplier details)?

2. Intrinsic Factors – physical characteristics and composition of the product during and after processing

   a. What hazards may result if the food composition is not controlled?

   b. Does the food permit survival or promote pathogen growth and/or toxin formation during subsequent steps in the manufacturing process or distribution/storage?

   c. Are there similar products already in the marketplace, and if so, which hazards have been associated with those products? What is the food safety record of those products?

3. Processing procedures

   a. Does the process include a controllable processing step that destroys pathogens? If so, which pathogens? Consider not only vegetative cells but also spores, which are typically more resistant to inactivation treatments compared to their vegetative counterparts.

   b. Is the product susceptible to recontamination between processing and packaging? If so, what are the biological, chemical (including radiological), or physical hazards potentially associated with the process environment?

4. Microbial content of the food

   a. What is the baseline microbial content of the food?

   b. Does the microbial population change during the normal storage time of the food prior to consumption?

   c. Do changes in the microbial population affect the safety of the food?

   d. Based on the answers to the above questions, is there a significant likelihood of any biological hazards?

5. Facility design

   a. Does the layout of the facility provide an adequate separation of raw materials from RTE foods when this is necessary for food safety? If not, what are the hazards that could contaminate the RTE product?

b. Is positive air pressure maintained in product packaging areas? Is this required for product safety?

c. Is the traffic pattern for people and moving equipment a significant source of contamination?

6. Equipment design and use

a. Will the equipment provide the necessary time-temperature control to ensure a safe product?

b. Can the equipment be sufficiently controlled so that the variation in performance will be within the tolerances required to produce a safe product?

c. Is the equipment reliable and maintained in good repair?

d. Is the equipment easy to clean and sanitize?

e. Can parts of the equipment contaminate the product and thereby introduce physical hazards?

f. What product safety devices are used to control the potential for physical hazards to contaminate the product? Examples include: metal detectors, magnets, sifters, filters, screens, thermometers, bone removal devices, dud detectors

g. Are allergen protocols needed for using the same equipment for different products?

7. Packaging

a. Does the method of packaging affect the rate of growth of microbial pathogens and/or the formation of toxins?

b. Is the package clearly labeled with the appropriate storage instructions, e.g., “Keep refrigerated,” if required for safety?

c. Does the package include instructions for the safe handling and preparation of the food by the end user?

d. Is the packaging material resistant to damage and effective in preventing post-packaging microbial contamination?

e. Are tamper-evident packaging features used?

f. Is each package and case legibly and accurately coded?

g. Does each package contain the proper label?

h. Are allergenic ingredients included in the list of ingredients on the label?

8. Employee health, hygiene, and education

    a. Can employee health or personal hygiene practices impact the safety of the food being processed, and in what way(s)?

    b. Do the employees understand the process and the factors they must control to assure the preparation of safe foods?

    c. Will the employees inform management of a problem that could impact food safety?

9. Storage conditions between packaging and the end user

    a. What is the likelihood that the food will be improperly stored at the wrong temperature?

    b. Would an error in storage lead to a microbiologically unsafe food?

10. Intended use and user

    a. Will the food be heated by the consumer?

    b. Will there likely be leftovers? If so, how and maximally for how long should they be stored? How should they be re-heated?

    c. Is the food intended for the general public?

    d. Is the food intended for consumption by a population with increased susceptibility to illness or a particular hazard (e.g., Infants, the elderly, the immuno-compromised, or pregnant women)?

    e. Is the food intended to be used for institutional feeding (e.g., in school cafeterias, hospitals) or in private homes?

2.4.2 Evaluate Potential Hazards to Determine Whether the Hazard Requires a Preventive Control (Hazard Evaluation)

See 21 CFR 117.130(c).

- Under 21 CFR 117.130(c)(1)(i), you must assess the severity of the illness or injury if the hazard were to occur and the probability that the hazard will occur in the absence of preventive controls.
- Under 21 CFR 117.130(c)(1)(ii), you must include an evaluation of environmental pathogens whenever an RTE food is exposed to the environment prior to packaging and the packaged food does

not receive a treatment or otherwise include a control measure (such as a formulation lethal to the pathogen) that would significantly minimize the pathogen.

- Under 21 CFR 117.130(c)(2), you must consider the effect of certain factors on the safety of the finished food for the intended consumer.

We discuss each of these points in the remainder of this section.

Consult the hazards in Chapter 3 and controls in Chapters 4 and 5 of this guidance document for each of the potential hazards that you entered in Column 2 of the Hazard Analysis Worksheet. These chapters offer guidance for completing your hazard analysis and developing your FSP. Chapters 6-13 each contain a section "Understand the Potential Hazard" that provides information about the significance of the hazard, the conditions under which it may develop in a processed product, and methods available to control the hazard.

Once you have identified all potential hazards, the next step is to evaluate each hazard and determine whether the hazard poses a significant risk to the end user or consumers in the absence of a preventive control. Narrow the list of potential hazards that you entered in column 2 to those that require a preventive control.

For example, at the receiving step for ingredients, you may identify soy as an allergen in your product because soy protein is one of the ingredients. Because it is an allergen, you would mark "Yes" in column 3 and explain that soy may cause allergic reactions in some consumers in column 4.

For each hazard also consider the following:

- Seriousness of the potential illness or injury resulting from exposure to the hazard, and
- The likelihood of occurrence in the absence of a preventive control.

2.4.2.1 Evaluating severity

To evaluate the severity of a potential hazard, you should consider certain factors, including

- susceptibility of intended consumers to foodborne illness (e.g., infants, children, and immunocompromised persons may be more susceptible to certain foodborne illnesses),
- the potential magnitude and duration of the illness or injury (e.g., how long an individual may be sick, and whether hospitalization or death is common), and
- the possible impact of secondary problems (e.g., chronic sequelae such as kidney damage or reactive arthritis).

If your facility does not have the expertise to evaluate the severity of a potential hazard, you should consult with outside experts.

2.4.2.2 Estimating the likely occurrence

The likelihood of occurrence of a particular food hazard in the food when consumed can be influenced by:

- Frequency of association of the hazard with the food or facility
- Effectiveness of facility programs such as CGMPs

- Method of preparation in the establishment
- Conditions during transportation
- Expected storage conditions
- Likely preparation and handling steps before consumption

Knowing your product, ingredients, processes, preparation methods, packaging, transportation, distribution, and likely use of the product will be helpful in estimating the likely occurrence of potential hazards. Hazards identified in one operation or facility may not be significant in another operation or facility producing the same or similar products because different equipment and processes may be used, the ingredients and their source may be different, or for other reasons. For example, one facility may package a beverage in glass and another may package the same product in plastic. You should consider each operation and facility location individually when estimating the likely occurrence of a food safety hazard.

When estimating likely occurrence, you should consider information from several sources, such as the following:

- Data from outbreaks of foodborne illness,
- Data from recalls,
- Information in the scientific literature, and
- Experience and historical information gathered by your facility.

2.4.2.2.1 Data from outbreaks

Your Food Safety Team should consider foodborne illness outbreaks in the same or similar products, as well as data on foodborne illness outbreaks provided from other product types that may be relevant, or from foods prepared in retail food establishments rather than in manufacturing facilities. Several publicly available resources can provide such information. For example, we provide information on our findings related to outbreaks, including a discussion, whenever possible, of factors that would have contributed to the outbreak at the processing or production site for the foods we regulate. Moreover, the Centers for Disease Control and Prevention (CDC) provides considerable information on outbreaks that occurred from processed foods, as well as from foods prepared in restaurants, retail establishments, and other locations. See Box 2-4 for a list of useful reports and the list of references in section 2.6 of this chapter for how to access these reports. Information may also be available on outbreaks from similar foods that occur in other countries. For example, the European Food Safety Authority (EFSA) publishes summaries of foodborne disease outbreaks in European countries.

Box 2-4. Sources of Data about Outbreaks [5]

Food and Drug Administration (FDA)

- Outbreak investigations – reports for FDA regulated foods

Centers for Disease Control and Prevention (CDC)

- Foodborne Outbreaks (including links to the List of Selected Multistate Foodborne Outbreak Investigations (see below) and Morbidity and Mortality Weekly Report reports on foodborne outbreaks)
- List of Selected Multistate Foodborne Outbreak Investigations - searchable database for selected U.S. outbreaks by year and by pathogen
- Attribution of Foodborne Illness – reports on foods associated with illness

Center for Science in the Public Interest (CSPI)

- Outbreaks & Recalls

2.4.2.2.2 Data from recalls

Recalls provide useful information in understanding the likely occurrence of potential hazards and the foods in which they occur. We categorize recalls as specified in 21 CFR 7.3(m):

Recall classification means the numerical designation, i.e., I, II, or III, assigned by the Food and Drug Administration to a particular product recall to indicate the relative degree of health hazard presented by the product being recalled.

- Class I is a situation in which there is a reasonable probability that the use of, or exposure to, a violative product will cause serious adverse health consequences or death (21 CFR 7.3(m)(1);
- Class II is a situation in which use of, or exposure to, a violative product may cause temporary or medically reversible adverse health consequences or where the probability of serious health consequences is remote (21 CFR 7.3(m)(2); and
- Class III is a situation in which use of, or exposure to, a violative product is not likely to cause illness or injury (21 CFR 7.3(m)(3).

Federal and state websites post information on food recalls. See Box 2-5 for a list of some helpful federal websites that provide data about recalls. See the list of references in section 2.6 of this chapter for the links to access this information.

[5] See section 2.6 of this chapter for information on how to access these sources of data about outbreaks.

Box 2-5. Sources of Data About Recalls[6]

- **Food and Drug Administration (FDA) Recalls, Market Withdrawals, & Safety Alerts**
- **U.S. Department of Agriculture (USDA) Food Safety and Inspection Service Recall Archive**
- **Foodsafety.gov (Gateway to Federal Food Safety Information), Recalls & Alerts**

2.4.2.2.3 Information in the scientific literature

Peer-reviewed scientific journals and other sources of technical literature (e.g., Codex Alimentarius Commission (Codex), the Food and Agriculture Organization and the World Health Organization) provide considerable information on foodborne hazards, including their occurrence, their potential growth in foods (e.g., for biological hazards), and their control. A useful search engine is Google Scholar. USDA provides a microbial modeling program that is available online and can be used to evaluate potential growth of pathogens under a variety of conditions. ComBase is an online tool for quantitative food microbiology. It contains the ComBase database of microbial growth and survival curves and the ComBase Predictor that uses the data to predict growth or inactivation of microorganisms. Keep in mind that modeling programs may not reflect exactly what will occur in a particular food, but they can provide an estimate of relative risk of different scenarios. Codex maintains internationally recognized codes of practice that are based on scientific literature and are available in several languages. Trade associations also provide food safety recommendations for specific types of foods and industry needs.

We provide other guidance documents that contain product-specific food safety information (e.g., on shell eggs, cheese, fruits, vegetables, and milk). These guidance documents, which represent FDA's current thinking on a topic, are organized by topic and by year of publication, with recently added guidance documents at the top of the page.

2.4.2.2.4 Establishment's historical information

You may already have considerable information on your products from various laboratory tests on finished products, ingredients, in-process materials, or environmental monitoring. In addition, you may have experienced a contamination problem in the past that suggests a hazard is reasonably foreseeable, or received consumer complaints about certain hazards, such as physical hazards.

You should evaluate the potential hazards independently at each processing step to determine whether you should identify that hazard as one requiring a preventive control. For example, you would identify a hazard as one requiring a preventive control if:

- it is reasonably likely that the hazard can be introduced at an unsafe level at that processing step; or
- it is reasonably likely that the hazard can increase to an unsafe level at that processing step; or

[6] See section 2.6 of this chapter for information on how to access these sources of data about recalls.

- the hazard was identified in an ingredient or at another processing or handling step and it can be controlled (i.e., significantly minimized or prevented) at the current processing step.

When evaluating whether a hazard requires a preventive control, you should consider the method of distribution and storage and the intended use and consumer of the product (information which you developed as part of your preliminary steps in conducting a hazard analysis).

If you determine that a potential hazard requires a preventive control, you should answer "Yes" in column 3 of the Hazard Analysis Worksheet. If you determine that it does not require a preventive control, you should answer "No" in that column. In column 4, record your reason for your "Yes" or "No" answer. If the hazard does not require a preventive control, you would not complete columns 5 and 6.

2.4.2.3. Evaluating environmental pathogens whenever a ready-to-eat food is exposed to the environment

If the food you make is ready-to-eat (see the definition in 21 CFR 117.3, which we included in the Glossary in section III of the Introduction of this guidance), the food could be contaminated with environmental pathogens such as *Listeria monocytogenes* (*L. monocytogenes*) or *Salmonella*. See 21 CFR 117.130(c)(1)(ii) for when the PCHF requirements specify that you must consider environmental pathogens in your hazard analysis.

2.4.2.4. Evaluation factors

When evaluating hazards, you must consider the effect of the following on the safety of the finished food for the consumer (21 CFR 117.130(c)(2)):

- The formulation of the food: The addition of certain ingredients such as acids and preservatives may be critical to the safety of the food, because they may inhibit growth of, or kill, microorganisms of public health significance. This could impact the evaluation at steps during production and storage with respect to the hazard of ''pathogen growth.'' A multicomponent food may have individual ingredients that do not support growth of undesirable microorganisms (e.g., because of pH or a_w), but when put together there may be an interface where the pH and a_w change (e.g., pies, layered breads). The formulation may contain an ingredient (e.g., a flavoring, coloring, or incidental additive) that is (or contains) an allergen that requires label control and possibly controls to prevent cross-contact.
- The condition, function, and design of the facility and equipment: The condition, function, or design of a facility or its equipment could potentially result in the introduction of hazards into foods. For example, older equipment (e.g., older slicing, rolling and conveying equipment) may be more difficult to clean (e.g., because of close fitting components or hollow parts) and, thus, provide more opportunities for pathogens to become established in a niche environment than modern equipment designed to address the problem of pathogen harborage in niche environments; in such instances enhanced sanitation controls may be appropriate. Equipment designed such that there is metal-to-metal contact may generate metal fragments; a preventive control such as metal detectors may be appropriate. A facility that manufactures, processes, or packs an RTE product such as fresh soft cheese may have cold, moist conditions that are conducive to the development of a niche where the pathogen *L. monocytogenes* can become established and contaminate food-contact surfaces and, eventually, foods; enhanced sanitation controls may be appropriate for such facilities. Facilities with closely spaced equipment should consider the impact of the close spacing on the potential for allergen cross-contact to be a hazard; targeted food allergen controls may be appropriate.

- Raw materials and other ingredients: A food can become contaminated through the use of contaminated food ingredients. Ingredients such as flavorings, colorings, or incidental additives may contain ''hidden'' allergens. Machinery-harvested produce may be contaminated with physical hazards, because the machinery can pick up foreign material from the field.
- Transportation practices: The safety of a food can be affected by transportation practices for incoming raw materials and ingredients or for outgoing finished product. For example, when a food requires time/temperature control for safety, time/temperature controls would be important during transportation. Distributing a food in bulk without adequate protective packaging makes the product susceptible to contamination during transportation—e.g., from pathogens or chemicals present in an inadequately cleaned vehicle or from other inadequately protected foods that are being co-transported and are potential sources of contamination.
- Manufacturing/processing procedures: Hazards may arise from manufacturing/processing processes such as cooling or holding of certain foods due to the potential for germination of pathogenic sporeforming bacteria such as *Clostridium perfringens (C. perfringens)* and *Bacillus cereus (B. cereus)* (which may be present in food ingredients) as a cooked product is cooled and reaches a temperature that will allow germination of the spores and outgrowth. Hazards also may arise from manufacturing/processing processes such as acidification due to the potential for germination of spores of *C. botulinum*, with subsequent production of botulinum toxin, if the acidification is not done correctly. Toxins can be produced by the bacteria *Staphylococcus aureus (S. aureus)* or *B. cereus* in a product that has been heated and held at room temperature during the manufacturing process if the product formulation supports growth and toxin formation by the bacteria and *S. aureus* or *B. cereus* is present in the ingredients of the product or is introduced by poor employee hygiene (e.g., *S. aureus*). Physical hazards may occur from metal fragments generated during the manufacture of food on equipment in which metal (e.g., wires, saw blades or knives) is used to cut products during manufacturing.
- Packaging activities and labeling activities: Preventive controls for glass may be needed for products packed in glass. Preventive controls for *C. botulinum* may be needed when packing certain foods in modified atmosphere packaging. Label controls may be needed to ensure all food allergens are listed on the label of packaged foods that contain allergens.
- Storage and distribution: Biological hazards are more likely to require a preventive control during storage and distribution in foods that require refrigerated storage to maintain safety than in shelf-stable foods.
- Intended or reasonably foreseeable use: Some foods that are intended to be cooked by the consumer may also have uses that do not include cooking, such as soup mixes used to make dips. Whenever an RTE food is exposed to the environment prior to packaging and the packaged food does not receive a treatment or otherwise include a control measure (such as a formulation lethal to the pathogen) that would significantly minimize the pathogen, hazards such as *Salmonella* spp., *L. monocytogenes*, and *Escherichia coli* O157:H7 (*E. coli* O157:H7) must be considered to determine if they require a preventive control. (See 21 CFR 117.130(c)(1)(ii).)
- Sanitation, including employee hygiene: Sanitation measures and practices can impact the likelihood of a hazard being introduced into a food. For example, the frequency with which a production line is shut down for a complete cleaning can impact the potential for food residues to transfer pathogens from equipment to foods (e.g., pathogens present on raw produce that could carry over into the next production cycle on a line). Practices directed at worker health and hygiene can reduce the potential for transfer of pathogens such as *Salmonella* spp., hepatitis A, and norovirus.
- Any other relevant factors, such as the temporal (e.g., weather-related) nature of some hazards (e.g., levels of some natural toxins): Hazards such as aflatoxin are subject to a weather-dependent effect in that aflatoxin levels in some raw agricultural commodities are more of a problem in some years than in others.

As noted earlier, identifying a hazard at a processing step as one that requires a preventive control does not mean that the hazard must be controlled at that processing step. Once you

determine that a hazard requires a preventive control, the next step is to identify control measures to control the hazard.

2.5 Identify Preventive Control Measures

Box 2-6. Definition of "Preventive Controls" in Part 117

Preventive Controls

Those risk-based, reasonably appropriate procedures, practices, and processes that a person knowledgeable about the safe manufacturing, processing, packing, or holding of food would employ to significantly minimize or prevent the hazards identified under the hazard analysis that are consistent with the current scientific understanding of safe food manufacturing, processing, packaging, or holding at the time of the analysis.

21 CFR 117.3

For each hazard that your Food Safety Team first identified in Column 2 as potentially associated with an ingredient, processing step, or the environment, and then identified in Column 3 as requiring a preventive control, you must identify and implement preventive controls to provide assurances that any hazards requiring a preventive control will be significantly minimized or prevented. See 21 CFR 117.135. If a process control can be applied at a point or step in the food production process to prevent or eliminate the food safety hazard, or reduce it to an acceptable level, you should classify the point or step as a Critical Control Point (CCP). There are several control approaches, which may or may not include CCPs, that you can consider, depending on the potential hazard and where in the process flow diagram you determine the control measure should be applied. These include:

- Supply-chain controls
- Food allergen controls
- Sanitation controls
- Process controls

Supply-chain controls involve verification of controls used by suppliers to control hazards in raw materials or other ingredients before receipt by a manufacturer/processor. Food allergen controls include labeling and controls to prevent cross-contact, such as product sequencing, in addition to sanitation controls (i.e., to prevent cross-contact with allergens from other foods produced on the same line). Sanitation controls may be important to prevent contamination with microbial pathogens, especially for RTE foods that are exposed to the environment. Process controls are applied at specific processing steps, where critical parameters such as time and temperature may be identified to control the hazard of concern. See Box 2-7 for some examples of in-process controls.

Box 2-7. Examples of In-Process Controls

Examples of In-Process Controls
• Acidification • Cooking • Drying • Fermentation • Filtering • Freezing • High pressure processing • Irradiation • Metal detection • Pasteurization • Refrigeration • Retort processing • Use of x-ray area

For every hazard you identify as requiring a preventive control, you must identify and implement at least one preventive control measure. See 21 CFR 117.135. Importantly, remember that more than one hazard may be addressed by a specific control measure. For example, several vegetative pathogens, such as *Salmonella*, *L. monocytogenes*, and *E. coli* O157:H7, are killed by cooking. Several chapters in this guidance provide one or more control strategy examples for how one or more hazards can be controlled, because there are often more ways than one to control a hazard. The control strategy examples also contain control measure information. Record the control measure(s) that you choose in column 5 of the Hazard Analysis Worksheet for each "Yes" answer in column 3.

When identifying preventive controls for your food process, your Food Safety Team should also consider

- The effect of the control on identified potential food safety hazards (e.g., Does the preventive control significantly minimize or prevent the potential food safety hazards identified? Is the preventive control hazard-specific or does it control more than one hazard? Does the control effectiveness depend upon other controls? Can the preventive control be validated and verified?)
- The feasibility of monitoring those controls (e.g., Are the critical limits (minimum or maximum values) and, if appropriate, operating limits, for the preventive control measureable and practical? Can you obtain the results of monitoring quickly (i.e., real-time) to determine if the process is in control? Are you monitoring a batch or continuous process? Are you monitoring continuously or doing spot checks? Can the parameters be monitored in-line or must the product be sampled? Will the monitored parameters be indirectly linked to the critical limit (i.e., belt speed or pump flow rate for time of process)? Who will perform the monitoring or checks and what are the required qualifications? How is the monitoring to be verified?)

- The location of the control with respect to other processing control measures (e.g., Is the application of the control measure at the last point in the process to ensure control of the targeted potential food safety hazard? Will the failure of an upstream control result in failure of downstream controls (i.e., acidification failure impacting thermal process efficacy for an acidified food)? Are monitoring activities appropriate to ensure control at this step?)
- Corrective actions that will be needed in the event of a failure of a control measure or a significant processing variability (e.g., Can the process control and critical parameter be brought quickly back into control? How will you determine if the control measure is once again under control? Can the implicated product be identified and its safety evaluated? Can the cause of the loss of control be identified and corrected? What actions would be needed to reduce the likelihood of the failure to recur? Can the product be reprocessed? What actions would be necessary to prevent unsafe product from entering commerce (e.g., can product be diverted to animal food or does the product need to be destroyed)?)
- The severity of the consequences in case of a failure of a control measure (e.g., Is it reasonably likely that unsafe food would be produced as a result of the control measure failure? Is the hazard that could occur reasonably likely to cause serious adverse health consequences or death?)
- Whether the control measure is applied to eliminate or significantly reduce the level of the hazard (e.g., Will the control measure eliminate the hazard, or is the control measure only able to minimize the hazard?)
- Synergistic effects between control measures (e.g., Consider whether one control measure can enhance the efficacy of another control measure. For example, formulation process controls may combine the use of preservatives, acidification, and water activity at levels that individually will not control pathogen growth, but they work together to do so.)

You use your written hazard analysis to design the approaches you will use to control the hazards. The more thorough the hazard analysis, the more targeted your controls will be to ensure hazards are significantly minimized or prevented, and the more effective your food safety program will be in preventing illness or injury to consumers.

In the chapters that follow we address managing food safety hazards through heat treatments, time/temperature control, product formulation, sanitation controls, and food allergen controls. We address supply-chain controls in a separate guidance.

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Hazard Analysis and Risk-Based Preventive Controls for Human Food: Draft Guidance for Industry[7]

This draft guidance, when finalized, will represent the current thinking of the Food and Drug Administration (FDA or we) on this topic. It does not establish any rights for any person and is not binding on FDA or the public. You can use an alternative approach if it satisfies the requirements of the applicable statutes and regulations. To discuss an alternative approach, contact FDA's Technical Assistance Network by submitting the form available at http://www.fda.gov/Food/GuidanceRegulation/FSMA/ucm459719.htm.

Chapter 3: Potential Hazards Associated with the Manufacturing, Processing, Packing, and Holding of Human Food

Table of Contents

[7] This guidance has been prepared by the Office of Food Safety in the Center for Food Safety and Applied Nutrition at the U.S. Food and Drug Administration.

3.1 Purpose of this Chapter

The guidance in this chapter is intended to help you consider the biological, chemical, and physical hazards that are commonly of concern in food plants and that should be addressed in a hazard analysis. It addresses ingredient-related hazards, process-related hazards, and hazards that may be introduced from the food-production environment (facility-related hazards). It does not provide an exhaustive compendium of hazards or details about each hazard. Where possible, we cite scientific literature, regulations, and/or guidance (issued by FDA or our food safety regulatory partners) that may provide useful detailed discussion or analysis of hazards of concern. See the definition of "hazard" in 21 CFR 117.3.

It is important for you to understand the potential hazards that may be associated with your products using the raw materials and other ingredients, processes, and equipment specific for those products, as well as the environment of your specific facility. If you identify hazards requiring a preventive control, you will then have to determine what preventive controls are needed to reduce food safety risks and ensure the safety of your products for human consumption. See 21 CFR 117.130 and 117.135. Although this chapter briefly describes the types of preventive controls that may be appropriate for you to implement to control certain hazards, see Chapter 4 and Chapters 6 through 13 of this guidance for more detailed discussion of applicable preventive controls.

3.2 Potential Hazards

Food products can become contaminated with biological, chemical (including radiological), or physical hazards. Table 3-1 provides examples of potential hazards and is not exhaustive.

Table 3-1 Examples of Potential Hazards

Hazard Category	Hazard Sub-category	Examples
Biological	Bacteria	• *Bacillus cereus* (*B. cereus*) • *Campylobacter jejuni* (*C. jejuni*) • *Clostridium botulinum* (*C. botulinum*) • *Clostridium perfringens* (*C. perfringens)* • Shiga-toxin producing *Escherichia coli* such as O157:H7 (*E. coli* O157:H7) • *Listeria monocytogenes* (*L. monocytogenes*) • *Salmonella* spp. • *Shigella* spp. • *Staphylococcus aureus* (*S. aureus*)

Hazard Category	Hazard Sub-category	Examples
Biological	Protozoa and Parasites	• *Cryptosporidium parvum* • *Cyclospora cayetanensis* • *Giardia lamblia (G. intestinalis)* • *Trichinella spiralis*
Biological	Viruses	• Norovirus • Hepatitis A • Rotavirus
Chemical	Pesticide residues	• Organophosphates • Carbamates • Chlorinated hydrocarbons • Pyrethroids
Chemical	Heavy Metals	• Lead • Arsenic • Cadmium • Mercury
Chemical	Drug residues (veterinary antibiotics)	• Chloramphenicol • Beta- Lactams
Chemical	Industrial chemicals	• Ammonia
Chemical	Environmental contaminants	• Dioxins
Chemical	Mycotoxins	• Aflatoxin • Patulin • Ochratoxin • Fumonisin • Deoxynivalenol
Chemical	Allergens	• Milk, eggs, fish, crustacean shellfish, tree nuts, peanuts, wheat, and soybeans (commonly called “the Big 8”)
Chemical	Unapproved colors and additives	• FD&C Red #4 • Melamine

Hazard Category	Hazard Sub-category	Examples
Chemical	Substances associated with a food intolerance or food disorder	• Lactose • Yellow #5 • Sulfites • Carmine and Cochineal • Gluten
Chemical	Radionuclides	• Radium 226 and 228 • Uranium 235 and 238 • Strontium 90 • Cesium 137 • Iodine 131
Physical	N/A	• Metal • Glass • Hard plastic

As discussed in Chapter 2 of this guidance, when conducting your hazard analysis you must consider the potential for biological, chemical, and physical hazards to be related to raw materials and other ingredients (ingredient-related hazards), processes (process-related hazards), and the food-production environment (facility-related hazards) (21 CFR 117.130). In Chapter 2 we also provide examples of questions to be considered when identifying potential hazards in the following areas:

- Ingredients;
- Intrinsic factors;
- Processing procedures;
- Microbial content of the food;
- Facility design;
- Equipment design and use;
- Packaging;
- Employee health, hygiene, and education; and
- Storage conditions between packaging and the end user.

Throughout this chapter, we discuss potential biological, chemical, and physical hazards from the perspective of ingredient-related hazards, process-related hazards, and facility-related hazards, considering the issues and factors listed immediately above.

3.3 Biological Hazards

You must conduct a hazard analysis to identify and evaluate known or reasonably foreseeable biological hazards, including microbiological hazards such as parasites, environmental pathogens, and other pathogens. See 21 CFR 117.130(b)(1)(i). When your hazard analysis identifies a known or reasonably foreseeable biological hazard that requires a preventive control, you must identify and implement a preventive control for the biological hazard. See 21 CFR 117.135(a)(1).

The biological hazards that are the focus of this guidance are bacterial pathogens (e.g., *Salmonella* spp., *Listeria monocytogenes*, *Clostridium botulinum*, and Shiga-toxin producing *Escherichia coli* (STEC) such as O157:H7) that may be associated with foods or food processing operations and can cause consumer illness or disease. The other biological hazards, viruses (e.g., norovirus and hepatitis A) and parasites (e.g., *Cryptosporidium* spp. and *Giardia intestinalis*), are also known to cause illness or disease, but these would generally be addressed by following Current Good Manufacturing Practice (e.g., worker hygiene and disease control) in facilities and our regulation entitled "Standards for the Growing, Harvesting, Packing, and Holding of Produce for Human Consumption" (21 CFR part 112) (e.g., worker hygiene and disease control, water safety) on farms that supply raw agricultural commodities to facilities.

Food products can become contaminated with bacterial pathogens that can be:

- Ingredient-related hazards - i.e., introduced from raw materials and other ingredients;
- Process-related hazards - e.g., if the pathogens:
    - Survive processing that was intended to significantly minimize the pathogen;
    - Increase in number due to lack of time/temperature control or due to the food's formulation; or
    - Selectively grow, and/or produce toxin, in a food as a result of using reduced oxygen packaging;
- Facility-related hazards – e.g., if the pathogens are introduced from:
    - Food processing equipment (e.g., insanitary equipment and utensils);
    - Cross-contamination between raw and cooked products;
    - Air; or
    - Contaminated water or sewage; or
- People-related hazards – e.g., due to people handling the product during packing or processing. (Such people-related hazards are sometimes controlled by following Current Good Manufacturing Practice (e.g., worker hygiene and disease control)).

For further details on the sources of biological hazards that can be introduced into food products, see Tables 1A through1Q and Tables 3A through 3- of Appendix 1 of this guidance.

Bacterial pathogens can be classified based on whether they form spores ("sporeformers") or whether they only exist as vegetative cells and do not form spores ("non-sporeformers"). Spores are not hazardous as long as they remain in the spore state. Unfortunately, spores are very resistant to heat, chemicals, and other treatments that would normally kill vegetative cells of both sporeformers and non-sporeformers. As a result, when spores are a concern, the process steps used to kill them are often much more severe than those necessary to kill vegetative cells.

When spores survive a processing step designed to kill vegetative bacteria, they may become a hazard in the food if they are exposed to conditions that allow germination and growth as vegetative cells. This can be particularly serious when a processing step has removed most of their competition. Thus, other controls such as reduced pH or water activity (a_w) or temperature control (refrigeration or freezing) may be needed to control sporeformers that remain after a kill step.

Because the characteristics of foodborne pathogens differ, the preventive controls that you identify and implement to control specific pathogens should be based on the characteristics of those specific pathogens. In the remainder of this section on biological hazards, we briefly review characteristics of common vegetative and sporeforming foodborne pathogens. For more detailed information, see FDA's *Bad Bug Book* (FDA 2012c).

Table 3-2 is a Quick Reference Guide to help you identify potential pathogens by biological classification and potential sources or entry points in your facility. The potential hazards listed in Table 3-2 will not apply to all facilities.

Table 3-2 Quick Reference Guide for Common Sources of Biological Hazards

Primary Source	Bacteria	Parasites	Viruses
Ingredient-related (e.g., contamination of raw materials and other ingredients)	*Salmonella* spp. (e.g., poultry, produce, nuts) *E. coli* O157:H7 & similar STEC (e.g., ruminant animals, dropped fruit, sprouts) *Campylobacter* spp. (e.g., poultry and raw milk) *B. cereus* (e.g., rice and other grains) *C. botulinum* (spores may be found in soil and on certain root crops.) *C. perfringens* (e.g., spices, may come in soil on produce) *L. monocytogenes* (e.g., raw agricultural commodities, other contaminated products used as ingredients)	*Cryptosporidium parvum* (contaminated water used as an ingredient) *Cyclospora cayetanensis* (berries) *Toxoplasma gondii* (meat)	Norovirus (produce, shellfish) Hepatitis A virus (produce, fruits)
Process-related (e.g., poor or ineffective process controls, including by a supplier)	*Salmonella* spp. survive inadequate heat treatment *C. perfringens* (improperly cooled cooked foods) *L. monocytogenes* (raw agricultural commodities, contaminated products)	*Cryptosporidium parvum* (contaminated water source)	N/A

Primary Source	Bacteria	Parasites	Viruses
Facility-related (may be caused by poor sanitation practices (e.g., inadequate cleaning and sanitizing of potential harborage sites), poor plant and equipment design, and poor pest management practices)	*L. monocytogenes* (e.g., reservoirs include floors, cold wet areas, equipment, drains, condensate, coolers, and soil) *Salmonella* spp. (pests)	N/A	Norovirus (only when active shedding occurs in facility through vomiting and diarrhea)
People-related (individuals who are carriers, showing no signs of disease, who are shedding the hazard, or who are infected and are actively ill)	*S. aureus* *Shigella* spp. *Salmonella* spp.	*Cryptosporidium parvum*	Hepatitis A virus Norovirus Rotavirus

3.3.1 Characteristics of Vegetative Foodborne Pathogens

Table 3-A in Appendix 3 of this guidance contains information on the physical conditions (i.e., a_w, acidity (pH), temperature, and oxygen requirements) that will limit growth for most of the vegetative pathogens that are of greatest concern in food processing. Data shown are the minimum or maximum values - i.e., the extreme limits reported among the references cited. These values may have been obtained in laboratory media, which may be more favorable to growth than many foods. These values may not apply to your specific processing conditions.

***Brucella* spp.** is the bacterium responsible for brucellosis. An estimated 840 foodborne cases of brucellosis occur annually in the United States (Scallan et al., 2011) When sheep, goats, cows, or camels are infected with the pathogen, their milk becomes contaminated with the bacteria. The most common way for humans to be infected is by eating or drinking unpasteurized/raw dairy products from infected animals. *Brucella* can also enter the body through skin wounds or mucous membranes following contact with infected animals. Symptoms include: fever; sweats; malaise; anorexia; headache; pain in muscles, joints and/or back; and fatigue. Some signs and symptoms may persist for prolonged periods of time or may never go away.

***Campylobacter jejuni* (*C. jejuni*)** is the bacterium responsible for campylobacteriosis. An estimated 845,000 foodborne cases of campylobacteriosis occur annually in the United States (Scallan et al., 2011). Symptoms include diarrhea, fever, abdominal pain, nausea, headache, and muscle pain. Symptoms start from 2 to 5 days after consumption of contaminated food and last from 7 to 10 days. A small percentage of patients develop complications that may be severe. These include bacteremia and infection of various organ systems, such as meningitis, hepatitis, cholecystitis, and pancreatitis. Autoimmune disorders are another potential long-term complication associated with campylobacteriosis; for example, Guillain-Barré syndrome (GBS). Everyone is susceptible to infection by *C. jejuni.* Campylobacteriosis occurs more frequently in the summer months than in the winter.

Pathogenic strains of *Escherichia coli* (*E. coli*) are responsible for four types of illness: gastroenteritis or infantile diarrhea, caused by enteropathogenic *E. coli* (EPEC); travelers' diarrhea, caused by enterotoxigenic *E. coli* (ETEC); bacillary dysentery, caused by enteroinvasive *E. coli* (EIEC); and hemorrhagic colitis, caused by enterohemorrhagic *E. coli* (EHEC). EHEC is the most severe, with potential for serious consequences such as hemolytic uremic syndrome, particularly in young children. An estimated 205,800 foodborne cases from all four types of *E. coli* occur annually in the United States (Scallan et al., 2011). Symptoms vary for the different forms of illness, but include abdominal pain, diarrhea, vomiting, fever, chills, dehydration, electrolyte imbalance, high body fluid acidity, and general discomfort. Symptoms start from 8 hours to 9 days after consumption of contaminated food and last from 6 hours to 19 days, with both periods varying significantly between the illness types. Everyone is susceptible to all forms of infection from *E. coli*, but EPEC is most commonly associated with infants, and all types tend to result in more severe symptoms in the very young and elderly.

***Listeria monocytogenes* (*L. monocytogenes*)** is the bacterium responsible for listeriosis. An estimated 1,600 foodborne cases of listeriosis occur annually in the United States (Scallan et al., 2011). *L. monocytogenes* produces mild flu-like symptoms in many individuals. However, in susceptible individuals, including pregnant women, newborns, and the immunocompromised, it can result in more severe symptoms, including septicemia, meningitis, encephalitis, spontaneous abortion, and stillbirth. Symptoms start from 3 days to 3 weeks after consumption of contaminated food. Mortality is high (approximately 25%) in those that display the more severe symptoms.

***Salmonella* spp.** is the bacterium responsible for salmonellosis. An estimated 1,029,000 cases of foodborne salmonellosis occur annually in the United States (Scallan et al., 2011). Symptoms include: nausea, vomiting, abdominal cramps, diarrhea, fever, and headache. Symptoms start from 6 hours to 2 days after consumption of contaminated food and generally last from 4 to 7 days. The most severe form, typhoid fever, is caused by *Salmonella* Typhi. Everyone is susceptible to infection by *Salmonella* spp*.,* but symptoms are most severe in the elderly, infants, and the infirmed. Infections by *Salmonella* spp*.* and other closely related bacterial pathogens, such as *Shigella* spp*., E. coli*, and *Yersinia enterocolitica,* can lead to chronic reactive arthritic symptoms in pre-disposed individuals.

Shigella spp. is the bacterium responsible for shigellosis. Shigella infections may be acquired from eating contaminated food. Foods may become contaminated by infected food handlers who do not wash their hands before handling food. An estimated 131,000 foodborne cases of shigellosis occur annually in the United States (Scallan et al., 2011). Symptoms include: abdominal pain; cramps; diarrhea; fever; vomiting; blood, pus, or mucus in stools; continuous or frequent urges for bowel movement; and death. Symptoms start from 12 hours to 2 days after consumption of contaminated food and last from 1 to 2 weeks. Everyone is susceptible to infection by *Shigella* spp*.*

***Staphylococcus aureus* (*S. aureus*)** is a common bacterium found on the skin and in the noses of many healthy people and animals. The bacterium is responsible for producing toxins as it grows in foods, causing staphylococcal food poisoning. An estimated 241,000 foodborne cases of staphylococcal food poisoning occur annually in the United States (Scallan et al., 2011). Symptoms include: nausea, vomiting, diarrhea, abdominal pain, and weakness. Staphylococcal toxins are fast acting and can cause illness in as little as 30 minutes. Symptoms usually start within one to six hours after eating contaminated food. Everyone is susceptible to intoxication by *S. aureus* toxin, with more severe symptoms, including occasional death, occurring in infants, the elderly and debilitated persons.

3.3.2 Characteristics of Spore-Forming Foodborne Pathogens

Table 3-A in Appendix 3 contains information on the conditions that will limit growth for most of the spore-forming pathogens that are of greatest concern in food processing. Data shown are the minimum or maximum values – i.e., the extreme limits reported among the references cited. These values may have been obtained in laboratory media, which may be more favorable to growth than many foods. These values may not apply to your processing conditions.

***Bacillus cereus* (*B. cereus*)** is the bacterium responsible for *B. cereus* food poisoning. An estimated 63,400 foodborne cases of *B. cereus* food poisoning occur annually in the United States (Scallan et al., 2011). There are two forms of illness, associated with two different toxins. In one form of illness, *B. cereus* produces an emetic toxin in the contaminated food; the emetic toxin causes nausea and vomiting, starting from 30 minutes to 6 hours after consumption of the food. In the other form of illness, associated with an infection due to high numbers of *B. cereus* in the contaminated food, *B. cereus* produces a diarrheal toxin in the intestines of the affected consumer after the consumer ingests food; the diarrheal toxin causes diarrhea, starting from 6 to 15 hours after consumption. Symptoms in both forms of illness last about 24 hours. Everyone is susceptible to *B. cereus* food poisoning.

***Clostridium botulinum* (*C. botulinum*)** toxin is the toxin responsible for a severe paralytic illness called botulism. *C. botulinum* is found in soil and grows best in low oxygen conditions. The bacteria form spores that can survive in a dormant state until exposed to conditions that support their germination and growth, such as in inadequately processed low-acid canned foods. Foodborne botulism is caused by eating foods that contain the botulinum toxin, which is formed during growth of *C. botulinum*. There are seven types of botulism toxin designated by letters A through G; only types A, B, E and F have caused botulism in humans. An estimated 55 foodborne cases of botulism occur annually in the United States (Scallan et al., 2011). Symptoms include: weakness; vertigo; double vision; difficulty in speaking, swallowing, and breathing; abdominal swelling; constipation; paralysis; and, possibly, death. Symptoms start from 18 to 36 hours after eating a contaminated food, but can occur as early as 6 hours or as late as 10 days after exposure. Everyone is susceptible to intoxication by *C. botulinum* toxin; only a few micrograms of the toxin can cause illness. Mortality is high; without the antitoxin and respiratory support, death is likely.

***Clostridium perfringens* (*C. perfringens*)** is the bacterium responsible for perfringens food poisoning. *C. perfringens* causes illness when large numbers of the bacteria are consumed in contaminated food. The bacterium then produces enough toxin in the intestines to cause illness. *C. perfringens* spores can survive high temperatures. During cooling and holding of food at warm temperatures, the spores germinate and the resulting vegetative cells of the bacteria grow. An estimated 966,000 foodborne cases of perfringens food poisoning occur annually in the United States (Scallan et al., 2011). Symptoms include: abdominal cramps and diarrhea. Symptoms typically start from 8 to 12 hours after eating a contaminated food, but can occur as early as 6 hours after exposure and last for about a day. Everyone is susceptible to perfringens food poisoning, but it is more common in the young and elderly, who may experience more severe symptoms lasting for one to two weeks.

3.3.3 Potential Ingredient-Related Biological Hazards

See Table 3-2 in this chapter and Tables 1A through 1Q in Appendix 1 of this guidance for information that can help you identify potential ingredient-related biological hazards that may be associated with specific food products. See Chapter 4 – Preventive Controls, as well as

Chapters 6 through 13, for recommendations on control of some specific ingredient-related biological hazards.

3.3.4 Potential Process-Related Biological Hazards

The purpose of this section is to help you identify potential process-related biological hazards for the foods that you produce. See Chapter 4 – Preventive Controls, as well as Chapters 6 through 13, for recommendations on control of some specific process-related biological hazards.

Some process-related biological hazards can occur if something goes wrong with a process control. For example, pathogens that you intend to control by cooking could survive if your product is undercooked during application of a heat treatment; pathogens that you intend to control by refrigeration could multiply and/or produce toxin if there is a lack of proper refrigerated holding during product assembly; and pathogens that you intend to control by a_w could multiply and/or produce toxin if the product is not properly formulated (e.g., too little sugar is used, resulting in an increase in the a_w). Other process-related biological hazards are not related to something going wrong with a process control. For example, if you plan to use reduced oxygen packaging (ROP) to prevent the growth of spoilage organisms and extend the shelf life of the product, the extended shelf life provides more time for toxin production or pathogen growth if pathogens are present and temperatures are suitable for growth. As another example, if you manufacture a product by adding spices after a process control that would significantly minimize pathogens, pathogens in the added spices could introduce pathogens to the treated product. As yet another example, pathogens could be introduced to a treated product after packaging if there is a lack of container integrity.

In the following sections on process-related biological hazards, we describe examples of these kinds of process-related biological hazards.

3.3.4.1 Bacterial pathogens (vegetative and sporeforming) that survive after treatment

If a process that you design to kill bacterial pathogens and/or their spores does not work as intended, the bacterial pathogens and/or their spores that you intended to control can be present in your food product. The primary pathogens of concern are *L. monocytogenes*, *Salmonella* spp., *S. aureus* and *C. jejuni*, pathogenic strains of *E. coli*, *Yersinia enterocolitica* (*Y. enterocolitica), B. cereus C. perfringens, and C. botulinum*. See Appendix 3 of this guidance for limiting conditions for growth of bacterial pathogens.

See Chapter 4 of this guidance for an overview of recognized and established processing conditions to control pathogens and for factors to consider when designing your process to prevent problems. For example:

- Some foods heat faster than others. Bacterial pathogens in the cold spot of the food will be inactivated more slowly than those at the surface because those in the cold spot are subjected to less heat. If the minimum process for lethality is not achieved at the cold spot, pathogens may survive the treatment.
- Certain characteristics of food make it either easier or harder to destroy bacterial pathogens, if present. For example, pathogens are more easily destroyed in foods with an acidic pH; sugars and oils tend to shield pathogens from the effects of heat; and the presence of moisture, both in and

surrounding the food, make destruction easier. If these have not been taken into account in designing the process, pathogens may survive the treatment.

- Spores of bacterial pathogens are more heat tolerant than the vegetative cells of the same pathogen and different bacterial pathogens have different heat resistances (see Appendix 3 of this guidance). If the process is not designed to control the most resistant pathogen of concern in the food, pathogens may survive the treatment.

See also Chapter 6 – Use of Heat Treatments as a Preventive Control for more detailed recommendations to control process-related biological hazards through heat treatments.

3.3.4.2 Bacterial pathogens that grow and/or produce toxin

3.3.4.2.1 Due to lack of proper time/temperature control

Bacterial pathogens that are introduced from contaminated ingredients into a product that does not undergo a lethality process, or that survive a lethality process as a result of a problem with a process control, can multiply ("grow") and, depending on the pathogen, produce toxin as a result of time and temperature abuse of food products. Certain bacterial pathogens (e.g., *E. coli* O157:H7, *S. aureus,* and *L. monocytogenes)* grow well in time- and temperature-abused food. Time and temperature abuse occurs when a product is allowed to remain at temperatures favorable to bacterial pathogen growth for sufficient time to result in unsafe levels of the pathogens or their toxins in the product. Most bacterial pathogens will grow well in cooked foods that are temperature-abused if their growth is not otherwise controlled by means such as drying, salting, or acidification, because competing bacteria are significantly reduced by the cooking process. Uncooked foods that have high water activities and pH, such as batters, which are subjected to time/temperature abuse (e.g., using room-temperature batter for several hours), can support growth and toxin production by pathogens such as *S. aureus*.

Vegetative pathogens may grow in products during processing steps and may be ultimately destroyed by a lethal step such as cooking. However, too much bacterial growth before the lethal step may render the lethal process inadequate. Moreover, if the time and temperature abuse allows production of toxin, such as toxin production from *S. aureus* in temperature-abused custard pies, this toxin will not be destroyed by a heat step later in the process.

In evaluating the potential for bacterial pathogens to grow and/or produce toxin in your food products, you should consider the following factors:

- The types of pathogenic bacteria that are known or reasonably likely to be present;
- Whether those pathogens can grow in the food;
- The infective dose of the pathogenic bacteria;
- The expected initial level of the pathogenic bacteria in the food.

See Chapter 4 of this guidance for an overview of processing conditions to minimize pathogen growth by controlling temperatures to prevent pathogen growth and time of exposure to temperatures at which growth can occur. See also Chapter 7 – Use of Time/Temperature Control as a Process Control for more detailed recommendations to control process-related biological hazards through time/temperature controls. Tables 3-A and 3-B (Appendix 3 of this guidance) provide the limiting temperature conditions for growth of vegetative and sporeforming bacterial pathogens.

3.3.4.2.2 Due to lack of proper cooling after heat treatments

Depending upon the food and ingredients, heat treated foods can still possibly have viable forms (i.e., spores) of pathogenic bacteria present. Sometimes, vegetative cells that are particularly heat tolerant, (like *Listeria monocytogenes*) survive the cooking process; however, this should not be the case if the appropriate target pathogen was selected to be controlled by the applied process. More often, it is spores that survive the cooking process if they are present, and they begin to germinate when the product temperature begins to drop below 140°F. In addition, they will be present in the food during storage. Some spores such as those from pathogens such as non-proteolytic *C. botulinum* and some strains of *B. cereus* have the ability to germinate and grow at refrigeration temperatures, although long times are required. Other spores that remain in the food remain dormant until the product is temperature abused. In such an event, pathogenic spores that may be present are able to germinate, grow and possibly produce toxin due to the fact that most spoilage bacteria have been eliminated by the reduction step.

See Chapter 4 of this guidance for an overview of processing conditions to minimize pathogen growth by controlling temperatures during cooling after cooking. See also Chapter 7 – Use of Time/Temperature Control as a Process Control for more detailed recommendations to control process-related biological hazards through time/temperature controls.

3.3.4.2.3 Due to poor formulation control

Products most susceptible to biological hazards due to problems with formulation are RTE products that either do not receive a kill step in their process or that receive a kill step for vegetative pathogens but not spores and that may require refrigeration for safety during their manufacture and shelf life. For this category of products, product formulation can play a significant role in significantly minimizing or preventing hazards. For example, a naturally acidic product with a pH below 4.6 may rule out *C. botulinum* as a hazard requiring a preventive control, since this pH will prevent spore germination, growth, and toxin production. Formulation parameters such as pH, a_w, use of preservatives, and oxygen availability, can work in concert to establish an ecosystem that is designed to inhibit the growth of the pathogens that may be present. If not, just as described for foods that have been time and temperature abused, bacterial pathogen growth and toxin formation can result due to this lack of inhibition and control.

In determining the potential for a process-related hazard due to poor formulation control, we recommend that you know the formulations or ingredient lists of your incoming products, as well as the equilibrated pH, titratable acidity, a_w, percent moisture, percent sodium and percent sugar, as appropriate, of the finished combined product. Many of the products susceptible to biological hazards due to problems with formulation are made up of multiple ingredients, each with their own specific set of formulation parameters. Any one individual component not meeting the required formulation criteria to ensure that the designed preventive control system is achieved may result in a food that does not inhibit the growth or toxin formation of a pathogen that may be present in the food.

In determining the potential for a process-related biological hazard due to poor formulation control, we also recommend that you consider the interactions that may occur among the various products, raw materials, and other ingredients when combined. Layering product components of significantly different pH or a_w values alters the microenvironments at the interfaces of the components. A simple example is an éclair filled with a cream filling. The pH

and a_w at the interface of the pastry and the filling will be affected by the difference between the higher pH and lower a_w of the pastry and the potentially lower pH and higher moisture content of the filling, potentially resulting in an environment favorable to microbial growth. A microorganism that is in the filling may not grow due to the pH, but the pH of the pastry may favor growth of a microorganism at the interface during the product's shelf life. Characteristics such as oxygen-reduction (redox) potential and the effectiveness of antimicrobials are also likely to differ at component interfaces and may impact pathogen survival and growth.

In determining the potential for a process-related hazard due to poor formulation control, we also recommend that you consider how the equilibrium pH and a_w of the finished product compares to that of the individual components. If a finished formulated product is a more homogeneous mixture of the components, then the resulting final equilibrium pH and a_w may be significantly different from that of the individual components. A good example is hummus, which is typically made from chick peas (garbanzo beans), which may be rehydrated from a dry state, blended with acidifying agents, oils and spices and then pureed. The final product with a smooth texture will have an equilibrium pH, and possibly a_w, different from the original ingredients. If a topping of pine nuts, or oil, or diced red peppers is added to the top in the container as "decoration" then those additions could then significantly change the microenvironment at the interface and may require a control (such as acidification).

See Chapter 4 of this guidance for an overview of formulation-based controls. See Chapter 8 – Use of Formulation as a Preventive Control for more detailed recommendations to control process-related biological hazards through product formulation.

3.3.4.2.4 Due to reduced oxygen packaging (ROP)

From a food safety standpoint, packaging serves two functions: (1) It prevents contamination of the food; and (2) it makes possible, or extends the effectiveness of, food preservation methods. For example, packaging can maintain the atmosphere in a controlled or modified atmosphere package or a vacuum package, or it can prevent rehydration of a dried food. All of these different packaging methods are grouped into a category that we call ROP. ROP is used to prevent the growth of spoilage organisms, thereby extending the shelf life of the product. There are some other product quality benefits as well, such as reductions in rancidity, shrinkage, and color loss.

However, ROP does not control the growth of all bacterial pathogens and can create a process-related biological hazard. The extended shelf life provides more time for toxin production or pathogen growth if pathogens are present and temperatures are suitable for growth. Lower oxygen levels favor pathogens that can grow in the absence of oxygen over the aerobic spoilage organisms that require oxygen for growth. For this reason, you may get toxin production before you get spoilage - something that is less likely to happen in traditional packaging.

The major concern with ROP is *C. botulinum,* although there may also be concerns with other pathogens such as *L. monocytogenes*, particularly in refrigerated RTE foods. You should not use ROP unless barriers for *C. botulinum* are present. These barriers include: a_w below 0.93; pH below 4.6; salt above 10%; thermal processing in the final container; and freezing with frozen storage and distribution. Each of these barriers by itself can be effective in the control of *C. botulinum* growth. Refrigeration below 38°F (3.33°C) can prevent growth of all strains of *C. botulinum,* but because temperatures above this are commonly employed for refrigeration,

temperature should not be relied on as the only control. Combinations of barriers that individually would not control growth of *C. botulinum* can work together to prevent growth.

For a further discussion on the potential for ROP to create a process-related biological hazard, see Annex 6 of the 2013 Food Code (FDA, 2013b).

3.3.4.3 Bacterial pathogens in ingredients added after process controls

The manufacture of certain RTE products involves, by design, the addition of ingredients after any process controls are applied. For example, the production of some fresh vegetable salad kits includes the addition to the final product, prior to packaging, of various ingredients such as nuts, dried berries, and seeds. The process control for the salad components (e.g., chlorine wash) is applied to the various fresh cut vegetables that are mixed in preparation for packaging, while the nuts, berries, and seeds are added just prior to packaging. As another example, the production of some fresh-baked pastry products includes the addition of toppings, such as frostings, nuts, dried fruit, confections (e.g., sprinkles). A facility that produces products containing ingredients added after a process control should consider the potential for the added components to be a process-related biological hazard as part of its hazard analysis.

3.3.4.4 Bacterial pathogens introduced after packaging due to lack of container integrity

Food manufactured and processed (e.g., heat treated) in a container and/or clean-filled after treatment can become contaminated if its container forms a leak or loses seal integrity, thereby exposing the processed food to a variety of biological hazards. The primary pathogens of concern include *C. botulinum*, *L. monocytogenes*, pathogenic strains of *E. coli*, *Salmonella* spp., *S. aureus*, and *B. cereus*.

The primary causes of recontamination of foods after a process control step and packaging are defective container closures and contaminated cooling water. Poorly formed or defective container closures can increase the risk of bacterial pathogens entering the container through container handling that occurs after the product has been filled and the container has been sealed. This risk is a particular concern during container cooling performed in a water bath. As the product cools, a vacuum is drawn in the container. Contaminated cooling water can enter through the container closure, especially if the closure is defective.

3.3.5 Potential Facility-Related Biological Hazards

Foodborne illnesses due to commercially produced foods have been traced to post-process contamination due to the poor implementation of CGMPs, such as by exposure or contact with contaminated equipment during processing such as conveying, holding, chilling or packaging. Examples of events and foodborne illness outbreaks due to contamination of RTE foods are quite extensive and readily available in scientific literature. Typically in these events, foods that were processed by some means (e.g., cooked, pasteurized, dried) to reduce the presence of microorganisms, in particular pathogens identified as hazards requiring a preventive control, were subsequently exposed to the environment where they were recontaminated with pathogens. As discussed in the following sections on facility-related biological hazards, there are challenges to prevent this from happening.

Table 3-3 provides a list of examples, adapted in part from ICMSF Book 7, Chapter 11 (ICMSF, 2002) and from FDA documents that highlight the public health impact of contamination of RTE foods with environmental pathogens.

Table 3-3. Examples of Pathogens Identified from Outbreaks Attributed to Contamination with Environmental Pathogens

Product	Environmental Pathogen	Details	Reference
Chocolate	*S.* Napoli	Possibly contaminated water used in double-walled pipes, tanks and other equipment	Gill, *et. al.* (1983)
Chocolate	*S.* Eastbourne	From processing environment	Craven, *et. al.* (1975)
Butter (from pasteurized cream)	*L. monocytogenes*	From processing environment	Lyytikainen *et. al.* (2000)
Peanut butter	*S.* Tennessee	From processing environment	FDA (2007a, 2007b)
Peanut butter	*Salmonella* spp.	From processing environment	Cavallaro et al. (2011); FDA (2009b, 2009c)
Whole white pepper	*S.* Rissen	From processing environment	FDA (2009d)
Cantaloupes	*L. monocytogenes*	From processing environment	FDA (2012a)
Peanut butter	*S.* Bredeney	From processing environment	FDA (2012b)
Soft cheeses (from pasteurized milk)	*L. monocytogenes*	From processing environment	FDA (2013c)
Soft cheese (from pasteurized milk)	*L. monocytogenes*	From processing environment	FDA (2014a)

The PCHF requirements specify that your hazard evaluation must include an evaluation of environmental pathogens whenever a ready-to-eat food is exposed to the environment prior to packaging and the packaged food does not receive a treatment or otherwise include a control measure (such as a formulation lethal to the pathogen) that would significantly minimize the pathogen. (See 21 CFR 117.130(c)(1)(ii).) Effectively designed and implemented CGMPs are key to keeping biological hazards out of your food products. However, experience has shown that application of CGMPs – even in combination with a HACCP plan - cannot guarantee that contamination of a processed food from the environment will not occur. This is one reason why the PCHF requirements specify that sanitation controls include procedures, practices, and processes to ensure that the facility is maintained in a sanitary condition adequate to significantly minimize or prevent hazards such as environmental pathogens (21 CFR 117.135(c)(3)). In addition, the PCHF requirements specify that, as appropriate to the facility,

the food, and the nature of the preventive control and its role in the facility's food safety system, you must conduct activities that include environmental monitoring, for an environmental pathogen or for an appropriate indicator organism, if contamination of an RTE food with an environmental pathogen is a hazard requiring a preventive control, by collecting and testing environmental samples.

In the following sections, we provide information to help you determine whether an environmental pathogen is a hazard requiring a preventive control in your facility. Although Table 3-3 includes some examples of outbreaks of foodborne illness caused by facility-related biological hazards other than environmental pathogens, we do not discuss those other facility-related biological hazards in this chapter.

3.3.5.1 Sources of facility-related biological hazards

The likelihood of product contamination with a facility-related environmental pathogen increases as the prevalence of the environmental pathogens in the processing environment increases. The prevalence of the environmental pathogens in the processing environment can be influenced by the raw materials used in the process, the type of process, and the hygienic practices applied to keep to keep the processing area clean and hygienic. Table 3-4 is a quick reference guide to help you identify some of the most common sources for facility-related hazards that can contaminate the food processing environment; Table 3-4 does not provide an exhaustive list of such pathogens.

Table 3-4. Quick Reference Guide for Common Sources of Facility-Related Biological Hazards

Source	Examples
Raw agricultural commodities	• Raw milk • Cocoa beans • Fruits and vegetables • Nuts • Unprocessed spices
Food handlers and maintenance personnel	• Transfer of biological hazards from one point to another on, for example, shoes and other clothing • Improper hand washing • Transfer of biological hazards to foods through improper handling or maintenance practices
Air and water	• Lack of appropriate air filtration for cooling, drying, air conveying • Improper air flow from "raw" to RTE areas • Aerosols from improper cleaning practices

Source	Examples
Insects and pests	• Flies • Cockroaches • Rodents
Transport equipment	• Forklifts • Trolleys • Racks • Carts

With these varied sources for potential contamination, it is easy to understand how a failure of one or more steps in your CGMPs can lead to contamination of the processing environment and, ultimately, your food products with facility-related biological hazards.

3.3.5.2 Transient vs. resident facility-related environmental pathogens

Once bacterial pathogens have been introduced into the processing environment, experience has shown that pathogens may be present as "transient" contamination or "resident" contamination within the facility.

3.3.5.2.1 Transient contamination

Bacterial pathogens, including environmental pathogens, are typically introduced into the processing facility through, for example, incoming raw materials, personnel, or pests. It is important to ensure that these microorganisms remain transient and do not become established in the environment where they can grow and multiply. Transient contaminants can, however, result in a diversity of pathogens in the processing environment that can show up in the processing lines and finished product. This phenomenon is typical for food operations using a wide variety of ingredients, in particular raw commodities, because these materials can contain very diverse microflora. Generally though, the proper application of cleaning and sanitizing in accordance with CGMPs is adequate to control the transient bacteria in the processing facility. So, contamination detected from day-to-day may be found to be quite diverse.

3.3.5.2.2 Resident contamination

Bacterial pathogens causing resident contamination can also be introduced into the processing facility, where the pathogens then become established in a harborage site, multiply, and persist for extended periods of time, even years. A harborage site, or niche, is a site in the environment or on equipment (e.g., junctions, cracks, holes, and dead-end areas) that enables the accumulation of residues (food debris, dust, and water) and permits the growth of microorganisms such as *L. monocytogenes* and *Salmonella*. These sites may be difficult to inspect or access and therefore can protect environmental pathogens during routine cleaning and sanitizing. Thus, while common cleaning and sanitation practices are adequate to control the presence of transient contaminants, such practices do not control the presence of resident contaminants once they have become established. Sanitation controls, including proper personnel practices and equipment and facility design, are key to preventing transient bacterial pathogens from becoming resident strains. Once an environmental pathogen has become

established as a "resident strain," there is a persistent contamination risk for foods processed in that facility. The facility will need to use intensified sanitation procedures to eliminate the contamination. Of all the bacterial pathogens, *Salmonella* and *L. monocytogenes* have the most extensive history of being able to set up residence in a processing facility. Although not as likely, the potential exists for the other pathogens discussed previously in this chapter to become established as resident contaminants.

Key determinants for the pathogens to become established in a food processing environment are: 1) The temperature at which the food processing environment is maintained; 2) the available moisture in the food processing environment; and 3) the availability of nutrients for growth. For processed foods, this typically translates into two primary categories of food processing environments by the nature of the products that are manufactured and packaged in a facility:

- Frozen/refrigerated and wet
- Warm/ambient and dry

In both cases, proper cleaning is needed to minimize nutrient availability. The pathogen most often associated with cold and wet processing environments is *L. monocytogenes,* and the pathogen most often associated with warm and dry processing environments is *Salmonella* (Scott et. al., 2009; ICMSF, 2005).

3.3.5.3 Facility-related environmental pathogens associated with wet vs. dry processing environments

Food processing operations can typically be classified into one of two simple categories – wet processing environments or dry processing environments (Table 3-5). This very simple distinction has significant implications for the strategy that must be applied to control food contamination from environmental pathogens.

Table 3-5. Some Examples of Foods Processed in Wet and Dry Processing Environments

Processing Environment Conditions	Examples of Foods
Wet	• Ice Cream • Refrigerated Dairy Products • Refrigerated Deli Salads • Refrigerated and Frozen Meals • Refrigerated Beverages (non-juice)
Dry	• Chocolate and Confections • Milk Powders • Baked Goods • Dehydrated Soups

Processing Environment Conditions	Examples of Foods
	• Powdered Beverages • Nut/nut products

3.3.5.3.1 Wet process environments

The most effective strategy to prevent the contamination of finished products with *L. monocytogenes* is to maintain an environment as dry as possible. Wet environments have some very obvious characteristics that lead to problems with contamination by *L. monocytogenes*, such as:

- Wet floors due to constant wet cleaning will facilitate the transfer of *Listeria* spp., including *L. monocytogenes,* from an environmental source to food contact surfaces;
- Wet floors can create harborage sites if they are not well maintained and have broken/cracked grout or tiles. These structures may provide protected harborage to environmental pathogens even when the floors are cleaned and sanitized.
- Condensation on overhead structures as a result of air temperature and humidity control issues and from use of water in cooking and cooling operations creates a means of transfer of *Listeria* spp., including *L. monocytogenes,* from non-food-contact surfaces to exposed product and equipment food-contact surfaces.
- Frost formation due to condensation at freezer entry and exit points provides an opportunity for moisture accumulation and a constant source of water for *Listeria* spp. to multiply.
- Inadequate sanitation practices on floor freezer and cooler units may provide the moisture to support *Listeria* spp., including *L. monocytogenes,* if water sources are not properly plumbed to hygienically designed drains.

Wet floors can serve as vectors for spreading *Listeria* spp. via the movement of people and equipment and material handling items such as totes and pallets. Wet floors can also serve as vectors for pathogen transfer when personnel walk through standing water on poorly designed floors and drains and during cleaning. *L. monocytogenes* does not spread alone through the air; however, in wet environments, aerosols from high pressure water hoses used during cleaning operations help spread *L. monocytogenes* throughout the environment and from one surface (e.g., floors) to another surface (e.g., food contact surfaces, such as conveyors, tables, and product containers). In many facilities, certain processing operations are inherently wet, such as product debagging, raw material preparation, mixing and formulation of liquid product components, cooking, and blanching. In these cases, the best that can be done is to control the personnel, equipment traffic, and cleaning practices that are involved with the specific operation. The intent is to minimize water accumulation and aerosol formation to prevent in-process and finished product recontamination.

We recommend that wet processing areas be dried out as much as possible. This continues to be an ongoing challenge for the food industry that has for many years depended upon the unlimited use of water for equipment and facility cleaning practices.

3.3.5.3.2 Dry process environments

Moisture control is critically important in preventing *Salmonella* contamination in low-moisture products (ICMSF, 2005). Water in the dry processing environment is one of the most significant risk factors (perhaps the single most important factor) for *Salmonella* contamination, because water allows for pathogen growth, significantly increasing the risk for product contamination. Water, present even in very small amounts for short, sporadic time periods, may allow *Salmonella* to grow in the environment. At times, moisture is obvious in the form of water droplets or puddles from wet cleaning or from other not-so-apparent sources such as high relative humidity or moisture accumulating inside of equipment.

Salmonella can, to varying degrees, be introduced into low-moisture product manufacturing facilities and become established in those environments. Harborage sites may develop and become a source of product contamination, unless the sites are identified and eliminated (CAC, 2008).

Growth of *Salmonella* is only possible in the presence of water. Because food particles and dust are normally expected to be present in processing areas, adequate nutrients are always available to microorganisms. Growth cannot occur, however, if the plant environment is sufficiently dry. The potential *Salmonella* harborage sites become more important when water is present for a sufficient period of time. The presence of water in the dry processing environment can result from improper use of water during cleaning, which has been linked to the occurrence and spread of *Salmonella* (CAC, 2008). Other events resulting in the presence of water in a dry area include condensate formation, leaking water or steam valves, infiltration of water following heavy rains (e.g., leaky roofs) and the use of water showers in the case of fire emergencies. (CAC, 2008). We recommend that you remove water immediately from the primary *Salmonella*-controlled hygiene areas (areas where RTE food is exposed to the environment) following such events in order to keep the plant environment as dry as possible.

You should maintain dry conditions at all times in primary *Salmonella*-controlled hygiene areas, except for the occasions when you have determined that controlled wet cleaning is necessary. Potential problems arise when there is visible water present in the dry areas or when there are areas in which standing water has dried out. *Salmonella* may be found both in wet spots and in spots where standing water has dried (Zink, 2007). The latter situation may present an additional risk of spread via the generation of airborne contaminated dust**.**

3.4 Chemical Hazards

You must conduct a hazard analysis to identify and evaluate known or reasonably foreseeable chemical hazards. See 21 CFR 117.130(b)(1)(ii). When your hazard analysis identifies a known or reasonably foreseeable chemical hazard that requires a preventive control, you must identify and implement a preventive control for the chemical hazard. See 21 CFR 117.135(a)(1).

The chemical hazards that are the focus of this section of this chapter include ingredient-related chemical hazards (i.e., pesticide and drug residues, heavy metals, environmental contaminants, histamine due to decomposition, natural toxins (e.g., mycotoxins), radiological hazards, unapproved food and color additives, food allergens, and substances associated with a food intolerance or food disorder) and process-related chemical hazards (i.e., food allergens, substances introduced by misformulation and the introduction of industrial chemicals or other contaminants from the food processing environment).

Food products can become contaminated with chemical hazards that are introduced at any stage in food production and processing. Some ingredient-related chemical hazards are natural components of food, such as food allergens, or are produced in the natural environment, such as mycotoxins, whereas other ingredient-related hazards (e.g., pesticides, drug residues, heavy metals, environmental contaminants) are contaminants of raw materials and other ingredients. Some process-related chemical hazards may be included in product formulation (e.g., sulfites that are a hazard for those consumers who are sensitive to them), whereas other process-related chemical hazards may be unintentionally introduced into food, such as industrial chemicals that are used in a facility for purposes other than food production. Process contaminants may also form during heating (e.g., acrylamide).[8] For further details on the sources of ingredient-related and process-related chemical hazards, see Tables 2A through 2Q and Tables 3A through 3Q of Appendix 1 of this guidance.

A chemical hazard may cause immediate effects, or may be associated with potential long-term effects after chronic exposure to the chemical. One example of an immediate effect is gastrointestinal illness such as nausea, which can be caused by elevated levels of industrial chemicals (such as caustic cleaning compounds). Caustic cleaning compounds can also cause burning of the mouth and esophagus. Ammonia in food contaminated by a refrigerant leak has caused gastrointestinal illness (stomachache and nausea) and headaches (Dworkin, et al. 2004). Sulfites have resulted in diarrhea, headache, difficulty breathing, vomiting, nausea, abdominal pain and cramps in sulfite-sensitive individuals (Timbo et al. 2004). Examples of long-term effects include impaired cognitive development in children chronically exposed to relatively low levels of lead (e.g., in contaminated candy) (FDA, 2006a) and liver cancer resulting from chronic exposure to the mycotoxin, aflatoxin (Williams et. al, 2004 and Shephard, 2008).

FDA has set action levels and tolerances for some contaminants (FDA, 2015f). They represent limits at or above which FDA will take legal action to remove products from the market. Where no established action level or tolerance exists, FDA may take legal action against the product at the minimal detectable level of the contaminant. Action levels and tolerances are established based on the unavoidability of the poisonous or deleterious substances and do not represent permissible levels of contamination where it is avoidable. For example, FDA has established an action level of 3 ppm polychlorinated biphenyl (PCB) residues in red meat on a fat basis (FDA, 1987). FDA also has issued for public comment a draft guidance for industry that would, when finalized, establish an action level of 100 ppb for inorganic arsenic in infant rice cereal (FDA 2016). FDA has established tolerances for polychlorinated biphenyls (PCB's) in foods such as milk and other dairy products, poultry, eggs, and infant and junior foods (see 21 CFR 109.30).

Further, under the Federal Food, Drug, and Cosmetic Act (FD&C Act), certain substances, such as food additives, color additives, new animal drugs, and pesticides require premarket approval before they may be legally used.

[8] Some processing contaminants are formed during the heating of certain ingredients or finished foods (e.g., acrylamide). We have not included such contaminants in Table 3-6 as potential process-related chemical hazards that may require a preventive control as part of a food safety plan under part 117 because we believe that more information is needed regarding appropriate levels and effective controls. As stated in our "Guidance for Industry: Acrylamide in Foods" (FDA, 2016a), we recommend that manufacturers evaluate approaches to acrylamide reduction that may be relevant to their particular processes and consider adopting approaches, if feasible, that reduce acrylamide levels in their products.

FDA also has issued guidances to provide information to industry on methods to reduce levels of specific chemicals in foods. For example, FDA has issued guidance providing information to help growers, manufacturers, and food service operators reduce acrylamide levels in certain foods (FDA, 2016a). Similarly, the Codex Alimentarius Commission has established a number of codes of practice for controlling mycotoxins, heavy metals, and other chemicals in foods (CAC, 2012).

Chemical residues in a food are not always considered hazards and their occurrence may be unavoidable. Because the particular chemical and its levels in the food determine whether it is a hazard, and because mechanisms whereby a chemical hazard can be introduced into a food product are both varied and dependent on the nature of the chemical, the preventive controls that you identify and implement to control specific chemical hazards should be based on the characteristics of those chemicals and the mechanisms whereby they could be introduced into your food product. In the following sections on chemical hazards, we describe some common preventive controls for controlling chemical hazards. For additional information on the control of chemical hazards, see Chapter 4 – Preventive Controls and Chapter 12 – Preventive Controls for Chemical Hazards.

In the remainder of this section on chemical hazards, we briefly describe characteristics of some chemical hazards that are of concern in foods and processing environments, including mechanisms whereby they can be introduced into a food product. We do not discuss seafood toxins in this guidance because seafood is exempt from the PCHF requirements; for a discussion of seafood toxins see our *Fish and Fishery Products Hazards and Controls Guidance* (FDA, 2011).

Table 3-6 is a quick reference guide to help you identify some of the most common sources of chemical hazards; Table 3-6 does not provide an exhaustive list of such hazards

Table 3-6. Quick Reference Guide for Common Sources of Chemical Hazards

Source	Examples
Ingredient-related chemical hazards	• Pesticide residues on produce raw agricultural commodities • Drug residues in milk • Heavy metals in or on produce raw agricultural commodities • Environmental contaminants (e.g., dioxins) • Mycotoxins in grains • Histamine in some aged cheeses • Radiological hazards in foods from areas after a nuclear accident • Unapproved food or color additives • Food allergens and substances associated with a food intolerance or food disorder (e.g., sulfites, gluten)

Source	Examples
Process-related chemical hazards	• Undeclared food allergens due to mislabeling or cross-contact • Improper addition of substances associated with a food intolerance (e.g., sulfites) • Improper use of a color additive such as Yellow No. 5 • Contamination with industrial chemicals such as cleaners or sanitizers • Radiological hazards from use of contaminated water supply
Facility-related chemical hazards	• Heavy metals due to leaching from equipment, containers, or utensils

3.4.1 Ingredient-Related Chemical Hazards

3.4.1.1 Pesticides

Pesticide residues may be of concern in food crops and in foods of animal origin (as a result of pesticide residues in animal food). The term pesticide is used for products such as insecticides, fungicides, rodenticides, insect repellants, herbicides or weed killers, and some antimicrobials that are designed to prevent, destroy, repel, or reduce all types of pests (See EPA "Setting Tolerances for Pesticide Residues in Foods") (EPA, 2015). Three federal government agencies share responsibility for the regulation of pesticides. Pesticides that have been registered (i.e., approved) with the U.S. Environmental Protection Agency (EPA) may be applied according to label directions directly to raw agricultural commodities or food (see 40 CFR 180). For a registered pesticide that could potentially result in residues in or on food, the EPA establishes a tolerance, which is the maximum amount of residue that is permitted in or on a food. FDA is responsible for enforcing pesticide tolerances for foods other than meat, poultry, and certain egg products, which are the responsibility of the U.S. Department of Agriculture Food Safety and Inspection Service (USDA FSIS) (FDA, 2012d). A detailed description of how FDA enforces pesticide residues in animal food is available in CPG Sec. 575.100 Pesticide Residues in Food and Feed – Enforcement Criteria (FDA, 2015e). If pesticide residues are present in food in the absence of, or in excess of, a tolerance, the food is deemed adulterated under section 402(a)(2)(B) of the FD&C Act (21 U.S.C. 342(a)(2)(B)). The most common reasons for adulteration of food products with pesticide residues are the improper treatment of raw materials with registered pesticides, and raw materials being exposed to prohibited pesticides.

Fruits and vegetables that have been grown in the United States usually are in compliance with EPA's pesticide tolerance regulations. If you obtain produce from a foreign country you should take steps to ensure that the imported produce will be in compliance with U.S. pesticide tolerance regulations, such as by considering pesticide residues to be chemical hazards that warrant preventive controls, such as supply-chain controls with a supplier verification program.

3.4.1.2 Animal drug residues

Animal drug residues may be of concern for foods of animal origin, including muscle meat, organ meat, fat/skin, eggs, honey, and milk. In the United States, animal drugs require approval by FDA before they can be administered to food-producing animals. Depending on the chemical property of the drug, residues of certain drugs can become concentrated during food manufacturing and processing. For example, if a fat-soluble, heat-stable drug residue is present in raw milk, the drug can get concentrated when the milk is converted to full fat cheese (Cerkvenik et al., 2004; Imperiale et al., 2004). Potential effects of drug residues range from short-term effects as a result of acute allergic reactions (e.g., penicillin) to long-term effects from drug resistant bacteria (Dayan, 1993). An example of an unapproved drug residue that has adulterated food is fluoroquinolone, which is an antibiotic that has not been approved for use on honey bees in the United States and has been detected in honey products from certain regions outside the United States (FDA, 2015a).

Drug residues in a food derived from an animal (such as milk) are considered a hazard if a tolerance has not been established for the particular drug-food combination, or if the tolerance level has been exceeded. Animal drugs used according to labeled directions should not result in residues in meat, poultry, milk, or egg products. When your hazard analysis identifies drug residues that require a preventive control, supply-chain controls with a supplier verification program could be an appropriate preventive control to manage the potential risk.

3.4.1.3 Heavy metals

Heavy metals, including lead, cadmium, arsenic, and mercury, may be of concern in certain foods as a result of agricultural practices (e.g., use of pesticides containing heavy metals or because crops are grown in soil containing elevated levels of heavy metals due to industrial waste), or the leaching of heavy metals from equipment, containers or utensils that come in contact with foods. Consumption of heavy metals in foods can lead to adverse health consequences. For example, lead exposure can impair cognitive development in children (FDA, 2006a). Consumption of inorganic arsenic has been associated with cancer, skin lesions, developmental effects, cardiovascular disease, neurotoxicity, and diabetes in humans (JEFCA, 2010).

When your hazard analysis identifies a heavy metal that requires a preventive control, the type of control would depend on how the heavy metal could get into your food product. In some cases, high levels of heavy metals may result from the environment (e.g., high lead levels in carrots that were grown in lead-contaminated soil). If your food product contains a food crop that is known to have been contaminated with a heavy metal through contaminated soil, a preventive control such as a supply-chain control with a verification program to ensure that the grower conducts an assessment of the growing region prior to its use for agriculture may be appropriate. In other cases, an unsafe level of a heavy metal such as lead could be introduced into a food product as a result of a food-contact surface constructed with lead solder. CGMP controls, such as the controls on equipment and utensils in 21 CFR 117.40, generally can control chemical hazards such as heavy metals that can leach from food-contact surfaces.

3.4.1.4 Environmental contaminants

Environmental contaminants may be of concern in certain foods as a result of their presence in the environment. When your hazard analysis identifies an environmental contaminant that

requires a preventive control, the type of control would depend on how the environmental contaminant could get into your food product. In some cases, high levels of environmental contaminants (e.g., dioxin) may result from accidental contamination of animal feed (WHO, 2014). In 2008, pork meat and pork products were recalled in Ireland when up to 200 times the safe limit of dioxins were detected in samples of pork, although risk assessments indicated no public health concern. The contamination was traced back to contaminated feed. In 1999, high levels of dioxins were found in poultry and eggs from Belgium and in several other countries. The cause was traced to animal feed contaminated with illegally disposed PCB-based waste industrial oil. Because dioxins tend to accumulate in the fat of food-producing animals, consumption of animal-derived foods (e.g., meat, poultry, eggs, fish, and dairy products) is considered to be the major route of human exposure, and FDA has developed a strategy for monitoring, method development, and reducing human exposure (FDA, 2002).

3.4.1.5 Mycotoxins and other natural toxins

Natural toxins, such as mycotoxins, histamines and other biogenic amines, and plant-produced substances (such as the toxin hypoglycin A found in the tropical fruit ackee) are well recognized as hazards in raw or processed agricultural commodities (FDA, 2005a; FDA 2005b; FDA, 2005c; FDA, 2005d).

Mycotoxins are a common group of natural toxins that include aflatoxin, fumonisin, deoxynivalenol (vomitoxin), ochratoxin, and patulin (see Table 3-7). Mycotoxins are toxic metabolites produced by certain fungi (i.e., molds) that can infect and proliferate on agricultural commodities (e.g., grains such as wheat and corn, peanuts, fruits, and tree nuts) in the field and during storage. Mycotoxins may produce various toxicological effects. Some mycotoxins are teratogenic, mutagenic, or carcinogenic in susceptible animal species and are associated with various diseases in domestic animals, livestock, and humans in many parts of the world. The occurrence of mycotoxins in human and animal foods is not entirely avoidable; small amounts of these toxins may be found on agricultural commodities. Occurrence of these toxins on commodities susceptible to mold infestation is influenced by environmental factors such as temperature, humidity, and the extent of rainfall during the pre-harvesting, harvesting, and post-harvesting periods. The molds that produce mycotoxins typically grow and become established in the agricultural commodity during stressful growing and holding conditions, such as insect damage to the crop, drought stress, and wet storage (e.g., from condensation). Although mycotoxins are not a hazard requiring a preventive control during times and locations with good growing and harvest conditions, a preventive control such as supply-chain controls with a supplier verification program may be appropriate if you use agricultural commodities susceptible to mycotoxin formation, because growing and harvest conditions vary from year to year.

Table 3-7 Common Mycotoxins Associated with Commodities

Mycotoxins	Commodities Associated with Mycotoxins
Aflatoxin	Peanuts, dried corn, tree nuts
Ochratoxin	Coffee, raisins, cereal grains
Fumonisins	Dried corn
Deoxynivalenol	Wheat, barley

Mycotoxins	Commodities Associated with Mycotoxins
Patulin	Apples

Histamines and other biogenic amines are produced from the breakdown of amino acids by bacteria in animal-derived foods (e.g., histamine is produced from the amino acid histidine). Effects of foodborne histamines or other biogenic amines generally are acute effects, including headache, nausea, heart palpitations, facial flushing, itching, urticaria (hives), and gastrointestinal upset. Consumption of certain cheeses, especially aged cheeses, has been associated with illness from histamines (Taylor and WHO, 1985; Stratton et. al, 1991). If you determine that cheeses you use as a raw material present a histamine hazard, you must identify and implement a preventive control (see 21 CFR 117.135(a)). If you purchase such cheeses, we recommend a supply-chain control with a supplier verification program as well as temperature controls to minimize growth of histamine-producing microorganisms.

An example of a natural toxin produced by a plant is hypoglycin A, a heat stable toxin found in the tropical fruit ackee. The level of hypoglycin A in the edible portion of the ackee fruit decreases as the fruit ripens. Only properly ripened and processed ackee products with hypoglycin A at negligible levels are safe for consumption (FDA, 2015f). Although some persons consume unripe ackee with no adverse effects, other persons who consume unripe ackee with hypoglycin A exhibit symptoms that range from mild (e.g., vomiting) to severe (e.g., vomiting with profound hypoglycemia, drowsiness, muscular exhaustion, and possibly coma and death).

3.4.1.6 Chemical hazards that may be intentionally introduced for purposes of economic gain

The PCHF requirements specify that you must consider, as part of your hazard identification, known or reasonably foreseeable hazards that may be intentionally introduced for purposes of economic gain (21 CFR 117.130(b)(2)(iii)). We recommend that you focus on circumstances where there has been a pattern of such adulteration in the past, suggesting a potential for intentional adulteration even though the past occurrences may not be associated with the specific supplier or the specific food product. Table 3-8 is a quick reference guide listing circumstances where there has been a pattern of such adulteration in the past. Additional resources include a free on-line food fraud database made available by the U.S. Pharmacopeial Convention (USP)[9] (USP, 2014 and USP, 2016), a report from the Congressional Research Service (Congressional Research Service, 2014), and a report that identifies 137 unique incidents in 11 food categories (Everstine et al., 2013).

[9] USP is a scientific nonprofit organization that sets standards for the identity, strength, quality, and purity of medicines, food ingredients, and dietary supplements manufactured, distributed and consumed worldwide.

Table 3-8. Quick Reference Guide for Hazards That May Be Intentionally Introduced for Purposes of Economic Gain

Food Containing the Hazard	Hazard	Details	Reference
Milk	Melamine	Milk firms in one country added melamine, a nitrogen-rich industrial by-product, to diluted dairy products to increase the apparent protein content	FDA, 2008
Turmeric	Lead chromate	A chemical with a vibrant yellow color that has been used as an adulterant in turmeric to change the color of the spice to suggest that it is of a higher quality	FDA, 2013d
Paprika	Lead oxide	A red chemical that has been used as an adulterant in paprika to change the color of the spice to suggest that it is of a higher quality	Lead Action News, 1995
Chili powder	Sudan I	An orange-red powder that had been added to chili powder as a coloring agent, but is now banned in many countries because the International Agency for Research on Cancer has classified it as a category 3 carcinogen (not classifiable as to its carcinogenicity to humans)	United Kingdom Food Standards Agency, 2005

In determining whether a hazard that may be intentionally introduced for purposes of economic gain is a hazard requiring a preventive control, we recommend that your hazard analysis consider both the country of origin of an ingredient that may contain the hazard and any specific supplier associated with an ingredient containing that hazard. For example, one example listed in Table 3-8 is a widespread incident of economically motivated adulteration in which some milk firms in one country added melamine, a nitrogen-rich industrial by-product, to diluted dairy products to increase the apparent protein content (FDA, 2008). This adulteration resulted in significant public health consequences, with more than 290,000 ill infants and 6 deaths in that country. In light of this incident, we recommend that you include in your hazard analysis the potential for melamine to be an economically motivated adulterant in your food products when using milk products from a country where melamine adulteration has occurred and, based on the outcome of that hazard analysis, determine whether melamine is a hazard that must be addressed in your food safety plan. At present, we do not expect you to consider the potential for melamine to be a significant hazard when using domestic milk products, or milk products from other countries when there is no history of melamine adulteration associated with those countries.

If you determine through your hazard analysis that a hazard that may be intentionally introduced for purposes of economic gain is a hazard requiring a preventive control, we recommend that you address that hazard through your supply-chain program.

3.4.2 Chemical Hazards That Can Be Either Ingredient-Related or Process-Related

3.4.2.1 Food allergens

Researchers estimate that up to 15 million Americans and more than 17 million Europeans have food allergies (FARE, 2015). A number of foods contain allergenic proteins, which are natural constituents of the food that can pose a health risk to certain sensitive individuals. The symptoms of food allergies can include a tingling sensation in the mouth, swelling of the tongue and throat, nausea, difficulty in breathing, chest pain, hives, rash, itchy skin, vomiting, abdominal cramps, diarrhea, sudden drop in blood pressure, loss of consciousness, and, in severe cases, death. Symptoms of a food allergy usually come on suddenly, can be triggered by a small amount of food, and happen every time the food is eaten. The symptoms are the result of the body's immune system reacting to a specific food or an ingredient in the food.

Allergic consumers must avoid allergens to prevent potentially life threatening reactions. Undeclared food allergens are chemical hazards that can get into food because either: (1) The food manufacturer did not properly declare a food allergen ingredient on the product label; or (2) unintended (and, thus, undeclared) food allergens are present in a food due to incorrect labeling or due to allergen cross-contact.

This section of this chapter provides a general discussion of food allergen hazards and common mechanisms to control them. For more detailed information, see Chapter 11 – Food Allergen Controls, which provides a comprehensive guide to food allergen control. An additional resource is "Managing Allergens in Food Processing Environments," a publication of the Grocery Manufacturer's Association (GMA, 2009).

3.4.2.1.1 The "Big Eight" food allergens

The Food Allergen Labeling and Consumer Protection Act (FALCPA) of 2004 amended the FD&C Act and defined the following eight foods and any ingredients that contain protein derived from these eight foods (with certain exemptions noted in section 201(qq)(2) of the FD&C Act (21 U.S.C. 321(qq)(2)) as major food allergens: milk, eggs, fish, crustacean shellfish, tree nuts, peanuts, wheat, and soybeans. The eight foods or food groups cause more than 90% of the food allergies in the United States (FDA, 2015c) and are commonly referred to as "the big eight" food allergens. FDA has published guidance on labeling the food allergens identified in FALCPA – See "Guidance for Industry: Questions and Answers Regarding Food Allergens, including the Food Allergen Labeling and Consumer Protection Act of 2004" (FDA, 2006b). Immediately below, we provide more information about each of "the big eight food allergens."

- **Crustacea:** The class of Crustacea, or shellfish, includes shrimp, crab, lobster, and crayfish. Crab and shrimp are the most commonly consumed shellfish in the United States. The major shellfish allergen is tropomyosin, a muscle protein that accounts for 20% of the dry weight of shrimp (GMA, 2009).

- **Egg:** Most egg allergic proteins are found in the egg white (albumin) rather than the yolk.
- **Fish:** Different fish species (e.g., bass, cod, and flounder) have been found to have structurally-related proteins, and this may explain why individuals with a fish allergy are allergic to multiple types of fish. Cooking may reduce the allergenicity of fish, but it does not eliminate it.
- **Milk (Dairy):** Cow's milk contains a number of different proteins that are grouped into two categories: caseins, which constitute 80% of the total protein, and whey proteins, which make up 20%.
- **Peanut:** Peanut seeds contain an average of about 29% protein, classified as albumins or globulins.
- **Soy:** Globulins are the major proteins in soybeans.
- **Tree Nuts:** Tree nuts include almonds, Brazil nuts, cashews, filberts/hazelnuts, macadamia nuts, pecans, pine nuts, pistachios, and walnuts. FDA lists the nuts considered "tree nuts" in its 2006 "Guidance for Industry: Questions and Answers Regarding Food Allergens, including the Food Allergen Labeling and Consumer Protection Act of 2004 (Edition 4)" (FDA, 2006b) and its 2013 Guidance for Industry: A Food Labeling Guide (FDA, 2013a).
- **Wheat:** Wheat proteins include the globulins, prolamins (i.e., glutenin and gliadin), and glutelins. About 25% of wheat-allergic children react to other cereal grains (i.e., barley, oats, or rye). Gluten is a mixture of proteins that occur naturally in wheat, rye, barley and crossbreeds of these grains. It is associated with celiac disease, which affects as many as 3 million people in the United States by the body's natural defense system attacking the lining of the small intestine and preventing the proper absorption of nutrients (FDA, 2015(d)).

3.4.2.1.2 Undeclared food allergen hazards due to incorrect label design

FALCPA also amended section 403 of the FD&C Act (21 U.S.C. 343) to prescribe certain requirements for what you must declare on the product label for any food product that contains any of the "big eight allergens," including allergenic whole foods (such as milk) and any ingredients that contain protein derived from these foods (such as casein derived from milk). See section 403(w) of the FD&C Act (21 U.S.C. 343(w)) and our guidance entitled "Guidance for Industry: Questions and Answers Regarding Food Allergens, including the Food Allergen Labeling and Consumer Protection Act of 2004" (FDA, 2006b).

An undeclared food allergen (including a food allergen contained in flavorings, colorings, and incidental additives) due to an incorrect label design that does not address all of the labeling requirements of FALCPA is a chemical hazard. See 21 CFR 117.130(b)(1)(ii).

3.4.2.1.3 Undeclared food allergen hazards due to incorrect application or use of a product label

If you apply the wrong label to a food, or use the wrong packaging (e.g., using packaging for "chocolate ice cream" rather than for "chocolate ice cream with almonds"), consumers who have a food allergy could purchase a food that would cause an allergic reaction. An undeclared food allergen due to applying the incorrect food label to a product, or using the wrong packaging, is a chemical hazard. See 21 CFR 117.130(b)(1)(ii).

3.4.2.1.4 Undeclared food allergen hazards due to allergen cross-contact

Cross-contact results from the unintentional incorporation of undeclared allergens into foods that are not intended to include those allergens. Cross-contact can occur either between foods that contain different food allergens or between foods with and without food allergens. Introduction of an allergen through cross-contact may occur during receiving, handling,

processing and storage of ingredients and foods, utensils, and packaging; through improper handling and cleaning of equipment, utensils, and facilities; and through improper facility design.

An undeclared food allergen due to allergen cross-contact is a chemical hazard. See 21 CFR 117.130(b)(1)(ii). Allergen cross-contact can result from:

- Failure to schedule the production of two different products appropriately, resulting in an allergen-containing product contaminating a product without food allergens.
- Failure to adequately clean between two different formulations of a product that do and do not contain allergens, resulting in an allergen-containing product contaminating a product without the allergen.
- Failure to store allergen-containing ingredients separately from ingredients that do not contain allergens, where leakage of allergen-containing materials results in contamination of the non-allergen containing product.
- Failure to handle powdered allergens in a way that prevents particles from blowing onto foods or food contact surfaces for foods that do not contain that allergen.

3.4.2.2 Food additives, color additives, and GRAS substances, including substances associated with food intolerance or food disorder

Under sections 201(s) and 409 of the FD&C Act (21 U.S.C 321(s) and 348, respectively), a substance that is added to food requires premarket review and approval as a food additive unless it satisfies the statutory exclusion from the definition of "food additive" for a substance that is generally recognized as safe (GRAS) under the conditions of its intended use (section 201(s) of the FD&C Act or is otherwise excepted from the statutory definition of food additive (e.g., as a color additive, as a dietary ingredient intended for use in a dietary supplement, or as a new animal drug).

Under sections 201(t) and 721 of the FD&C Act (21 U.S.C 321(t) and 379(e), respectively), a color additive requires premarket review and approval; there is no statutory GRAS exclusion applicable to a color additive.

Generally, a food additive, color additive, or GRAS substance is known to be safe for use in food only under specific conditions of use, such as a maximum level of use or use only in certain food categories. The potential risk to consumers increases when these substances are not properly controlled, such as exceeding the usage rates or accidentally introducing an additive into a food for which it was not approved.

For some consumers, certain substances (including substances that are lawfully used in food as food additives, color additives, GRAS substances, and components of whole foods such as milk) can cause hypersensitivity reactions because the substance irritates the stomach, or the body cannot properly digest it. The symptoms include nausea, abdominal pain, diarrhea, vomiting, gas, cramps or bloating, heartburn, headaches, irritability, or nervousness. Symptoms of food intolerance usually occur gradually, in comparison with the sudden onset from an allergic reaction, and may only occur when a lot of a food is consumed or the food is consumed often.

- **Lactose:** Some people are intolerant to lactose, a sugar that is a component of milk, because they lack the enzyme to digest lactose. The symptoms include abdominal pain, diarrhea, vomiting, gas, cramps or bloating. People who have a lactose intolerance avoid milk or milk products and rely on the allergen labeling for milk to identify the types of products that may cause them problems.

- **Sulfiting agents:** Sulfiting agents are used as chemical preservatives in various products. People sensitive to sulfiting agents can experience symptoms that range from mild to life-threatening reactions. As noted previously, sulfites have resulted in diarrhea, headache, difficulty breathing, vomiting, nausea, abdominal pain and cramps in sulfite-sensitive individuals (Timbo et al. 2004).
- The sulfiting agents permitted in foods that must be listed on the ingredient label, unless they are added to food as an "incidental substance," are: sulfur dioxide (21 CFR 182.3862), sodium sulfite (21 CFR 182.3798), sodium bisulfite (21 CFR 182.3739), sodium metabisulfite (21 CFR 182.3766), potassium bisulfite (21 CFR 182.3616), and potassium metabisulfite (21 CFR 182.3637). Sulfiting agents are considered to be incidental only if they have no technical effect in the finished food and are present at less than 10 parts per million (ppm) (21 CFR 101.100(a)(4)). The quantity of sulfiting agents added to food should not exceed the amount necessary to achieve the intended technical effect(s).
- **Yellow No. 5:** Yellow No. 5 (tartrazine) is a color additive subject to color certification under section 721(c) of the FD&C Act. (21 U.S.C. 379e) People sensitive to Yellow No. 5 can experience symptoms that range from mild to moderately severe. For example hives occur in some intolerant individuals, but in asthmatic individuals Yellow No.5 can trigger allergic-type reactions (including bronchial asthma). To help protect people who are sensitive to Yellow No. 5, FDA's regulation for Yellow No. 5 states that any food for human use that contains Yellow No. 5 must specifically declare the presence of the color additive by listing it as an ingredient (21 CFR 74.705(d)(2)). If Yellow No. 5 is added but is not declared, the product would be both misbranded under section 403(m) of the FD&C Act (21 U.S.C. 343(m) and adulterated under section 402(c) of the FD&C Act (21 U.S.C 342(c)).
- **Cochineal extract and carmine:** Cochineal extract and carmine are color additives permitted for use in foods in the United States under conditions of safe use listed in 21 CFR 73.100. For sensitive consumers, cochineal extract and carmine can cause severe allergic reactions, including anaphylaxis (74 FR 207, January 5, 2009). Although the color additives cochineal extract and carmine cause allergic reactions, they are not included in the eight major food allergens identified in FALCPA. As a result, the color additives cochineal extract and carmine are not included in the definition of "food allergen" in part 117 and are not subject to the food allergen controls specified in the PCHF requirements. In addition, FDA's specific labeling requirement in the color additive listing for cochineal extract and carmine (21 CFR 73.100(d)(2)), rather than the more general labeling requirements of FALCPA, govern the food labeling requirements cochineal extract and carmine. All human foods containing cochineal extract or carmine are required to declare the presence of the color additive by listing its respective common or usual name, "cochineal extract" or "carmine," in the statement of ingredients ((21 CFR 73.100(d)(2)). Additional information on the labeling requirements for these two color additives can be found in FDA industry guidance, *Cochineal Extract and Carmine: Declaration by Name on the Label of All Foods and Cosmetic Products That Contain These Color Additives; Small Entity Compliance Guide* (FDA, 2009a). Control strategies for cochineal extract and carmine are similar to those applied to food allergen labeling controls.

In addition, some consumers have celiac disease, which is a hereditary, chronic inflammatory disorder of the small intestine triggered by the ingestion of certain storage proteins (referred to as gluten) occurring in wheat, rye, barley, and crossbreeds of these grains. As discussed in section 3.4.2.1.1 of this chapter, celiac disease affects as many as 3 million people in the United States (FDA, 2015(d)).

3.4.2.2.1 Unapproved food additives and color additives

A substance (other than a food contact substance subject to a notification under section 409(h)) that is a food additive or a color additive must be used in accordance with a food additive regulation permitting that specific use or a color additive listing. Otherwise, the presence of that substance in food would make the food adulterated under section 402(a)(2)(C) of the FD&C Act

(21 U.S.C. 342(a)(2)(C)). Under the PCHF requirements, an unapproved food or color additive is a chemical hazard (see 21 CFR 117.130(b)(1)(ii)).

Some food and color additives are specifically prohibited from use in food because we have determined that the chemical additive poses a potential risk to public health (see 21 CFR part 189 and 21 CFR 81.10). Examples of such food and color additives are coumarin, safrole, and FD&C Red No. 4 (Red No. 4) (FDA, 2015b). We consider a prohibited food additive or color additive to be an unapproved food additive or color additive for the purposes of the PCHF requirements and, thus, to be a chemical hazard. You should consult 21 CFR if you have questions about the regulatory status or safety of a particular additive when formulating your food products. An additional resource for you is the *Food Additive Status List* on our website (FDA, 2014b).

3.4.2.2.2 Chemical hazards due to misformulation

A food ingredient can be a chemical hazard if it is added in excess of a maximum use level, regardless of whether the maximum use level is established due to food intolerance (such as for sulfites) or is otherwise a condition of safe use of a food additive, color additive, or GRAS substance. Control strategies to prevent misformulation of substances generally include process controls to ensure that excessive amounts are not added.

3.4.2.2.3 Chemical hazards due to incorrect labeling of substances associated with food intolerance or food disorder

Although the mechanisms whereby persons experience food intolerance or food disorder are different from the mechanisms that cause food allergy, reactions due to food intolerance or food disorder can cause significant health problems for those affected, and the principal means that consumers have to avoid the symptoms of food intolerance are the same means that consumers use to avoid symptoms of food allergy – i.e., avoid foods containing the substance that causes the problem. For example, people who are intolerant to lactose, a sugar that is a component of milk, avoid food products containing milk to avoid the symptoms associated with lactose intolerance. In addition, people who have celiac disease avoid food products containing wheat and other sources of gluten.

Undeclared substances associated with a food intolerance or food disorder are chemical hazards that can get into food because either: (1) The food manufacturer did not properly declare the substance on the product label; (2) unintended (and, thus, undeclared) substances are present in a food due to incorrect labeling. Control strategies to prevent incorrect labeling of substances associated with a food intolerance or food disorder are analogous to those used to prevent incorrect labeling of food allergens and, thus, you may find Chapter 11—Food Allergen Controls helpful in preventing incorrect labeling of substances associated with a food intolerance or food disorder. The preventive controls in that comprehensive guide to food allergen control do not explicitly address substances associated with food intolerance or food disorder, but may nonetheless be useful in addressing chemical hazards due to incorrect labeling of such substances.

3.4.2.4 Process contaminants produced during heating

There are several process-related contaminants that are produced during heating of specific ingredients or finished foods that may be a health (e.g., cancer) concern. For example,

acrylamide is formed during high-temperature cooking processes (including frying, roasting, or baking) due to interaction between sugars and amino acids that are naturally present in foods. Acrylamide is found mainly in foods made from plants, including potato products, grain products, and coffee.

As noted in footnote 8, we have not included such contaminants in Table 3-6 as potential process-related chemical hazards that may require a preventive control as part of a food safety plan under part 117 because we believe that more information is needed regarding appropriate levels and effective controls. We have published a guidance document, *Guidance for Industry: Acrylamide in Foods* (FDA, 2016a) to help growers, manufacturers, and food service operators reduce acrylamide levels in certain foods. Control strategies to reduce acrylamide in food may include controlling temperatures during cooking and ingredient substitution.

3.4.2.3 Radiological hazards

Radiological hazards rarely occur in the food supply; however, when they do occur, these hazards can present a significant risk when exposures occur over a period of time (WHO, 2011). Consuming food contaminated with radionuclides will increase the amount of radioactivity a person is exposed to, which could have adverse health effects. The health effect depends on the radionuclide and the amount of radiation to which a person is exposed. For instance, exposure to certain levels of radioactive iodine is associated with increased risk of thyroid cancer (WHO, 2011).

Radiological hazards can become incorporated into food through the use of water that contains the radionuclides during food production or manufacture. There are areas in the United States where high concentrations of some radionuclides, such as radium-226, radium-228, and uranium, can be detected in well water (Ayotte et al., 2007; Focazio et al., 2001). You should be aware of the condition of the water used for production and manufacture in your facilities. For example, if your facility uses well water and there are elevated levels of radionuclides in the well water, you should not use the water. The CGMPs require that water that contacts food, food-contact surfaces, or food-packaging materials be safe and of adequate sanitary quality (see 21 CFR 117.37(a)).

Radiological hazards also may result from accidental contamination, e.g., contamination arising from accidental release from a nuclear facility or from damage to a nuclear facility from a natural disaster. In 2011, following damage to a nuclear power plant during an earthquake and tsunami in Japan, radioactivity was subsequently detected in foods, particularly milk, vegetables, and seafood produced in areas neighboring the plant (WHO, 2011). You should be vigilant regarding accidental releases of radiological hazards and their potential to contaminate your food product, either directly due to contamination of natural resources near your facility or as a result of raw materials and other ingredients that you obtain from a region that has experienced an accidental release of radiation.

3.4.3 Facility-Related Chemical Hazards

Industrial chemicals or other contaminants from the food processing environment can contaminate food during production – e.g., if chemicals used to clean a production line are not adequately removed from the production line or if heavy metals are leaching from containers or utensils. In this guidance, we do not discuss preventive controls for facility-related chemical hazards such as cleaning chemicals and the leaching of heavy metals from containers or utensils, because such hazards are usually addressed through CGMPs.

3.5 Physical Hazards

You must conduct a hazard analysis to identify and evaluate known or reasonably foreseeable physical hazards (such as stones, glass, and metal fragments). See 21 CFR 117.130(b)(1)(iii). When your hazard analysis identifies a known or reasonably foreseeable physical hazard that requires a preventive control, you must identify and implement a preventive control for the physical hazard. See 21 CFR 117.135(a)(1).

Physical hazards are broadly classified as "hard/sharp" physical hazards and "choking" hazards. Both categories can cause injury to the consumer. These injuries may include dental damage, laceration of the mouth or throat, laceration or perforation of the intestine, and choking and may even lead to the death. Because physical hazards cover a broad range of contaminants, such as glass, metal, plastic, wood, and stones, such contamination can occur throughout the processing facility, including the receiving dock for ingredients and supplies.

In this section of this guidance we describe common physical hazards – i.e., metal, glass, and hard plastic physical hazards.

- **Metal:** Metal-to-metal contact during processing can introduce metal fragments into products. For example, metal fragments can break off during mechanical cutting and blending operations, and some metal equipment has parts that can break or fall off, such as wire-mesh belts. FDA's Health Hazard Evaluation Board (FDA, 2005e; Olsen, 1998) has supported regulatory action against products with metal fragments of 0.3 inches (7 mm) to 1.0 inches (25 mm) in length. Such fragments have been shown to be a hazard to consumers. Metal hazards can be controlled by the use of metal detection devices or by regular inspection of at-risk equipment for signs of damage.
- **Glass:** Glass fragments can be introduced into food whenever processing involves the use of glass containers. Normal handling and packaging methods, especially mechanized methods, can result in breakage. Ingesting glass fragments can cause injury to the consumer. FDA's Health Hazard Evaluation Board has supported regulatory action against products with glass fragments of the same size noted for metal. Most products packed in glass containers are intended to be a ready-to-eat (RTE) commodity. In your hazard analysis, you should consider the potential for glass fragments to originate from sources other than glass containers used in packaging. For example, some facilities that do not pack in glass prohibit the presence of glass in the production environment to reduce the risk of glass getting into the product. You can address glass fragments originating from sources such as overhead light fixtures through CGMPs.
- **Hard Plastic:** Hard plastic can be introduced into food when tools and equipment such as scoops, paddles, buckets or other containers develop fatigue, crack, and break as they wear. Hard plastic also can be introduced into food when plastic sieves and screens deteriorate. You should examine items to determine whether they are worn and remove worn items before they break, especially if they cannot be effectively cleaned (e.g., because of small cracks).

In general, there is overlap between facility-related physical hazards and process-related physical hazards. For example, equipment that has food-contact surfaces that break during food processing and result in physical debris being deposited in the food product can be considered a facility-related physical hazard (because the equipment is part of the facility) or a process-related physical hazard (because the equipment broke during processing). In general, in evaluating the potential for physical hazards in your food products, it does not matter whether you consider physical hazards to be facility-related or process-related. However, a few physical hazards can readily be classified as facility-related or process-related. For example, nuts and bolts used during maintenance procedures would be a facility-related hazard, but production equipment that has nuts and bolts that could fall out during production would be a process-related hazard.

Table 3-9 is a Quick Reference Guide to help you identify common sources of these physical hazards. See Chapter 13 – Preventive Controls for Physical Hazards for more detailed recommendations on control measures for physical hazards. In this guidance, we do not discuss ingredient-related physical hazards such as wood and stone, which are usually addressed through CGMPs or as a supply-chain control through your supplier program.

Table 3-9. Quick Reference Guide for Common Sources of Physical Hazards

Source	Metal – Ferrous & Non-ferrous	Plastic, Ceramic, and Glass	Other
Ingredient-related	• Farm field debris • Precut, ground, injected, sliced, items, where metal was not properly controlled by supplier.	• Farm field debris, • Packaging materials	• Pits or pit fragments, shells
Facility-related and process-related (processing/production environment, equipment, and pests (insects, birds, rodents, reptiles))	• Equipment • Grinders, slicers, knives • Sieves, screens, wire-mesh belts • Mixing paddles • Metal cans (shavings, lids) • Pumps • Cook Kettles with swept surface paddles • Drop buckets	• Equipment (inspection belts, small wares, buckets) • Facility (glass light fixtures, glass windows in doors, plastic strip curtains) • Glass containers • Scoops • Mixing paddles • Buckets	• Incomplete removal of pits or pit fragments, shells • Poor Design -- Particle size of food inappropriate for consumer – choking hazard
People-related (actions or behaviors)	• Jewelry • Hair pins	• Buttons • Zipper pulls	

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Hazard Analysis and Risk-Based Preventive Controls for Human Food: Draft Guidance for Industry[10]

This draft guidance, when finalized, will represent the current thinking of the Food and Drug Administration (FDA or we) on this topic. It does not establish any rights for any person and is not binding on FDA or the public. You can use an alternative approach if it satisfies the requirements of the applicable statutes and regulations. To discuss an alternative approach, contact FDA's Technical Assistance Network by submitting the form available at http://www.fda.gov/Food/GuidanceRegulation/FSMA/ucm459719.htm.

Chapter 4: Preventive Controls

Table of Contents

[10] This guidance has been prepared by the Office of Food Safety in the Center for Food Safety and Applied Nutrition at the U.S. Food and Drug Administration.

4.1 Purpose of this Chapter

The guidance provided in this chapter is intended to help you identify and implement preventive controls. The PCHF requirements specify that you must identify and implement preventive controls to provide assurances that any hazards requiring a preventive control will be significantly minimized or prevented and the food manufactured, processed, packed, or held by your facility will not be adulterated under section 402 of the Federal Food, Drug, and Cosmetic Act (FD&C Act) (21 U.S.C 342) or misbranded under section 403(w) of the FD&C Act (21 U.S.C. 343(w)). (See 21 CFR 117.135(a)(1)). This chapter provides an overview of common preventive controls that you could use to significantly minimize or prevent the occurrence of biological, chemical, and physical hazards in food products and the food production environment when the outcome of your hazard analysis is that one or more of these hazards requires a preventive control.

The guidance in this chapter also is intended to help you monitor the preventive controls that you identify and implement. As appropriate to the nature of the preventive control and its role in the facility's food safety system, the PCHF requirements specify that you must establish and implement written procedures, including the frequency with which they are to be performed, for monitoring the preventive control, and to monitor the preventive controls with adequate frequency to provide assurance that they are consistently performed. (See 21 CFR 117.145.)

This chapter does not provide all the details needed for identifying and implementing preventive controls. You have the flexibility to identify and implement preventive controls from among all procedures, practices, and processes that are available to you and that would provide assurances that the hazard is controlled (i.e., significantly minimized or prevented).

4.2 Overview of Preventive Controls

Part 117 defines "preventive controls" as those risk-based, reasonably appropriate procedures, practices, and processes that a person knowledgeable about the safe manufacturing, processing, packing, or holding of food would employ to significantly minimize or prevent the hazards identified by the hazard analysis that are consistent with the current scientific understanding of safe food manufacturing, processing, packing, or holding at the time of the analysis. (See 21 CFR 117.3.) Preventive controls include: (1) Controls at critical control points (CCPs), if there are any CCPs; and (2) controls, other than those at CCPs, that are also appropriate for food safety (See 21 CFR 117.135(a)(2)). The PCHF requirements specify that preventive controls must be written. (See 21 CFR 117.135(b)).The PCHF requirements also specify that preventive controls must include, as appropriate to the facility and the food: (1) Process controls; (2) Food allergen controls; (3) Sanitation controls; (4) Supply-chain controls; (5) Recall plan; and (6) Other controls. (See 21 CFR 117.135(c)).

Table 4-1 lists the sections in this chapter in which we address process controls, sanitation controls, food allergen controls, supply-chain controls, and recall plans. Although Table 4-1 includes supply-chain controls, we intend to provide more information in our forthcoming draft guidance "Supply-Chain Program for Human Food Products: Guidance for Industry." See Chapters 6 through 14 of this guidance for more detailed discussion of applicable preventive controls.

Table 4-1. Preventive Controls Addressed in this Chapter

Preventive Control	Chapter Section
Process Controls	4.3
Sanitation Controls	4.4
Food Allergen Controls	4.5
Supply-chain Controls	4.6
Recall Plans	4.7

Table 4-2 lists the chapters in this guidance in which we provide additional details regarding certain preventive controls.

Table 4-2. Other Chapters in the Guidance With Additional Information About Specific Preventive Controls

Preventive Control	Chapter
Heat Treatment Process Control	6
Time/Temperature Control Process Control	7
Formulation Process Control (e.g., water activity, pH, and chemical preservatives)	8
Dehydration/Drying Process Control	9
Sanitation Controls	10
Food Allergen Controls	11
Preventive Controls for Chemical Hazards	12
Preventive Controls for Physical Hazards	13
Recall Plan	14

The PCHF requirements specify that you must validate that the preventive controls that you identify and implement are adequate to control the hazard as appropriate to the nature of the preventive control and its role in the facility's food safety system. (See 21 CFR 117.160(a)). The PCHF requirements also specify that validation of the preventive controls must be performed (or overseen) by a preventive controls qualified individual. (See 21 CFR 117.160(b) and the definition of a preventive controls qualified individual in 21 CFR 117.3.) You do not need to validate: (1) Food allergen controls; (2) sanitation controls; (3) the recall plan; and (4) the supply-chain program. You also do not need to validate other preventive controls, if the preventive controls qualified individual prepares (or oversees the preparation of) a written justification that validation of the other control is not applicable based on factors such as the nature of the hazard, and the nature of the preventive control and its role in the facility's food safety system. (See 21 CFR 117.160(c).) We intend to discuss validation in forthcoming guidance.

4.3 Process Controls

Process controls include procedures, practices, and processes to ensure the control of parameters during operations such as heat processing, acidifying, irradiating, and refrigerating foods. Process controls must include, as appropriate to the nature of the applicable control and its role in the facility's food safety system: (1) Parameters associated with the control of the hazard; and (2) the maximum or minimum value, or combination of values, to which any biological, chemical, or physical parameter must be controlled to significantly minimize or prevent a hazard requiring a process control. (See 21 CFR 117.135(c)(1).) Process controls do not include those procedures, practices, and processes that are not applied to the food itself, e.g., controls of personnel or the environment that may be used to significantly minimize or prevent hazards.

Examples of processing parameters that can have a minimum or maximum value (or combination of values) include time, temperature, flow rate, line speed, product bed depth, weight, product thickness or size, viscosity, moisture level, water activity, salt concentration, pH and others, depending upon the process. If a process parameter does not meet a minimum or maximum value (or critical limit), the process is not in control (i.e., a deviation has occurred) and the potential for producing a product that presents a consumer-health risk exists.

Many process controls, such as the application of heat to a food to adequately reduce pathogens, are applied in the same manner and for the same purpose as control measures established within HACCP plans and applied at CCPs as recommended by the National Advisory Committee on Microbiological Criteria for Foods (NACMCF, 1998) and the Codex Alimentarius Commission (CAC, 2003). When a process control is applied to a CCP in a HACCP plan, the maximum or minimum values (or combination of values) for the parameters associated with the control of the hazard are called "critical limits." Critical limits have been defined by the NACMCF as a maximum and/or minimum value to which a biological, chemical or physical parameter must be controlled at a CCP to prevent, eliminate or reduce to an acceptable level the occurrence of a food safety hazard (NACMCF, 1998).

In addition to this guidance, a number of sources of scientific and technical information can be useful in establishing process parameters or critical limits. Our guidance documents entitled "*Fish and Fishery Products Hazards and Controls Guidance*" and "*Juice HACCP Hazards and Controls Guidance*" each have information that can be broadly applied to food products. Other government agencies may also provide information through technical staff, regulations, guidelines, directives, performance standards, tolerances, and action levels. For example, the guidance documents entitled "Meat and Poultry Hazards and Controls Guide" (FSIS, 2005) and FSIS Compliance Guideline HACCP Systems Validation (FSIS, 2015), provided by the Food Safety and Inspection Service (FSIS) of the U.S. Department of Agriculture, has information that can broadly be applied to food products, not just meat and poultry products subject to FSIS' jurisdiction. As another example, EPA lists maximum pesticide residues limits (MRLs) and tolerances in 40 CFR Part 180. (EPA, 2015) and provides Indexes to Part 180 Tolerance Information for Pesticide Chemicals in Food and Feed Commodities on its website (EPA, 2016). Trade associations, process authorities, industry scientists, university and extension scientists, and consultants can provide expertise and guidance. For example, the Grocery Manufacturer's Association (GMA) has provided guidance on Control of *Salmonella* in Low-Moisture Foods (GMA, 2009). Information can also be obtained from peer reviewed scientific literature. For a more comprehensive list of resources, see the training materials provided by the Food Safety Preventive Controls Alliance (FSPCA, 2016) In addition to (or in place of) information from such resources, you also can conduct scientific studies for specific products in-house, at a contract

laboratory, or at a university to establish appropriate process parameters and associated values.

You should use care when applying information from any of these sources to processing parameters for a specific product and process. Among other reasons, there may be important differences between the application of processing parameters as discussed in these sources how you would apply the processing parameters to your specific product and process. The processing parameters and/or minimum or maximum values may need to be adjusted to account for those differences. For example, the temperature (and time at that temperature) necessary to kill microorganisms in a food product can depend on the fat level in that food product.

Table 4-3 lists examples of the application of process controls to significantly minimize or prevent ingredient-related and process-related biological, chemical, and physical hazards and the section in this chapter that addresses each listed example.

Table 4-3 Common Process Controls

Process Control Subcategory	Hazard Category	Examples	Chapter Section
Lethal Treatments	Biological	• Heat treatments (also called thermal treatments) (e.g., cooking, roasting, baking) • High Pressure Processing (HPP) • Irradiation • Antimicrobial fumigation (e.g., with polypropylene oxide (PPO))	4.3.1
Time/Temperature of Holding	Biological	• Refrigeration • Freezing	4.3.2
Formulation	Biological	• Reducing the water activity • Reducing the pH • Adding preservatives	4.3.3
Dehydration/Drying	Biological	• Air-drying (forced air and heating) • Freeze drying • Spray drying	4.3.4
Recipe Management	Chemical	• Controlling the maximum level of food ingredients	4.3.5
Storage Conditions	Chemical	• Controlling moisture during storage of raw agricultural commodities	4.3.6
Physical Sorting	Chemical	• Reducing mycotoxin content through sorting by color and physical damage in raw agricultural commodities	4.3.7

Process Control Subcategory	Hazard Category	Examples	Chapter Section
Exclusion of Metal and Glass	Physical	• Using magnets • Using metal detectors • Using sieves, screens • Using X-ray systems	4.3.8

4.3.1 Treatments lethal to biological hazards

We use the term "lethality treatment" when referring to a treatment that is used to kill/destroy or inactivate microorganisms. In general, when discussing bacterial pathogens in this document we use the terms "kill" or "destroy" when discussing treatments lethal to vegetative cells and we use the term "inactivate" when discussing treatments lethal to spores. Common lethality treatments include: (1) Heat treatments (e.g., cooking, boiling, pasteurizing, baking, frying); (2) HPP; (3) irradiation; and (4) antimicrobial fumigation. We discuss each of these in the following sections of this chapter.

4.3.1.1 Use of Heat Treatment (Thermal Processing) as a Lethality Process Control

Heat treatment is a common lethality process control. Heat treatments generally fall into into the following two categories:

- Heat treatment that leads to commercial sterility: heat processing at high temperatures (> 212^{o}F (100°C)) under presssure with the objective of killing all forms of microorganisms, including the spores of bacteria. The treated products are shelf-stable without refrigeration. (Lower temperatures can lead to products that are shelf-stable in some cases, e.g., when the pH is low enough to prevent growth of surviving sporeformers.)
- Heat treatment that reduces microbial pathogens but does not lead to commercial sterility: heat processing at lower temperatures (e.g., 158°F (70°C) to 212°F (100°C)), with the processes designed to kill the vegetative forms of microorganisms with little to no effect on the spores of bacteria. The treated products are not shelf-stable and require controls such as refrigeration to control spores of bacterial pathogens.

This chapter does not address heat treatments that lead to commercial sterility of "low-acid canned foods." Such treatments are subject to the requirements of 21 CFR part 113 (Thermally Processed Low-Acid Foods Packaged in Hermetically Sealed Containers; commonly called "Low-Acid Canned Foods (LACF)) because the microbial hazards in LACF are not subject to the requirements for hazard analysis and risk-based preventive controls. Note that although some hermetically sealed containers (e.g., pouches and glass bottles) used to package thermally processed low-acid foods generally would not be viewed as "cans," the term "low-acid canned foods" has been used for decades as a shorthand description for "thermally processed low-acid foods packaged in hermetically sealed containers," and we continue to use that term (and its abbreviation, LACF) for the purposes of this guidance.

Pasteurization is an example of a lethal heat treatment that reduces microbial pathogens but does not lead to a shelf stable product. Pasteurization typically is applied to foods to kill non-sporeforming pathogens such as *Salmonella*, *Listeria monocytogenes*, and pathogenic strains

of *E. coli.* One example is the pasteurization of grade "A" milk and milk products that is covered by the 2015 Pasteurized Milk Ordinance (PMO) (FDA, 2015a). This chapter does not address pasteurization of milk; if you pasteurize milk, you should refer to 21 CFR 1240.61 and the specific requirements in your jurisdiction.

Thermal Destruction of Microorganisms

To design a lethal heat treatment for use as a preventive control, you should have a basic understanding of thermobacteriology (i.e., the relationship between bacteria and heat), including two key types of data and information:

- The kinetics of thermal inactivation or destruction of microorganisms, known as thermal death time data and;
- The rate at which heating occurs within the food material, also known as heat transfer or heat penetration.

Immediately below, we describe basic concepts associated with thermal death time data and heat transfer/heat penetration. For a more extensive review of thermobacteriology, including graphical representations of the relationship of D values and z values to Thermal Death Time, refer to Stumbo, Chapter 7 (1973).

Some terms and concepts used to describe the thermal destruction of microorganisms include:

- **TDT (Thermal Death Time)** is the time necessary to kill a given number of microorganisms at a specified temperature. The TDT is obtained by keeping temperature constant and measuring the time necessary to kill the amount of cells specified.
- **D Value** (the decimal reduction time) is the time required to kill 90% of the microorganisms. Another way of expressing this is the time required at a specific temperature and under specified conditions to reduce a microbial population by one decimal (see discussion below).
- **z Value** refers to the degrees in Farhenheit required for the thermal destruction curve to cross one log cycle (i.e., for reducing the D value by a factor of 10).

Food processing experts evaluate treatments intended to kill or inactivate pathogens in food in terms of "logs" of kill, where the term "log" is a shorthand expression of the mathematical term logarithm. A logarithm is the exponent of the power to which a base number must be raised to equal a given number. In thermobacteriology, the base number is usually 10. As an example, the number 100 = 10^2 where the base number is 10 and the exponent is 2. Because the exponent is 2, the number 100 = log 2. Likewise, the number 1000 = 10^3 = log 3. The important thing to understand is that each "log" of kill is capable of causing a tenfold reduction in the number of microorganisms that the treatment is designed to kill, i.e., the most resistant microorganism of public health significance.

The decimal reduction time (D) is used synonymously with "log" in the context of thermobacteriology. A 1-log or 1D process would be one that is capable of reducing the level of the most resistant pathogen of concern in the food by 10 fold, e.g., from 10,000 cells of the microorganism per gram of food to 1,000 cells of the microorganism per gram of food. Importantly, it is not possible to technically achieve a level of reduction to zero, or "no microorganisms"; instead, as a technical matter the probability of finding the organism becomes less likely as the magnitude of reduction increases. Thus, a 5-log reduction process would be one that is capable of reducing the level of the most resistant pathogen of concern in the food

by 100,000 fold, e.g., from 10,000 cells of the microorganism per gram of food to a probability of 1 cell in 10 g of food.

Table 4-4 provides examples of how food processing experts would describe the effect of lethal heat treatments on microorganisms in foods using terms commonly associated with thermobacteriology.

Table 4-4. The concept of log reductions of microorganisms in foods

Initial number of the most resistant microorganism of public health significance per gram of food	Log reduction (also known as D)	Decrease in most resistant microorganism of public health significance per gram of food	Percent of change	Final number of bacteria per gram of food
10,000 or log 4[1]	1	10-fold	90%	1,000 or log 3
10,000 or log 4	2	10 X 10 = 100 fold	99%	100 or log 2
10,000 or log 4	3	10 X 10 X 10 = 1000-fold	99.9%	10 or log 1
10,000 or log 4	4	10 X 10 X 10 X 10 = 10,000-fold	99.99%	1 or log 0
10,000 or log 4	5	10 X 10 X 10 X 10 X 10 = 100,000-fold	99.999%	0.1 or log -1[2]
10,000 or log 4	6	10 X 10 X 10 X 10 X 10 = 1,000,000-fold	99.9999%	0.01 or log -2

[1] Additional equivalent ways to express 10,000 include 10^4, 10^4, and 10E4
[2] Additional equivalent ways to express 0.1 include 10^{-1} or 1 in 10.

Relative Heat Resistance of Microorganisms

Some microorganisms are more resistant to heat than other microorganisms and, thus, the require more stringent heating conditions to kill or inactivate them. Table 4-5 shows the relative heat resistance of common types of microorganisms.

Table 4-5. Relative Heat Resistance of Microbial Forms

Resistance to Heat	Microbial Form
Highest	Bacterial Spores
Moderate	• Some Vegetative bacterial cells • Cysts of Parasites • Fungi, including fungal spores
Least	• Some vegetative bacterial cells • Viruses

As already noted, this chapter addresses relatively mild heat treatments that reduce microbial pathogens but do not lead to commercial sterility. These relatively mild heat treatments are used to reduce the number of vegetative cells of bacterial pathogens such as *Listeria monocytogenes* (*L. monocytogenes*), *Salmonella,* and enteropathogenic *E. coli*, and the spores of non-proteolytic strains of *Clostridium botulinum* (*C. botulinum*) and *Bacillus cereus* (*B. cereus*). These processes are designed to ensure product safety by achieving a 6-log reduction

(6D). For a more detailed review of the relative heat resistance of food pathogens in mildly heat processed foods, see Jay (1996), FDA (2000), and Farkas (2007).

Factors Affecting the Heat Resistance of Microorganisms

In addition to the inherent heat resistance of specific microorganisms (or life stages of microorganisms, such as the spore stage), other factors associated with foods (such as water activity, pH, salt content, fat, and protein) can affect the heat resistance of microorganisms. Table 4-6 lists the most common factors that you should consider when designing a heat treatment as a process preventive control.

Table 4-6. Factors That Influence the Heat Resistance of Microorganisms in Foods

Factor	Effect on Microbial Heat Resistance
Water	As the humidity or moisture goes down, in general the heat resistance increases
Fat	As the fat content increases, there is a general increase in heat resistance of some microorganisms
Salts	The effect of salt varies and depends on the kind of salt and concentration. Some salts that decease water activity appear to increase heat resistance of microorganisms while other salts that may increase water activity (e.g., Ca^{2+} and Mg^{2+}) appear to decrease heat resistance.
Carbohydrates	The presence of sugars can increase the heat resistance of microorganisms due in part to the decrease in water activity. However, the impact can be variable, particularly among sugars and sugar alcohols.
pH	Most microorganisms are more heat resistant near their optimum pH for growth. Generally, as the pH increases or decreases relative to this optimum pH, the microorganisms become more sensitive to heat.
Proteins	Proteins have a protective effect and, thus, increase the heat resistance of microorganisms.

Other factors that can influence the heat resistance of microorganisms include the numbers of organisms, the age of the microorganisms, the temperatures at which microbial growth occurs, the presence of inhibitory compounds, and the time-temperature combination utilized. For a comprehensive compilation of data and research on the effect of food factors on the heat resistance of food pathogens of public health concern, see ICMSF (1996).

Lethal Heat Treatments

Cooking:

Baking, boiling, roasting, steaming, and frying are conventional heating methods used for cooking a wide variety of foods (e.g., cereal-grain products, vegetables, soups, sauces, legumes, and assembled multi-component meals). Cooking is performed for two primary reasons: to make food palatable and to make it safe by eliminating vegetative pathogens such as *Salmonella*, *L. monocytogenes*, and enteropathogenic *E. coli*. This discussion focuses on the food safety aspects of the cooking methods.

You should design a cooking process to target heat resistant vegetative pathogens, such as *L. monocytogenes*. Typically, we recommend a thermal process that achieves a 5D to 7D

reduction for most cooking treatments. However, if the expected initial microbial load is low, a less severe thermal process may be adequate. For cooking processes that target pathogenic sporeformers such as *C. botulinum* type E and non-proteolytic types B and F (i.e., 194°F (90°C)) for 10 min), generally a 6D reduction in the level of contamination is suitable.

Table 3-D in Appendix 3 of this document provides 6D process times for a range of cooking temperatures, with *L. monocytogenes* as the target pathogen. It is possible that higher levels of destruction may be necessary in some foods, e.g., if you expect especially high initial levels of the target pathogen.

Table 3-E in Appendix 3 of this document provides 6D process times for a range of heating temperatures, with non-proteolytic *C. botulinum* type B (the most heat-resistant form of non-proteolytic *C. botulinum*) as the target pathogen.

There are a variety of ways to control the application of these cooking processes depending upon the type of food and the method of delivery (e.g., boiling, steaming). For example, for liquid and semi-liquid food products that are batch-cooked in a cooking vessel such as a kettle agitated during the thermal process, the simplest way to control the process is to check the internal temperature of the product at the end of the designated cooking time (i.e., check the time-temperature parameters of the treatment). A dial thermometer with a long probe works quite well. If the temperature is taken at or near the center of the cooking vessel, it is reasonable to assume that all product in the cooking vessel is at or above that temperature, because foods processed in this manner generally heat by convection or forced convection. You can monitor a simple boiling heat process by visually observing and timing the boil. Usually, a temperature distribution study is performed to ensure that no point in the cooking vessel is at a lower temperature than the minimum value (or critical limit) for temperature required during the process.

Heating food with large particles, like vegetables in stews and some soups, occurs primarily by conduction, rather than by convection. Particle size and consistency can greatly affect the rate of heating at the center of the particle. You cannot control cooking processes for products with large particles by periodically checking the internal temperature of some of the product particles as they leave the cooker because you cannot verify that each particle reached the appropriate temperature for adequate time. Therefore, you should establish the process scientifically and validate it through a scientific study demonstrating that if the minimum/maximum values are met for all the critical factors (e.g., cooking temperature, time, particle size) all particles will receive an adequate heat treatment.

Normally, a study to validate a cooking process is performed by a person or group knowledgeable in the design of thermal processes to determine the critical parameters required for the heat process being applied to ensure that it delivers the desired reduction level (logs of kill, as described in section 4.3.1.1 of this chapter). A preventive controls qualified individual must conduct (or oversee) such a study. See 21 CFR 117.180(a). (Because it is common practice for these studies to be conducted by entities with special expertise in the area, the preventive controls qualified individual likely will oversee, rather than conduct, the study.) Once that study has been completed, the person conducting the study will provide a time and temperature for the processor to monitor during processing, as well as any other parameters that are critical to delivery of an adequate heat treatment, such as maximum particle size). You can then monitor the time and temperature of the heat process to effectively ensure that all product particles have achieved the desired internal temperature. It may also be necessary to monitor other factors of the product or the process, such as the internal temperature of the

product before the start of the process--called the initial temperature (IT), particle size, or relative humidity, where they affect the rate of heating. These factors, and their limits, will be determined by the process design study.

For some products, such as soups or sauces, you may be able to monitor End-Point Internal Product Temperature (EPIPT), a measurement of the internal temperature of the product at the end of the heat process, instead of performing continuous time and temperature monitoring. This approach is suitable if you have conducted a scientific study to validate that the EPIPT that you have selected will provide an appropriate reduction (e.g., 6D) in the numbers of the target pathogen in the slowest heating unit or portion of product under the worst set of heating conditions covered by the scientific study. If you want to monitor EPIPT, you should:

- Conduct a temperature distribution study within the heating system to identify any cold spots;
- Conduct a heat penetration study that accounts for the slowest heating product under the worst case heating conditions covered by the scientific study; and
- Identify other critical factors of processing and/or packaging that affect the rate of product heating when scientifically establishing a heat process.

You should use the EPIPT as a monitoring technique only under those conditions that were evaluated by the scientific study, with those conditions identified as process parameters with minimum/maximum values (or critical limits) that are monitored as part of your process controls. See “Chapter 6 – Use of Heat Treatments as a Process Control” in this guidance for additional information about the EPIPT monitoring technique.

Other common forms of cooking that are used to produce commercially manufactured foods are baking and roasting. These are essentially the same unit operation because they both use heated air to alter the eating quality of foods. However, the term “baking” is usually used when heated air is applied to flour-based foods or fruits, and the term “roasting” is usually used when heated air is applied to meats, nuts, or vegetables. Baking and roasting operations use dry heat in gas-fired or electric ovens. For some products such as bakery products, the effectiveness of the dry heat in ovens is increased by the addition of steam for various cooking purposes. Cooking equipment may be batch-type or continuous. In a continuous system the food is moved through the cooking equipment by conveyor or auger systems. The methods of controlling and monitoring the time-temperature parameters of these types of cooking processes will vary depending upon whether it is batch-type or continuous process. See “Chapter 6 – Use of Heat Treatments as a Process Control” for an example using baking as a preventive control.

Emerging Technologies Based on Thermal Effects

Microwave, radio frequency, ohmic heating, and inductive heating are heat-based processes that can kill microorganisms by thermal effects. Microwave and radio frequency heating are based on the use of electromagnetic waves of certain frequencies to generate heat in a material through two mechanisms - dielectric and ionic. Ohmic heating is the process of passing electric currents (primarily alternating) through foods or other materials to heat them. The heating occurs in the form of internal energy generation within the material. Ohmic heating is distinguished from other electrical heating methods either by the presence of electrodes contacting the food (as opposed to microwave heating, where electrodes are absent), and depends on frequency of the current and waveform (typically sinusoidal). Inductive heating is a process of inducing electric currents within the food due to oscillating electromagnetic fields generated by electric coils.

For any of these heat-based processes, the magnitude of time/temperature history and the location of the cold points will determine the effect on microorganisms. The effectiveness of these processes also depends on water activity and pH of the product. Although the shape of the destruction or inactivation curves is expected to be similar to those in conventional heating, the intricacies of each of the technologies need special attention if you plan to use them for microbial destruction or inactivation. For instance, in microwave heating a number of factors influence the location of the cold points, such as the composition, shape, and size of the food, the microwave frequency, and the applicator design. The location of the coldest-point and time/temperature history can be predicted through simulation software, and we expect that food processors may be able to use these emerging technologies in the future.

For a detailed overview of these processing technologies, as well as alternative thermal processing techniques, see Sun (2005).

4.3.1.2 Use of High Pressure Processing (HPP) as a Lethality Process Control

The pressure processing of foods for preservation was studied as early as the end of the 19th century and the beginning of the 20th century in the United States by people like Hite (1899) and Bridgman (1912). However the potential microbiological effects of HPP were not recognized by the food industry until around 1985. HPP has recently received a great deal of attention in the food, pharmaceutical, and biotechnology industries. Japan has been a leader in this technology, producing products such as jams, jellies, fruit juices, and yogurt.

Microorganisms vary in their sensitivity to high pressure. If you plan to use HPP, you should consider the organism of concern, product characteristics and, whether the process is to result in product that is to be refrigerated or that will be shelf stable. Destruction of the microorganism is primarily caused by changes in the structure and permeability of the cell wall which causes fluids to be forced into the cell.

Bacterial spores are well established as the most pressure-resistant biological forms known. Spores resist inactivation by high pressure alone and most require the addition of heat or some other mechanism to achieve appropriate levels of destruction. *C. botulinum* is one of the most pressure-resistant and hazardous microorganisms, which is a challenge in the design of high-pressure processes. Because of this, the best candidates for HPP continue to be acid foods and foods that will be refrigerated following processing (which provide control of sporeformers).

High pressure processing of foods requires pressures of 400 to 700 MPa, or 4000 - 7000 bars (58,000 - 101,000 psig). The unit of measure frequently used for HPP in the food industry is the pascal (Pa) or megapascal (MPa, 1,000,000 Pa). Most commercial food industry applications use pressures in the range of 600 to 700 MPa.

High pressure processing requires very specialized and costly equipment. Currently foods using HPP are being processed by batch systems. For batch processing, the food is packaged in a flexible or semi-flexible package, prior to placing the product in the HPP system, where the product is placed into a chamber and immersed in water or some other pressurizing fluid, then subjected to the high pressure for a time of 1 - 20 minutes, depending on the temperature and pressure. The chamber would then be depressurized and the product removed. Applications and the feasibility for commercialization for other HPP systems such as semi-continuous,

continuous, and pulsed HPP have been described elsewhere (FDA, 2000; Indrawati et al. 2003; Z. Berk, 2009).

For a detailed review of the application and use of HPP as a process control, see FDA (2000 and 2001) and Hogan et al. (2005).

4.3.1.3 Use of Irradiation as a Lethality Process Control

The application of radiation treatments to food for the purpose of improving safety (e.g. by reducing or eliminating pathogenic bacteria) or extending shelf life by (e.g. by reducing or eliminating spoilage microorganisms and insects) can use sources that have high enough energy levels to cause ionization (the creation of ions by expulsion of orbital electrons from atoms) or have lower energy levels that will not cause ionization. These are known as ionizing and non-ionizing radiation, respectively. The most commonly used form of radiation to treat foods as a lethality process control is ionizing radiation and the discussion in this section of this chapter focuses on ionizing radiation. Non-ionizing radiation in the form of lower energy electromagnetic waves such as UV light and infrared heating can be used to treat foods similar to that described for microwaves, radio frequency, and ohmic heating in the section of this chapter entitled "Emerging Technologies Based on Thermal Effects" and will not be addressed here. For more information on the application of infrared (IR) radiation in food processing operations, see the review by Krishnamurthy et al. (2008). For more information on the application and use of UV light in food processing, see the discussion by FDA (2000, 2001).

FDA is responsible for regulating the sources of radiation that are used to irradiate food (21 CFR Part 179 Subpart B). Irradiation is considered a food additive in the United States and, as such, its use in foods requires premarket approval by FDA (21 CFR Part 179). There are three sources of ionizing radiation approved for use on foods (21 CFR 179.26):

- Gamma rays – emitted from radioactive forms of the element cobalt (Cobalt 60) or the element cesium (Cesium 137). Gamma radiation is also used routinely in medicine to sterilize medical and dental products and for the radiation treatment of cancer.
- X-rays – produced by reflecting a high-energy stream of electrons into food off a target substance (usually one of the heavy metals) using electron accelerators. X-rays are also widely used in medicine and industry to produce images of internal structures.
- Electron beam – (or e-beam) is similar to X-rays and is a stream of high-energy electrons propelled from an electron accelerator into food.

Some common terms that are used when describing the application of ionizing radiation in the treatment of foods are:

- Dose (absorbed) – The amount of energy absorbed per unit mass of irradiated material.
- D_{10} value – Amount of radiation required to reduce the population of a specific microorganism by 90% (one $\log_{10}$ cycle) under the stated conditions.
- Gray (Gy) - A unit of absorbed dose of ionizing radiation, equal to 1 joule/kg of absorbed energy.
- Electron volt (eV) – A unit of energy. One electron volt is the kinetic energy acquired by an electron in passing through a potential difference of one volt in a vacuum.

The primary reason food irradiation is used as a lethal process control is to inactivate pathogens and microorganisms that cause food spoilage (Farkas et al., 2014). The application of ionizing radiation damages DNA and very effectively inhibits DNA synthesis and further cell division in

microorganisms that are exposed to these forms and levels of energy. The amount of radiation energy used to bring about the control of microorganisms varies according to the radiation resistance of the particular organism, which is often specific to the species level and the number or load of the microorganisms present.

Radiation treatment at doses of 2–7 kiloGray (kGy), depending on the source of radiation and the food, have been reported to effectively eliminate potentially pathogenic non-sporeforming bacteria, including both long-time recognized pathogens such as *Salmonella* and *S. aureus,* as well as more recently emerged pathogens such as *Campylobacter*, *L. monocytogenes* or *E. coli* O157:H7, from suspected food products (Farkas, 1998). As an example, Table 4-7 provides a summary of compiled data on the ranges of decimal reduction doses (D_{10} values) for the most important non-sporeforming pathogenic bacteria determined in various foods under various conditions.

Table 4-7. D_{10} Values (kGy) for Some Foodborne Non-sporeforming Pathogenic Bacteria

Bacteria	Non-frozen food	Frozen food
Vibrio spp.	0.02-0.14	0.04-0.44
Yersinia enterocolitica	0.04-0.21	0.20-0.39
Campylobacter jejuni	0.08-0.20	0.18-0.32
Aeromonas hydrophila	0.11-0.19	0.21-0.34
Shigella spp.	0.22-0.40	0.22-0.41
Escherichia coli O157:H7	0.24-0.43	0.30-0.98
Staphylococcus aureus	0.26-0.57	0.29-0.45
Salmonella spp.	0.18-0.92	0.37-1.28
Listeria monocytogenes	0.20-1.0	0.52-1.4

Adapted from Farkas et al., 2014

Bacterial spores are more resistant to irradiation than non-sporeforming bacteria. The spores of *C. botulinum* types A and B are particularly resistant.

For illustrative purposes, Table 4-8 lists the approved uses of ionizing radiation for application as a process control in food processing as of April, 2016. We adapted Table 4-8 from 21 CFR 179.26(b), which specifies the limitations on the approved uses of ionizing radiation for the treatment of food and includes uses for purposes other than as a process control. For example, 21 CFR 179.26(b) also specifies limitations on the use of ionizing radiation for use in disinfestation of arthropod pests in food. You should refer to 21 CFR 179.26 for the most current limitations on the approved uses for the treatment of food using ionizing radiation.

Table 4-8. Approved Uses for the Treatment of Food Using Ionizing Radiation

Use	Limitations
For control of *Trichinella spiralis* in pork carcasses or fresh, non-heat-processed cuts of pork carcasses	Minimum dose 0.3 kiloGray (kGy) (30 kilorad (krad)); maximum dose not to exceed 1 kGy (100 krad).
For microbial disinfection of dry or dehydrated enzyme preparations (including immobilized enzymes)	Not to exceed 10 kGy (1 megarad (Mrad)).

Use	Limitations
For microbial disinfection of the following dry or dehydrated aromatic vegetable substances when used as ingredients in small amounts solely for flavoring or aroma: culinary herbs, seeds, spices, vegetable seasonings that are used to impart flavor but that are not either represented as, or appear to be, a vegetable that is eaten for its own sake, and blends of these aromatic vegetable substances. Turmeric and paprika may also be irradiated when they are to be used as color additives. The blends may contain sodium chloride and minor amounts of dry food ingredients ordinarily used in such blends	Not to exceed 30 kGy (3 Mrad).
For control of food-borne pathogens in fresh (refrigerated or unrefrigerated) or frozen, uncooked poultry products that are: (1) Whole carcasses or disjointed portions (or other parts) of such carcasses that are "ready-to-cook poultry" within the meaning of 9 CFR 381.l(b) (with or without non-fluid seasoning; includes, e.g., ground poultry), or (2) mechanically separated poultry product (a finely comminuted ingredient produced by the mechanical deboning of poultry carcasses or parts of carcasses)	Not to exceed 4.5 kGy for non-frozen products; not to exceed 7.0 kGy for frozen products.
For the sterilization of frozen, packaged meats used solely in the National Aeronautics and Space Administration space flight programs	Minimum dose 44 kGy (4.4 Mrad). Packaging materials used need not comply with §179.25(c) provided that their use is otherwise permitted by applicable regulations in 21 CFR parts 174 through 186.
For control of foodborne pathogens in, and extension of the shelf-life of, refrigerated or frozen, uncooked products that are meat within the meaning of 9 CFR 301.2(rr), meat byproducts within the meaning of 9 CFR 301.2(tt), or meat food products within the meaning of 9 CFR 301.2(uu), with or without non-fluid seasoning, that are otherwise composed solely of intact or ground meat, meat byproducts, or both meat and meat byproducts	Not to exceed 4.5 kGy maximum for refrigerated products; not to exceed 7.0 kGy maximum for frozen products.
For control of *Salmonella* in fresh shell eggs.	Not to exceed 3.0 kGy.
For control of microbial pathogens on seeds for sprouting.	Not to exceed 8.0 kGy.
For the control of *Vibrio* bacteria and other foodborne microorganisms in or on fresh or frozen molluscan shellfish.	Not to exceed 5.5 kGy.
For control of food-borne pathogens and extension of shelf-life in fresh iceberg lettuce and fresh spinach.	Not to exceed 4.0 kGy.
For control of foodborne pathogens, and extension of shelf-life, in unrefrigerated (as well as refrigerated) uncooked meat, meat byproducts, and certain meat food products	Not to exceed 4.5 kGy.
For control of food-borne pathogens in, and extension of the shelf-life of, chilled or frozen raw, cooked, or partially cooked crustaceans or dried crustaceans (water activity less than 0.85), with or without spices, minerals, inorganic salts, citrates, citric acid, and/or calcium disodium EDTA	Not to exceed 6.0 kGy.

Adapted from 21 CFR Part 179.26(b)

For additional information on processes, application, and equipment used in the ionizing radiation treatment of foods see FDA (2004), Lacroix (2005), Fellows (2009a), Farkas and Mohacsi-Farkas (2011) and FDA (2015b).

4.3.1.4 Use of Antimicrobial Fumigation as a Lethality Process Control

In California, treatment processes for almonds must use technologies that have been determined to achieve a minimum 4-log reduction of *Salmonella* in almonds (see 7 CFR part 981, Almonds Grown in California). The Almond Board of California (ABC) has processes in place to review treatment processes for scientific adequacy. ABC has funded research projects demonstrating that fumigation with propylene oxide (PPO) (a registered fumigant in the United States for the reduction of bacteria, yeasts, and mold on raw nut meats) is an effective treatment for achieving a minimum 4-log reduction of *Salmonella* in almonds (ABC, 2008).

4.3.2 Use of Time-Temperature as a Process Control

Temperature is an essential factor that affects the growth of bacteria. Bacterial growth can occur over a wide range of temperatures from about 23°F (-5°C) to 194°F (90° C). Table 4-9 lists four types of bacteria based on their temperature growth ranges.

Table 4-9. Temperature Ranges for the Growth of Microorganisms

Group	Minimum Temperature °C (°F)	Optimum Temperature °C (°F)	Maximum Temperature °C (°F)
Thermophiles	40 - 45 (104 - 113)	55 - 75 (131 - 167)	60 - 90 (140 - 194)
Mesophiles	5 - 15 (41 - 59)	30 - 45 (86 - 113)	35 - 47 (95 - 117)
Psychrophiles	-5 - +5 (23 - 41)	12 - 15 (54 - 59)	15 - 20 (59 - 68)
Psychrotrophs	-5 - +5 (23 – 41)	25 - 30 (77 - 86)	30 - 35 (86 - 95)

Thermophiles grow at hot temperatures above 131°F (55°C). Mesophiles grow at or near room temperatures. Psychrophiles grow at or near refrigeration temperatures. Psychrotrophs are capable of growth at refrigeration temperatures, but their optimal growth temperature is in the mesophilic range.

Most pathogenic bacteria are mesophiles and their optimum growth temperature corresponds to human body temperature (see Table 3-A of Appendix 3 of this guidance). Typically, the higher the temperature (within the normal growth range), the more rapid the growth of the microorganism.

It is not only the temperature that is of concern; it is the total time of exposure at temperatures that allow growth that needs to be controlled. The most general recommendation is to hold cold foods below 41°F (5°C) and to keep hot foods above 135°F (57°C). However, in some situations it may not be possible to completely avoid product exposure to mesophilic temperatures.

4.3.2.1 Use of Refrigeration as a Time-Temperature Process Control

Refrigeration works well for controlling the growth of most pathogenic bacteria. However, some pathogens, like *L. monocytogenes* and *Yersinia enterocolitica*, can grow at temperatures close to freezing. Refrigeration has the added advantage of slowing down biological and chemical processes that result in spoilage, oxidative rancidity, and other quality defects.

Control of temperature during storage can be accomplished in several ways, such as ice, chemical coolant gel packs, and mechanical dry refrigeration (e.g., in a cooler).

Controlling temperature with ice or gel packs can be effective if there is an adequate amount of ice or gel packs. Therefore, you should monitor the control by checking whether an adequate amount of coolant is present on the product at all times, including when it is shipped and when it is received and checking the temperature of the food with a thermometer or temperature recording device.

For mechanical dry refrigerated storage in a cooler, if the ambient temperature can be related to the product temperature, monitoring the temperature of the storage area will ensure that the product temperature is under control. Ordinarily monitoring of the cooler requires use of continuous monitoring instruments such as recorder thermometer charts, maximum-indicating thermometers, and high temperature alarms.

Time/Temperature

When food is removed from refrigeration, the temperature of the food gradually increases and can reach the temperature associated with the growth range specific to particular pathogens. Bacterial pathogens go through a lag phase, where little or no growth occurs as the microorganisms adjust to their new environment. Depending upon the ambient temperature, it is possible that food can stay out of refrigeration for at least a couple of hours with no risk of significant pathogen growth. As the product temperature approaches the growth range, pathogens enter what is called the "log phase" (because they grow logarithmically). The object is to prevent that from happening, ideally keeping pathogens in their lag phase. We call the temperature range of concern (41°F (5°C) to 135°F (57°C)) the "danger zone."

Traditionally, the rule of thumb for foods that will support microbial growth has been no more than 4 hours in the danger zone (41°F (5°C) to 135°F (57°C)). Different pathogens have different rates of growth at different temperatures, and the rate of growth will be affected by the type of food and its inherent properties. Therefore, the actual maximum time that a product may be safely held in the danger zone depends on a number of factors, including the type of pathogens that are present and the ability of the food to support their growth. Guidance on this issue is available in the US Food Code[11] (FDA, 2013) and in Table 3-B in Appendix 3 of this document. You may set limits based on these factors or based on studies done on your own specific food products, rather than relying on the 4-hour rule of thumb. Food inspectors should also use these factors when they evaluate the significance of time - temperature abuse.

Control of time and temperature during processing may be more complicated than during storage, because it involves information about the time and temperature exposure of the product during production. You can obtain this information in a variety of ways, such as marking units of product and tracking how long they remain at unrefrigerated temperatures; monitoring the ambient temperature in a chill room operation; or monitoring product temperatures during different phases of production. See "Chapter 7 – Use of Time/Temperature Control as a

[11] The U.S. Food Code (FDA, 2013) is a model that assists food control jurisdictions at all levels of government by providing them with a scientifically sound technical and legal basis for regulating the retail and food service segment of the industry (restaurants and grocery stores and institutions such as nursing homes). Local, state, tribal, and federal regulators use the FDA Food Code as a model to develop or update their own food safety rules and to be consistent with national food regulatory policy. Although the target audience for the U.S. Food Code does not include most food processing facilities, the U.S. Food Code nonetheless contains scientifically-based information that you can use as a resource where appropriate in establishing some preventive controls particularly regarding use of refrigeration to control the growth of microbial pathogens.

Process Control" of this guidance for additional information about the application of time-temperature holding conditions.

Cooling after Cooking

Cooling after cooking can be a critical function influencing the safety of a food (FDA, 2013). Depending upon the food and ingredients, cooked foods can still have viable pathogenic bacteria present. For example, the spores of sporeforming pathogens such as *C. botulinum* can survive cooking processes. For non-sporeforming pathogens that are particularly heat tolerant (such as *L. monocytogenes*), vegetative cells can sometimes survive the cooking process; however, this should not be the case if you selected the appropriate target pathogen for control by the applied process and you validated the control. More often, it is the spores of sporeforming pathogens (such as *C. botulinum*) that survive the cooking process if they are present because temperatures that can only be achieved under pressure are usually needed to inactivate spores. These spores will begin to germinate when the product temperature drops to a temperature at which they can grow (usually below 135°F (57°C)) and will be present in the food during storage. Some spores, such as those from non-proteolytic *C. botulinum* and some strains of *B. cereus*, have the ability to germinate and grow at refrigeration temperatures, although long times are required. Other spores that may be present in the food remain dormant until the product is temperature-abused (i.e., held in the temperature range at which these pathogens can grow). In such an event, pathogenic spores are able to germinate, grow, and the resulting cells can possibly produce toxin due to the fact that most spoilage bacteria (which may otherwise compete for growth) have been eliminated by the cooking process. For further discussion on the importance of cooling food after cooking see Factors that Influence Microbial Growth (Chapter 3 in the Evaluation and Definition of Potentially Hazardous Foods) (FDA, 2001).

If the cooking process is adequate to inactivate spores and the product is protected from recontamination during cooling, the cooling step will not be critical. Situations where these conditions exist are probably limited to certain pressurized steam processes.

Simply putting food in a refrigerator is not adequate to prevent microbiological growth. When large volumes of hot food are cooled, it can take a long time, sometimes as long as 36 hours, to chill the food to a point where pathogen growth is inhibited. The U.S. Food Code specifies the application of a two part cooling protocol In order to cool foods safely and keep bacteria in the lag phase. First, drop the temperature from 135°F (57°C) to 70°F (21°C) within two hours. The temperature must be lowered through this range quickly because foodborne pathogens multiply most rapidly between these temperatures. Second, after dropping the initial temperature to 70°F (21°C), you can take up to additional 4 hours to get the product down to 41°F (5°C). FSIS also recommends a two part cooling for meat and poultry, but uses slightly different temperatures: "temperature should not remain between 130°F (54°C) and 80°F (27°C) for more than 1.5 hours nor between 80°F (27°C) and 40°F (4°C) for more than 5 hours" (FSIS, 1999). Both these protocols are adequate to minimize the potential for growth of foodborne pathogens.

A blast freezer is one of the best cooling methods. High velocity cold air can drop the temperature of large volumes of hot food in less than an hour. The containers of food that have been chilled can then be shifted to a holding cooler.

Cooling tunnels and spiral freezers are similar to blast freezers but are more compatible with moving production lines. They use high velocity cold air, or liquid carbon dioxide or nitrogen for

rapid cooling. Products may be frozen before or after packaging depending upon the product and package size.

Heat exchangers are used for cooling liquids like milk and juice after pasteurization. Lines containing a coolant such as water or cold, raw product run adjacent to lines of hot, pasteurized product. No actual exchange or co-mingling of coolant or raw product with heat-treated product occurs. However, the cold raw liquid, for example, picks up heat from the hot, pasteurized juice. This helps preheat the raw product and also helps precool the heat-treated liquid. See "Chapter 6 – Use of Heat Treatments as a Process Control" in this guidance for additional information about heat exchangers.

Cook-chill operations are typically used in large institutional settings such as prisons, hospitals, and schools as well as in food processing plants. Food is cooked in nylon reinforced plastic bags or is cooked and then pumped into these bags. The bags are chilled in a tumble chiller that tumbles the bags in ice water. This drops the temperature of large volumes of hot food quickly. Typically, an ice tank where coils of refrigerant are run through the tank of water provides the large volume of cold water needed.

Be advised that food can be recontaminated during the cooling process as a result of hand contact, condensate drip, or contact with other foods. See "Chapter 10 – Sanitation Controls" in this guidance for additional information about controlling the risk of recontamination.

4.3.2.2 Use of Freezing as a Time-Temperature Process Control

Foods are microbiologically stable when held at temperatures below 17.6^{o}F (-8^{o}C). During frozen storage, populations of viable microorganisms in most foods will decrease; however, some microorganisms remain viable for long periods of time during frozen storage. Most viruses, bacterial spores, and some bacterial vegetative cells survive freezing unchanged. Some of the other microorganisms are sensitive to the freezing and thawing process (i.e., freezing, frozen storage, or thawing). Since multi-celled organisms (such as such as parasitic protozoa, nematodes, and trematodes) are generally more sensitive to low temperatures than are bacteria; freezing and frozen storage are good methods for killing these organisms in various foods. This is especially important if consumers are likely to eat the foods raw or undercooked. See Kennedy (2003) and Fellows (2009b) for a detailed review on the use of freezing technologies in the preservation of foods.

4.3.3 Use of Product Formulation as a Process Control

Most food preservation techniques used by processors employ knowledge of factors (such as water activity, pH, temperature, nutrients, chemical inhibitors, competitive microflora, and atmosphere) that affect the growth of bacteria. For more information on how these factors affect microbial growth, see International Commission on Microbiological Specifications for Foods (ICMSF) (1996, 2002), Jay (1996), and Zeuthen and Bogh-Sorensen (2003).

In this section of this chapter, we discuss two key factors that are frequently used as a formulation process control – i.e., water activity and pH. We also discuss the use of preservatives as a formulation process control.

4.3.3.1 Use of Water activity (a_w) as a Formulation Process Control

Microorganisms need water to survive as well as to grow. Water activity (a_w) refers to the availability of water to the organism. In general, microorganisms survive and grow better when the water activity is high than when the water activity is low.

If you have a closed container of water, the air over the water becomes saturated with water. The relative humidity is 100%, which equals a water activity of 1.0. Thus, water has a water activity of 1.0. Foods are more complex systems than water, and the water can bind to components of the food so not all the water in the food is available to microorganisms; thus, the water activity of most food products is less than 1.0.

Water activity is directly related to the vapor pressure of the water in a solution. You can determine water activity by measuring the equilibrium relative humidity of the air over the solution in a closed container. Relative humidity divided by 100 equals the water activity:

$$\mathbf{(a_w) = RH/100}$$
or
$$\mathbf{a_w = p/p_o}$$

Foods vary in their water activity as shown in Table 4-10. Although you can measure the water activity of your specific food if you have the appropriate equipment, for many purposes you can rely on the water activity values shown in Table 4-10.

Table 4-10. Principal Groups of Foods Based on Water Activity (a_W) (ICMSF, 1980)

Water Activity	Food Groups
0.98 and above	• Fresh meats and fish • Fresh fruits and vegetables • Milk and other beverages • Canned vegetables in brine • Canned fruit in light syrup
Below 0.98 to 0.93	• Evaporated milk • Tomato paste • Lightly salted pork and beef products • Canned cured meats • Fermented sausages (not dried) • Cooked sausages • Processed cheese • Gouda cheese • Canned fruits in heavy syrup • Bread
Below 0.93 to 0.85	• Dry or fermented sausage • Dried venison • Cheddar cheese • Sweetened condensed milk
Below 0.85 to 0.60	• Intermediate moisture foods • Dried fruits • Flour • Cereals • Jam and jellies • Molasses • Heavily salted fish • Meat extract • Nuts
Below 0.60	• Confectionery • Chocolate • Honey • Dried Noodles • Crackers • Potato Chips • Dried egg, milk and vegetables

Table 4-10 organizes the foods into five categories, based on their water activity. Table 4-11 further classifies these five categories into three categories – i.e., moist foods, intermediate-moisture foods (often included in the low-moisture foods category), and low-moisture foods. Moist foods (i.e., foods with water activity above 0.85) require refrigeration or another barrier to control the growth of pathogens (see Table 4-11). Intermediate-moisture foods (i.e., foods with water activities between 0.60 and 0.85) do not require refrigeration to control pathogens, but they may have a limited shelf life because of spoilage, primarily by yeast and mold. The microbiological stability of intermediate-moisture foods may depend on factors other than water activity, such as reduced pH, chemical preservatives, heat treatments, or combinations of these, even though the reduced water activity is of major importance. Low-moisture foods (i.e., foods with a water activity below 0.60) have an extended shelf life, even without refrigeration.

Table 4-11. Classification of Foods and Control Requirements Based on Water Activity

Water Activity	Classification	Requirements for Control
Above 0.85	Moist Foods	Require refrigeration or another barrier to control the growth of pathogens
0.60 and 0.85	Intermediate-Moisture Foods	• Do not require refrigeration to control pathogens • Limited shelf life because of spoilage, primarily by yeast & mold
Below 0.60	Low-Moisture Foods	Extended shelf life, even without refrigeration

See Table 4-12 for some examples of moist foods (water activities above 0.85). Most fresh meats, fruits, and vegetables, and many dairy products, fall into this category. The big surprise here is probably the bread. Most of us tend to think it is a dry, shelf-stable product. Actually, the "crumb" (interior) has a relatively high water activity. It is safe because of the multiple barriers of pH, water activity (the crust has a low water activity), and preferential growth by mold rather than pathogens. In other words, the bread spoils before it becomes hazardous.

Table 4-12. Examples of High Moisture (High Water Activity (a_w)) Foods

Moist Foods	Water Activity (a_w)
Lettuce	0.99
Apples	0.99
Milk	0.98
Bread	0.95

See Table 4-13 for some examples of intermediate-moisture foods (water activity between 0.60 and 0.85). Some unique products like soy sauce appear to be a high moisture product, but actually are in the intermediate-moisture category because salt, sugars or other ingredients bind the moisture. Because jams and jellies have a water activity that will support the growth of yeast and mold, they are mildly heat-treated immediately before packaging to prevent spoilage.

Table 4-13. Examples of Intermediate Moisture Foods

Intermediate Moisture Foods	Water Activity (a_w)
Soy sauce	0.80
Jams	0.80
Molasses	0.76
Honey	0.75
Flour	0.70
Dried fruit	0.70
Candies	0.65

See Table 4-14 for some examples of low-moisture foods (water activity below 0.60).

Table 4-14. Examples of Low-Moisture Foods

Low-Moisture Foods	Water Activity (a_w)
Dried noodles	0.50
Cookies	0.30
RTE Cereals	0.20
Crackers	0.10

Some of the intermediate and low water activity foods have naturally low water activity (e.g., molasses and flour). We do not discuss those foods because water activity does not have to be controlled during processing.

Other intermediate and low water activity foods, like dried fruit, strawberry jam, crackers, soy sauce, and dried noodles, start with a high water activity and, through processing, end up with a reduced water activity. This section of this chapter focuses on these types of foods.

Control of Water Activity

Some products require careful control of water activity for food safety, while others do not. For example, the production of jam does not need careful control of water activity for food safety because the food would not thicken (and, thus, become jam) unless the water activity was reduced through the addition of the necessary amount of sugar. On the other hand, dried fruit products need careful control of water activity for food safety, because fruit products with a variety of moisture levels could still appear to be "dried fruit."

There are two primary ways of reducing water activity in foods: (1) product formulation (such as by adding salt or sugar); and (2) dehydration (drying). In this section of this chapter, we discuss reducing water activity by product formulation. In section 4.3.4 of this document, we discuss reducing water activity by dehydration.

Every organism has a minimum, optimum, and maximum water activity for growth (see Table 3-A in Appendix 3 of this document). Yeasts and molds can grow at low water activity; however 0.85 is considered the safe cutoff level for pathogen growth. Water activity of 0.85 is based on the minimum water activity for *S. aureus* growth. For a detailed discussion and listing of the minimal water activities for microorganisms of public health concern, see ICMSF (1996).

There are two basic ways for how you can approach product formulation that uses control of water activity for food safety. One approach is to closely follow a scientifically established process for formulation that ensures a water activity of 0.85 or below. The other approach is to develop your own process for formulation and to validate it by taking finished product samples and testing them for water activity.

4.3.3.2 Use of Acidity (pH) as a Formulation Process Control

The term "pH" refers to a numeric scale used to describe acidity and alkalinity. The pH reflects the concentration of hydrogen ions and is expressed mathematically as the negative logarithm of the hydrogen ion concentration. The pH scale ranges from 0 to 14, with 7 being neutral.

pH = (-log of the [H+])

Microorganisms can only grow at certain pH levels (Table 4-15). Table 4-15 shows that mold and yeast can grow over a broad range of pH, including very low pH. Table 4-15 also shows that the pH range where bacteria can grow is more restricted in that bacteria don't grow at very low pH.

Table 4-15. Growth Limiting pH Ranges for Microorganisms

Type of Microorganism	pH Range for Growth
Bacteria (Gram+)	4.0 to 8.5
Bacteria (Gram -)	4.5 to 9.0
Molds	1.5 to 9.0
Yeast	2.0 to 8.5

Table 4-15 classifies bacteria as "Gram positive" and "Gram negative." In general, "Gram positive" and "Gram negative" are designations associated with the cell walls of bacteria, and how the bacterial cell walls appear under a microscope when a stain is used to see them. Gram positive bacteria appear blue, and gram negative bacteria appear red.

Lowering the pH is considered primarily a method of inhibiting the growth of bacteria rather than a method for killing bacteria. Although many microorganisms held at low pH for an extended time will be killed, keep in mind that some pathogenic bacteria, and in particular *E. coli* O157:H7, can survive acidic conditions for extended periods of time, even if their growth is inhibited. For details on the minimum and maximum pH limits for bacterial pathogens, see Table 3-A of Appendix 3 of this document.

Foods with a natural pH of 4.6 and below are considered acid foods. Some foods are naturally acidic, including most fruits (e.g., many peaches, pH 4.0; apples, pH 3.5). However, some tropical fruits, including some pineapple, may fall in the pH range above 4.6, depending in part on variety and growing conditions. Foods with a pH above 4.6 are said to be low-acid foods. Examples of low-acid foods include protein foods (such as milk and eggs), most vegetables, and starch based foods (such as bread and crackers).

Acidification

Because an acid pH can inhibit the growth of many bacteria, acidification of foods is a common formulation process control. Acidification is the direct addition of acid to a low-acid food. Examples of foods that are acidified as a process control include pickled beets and peppers. There are a variety of acids (such as acetic acid, lactic acid, and citric acid) that can be used to acidify foods, depending on the desired attributes of the finished product.

We have established specific CGMP requirements for thermally processed low-acid foods packaged in hermetically sealed containers (commonly called "low-acid canned foods" or LACF (21 CFR part 113). We also have established requirements for acidified foods (21 CFR part 114). At the time when we established these regulations, the focus of these CGMP requirements was the control of *C. botulinum*; when the pH of a food is 4.6 or below, spores of *C. botulinum* will not germinate and grow. As a result, the pH of 4.6 is a dividing line for the purpose of determining whether a food other than an acid food is subject to part 113 as an LACF or part 114 as an acidified food. See 21 CFR 114.3.

An acid food, such as tomatoes with a pH of 4.2, is not subject to either the LACF regulations or the acidified foods regulations. Under the acidified foods regulations, "acidified foods" are low-acid foods to which acid(s) or acid food(s) are added; they have a water activity greater than 0.85 and have a finished equilibrium pH of 4.6 or below (21 CFR 114.3(b)). The definition of acidified foods provides that carbonated beverages, foods that are stored, distributed, and retailed under refrigeration, and certain other foods are excluded from the coverage of 21 CFR part 114 (21 CFR 114.3(b)).

Processors of acidified foods must register with FDA to obtain a Food Canning Establishment number (21 CFR 108.25(c)(1)). Processors of acidified foods also must file a scheduled process with FDA (21 CFR 108.25(c)(2)); the scheduled process is the process selected by a processor as adequate for use under the conditions of manufacture for a food in achieving and maintaining a food that will not permit the growth of pathogens. The scheduled process includes control of pH and other critical factors equivalent to the process established by a competent processing authority (21 CFR 114.3). Acidified foods must be so manufactured, processed, and packaged that a finished equilibrium pH value of 4.6 or lower is achieved within the time designated in the scheduled process and maintained in all finished foods; manufacturing must be in accordance with the scheduled process (21 CFR 114.80(a)(1)). Sufficient control, including frequent testing and recording of results, must be exercised so that the finished equilibrium pH values for acidified foods are not higher than 4.6 (21 CFR 114.80(a)(2)). An equilibrium pH is achieved when a natural pH balance has been reached by all ingredients - which can take several days in foods with very large particulates (National Canners Association, 1968). You should refrigerate products that require several days to reach equilibrium pH to prevent the growth of *C. botulinum* or other pathogens.

There are several different methods of adding the acid to the product. One method is called direct acidification, where predetermined amounts of acid and the low-acid foods are added to individual finished product containers during production. With this method, it is important that the processor control the acid-to-food ratio. This is probably the most common method used for acidified vegetables. Another method of acidification is batch acidification. As the name implies, acid and food are combined in large batches and allowed to equilibrate. The acidified food is then packaged.

Acidified foods must be treated sufficiently to control spoilage microorganisms in addition to vegetative pathogens. Although one reason is to prevent spoilage triggering economic loss, the food safety reason is that the action of the spoilage organisms can raise the pH, compromising the safety of the product because any spores of *C. botulinum* that are in the food can germinate, grow, and produce botulinum toxin. The acidified foods regulation requires that you thermally process the food to an extent that is sufficient to destroy the vegetative cells of pathogenic and non-pathogenic microorganisms capable of reproducing in the food under the conditions in which the food is stored, distributed, retailed and held by the user. However, you may use permitted preservatives to inhibit reproduction of non-pathogenic microorganisms in lieu of thermal processing. (21 CFR 114.80(a)(1))

For further information on the use of acidification of foods as a process control, see 21 CFR part 114. The regulation provides detailed information on appropriate procedures to measure pH for foods.

Fermentation

During bacterial fermentation, acid-producing bacteria produce lactic acid, which reduces the pH. Because the reduced pH can inhibit the growth of many bacteria, bacterial fermentation of foods is a common formulation process control. Examples of low-acid foods fermented by bacterial fermentation to a pH below 4.6 include fermented olives, fermented cucumber pickles, cheeses, and sauerkraut. Molds are used to ferment some foods such as soy sauce, tamari sauce, and other oriental foods, mainly for taste and other characteristics.

In practice, fermentation is an art. You need to encourage growth of favorable organisms and discourage the growth of organisms that can cause spoilage. This is usually accomplished by adding salt or a starter culture to the food, or in some cases slightly acidifying it. A starter culture can be either yeast or bacteria.

In many fermented products, there is no process to eliminate the acid-producing bacteria. These fermented products are kept refrigerated so that the culture bacteria and bacteria not killed during the fermentation process do not spoil the product.

4.3.3.3 Use of Preservatives as a Formulation Process Control

Preservatives can be used to prevent the growth of microorganisms – e.g., if a food product is not thermally processed (or not thermally processed to an extent that is sufficient to kill the vegetative cells of non-pathogenic microorganisms (such as spoilage microorganisms) that are capable of reproducing in the food under the conditions in which the food is stored, distributed, retailed and held by the user). Preservatives work by denaturing protein, inhibiting enzymes, or altering or destroying the cell walls or cell membranes of microorganisms. Examples of products that use preservatives as a formulation process control include acidified foods that are either not thermally processed or only minimally thermally processed, hummus (which uses sodium benzoate to inhibit yeast and mold), and many breads (which use calcium propionate to inhibit mold).

Some of the more commonly used preservatives are:

- **Acetic aci**d and its salts (e.g., sodium acetate, sodium diacetate), which is added to reduce bacterial growth.
- **Benzoates**, which include benzoic acid, sodium benzoate and potassium benzoate. Benzoates are used primarily to inhibit yeast or mold. Also can inhibit bacterial pathogens (e.g., *S. aureus*, *L. monocytogenes*).
- **Natamycin** is applied on cheese to inhibit the growth of fungi.
- **Nisin** is used as an antimicrobial agent to inhibit the outgrowth of *C. botulinum* spores and toxin formation in a variety of pasteurized process cheese spreads.
- **Propionates,** which include propionic acid, and sodium, potassium and calcium propionates, are used in breads, cakes, and cheeses to inhibit mold. Also can inhibit bacterial pathogens (e.g., *S. aureus*, *Salmonella*).
- **Sorbates**, which include sorbic acid, and sodium and potassium sorbates. Sorbates are primarily used to inhibit yeast and mold. Also can inhibit bacterial pathogens (e.g., *E. coli* O157:H7, *L. monocytogenes*).

- **Sulfites,** such as sulfur dioxide, are used in a variety of products including lemon juice, seafood, vegetables, molasses, wines, dried fruit, and fruit juices. Sulfites are used primarily as an antioxidant but also have antimicrobial properties.

Table 4-16 provides examples of how some of these commonly used preservatives are used.

Table 4-16. Preservatives Commonly Used in Conjunction with Main Groups of Foods in the United States

Foodstuff	Acetic Acid	Benzoates	Natamycin	Nisin	Propionates	Sorbates	Sulfites
Fat Emulsions	+	+	-	-	-	++	-
Cheese	-	(+)	+	+	+	++	-
Vegetable Products	++	++	-	-	-	++	+
Fruit products	+	++	-	-	-	++	++
Beverages	-	++	-	-	-	++	(+)
Baked goods	+	-	-	-	++	++	-
Confectionery	-	(+)	-	-	-	++	-

Source: Adapted from Davidson and Branen 1993; Table 11 in Lück and Jager 1997, p 61
++ used frequently
+ used occasionally
(+) used in exceptional cases only
- not used

A food category that may benefit from the use of preservatives as a formulation process control is fresh, refrigerated, RTE deli salads. This category of food, which is typically formulated with multiple components, including spices and fresh vegetables, may experience a high bio-load at the time of preparation if treated ingredients are not used. Maintaining quality (e.g., by preventing spoilage by yeasts and molds) and ensuring product safety cannot always be achieved by reducing pH (e.g., by using an acidified food as a salad dressing (such as mayonnaise) or an acid food as a salad dressing (such as vinegar)). Antimicrobial substances such as potassium sorbate and propionic acid are commonly used for a variety of RTE deli salads to inhibit bacteria, yeast, and mold, extending the product shelf-life.

For further regulatory guidance on the use of antimicrobial substances, see FDA (1999). For a comprehensive review on the application of antimicrobials, see Davidson, et al. (2005).

4.3.4 Use of Dehydration/Drying as a Process Control

Dehydration (which reduces water activity) is one of the oldest methods of food preservation. In the United States, there are three primary methods of dehydration as a process control.

- Freeze-drying - used for a variety of products
- Forced air drying - used for solid foods like vegetables and fruit
- Spray drying - used for liquids and semi-liquids like milk

Dehydrated/dried products are usually considered shelf stable due to their low water activity (a_w) and, therefore, are often stored and distributed unrefrigerated. Examples of shelf-stable dehydrated/dried food products include milk powders, powdered beverages, pasta, and dried peas and beans.

If you use dehydration/drying as a process control, you should select a packaging material that will prevent rehydration of the product under the expected conditions of storage and distribution. Additionally, finished product package closures should be free of gross defects that could expose the product to moisture during storage and distribution.

See "Chapter 9 – Use of Dehydration/Drying as a Process Control" of this guidance for additional information on the use of dehydration/drying as a process control. For a detailed overview of dehydration/drying technologies commonly used in the United States (including freeze drying, forced air drying, and spray drying), as well as other dehydration technologies such as drum drying and fluid bed drying, see Greensmith (1998) and Heldman and Lund (2007). For a discussion on the effects of drying on microorganisms, see Jay (1996).

4.3.5 Use of Recipe Management as a Process Control for Food Ingredients

A food ingredient (such as a food additive, color additive, or GRAS substance) can be a chemical hazard if it is added in excess of a maximum use level, regardless of whether the maximum use level is established due to food intolerance (such as for sulfites) or is otherwise a condition of safe use of a food additive, color additive, or GRAS substance. Control strategies to prevent misformulation of food ingredients generally include recipe management to ensure that excessive amounts are not added.

4.3.6 Use of Storage Conditions as a Process Control for Mycotoxins

Mycotoxins are toxic metabolites produced by certain fungi (i.e., molds) that can infect and proliferate on raw agricultural commodities (e.g., grains such as wheat and corn, peanuts, fruits, and tree nuts) in the field and during storage. Contamination by toxigenic fungi during storage and transportation is caused by improper drying or re-wetting of the crop from rain or condensation. Thus, effective process controls involve correct drying and storage.

By far the most critical environmental factors determining whether a raw agricultural commodity will support mold growth are temperature, moisture content, and time, and each of these parameters can be manipulated and controlled to manage the prevention of mold growth in a raw agricultural commodity. The principal process control for prevention of mold growth in storage conditions is the control of moisture. Although low-temperature storage can help control mold growth in some conditions, large-scale storage of raw agricultural commodities generally takes place in structures that do not provide for low-temperature and, thus, low-temperature storage generally is not a control measure for mold during the storage of raw agricultural commodities.

4.3.7 Use of Physical Sorting as a Process Control for Mycotoxins

In most cases, mycotoxins in raw agricultural commodities are present in a very small proportion of individual seeds or kernels. As a result, removing the contaminated seeds or kernels mechanically is a practical and effective process control to reduce the mycotoxin content of the bulk raw agricultural commodity (West and Bullerman, 1991). Various techniques have been devised, based on color and visual appearance of decay or damage, to separate out

contaminated seeds during inspection processes. This may be manual or by more advanced electronic instrumental selection.

4.3.8 Use of Exclusion Strategies as a Process Control for Physical Hazards

4.3.8.1 Exclusion Strategies as a Process Control for Metal Hazards

Metal-to-metal contact during processing can introduce metal fragments into products. For example, metal fragments can break off during mechanical cutting and blending operations, and some metal equipment has parts that can break or fall off, such as wire-mesh belts. You can control metal hazards by using physical separation techniques (such as magnets, sieves, screens, or flotation tanks), by using electronic or X-ray metal detection devices, and by regularly inspecting at-risk equipment for signs of damage.

The effectiveness of physical separation techniques depends on the nature of the product. These measures are more likely to be effective in liquids, powders, and similar products in which the metal fragment will not become imbedded.

The use of electronic metal detectors is complex, especially with regard to stainless steel, which is difficult to detect. The orientation of the metal object in the food affects the ability of the equipment to detect it. For example, if a detector is not properly calibrated and is set to detect a sphere 0.08 inch (2 mm) in diameter, it may fail to detect a stainless steel wire that is smaller in diameter but up to 0.9 inch (24 mm) long, depending on the orientation of the wire as it travels through the detector. Processing factors, such as ambient humidity or product acidity, may affect the conductivity of the product and create an interference signal that may mask metal inclusion unless the detector is properly calibrated. You should consider these factors when calibrating and using this equipment.

X-ray devices can also be used for metal detection. One advantage in using such a device is that X-rays can detect non-metal foreign objects that may also be hazardous, such as glass fragments.

Preventive maintenance of equipment and periodically examining your processing equipment for damage that can contribute metal fragments can be a useful control measure, particularly when you have a piece of equipment that is prone to break, such as saw blades, or equipment that has metal-to-metal contact. The success of this strategy depends in large part on the nature of the equipment inspected and the frequency of the inspection. However, this approach will not necessarily prevent metal fragments from being incorporated into the product in all cases, but may enable you to separate products that may have been exposed to metal fragments. Visually inspecting equipment for damaged or missing parts may only be feasible with relatively simple equipment, such as band saws, small orbital blenders, and wire mesh belts. More complex equipment that contains many parts, some of which may not be readily visible, may not be suitable for visual inspection and may require controls such as metal detection or physical separation techniques.

See “Chapter 13-- Preventive Controls for Physical Hazards” of this guidance for additional information on the control of metal hazards.

4.3.8.2 Exclusion Strategies as a Process Control for Glass Hazards

Glass fragments can be introduced into food whenever processing involves the use of glass containers. Normal handling and packaging methods, especially mechanized methods, can result in breakage. Ingesting glass fragments can cause injury to the consumer. Most products packed in glass containers are intended to be a ready-to-eat (RTE) commodity that requires minimal handling on the part of the consumer before eating, so that consumers have little opportunity to detect glass inclusion.

This chapter addresses the hazard of glass fragments that may occur from the use of glass containers. You should address the hazard of glass fragments originating from sources such as overhead light fixtures through CGMPs.

You can help prevent glass from getting into your food products by periodically checking the processing areas and equipment for glass breakage. In addition, the line operator can listen for breakage and can look for broken glass on the floor. (You can enhance the utility of these controls by painting the floor under the processing line in a color that highlights the container glass.) These types of controls will not necessarily prevent glass fragments from being incorporated into your product, but they can enable you to separate products that may have been exposed to glass fragments from those that have not.

You also can help prevent glass fragments from getting into your food products by cleaning empty containers before filling into the product package. You can do so by using water or compressed air and inverting the container during or after cleaning. You should be mindful that container cleaning may not fully control glass hazards in some processes that use automated filling systems because this equipment can result in glass breakage during the filling and capping process.

See “Chapter 13--Preventive Controls for Physical Hazards” of this guidance for additional information on the control of glass hazards.

4.4 Sanitation Controls

CGMPs require sanitary operations (21 CFR 117.35) and sanitary facilities and controls (21 CFR 117.37). There are requirements applicable to the cleanliness of equipment and utensils, including food-contact surfaces (21 CFR 117.40), and plant construction and design (21 CFR 117.20(b)). To comply with these CGMP requirements, sanitation procedures, practices, and processes should take place every day in your facility.

Sanitation controls include procedures, practices, and processes to ensure that the facility is maintained in a sanitary condition adequate to significantly minimize or prevent hazards such as environmental pathogens, biological hazards due to employee handling, and food allergen hazards. Sanitation controls must include, as appropriate to the facility and the food, procedures, practices, and processes for the: (1) Cleanliness of food-contact surfaces, including food-contact surfaces of utensils and equipment; and (2) prevention of allergen cross-contact and cross-contamination from insanitary objects and from personnel to food, food packaging material, and other food-contact surfaces and from raw product to processed product. (See 21 CFR 117.135(c)(3).)

You determine which hazards require a sanitation control, rather than CGMPs, through your hazard analysis. Thus, some – but not all - of your sanitation procedures, practices, and

processes will be "sanitation controls"; other sanitation procedures, practices, and processes will be CGMPs. For your sanitation controls to be effective, you should first assess the sanitation procedures, practices, and processes that you will have in place to comply with the CGMP requirements. For example, equipment design that ensures that all surfaces can be accessed and cleaned is essential for the effective application of sanitation controls. Effective sanitary design should consider factors such as whether equipment includes hollow bodies or poorly developed welds and seams, as well as whether ease of disassembly allows adequate access to all food-contact surfaces to ensure thorough cleaning and sanitation. Sanitary design also applies to food facility structures (e.g., floors, walls, piping, and ceilings) to ensure effective cleaning and sanitation practices. The required elements for cleaning – time, temperature, mechanical force and chemical concentration – simply cannot be reliably applied if the equipment and facility structural design does not allow adequate access (Marriott and Gravani, 2010). Due to this link between your CGMP procedures, practices, and processes and your sanitation controls, your CGMP procedures, practices, and processes are sometimes called "prerequisite programs."

The nature of the processing conditions (i.e., wet or dry) required for the manufacture of a particular product (such as a dry processing environment for spray dried milk powder, and a wet processing environment for soft cheese) impacts the selection of the appropriate CGMP sanitation procedures, practices, and processes or the appropriate sanitation control. For example, moisture control is critically important in preventing contamination by an environmental pathogen, such as *Salmonella*, in low-moisture products. Water in a dry processing environment is one of the most significant risk factors for *Salmonella* contamination, because the presence of water allows for pathogen growth leading to product contamination from the environment or from insanitary food contact surfaces. Therefore, dry cleaning or controlled wet cleaning practices should be considered for use as sanitation control measures in a dry processing environment. Any time water is used for cleaning, the equipment should be thoroughly dried before use. Wet processing operations are subject to wet cleaning. However, water, in particular standing water, should be minimized even if facilities are wet cleaned. This is particularly true for facilities that need to control *L. monocytogenes* because they are producing RTE products exposed to the environment.

The nature of a bacterial pathogen (e.g., whether it is a transient or a resident strain of an environmental pathogen) also impacts the selection of the appropriate CGMP sanitation procedures, practices, and processes, or the appropriate sanitation control. (See section 3.2.5.2 (Transient vs. resident facility-related environmental pathogens) in "Chapter 3-- Potential Hazards Associated with the Manufacturing, Processing, Packing, and Holding of Human Food" in this guidance for additional information about transient and resident strains of environmental pathogens.

Table 4-17 lists examples of the application of sanitation controls to significantly minimize or prevent biological and chemical hazards and the section in this chapter that addresses each listed example.

Table 4-17. Examples of Sanitation Controls

Sanitation Control Subcategory	Examples	Chapter Section
Cleaning food-contact surfaces	• Applying a full wet clean with detergents and sanitizers for Clean in Place and Clean out of Place (CIP/COP) • Applying controlled wet clean with minimum water usage and wipe down (COP) • Dry cleaning with vacuums, brushes, wipes	4.4.1
Control cross-contact / cross-contamination	• Using hygienic zoning for separation of process operations such as raw vs. Work-in-Process (WIP) vs. finished product; wet vs. dry; personnel and materials flow; air balance • Using dedicated cleaning / sanitation practices in designated hygiene zones *(see cleaning food-contact surfaces)* • Cleaning between different products containing different allergens	4.4.2

See "Chapter 10 – Sanitation Controls" of this guidance for additional information about sanitation controls. In addition to this guidance, a number of sources of scientific and technical information can be useful in establishing sanitation controls. See Holah, 2014 and Marriott and Gravani, 2010.

4.4.1 Use of Sanitation Controls for the Cleanliness of Food-Contact Surfaces

The CGMP requirements for sanitary operations include specific requirements for cleaning food-contact surfaces. See 21 CFR 117.35(d). All food-contact surfaces, including utensils and food-contact surfaces of equipment, must be cleaned as frequently as necessary to protect against allergen cross-contact and against contamination of food (21 CFR 117.35(d)). Food-contact surfaces used for manufacturing/processing, packing, or holding low-moisture food must be in a clean, dry, sanitary condition before use (21 CFR 117.35(d)(1)). When the surfaces are wet-cleaned, they must, when necessary, be sanitized and thoroughly dried before subsequent use (21 CFR 117.35(d)(1)). In wet processing, when cleaning is necessary to protect against allergen cross-contact or the introduction of microorganisms into food, all food-contact surfaces must be cleaned and sanitized before use and after any interruption during which the food-contact surfaces may have become contaminated (21 CFR 117.35(d)(2)). Where equipment and utensils are used in a continuous production operation, the utensils and food-contact surfaces of the equipment must be cleaned and sanitized as necessary (21 CFR 117.35(d)(2).

Part 117 does not define the term "cleaning." In this guidance, we use the term "cleaning" to mean removing the "soil"– i.e., bacteriological nutrients, such as fats, carbohydrates, proteins,

and minerals"– that can build up on food-contact surfaces in the plant and processing equipment. Part 117 defines "sanitize" to mean to adequately treat cleaned surfaces by a process that is effective in destroying vegetative cells of pathogens, and in substantially reducing numbers of other undesirable microorganisms, but without adversely affecting the product or its safety for the consumer. (21 CFR 117.3) Although cleaning operations and sanitizing operations often are conducted separately – and sequentially – some systems (such as steam systems) both clean and sanitize the surfaces; we consider that such systems satisfy the definition of ''sanitize.'' (See 80 FR 55908 at 55956.)

Table 4-16 describes three types of cleaning strategies that you can use to remove soil, depending upon the processing conditions (wet or dry). Table 4-16 includes our recommendations for using these cleaning strategies. See Appendix 4 of this guidance for more details about these cleaning strategies.

Table 4-18. Types of Cleaning Strategies

Cleaning Strategy	Description and Recommendations
Wet Cleaning	Uses water-based and/or wet chemical cleaning solutions. When using wet cleaning, you should avoid certain practices, e.g., excessive use of water (e.g., floor is flooded with water), high pressure hoses. Instead, you should use water on an as-needed basis. You also should minimize and isolate your use of water to specific areas where possible. Drying after wet cleaning helps to minimize growth of remaining microorganisms.
Dry Cleaning	Does not use any water. Dry cleaning is the physical removal of residues (e.g., food particles and dust) without water. You should remove food residues by actions such as sweeping, brushing, scraping, or vacuuming the residues from equipment surfaces and the facility environment. Be careful to not distribute food particles to other equipment or areas during removal.
Controlled Wet Cleaning	Uses a limited amount of water, generally for dry operations. Complete drying should follow immediately after the controlled wet cleaning. You can move specific pieces of equipment out of the area to be wet cleaned, sanitized, and dried and then return the equipment after the area is cleaned.

After the surfaces are cleaned and rinsed you should sanitize food contact surfaces and other areas as appropriate. You should use all sanitizers in accordance with the EPA-registered (or similar registration in other countries) label use instructions, including approval for use in food establishments.

As noted in section 4.4, sanitation controls must include, as appropriate to the facility and the food, procedures, practices, and processes for the cleanliness of food-contact surfaces, including food-contact surfaces of utensils and equipment. (See 21 CFR 117.135(c)(3).) Examples of sanitation controls related to the cleanliness of food-contact surfaces include cleaning and sanitizing procedures, practices, and processes (including appropriate frequencies for these procedures, concentrations of cleaning and sanitizing compounds, method of application, and contact time) (Holah, 2014). See "Chapter 10 – Sanitation Controls" of this guidance for a practical example of the application of cleaning and sanitizing of food-contact surfaces as a preventive control for bacterial contamination.

4.4.2 Use of Sanitation Controls to Prevent Allergen Cross-contact and Cross-contamination

As noted in section 4.4, sanitation controls must include, as appropriate to the facility and the food, procedures, practices, and processes for the prevention of allergen cross-contact and cross-contamination from insanitary objects and from personnel to food, food packaging material, and other food-contact surfaces and from raw product to processed product. (See 21 CFR 117.135(c)(3).)

Table 4-19 describes three common practices that you can use to prevent allergen cross-contact and to prevent cross-contamination of foods from insanitary objects, poor hygienic practices, different processing operations, and environmental pathogens.

Table 4-19. Common Practices to Prevent Allergen Cross-contact and Cross-contamination

Practice	Description
Hygienic Zoning	Hygienic zoning for separation and segregation of process operations such as raw vs. work-in-process vs. finished product; wet vs. dry; personnel and materials traffic flow; air balance
Hygienic Zone Specific Cleaning	Dedicated cleaning / sanitation practices within hygiene zones
Allergen Specific Cleaning	Cleaning between different products containing different allergens

The objective of hygienic zoning is to reduce the potential for transient pathogens to enter sensitive areas in the facility, such as packing areas where an RTE product is exposed to the processing environment. Typically, this type of sanitation control is applied in facilities that make RTE products.

You should determine the need for, and scope of, a hygienic zoning program based on your facility, the products you make, and the outcome of your hazard analysis. For example, the need for, and scope of, a hygienic zoning program are likely to be very different for a flour mill, a facility that makes RTE refrigerated food, and a facility that makes canned acidified foods. In determining the need for, and scope of, a hygienic zoning program, you should take into account the structure of your plant, packaging, personnel and ingredient traffic flows, and any cross over areas. You also should consider potential contaminants from raw materials, air flow, support areas, and other activities taking place in the facility.

Some facilities implement hygienic zoning for quality reasons (e.g., to control mold contamination); however, the sanitation controls that are the subject of this guidance need only address food safety. See “Chapter 10 – Sanitation Controls” of this guidance for a practical example for the application of hygienic zoning to prevent recontamination by environmental pathogens.

4.5 Food Allergen Controls

Food allergen controls include procedures, practices, and processes to control food allergens. Food allergen controls must include those procedures, practices, and processes employed for: (1) Ensuring protection of food from allergen cross-contact, including during storage, handling,

and use; and (2) labeling the finished food, including ensuring that the finished food is not misbranded under section 403(w) of the FD&C Act (21 U.S.C. 343(w)). See 21 CFR 117.135(c)(2).

Examples of procedures, practices, and processes to ensure protection of food from allergen cross-contact are:

- Identifying and marking allergen-containing ingredients at receiving;
- Segregating and storing allergen-containing materials at receiving and warehousing;
- Scheduling production of products based on allergen-containing recipes;
- Physical separation of processes for non-allergen-containing and allergen-containing products;
- Sanitation and cleaning practices;
- Using full wet cleaning to remove allergenic materials prior to producing a non-allergen-containing product on the same line;
- Using dedicated cleaning utensils and equipment for removing allergenic materials from food processing equipment.

Examples of procedures, practices, and processes to label the finished food are:

- Performing label review for each new batch of labels received at the facility;
- Implementing procedures for application of correct label to product.

See "Chapter 11 - Food Allergen Controls" of this guidance for in-depth guidance on preventive control strategies for food allergen hazards.

4.6 Supply-chain Controls

Supply-chain controls include the supply-chain program required by 21 CFR part 117, subpart G (21 CFR 117.135(c)(4)). Subpart G specifies:

- The requirement to establish and implement a supply-chain program (21 CFR 117.405);
- General requirements applicable to a supply-chain program (21 CFR 117.410);
- Responsibilities of the receiving facility (21 CFR 117.415);
- Requirements for using approved suppliers (21 CFR 117.420);
- Requirements for determining appropriate supplier verification activities (including determining the frequency of conducting the activity) (21 CFR 117.425);
- Requirements for conducting supplier verification activities for raw materials and other ingredients (21 CFR 117.430);
- Requirements for an onsite audit (21 CFR 117.435); and
- Requirements for records documenting the supply-chain program (21 CFR 117.475).

In this section of this guidance, we discuss the use of ingredient specifications as a supply-chain control for several chemical hazards – i.e., pesticides, drug residues, heavy metals, and mycotoxins. See our forthcoming draft guidance "Supply-Chain Program for Human Food Products: Guidance for Industry" for in-depth guidance on supply-chain controls.

4.6.1 Supply-chain Controls for Pesticides

Pesticides used in the growing of vegetables fruits, and grain crops include fungicides, insecticides, and rodenticides that control pests found in growing environments. These may also be used in manufacturing environments. If you determine through your hazard analysis that a pesticide hazard requires a preventive control (e.g., due to residual pesticide level violations in a particular raw agricultural commodity), and that control is applied by your supplier, you would have a supply-chain program in which you would verify that your supplier controls pesticides. You could have specifications for your supplier that pesticide levels in raw materials and other ingredients must be within permitted levels and you could ask to review your supplier's pesticide control program. Your program could have verification activities such as periodic testing by you or your supplier for pesticide residues.

4.6.2 Supply-chain Controls for Drug Residues

Drug residues due to the use of antibiotics or related drugs in livestock are principally a potential concern for milk-based products. If you determine through your hazard analysis that a drug residue hazard requires a preventive control, and that control is applied by your supplier, you would have a supply-chain program in which you would verify that your supplier controls drug residues to ensure that drug residues in raw materials and other ingredients are within permitted levels.

4.6.3 Heavy Metals

Heavy metals are principally a concern in raw agricultural commodities grown in soils that are contaminated either naturally or through industrial activity. If you determine through your hazard analysis that a heavy metal hazard requires a preventive control, and that control is applied by your supplier, you would have a supply-chain program in which you would verify that suppliers source raw agricultural commodities from regions that do not have high levels of heavy metal contamination in soil, and specifications that heavy metals in raw materials and other ingredients will be within permitted levels.

4.6.4 Supply-chain Controls for Mycotoxins

Mycotoxins are toxic metabolites produced by certain fungi (i.e., molds) that can infect and proliferate on raw agricultural commodities (e.g., grains such as wheat and corn, peanuts, fruits, and tree nuts) in the field and during storage. Critical environmental factors determining whether a raw agricultural commodity will support mold growth are temperature, moisture content, and time, and each of these parameters can be manipulated and controlled to manage the prevention of mold growth in a raw agricultural commodity. As noted in section 4.3.7 of this chapter, effective process controls for mycotoxins involve correct drying and storage as well as physical sorting techniques to remove damaged or moldy raw agricultural commodities.

If you determine through your hazard analysis that a mycotoxin hazard requires a preventive control, and that control is applied by your supplier, you would have a supply-chain program in which you would verify that your supplier controls mycotoxins. You could have specifications that mycotoxins in raw materials and other ingredients will be within permitted levels.

4.7 Recall Plan

For food with a hazard requiring a preventive control, you must establish a written recall plan for the food. The written recall plan must include procedures that describe the steps to be taken, and assign responsibility for taking those steps, to perform the following actions as appropriate to the facility: (1) Directly notify the direct consignees of the food being recalled, including how to return or dispose of the affected food; (2) Notify the public about any hazard presented by the food when appropriate to protect public health; (3) Conduct effectiveness checks to verify that the recall is carried out; and (4) Appropriately dispose of recalled food—e.g., through reprocessing, reworking, diverting to a use that does not present a safety concern, or destroying the food. See 21 CFR 117.139.

We recommend that you consult our general guidance on policy, procedures, and industry responsibilities regarding recalls in 21 CFR part 7, subpart C (§§ 7.40 through 7.59) and FDA's Guidance for Industry: Product Recalls, Including Removals and Corrections (FDA, 2015c).

A recall can be disruptive to your operation and business, but there are several steps you can take in advance to minimize this disruptive effect:

- Adequately code products to make possible positive lot identification and to facilitate effective recall of all violative lots.
- Maintain such product distribution records as are necessary to facilitate location of products that are being recalled. You should maintain such records for a period of time that exceeds the shelf life and expected use of the product.

4.8 References

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Hazard Analysis and Risk-Based Preventive Controls for Human Food: Draft Guidance for Industry[12]

Chapter 5: Application of Preventive Controls and Preventive Control Management Components

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[12] This guidance has been prepared by the Office of Food Safety in the Center for Food Safety and Applied Nutrition at the U.S. Food and Drug Administration.

5.1 Purpose of this Chapter

The guidance provided in this chapter is intended to help you identify and implement preventive controls, and associated preventive control management components, as a part of your food safety plan. See 21 CFR 117.135 and 117.140. Note that if you determine through your hazard analysis that there are no hazards requiring preventive controls, you must still document that determination in your written hazard analysis (see 21 CFR 117.130(a)(2)). However, you would not need to establish preventive controls and associated preventive control management components.

This chapter provides an overview of the application of preventive controls to significantly minimize or prevent the occurrence of biological, chemical, and physical hazards in finished foods and the food production environment. This chapter also provides an overview of preventive control management components (i.e., monitoring, corrective actions, and corrections, and verification activities (and their associated records)). Chapters 6 through 13 of this guidance provide more detailed examples of the application of preventive controls and associated preventive control management components.

This chapter does not provide all the details needed for complete programs. You have the flexibility to identify and implement preventive controls, and associated preventive control management components, from among all procedures, practices, and processes that are available to you and that would provide assurances that the hazard is controlled (i.e., significantly minimized or prevented).

5.2 Overview of the Application of Preventive Controls for Biological Hazards

Table 5-1 provides examples of the application of preventive controls to significantly minimize or prevent the occurrence of ingredient-related and process-related biological hazards.

Table 5-1 provides general information about the effects of the listed preventive controls but is not intended to imply that a particular preventive control has been validated for control of specific pathogens in specific foods. You are responsible for validating specific preventive controls as appropriate to the nature of the preventive control and its role in your facility's food safety system (see 21 CFR 117.160(a)).

Table 5-1 does not address the application of preventive controls to facility-related hazards. See "Chapter 10 – Sanitation Controls" of this guidance for additional information on the application of sanitation controls to address facility-related hazards.

Table 5-1 Application of Common Preventive Controls to Ingredient-Related and Process-Related Biological Hazards

Preventive Control	Common Procedures, Practices, and Processes	Applicability to Spore-Forming Bacterial Pathogens	Applicability to Vegetative Bacterial Pathogens	Applicability to Bacterial Toxins	Applicability to Parasites
Process Control – Lethal Treatments	Heat (e.g., cooking, roasting, baking)	In general, heat processes will not eliminate spores of bacterial pathogens	Eliminates vegetative cells of pathogens	Will not eliminate preformed toxins of *S. aureus* and *B. cereus* emetic toxin	Heat processing will inactivate parasites found in foods; specific times and temperatures are dependent on the parasite, food matrix, and process used
Process Control – Lethal Treatments	Irradiation, ionizing	The doses approved in the U.S. will not eliminate spores of bacterial pathogens in most foods	Eliminates vegetative cells of pathogens	Will not eliminate preformed toxins of *S. aureus* and *B. cereus* emetic toxin	Limited uses for parasite control; depending on dose, approved uses for foodborne pathogens may inactivate parasites found in foods
Process Control – Lethal Treatments	Antimicrobial Fumigation, e.g., Propylene Oxide (PPO) or Ethylene Oxide (ETO)	Will not eliminate spores of bacterial pathogens	Defined PPO processes have been shown to reduce *Salmonella* by 5 logs in certain foods	Unknown, but unlikely to have an effect on preformed toxins of *S. aureus* and *B. cereus* emetic toxin	Ozone has been found to inactivate select parasites (e.g., *C. parvum* oocysts)

Preventive Control	Common Procedures, Practices, and Processes	Applicability to Spore-Forming Bacterial Pathogens	Applicability to Vegetative Bacterial Pathogens	Applicability to Bacterial Toxins	Applicability to Parasites
Process Control – Lethal Treatments	High Pressure Processing (HPP)	In general, HPP will not eliminate spores of bacterial pathogens (FDA, 2000)	Eliminates vegetative cells of pathogens (FDA, 2000)	Will not eliminate preformed toxins of *S. aureus* and *B. cereus*	• Will eliminate parasitic worms of *Trichinella spiralis* at ≥ 200 MPa for 10 min • No infectivity of *Cryptosporidium* oocysts when treated by HPP at $5.5X10^8$ Pa (80,000 psi) for 60 sec in apple and orange juice • Information is lacking on the pressure resistances of other parasites
Process Control – Time / Temperature of Holding	Refrigeration	Used to control growth of sporeforming bacterial pathogens	Depending on the temperature, refrigeration will inhibit growth of many pathogens. However, pathogens such as *L. monocytogenes* and some strains of *B. cereus* may grow at refrigeration temperatures	Will prevent the formation of toxins of *S. aureus*. Depending on the temperature, will prevent formation of *B. cereus* toxins. Will have no effect on preformed toxins	Limited information; generally not applicable to parasites because parasites do not grow in food

Preventive Control	Common Procedures, Practices, and Processes	Applicability to Spore-Forming Bacterial Pathogens	Applicability to Vegetative Bacterial Pathogens	Applicability to Bacterial Toxins	Applicability to Parasites
Process Control – Time / Temperature of Holding	Freezing	Used to control growth of spore forming bacterial pathogens, but the spores will survive freezing well	Freezing prevents growth of vegetative cells of pathogens. Depending on the temperature, the numbers of some pathogens may be reduced over time; however you cannot count on freezing to eliminate pathogens, and many can survive for an extended time	Freezing that prevents growth will prevent formation of toxins of *S. aureus* and *B. cereus* but have no effect on preformed toxins	There are specific schedules of time and temperature shown to inactivate parasites; *Cyclospora* is known to be at least somewhat resistant to freezing because an outbreak occurred attributed to raspberries in cake that was previously frozen at about 26°F (–3.3° C)
Process Control – Formulation	Water activity control	Reducing the water activity (e.g., by adding solutes such as sugar and salt) to 0.92 or below will inhibit outgrowth of spores	Reducing the water activity (e.g., by adding solutes such as sugar and salt) to 0.85 or below will inhibit growth of vegetative cells of pathogens	Water activity that prevents growth will prevent formation of toxins of *S. aureus* and *B. cereus* but have no effect on preformed toxins	Limited information; generally not applicable to parasites because they do not grow in food

Preventive Control	Common Procedures, Practices, and Processes	Applicability to Spore-Forming Bacterial Pathogens	Applicability to Vegetative Bacterial Pathogens	Applicability to Bacterial Toxins	Applicability to Parasites
Process Control – Formulation	Acidification	Lowering the pH by the addition of acid can inhibit spores from germinating, will not eliminate the spores	In, general, you can rely on added acid to prevent growth of vegetative bacterial pathogens, but you cannot rely on added acid to eliminate vegetative cells of bacterial pathogens	A pH that prevents growth will prevent formation of toxins of *S. aureus* and *B. cereus* but have no effect on preformed toxins	No information for use as control in foods
Process Control – Formulation	Adding preservatives	Will not eliminate spores of bacterial pathogens, but can prevent germination of spores of certain species	Various preservative chemicals have specific action against some vegetative cells of bacterial pathogens and/or fungi that prevent growth	Formulations that prevent growth will prevent formation of toxins of *S. aureus* and *B. cereus* but have no effect on preformed toxin	No information for use as control in foods
Process Control – Dehydration	Air drying	Will not eliminate spores of bacterial pathogens, but limits or inhibits outgrowth	While drying may inactivate some pathogens, others (e.g., *Salmonella*) may survive drying for fairly long times	Drying that prevents growth will prevent formation of toxins of *S. aureus* and *B. cereus* but have no effect on preformed toxin	No information on effect on parasites in foods

Preventive Control	Common Procedures, Practices, and Processes	Applicability to Spore-Forming Bacterial Pathogens	Applicability to Vegetative Bacterial Pathogens	Applicability to Bacterial Toxins	Applicability to Parasites
Process Control – Dehydration	Freeze drying	In general, serves to preserve microorganisms, but inhibits outgrowth	In general, serves to preserve microorganisms, but inhibits growth	Drying that prevents growth will prevent formation of toxins of *S. aureus* and *B. cereus* but have no effect on preformed toxin	No information on effect on parasites in foods
Process Control – Dehydration	Spray drying	In general, spores of bacterial pathogens will not be eliminated, but inhibits outgrowth	Some pathogens may survive spray drying depending upon the product formulation. Growth will be inhibited	Drying that prevents growth will prevent formation of toxins of *S. aureus* and *B. cereus* but have no effect on preformed toxin	No information on effect on parasites in foods

Chapters 6 through 9 of this guidance provide specific examples of the application of some of these preventive controls. Table 5-2 lists these chapters and the examples covered in these chapters. Table 5-2 also lists examples of sanitation controls, which are covered in Chapter 10.

Table 5-2 Chapters in this Guidance that Provide Examples of the Application of Common Preventive Controls for Ingredient-Related and Process-Related Biological Hazards

Hazard	Preventive Control	Examples of Preventive Controls	Chapter
Bacterial pathogens that survive the lethal treatment	Process Control – Lethal Treatments	• Cooking of RTE soups (frozen and refrigerated) • Baking of RTE cookies	6
Bacterial pathogens that grow, including those that produce toxin, due to time/ temperature abuse	Process Control – Time / Temperature of Holding	• Refrigeration of fresh fruit salads • Control of temperature during thawing to prevent microbial growth	7
Bacterial pathogens that grow, including those that produce toxin, due to poor formulation control	Process Control - Formulation	• Acidification of prepared vegetable salads • Water activity control in refrigerated cookie dough	8

Hazard	Preventive Control	Examples of Preventive Controls	Chapter
Bacterial pathogens that grow, including those that produce toxin, due to inadequate drying	Process Control – Drying/dehydration	• Drying of milk to produce spray-dried milk powder	9
Bacterial pathogens that contaminate product due to poor sanitation	Sanitation Control – Cleaning / sanitizing food contact surfaces	• Controlling presence of bacterial pathogens in RTE prepared sandwiches by sanitation	10
Recontamination of an RTE product with an environmental pathogen	Sanitation – Prevention of recontamination from the environment	• Use of hygienic zoning as a component of a program for prevention of recontamination of ice cream with environmental pathogens	10

5.3 Overview of the Application of Preventive Controls for Chemical Hazards

5.3.1 Examples of the Application of Preventive Controls for Chemical Hazards

Table 5-3 provides examples of the application of preventive controls to significantly minimize or prevent the occurrence of ingredient-related chemical hazards in finished foods. See "Chapter 12 – Preventive Controls for Chemical Hazards" of this guidance for further examples of the implementation of preventive controls for chemical hazards.

Table 5-3 Examples of the Control of Ingredient-Related Chemical Hazards

Preventive Control	Common Procedures, Practices, and Processes	Examples of Applicability to Chemical Hazards
Supply-Chain Program	Establish and implement a risk-based supply-chain program with supplier approval and verification activities (as a means of ensuring that raw materials and other ingredients are procured from those suppliers that can meet company specifications and have appropriate programs in place)	• Applicability to heavy metals: approved suppliers control arsenic and lead in raw agricultural commodities such as rice and carrots • Applicability to naturally occurring toxins: approved suppliers control growth of mycotoxin-forming fungi in stored raw agricultural commodities that are purchased by the facility as raw materials • Applicability to food and color additives and substances associated with a food intolerance: approved suppliers control presence of or use of identified substances and ensure safe levels are not exceeded

Preventive Control	Common Procedures, Practices, and Processes	Examples of Applicability to Chemical Hazards
Supply-Chain Program	Conduct verification activities appropriate to the hazard	• Sampling and testing (by supplier or receiving facility) to verify supplier control for chemical hazards such as pesticides, drug residues, heavy metals, and mycotoxins, when a supply-chain-applied control has been applied for such hazards • On-site audit to verify control of food allergens, such as when purchasing roasted almonds from a facility that handles multiple tree nuts
Process Controls	Recipe management procedures as appropriate	Facility programs to control product formulation to ensure that safe levels are not exceeded
Process Controls	Storage conditions	Control of moisture in stored raw agricultural commodities to prevent formation of mold
Process Controls	Physical sorting	Facility processing practices to sort (e.g., based on color, physical damage, or presence of mold) raw agricultural commodities to reduce levels of mycotoxins in processed foods

5.3.2 Considerations Applicable to Radiological Hazards

Contamination of foods by radionuclides (a radiological hazard) is a rare event. The most common way these radionuclides are incorporated into foods is through use of water that contains a radionuclide during the manufacture of a food. For example, in certain locations in the United States, high concentrations of radium-226, radium-228 and uranium have been detected in private wells (Ayotte et al., 200; Focazio et al., 2001). The most relevant information that would lead you to consider and evaluate a specific radiological hazard to determine whether it is a hazard requiring a preventive control would be publicly disseminated information following a particular event, such as contamination arising from accidental release from a nuclear facility or from damage to a nuclear facility from a natural disaster. For example, in 2011, radioactivity was detected in milk, vegetables and seafood produced in areas neighboring a nuclear power plant damaged during an earthquake and tsunami in Japan. We have issued guidance on levels of concern for radionuclides that could be a known or reasonably foreseeably hazard in certain circumstances, such as after an accident at a nuclear facility (FDA, 2001).

Your hazard analysis does not need to consider sources of radiation used in accordance with a food additive regulation. Such sources are safe for their intended use. As with any other equipment and substances used in the manufacture of food, you must comply with all applicable safety requirements established either under the terms of a food additive regulation or by an authority such as the Occupational Safety and Health Administration. Although the two most likely sources of radiological hazards that you would need to address are water used in the production of foods (as an ingredient or cleaning aid), and accidental contamination of your food product (or its ingredients) from accidental release of radionuclides from a nuclear facility, the

PCHF requirements do not limit your responsibilities to these two sources, because we cannot anticipate what might be a source in the future.

5.3.3 Examples of the Control of Food Allergen Hazards

Table 5-4 provides examples of the application of preventive controls to significantly minimize or prevent the occurrence of the ingredient-related and process-related undeclared food allergen hazards within finished foods. See "Chapter 11 – Food Allergen Controls" of this guidance for additional information on the application of food allergen controls.

Table 5-4 Application of Common Preventive Controls to Ingredient-Related and Process-Related Food Allergen Hazards

Preventive Control	Common Procedures, Practices, and Processes	How the Preventive Control Can Significantly Minimize or Prevent Undeclared Food Allergens due to Incorrect Product Label	How the Preventive Control Can Significantly Minimize or Prevent Undeclared Food Allergens due to Cross-Contact
Allergen Control – Labelling	Perform label design and review during product development prior to commercialization and label review for each new batch of labels received.	Label design and review minimize the potential for the label to not identify all of the food allergens present in the food	N/A
Allergen Control – Labelling	Implement procedures for application of correct label to product.	Label application procedures can help minimize the potential for an incorrect label to be applied to an allergen-containing food	N/A
Allergen Control – Allergen cross-contact	Identify and mark food allergen-containing ingredients (e.g., by color coding or with food allergen icons) at receiving.	N/A	Clearly identifying food allergens associated with raw materials or other ingredients simplifies handling practices to prevent allergen cross-contact
Allergen Control – Allergen cross-contact	Segregate and store food allergen-containing materials at receiving and warehousing.	N/A	Segregation of different food allergens can minimize the potential for allergen cross-contact during storage
Allergen Control – Allergen Cross-contact	Open and handle food allergen-containing ingredients at separate times / contain by using separate rooms, or by scheduling use of the same rooms at different times.	N/A	Handling food allergens separately can minimize the potential for inadvertent incorporation of a food allergen into a product for which it is not an ingredient

Preventive Control	Common Procedures, Practices, and Processes	How the Preventive Control Can Significantly Minimize or Prevent Undeclared Food Allergens due to Incorrect Product Label	How the Preventive Control Can Significantly Minimize or Prevent Undeclared Food Allergens due to Cross-Contact
Allergen Control – Allergen Cross-contact	Schedule production of products based on food allergen-containing recipes. Schedule production of products that do not contain food allergens before production of products that do contain food allergens or schedule production of products with a unique food allergen last.	N/A	Production scheduling can minimize the potential for inadvertent incorporation of food allergen into a product for which it is not an ingredient
Allergen Control – Allergen cross-contact	Physically separate processes for products that do not contain food allergens from products that do contain food allergens or separate processes for products that do not contain the same food allergens	N/A	Separating processes containing different food allergens can minimize the potential for inadvertent incorporation of food allergen into a product for which it is not an ingredient
Allergen Control – Allergen cross-contact	Implement production procedures for rework and work-in-process (WIP): using “like into like,” appropriate storage and handling, tracking	N/A	Control of rework can minimize the potential for inadvertent incorporation of food allergen into a product for which it is not an ingredient
Sanitation Control – Cleaning food contact surfaces	Use full wet cleaning to remove food allergen residues prior to producing a product that does not contain that food allergen on the same line.	N/A	Cleaning can minimize the presence of food allergen residues, preventing inadvertent incorporation of food allergen into a product for which it is not an ingredient
Sanitation Control – Cross-contact	Use hygienic zoning for physical separation of process operations, including personnel, that involve foods with and without a specific food allergen	N/A	Hygienic zoning can help prevent inadvertent incorporation of food allergen into a product for which it is not an ingredient
Sanitation Control - Cross-contact	Use dedicated cleaning utensils and equipment for removing food allergen residues from food processing equipment	N/A	Use of dedicated cleaning utensils/equipment can prevent transfer of food allergen residues, thereby preventing inadvertent incorporation of food allergen into a product for which it is not an ingredient

5.4 Overview of the Application of Preventive Controls for Physical Hazards

Table 5-5 provides an overview of the application of preventive controls to significantly minimize or prevent the occurrence of physical hazards in finished foods. See "Chapter 13 – Preventive Controls for Chemical Hazards" of this guidance for further examples for the implementation of preventive controls for physical hazards.

Table 5-5 Applicability of Preventive Controls to Physical Hazards

Preventive Control Category	Common Procedures, Practices, and Processes	Applicability to Metal Hazards	Applicability to Glass Hazards (Products Packed in Glass)	Applicability to Other Hard/Sharp Physical Hazards
Process Control – Exclusion	Use screens, flotation tanks, riffle board, sifters, magnets, inversion/air to exclude metal and glass	Physically removes metal fragments	Physically removes glass	Physically removes hard plastic, wood, stones
Process Control – Detection	Use metal or X-ray detectors to detect and divert foods containing metal and glass	Metal and X-ray detectors detect metal pieces, which generally allows for exclusion of foods containing metal	X-ray detectors detect glass pieces, which generally allows for exclusion of foods containing glass	X-rays can often detect hazardous objects such as hard plastic, stones, bones, pits

5.5 Preventive Control Management Components

5.5.1 Overview of Preventive Control Management Components

Preventive control management components include monitoring, corrective actions and corrections, and verification activities (and their associated records). You must apply appropriate preventive control management components by considering the nature of the preventive control and its role in the facility's food safety system to ensure the effectiveness of the preventive control. For example, monitoring may be limited for certain control measures such as preventive maintenance for equipment to prevent metal hazards (although you should have a record that the activity took place). When sanitation controls are required for environmental pathogens, little or no monitoring may be needed when cleaning and sanitation are conducted in accordance with established written protocols. Occasional verification that procedures are being followed may suffice. See 21 CFR 117.140.

5.5.2 Monitoring

You must establish and implement written procedures, including the frequency they are to be performed, for monitoring preventive controls (as appropriate to the nature of the preventive control and its role in your food safety system). See 21 CFR 117.145. Chapters 6 through 13 of this guidance provide examples of the application of preventive controls. Each of these chapters contains a section, "Establish Monitoring Procedures," that provides information about appropriate monitoring procedures for each control strategy example discussed.

To fully describe your monitoring program, the procedures should answer four questions: (1) What will be monitored? (2) How will monitoring be done? (3) How often will monitoring be done (frequency)? and (4) Who will do the monitoring?

What you monitor should be directly related to control of the hazard. For example, for process controls you would monitor parameters to ensure the minimum/maximum values are met. For other preventive controls, you could monitor that the activity has been conducted consistent with a defined procedure.

The frequency of monitoring depends upon the circumstances. Continuous monitoring is always desirable, and in some cases necessary. In other cases, it may not be necessary or practical. You should monitor often enough that the normal variability in the values you are measuring can be determined and a deviation from normal will be detected. This is especially true if these values are typically close to the control values. Even with continuous monitoring, you should periodically check the paper or electronic record of the continuous monitoring to determine whether deviations from the control value have occurred. The frequency of that check should be at least daily.

If a measurement shows that a deviation from the control value has occurred, you should assume that the control value had not been met since the last check in which the value was acceptable. As a result, the greater the time span between measurements, the more products you are putting at risk.

You should specify in the written procedures the position of the employee who will do the monitoring and describe how they are to perform the monitoring procedure. See Chapters 6 through 13 of this guidance for monitoring examples that include "who" and "how."

You must document your monitoring of preventive controls. See 21 CFR 117.145(c)(1). Although, as noted above, continuous monitoring (with associated records) is desirable, in some circumstances the monitoring records may be "exception records" that document loss of control. See 21 CFR 117.145(c)(2).

5.5.3 Corrective Actions and Corrections

You must establish and implement corrective action procedures that would apply if preventive controls are not properly implemented, as appropriate to the nature of the hazard and the nature of the preventive control. These include corrective action procedures that must be taken if you detect the presence of a pathogen or appropriate indicator organism in a ready-to-eat product as a result of product testing or if you detect the presence of an environmental pathogen or appropriate indicator organism through your environmental monitoring activities. See 21 CFR 117.150(a) and (a)(1).

A predetermined corrective action procedure has the following advantages: (1) It provides detailed instructions for an employee to follow in the event of a deviation in applying a preventive control; (2) it can be prepared at a time when an emergency situation is not calling for an immediate decision; and (3) it removes the obligation to reassess the food safety plan in response to a deviation.

Chapters 6 through 13 of this guidance provide examples of the application of preventive controls. Each of these chapters contains a section, "Establish Corrective Action Procedures," that provides information about appropriate corrective action procedures for each control strategy example discussed. An appropriate corrective action procedure must accomplish the following goals: (1) Ensure that the appropriate action is taken to identify and correct the problem that has occurred with the implementation of a preventive control; (2) ensure that the appropriate action is taken when necessary to reduce the likelihood that the problem will recur; (3) ensure that all affected food is evaluated for safety; and (4) ensure that all affected food is prevented from entering into commerce unless an evaluation has determined that the product is not adulterated under section 402 of the Federal Food, Drug, and Cosmetic Act (FD&C Act) (21 U.S.C. 342) or misbranded under 21 section 403(w) of the FD&C Act (21 U.S.C. 343(w)). See 21 CFR 117.150(a)(2).

You must document your corrective actions. See 21 CFR 117.150(d). For example, when documenting a decision that affected product is released into commerce, your documentation should explain how your decision was based on sound evidence that the deviation did not create a food safety hazard. As another example, you should document all product dispositions, including dispositions to reject or destroy the product.

If you have not established a written corrective action procedure for a preventive control, you still must take appropriate corrective actions when an unanticipated food safety problem indicates that a preventive control may not have been properly implemented. See 21 CFR 117.150(b)(1)(i). For example, you would take appropriate corrective actions if you detected a pathogen in a product when your production process should have controlled the pathogen. Although it may not be possible to anticipate all the problems that could happen, corrective actions need to be taken and fully documented when an unanticipated situation occurs. The corrective actions for the unanticipated problems would include standard corrective action procedures (e.g. identify and correct an implementation problem, take steps to reduce the likelihood it will recur, evaluate all implicated product for safety, and prevent adulterated or misbranded product from entering commerce). See 21 CFR 117.150(b)(2)(i). In addition when appropriate you must reanalyze the food safety plan (or the applicable portion of the food safety plan) to determine whether you need to modify the plan. See 21 CFR 117.150(b)(2)(ii).

A correction is an action to identify and correct a problem that occurred during the production of food, without other actions associated with a corrective action procedure. See the definition of "correction" in 21 CFR 117.3. The term ''correction'' focuses on the first step in a ''corrective action procedure'' (i.e., identify and correct the problem). Corrections may be appropriate instead of corrective actions when minor, isolated problems occur that do not directly impact product safety.

Here is an example of corrections vs. corrective actions. If you observe food residue on ''clean'' equipment prior to production, corrections would involve re-cleaning and sanitizing the equipment before it is used. Because you observed the food residue prior to production of food, and you corrected the problem in a timely manner, no food is affected and no actions are needed with respect to food. You are not required to record the correction because this isolated

incident does not directly impact product safety, and you made the corrections in a timely manner (i.e., before the production starts). On the other hand, if you make an RTE creamed vegetable soup using a continuous heat exchanger and hot-fill process, and after packaging the soup your review of temperature records of the processed soup at the discharge end of the hold tube shows that the soup did not reach the temperature you identified as a critical limit, corrective actions would involve destroying the product, reheating it or sending it to animal food as appropriate,[13] investigating the cause of the problem, and taking the actions needed to reduce the likelihood that the problem will recur based on the root cause of the problem. (Using an automatic flow diversion valve that diverts low-temperature product at the end of the hold tube back to the pre-heat kettle to be re-processed would avoid the need for taking corrective actions on product, although you would still investigate the cause and correct the problem.)

You must document all corrective actions in records that are subject to verification records review. When appropriate, you also must document corrections. See 21 CFR 117.150(d). You are not required to document corrections in records that are subject to verification records review when the corrections are taken in a timely manner and you identify and correct a minor and isolated problem that does not directly impact product safety. See 21 CFR 117.150(c)(2). However, we recommend that you document corrections such as re-running product through a functioning metal detector when the one used on the production line did not reject the test pieces used to verify that the metal detector was operating correctly, because it provides a record of both the problem and the steps you took to correct the problem. If the problem recurs on a frequent basis, such documentation also can alert you that equipment may need to be repaired or replaced. We also recommend that you record corrections taken when equipment is adjusted because, for example, temperature does not meet an operating limit (although the critical limit has not been violated); such information can be useful to identify trends that indicate equipment repairs may be needed.

The record of corrective actions should include information on the following four elements:

First, document the actions taken to identify and correct the problem with implementation of the preventive control. For example, explain how you identified what went wrong with a process control and how you restored process control.

Second, explain what you did to reduce the likelihood that the problem will recur. Evaluation of historical corrective action records can help to identify recurring problems. When critical limit deviations frequently reoccur, the process and the Food Safety Plan may need reanalysis and modification. A formal process may be needed to manage major changes that need to be implemented. This may include reissuing forms, retraining employees, phasing in changes, managing label information, informing suppliers, and other tasks, depending on the nature of the change.

Third, explain how you evaluated the safety of all affected food. Specific technical expertise may be required for this evaluation, depending on the nature of the deviation.

Fourth, explain what you did with any affected food, including identifying the amount of product involved and disposition of the affected product.

[13] For more information on sending human food to animal food use, refer to Draft Guidance for Industry: Questions and Answers Regarding the Reportable Food Registry as Established by the Food and Drug Administration Amendments Act of 2007, Section III.L (FDA, 2010).

5.5.4 Verification

Chapters 6 through 13 of this guidance provide examples of the application of preventive controls. Each of these chapters contains a section, "Establish Verification Procedures," that provides information about appropriate verification activities for each control strategy example discussed. The information covers validation of the adequacy of control measure (e.g., process establishment); evidence that monitoring is being conducted as required; evidence that appropriate decisions about corrective actions are being made as required; evidence of verification of the implementation and effectiveness of controls (such as product testing or environmental monitoring when appropriate); calibration of instruments, when appropriate, and review of records. See 21 CFR 117.155, 117.160 and 117.165. When calibration or an accuracy check of a preventive control monitoring instrument shows that the instrument is not accurate, you should evaluate the monitoring records since the last instrument calibration to determine whether the inaccuracy would have contributed to a deviation. For this reason, food safety plans with infrequent calibration or accuracy checks can place more products at risk than those with more frequent checks if a problem with instrument accuracy occurs.

5.5.5 Records

Chapters 6 through 13 of this guidance provide examples of the application of preventive controls. Each of these chapters contains a section, "Establish a Recordkeeping System," that provides information about appropriate records for each control strategy example discussed. Types and frequency of records vary, depending on factors such as the nature of the hazard and the nature of the control measure and its role in the food safety system.

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Hazard Analysis and Risk-Based Preventive Controls for Human Food: Draft Guidance for Industry[14]

This draft guidance, when finalized, will represent the current thinking of the Food and Drug Administration (FDA or we) on this topic. It does not establish any rights for any person and is not binding on FDA or the public. You can use an alternative approach if it satisfies the requirements of the applicable statutes and regulations. To discuss an alternative approach, contact FDA's Technical Assistance Network by submitting the form available at http://www.fda.gov/Food/GuidanceRegulation/FSMA/ucm459719.htm.

Appendix 1: Potential Hazards for Foods and Processes

Appendix Organization

This appendix contains information on the potential biological, chemical, and physical hazards that are food-related and process related. The potential hazard information presented covers the following 17 food (including ingredients and raw materials) categories:

- Bakery
- Beverage
- Chocolate and Candy
- Dairy
- Dressings and Condiments
- Egg
- Food Additives
- Fruits and Vegetables
- Game Meat
- Grains
- Multi-Component Foods (such as a refrigerated entrée or a sandwich)
- Nuts
- Oil
- Snack Foods
- Soups
- Spice

[14] This guidance has been prepared by the Office of Food Safety in the Center for Food Safety and Applied Nutrition at the U.S. Food and Drug Administration.

- Sweeteners

To help you to identify food-related and process-related hazards for the food categories listed above, this appendix contains three series of tables:

- **Tables 1A** through **1Q** contain information that you should consider for potential food-related biological hazards.
- **Tables 2A** through **2Q** contain information that you should consider for potential food-related chemical hazards.
- **Tables 3A** through **3Q** contain information that you should consider for potential process-related biological, chemical and physical hazards.

How to Use the Tables in Appendix 1

Information provided in each table is organized to describe:

- Food Categories
- Food Subcategories
- Hazards
- Example Products

Potential hazards that you should consider for each food subcategory are indicated by an "X" in the column for the hazard being assessed.

The tables in Appendix 1 encompass more than 200 pages. To reduce the printed size of this document (which includes all of the available chapters in this guidance), we have not included those tables. To access the tables in Appendix 1, see the separate Appendix 1 (complete with tables).

Hazard Analysis and Risk-Based Preventive Controls for Human Food: Draft Guidance for Industry[15]

Appendix 2: Food Safety Plan Forms

Table of Contents

[15] This guidance has been prepared by the Office of Food Safety in the Center for Food Safety and Applied Nutrition at the U.S. Food and Drug Administration.

Introduction

We recommend that you use worksheets to document the:

- Product description;
- Hazard analysis;
- Process controls;
- Sanitation controls; and
- Food allergen controls.

There is no standardized or mandated format for documenting the food safety plan. However, in this appendix we refer you to worksheets that were developed by Food Safety Preventive Controls Alliance (FSPCA). We recommend that you use forms such as these for documenting your food safety plan for two reasons: (1) These worksheets are used in training by the FSPCA and, thus, you will be familiar with these forms if you take this training; and (2) these worksheets are similar to forms used in documenting Hazard Analysis and Critical Control Point (HACCP) plans and prerequisite programs and, thus, these worksheets may be similar to forms you are already using.

The FSPCA makes these forms available on its website at http://www.iit.edu/ifsh/alliance/resources/fspca_materials. In this Appendix, we have modified the format of FSPCA's forms for consistency with the formats we use for making documents accessible for persons using assistive technology such as a screen reader. You may obtain the current copy of FSPCA's forms from its website.

In general, regardless of whether you use these worksheets, we recommend that you arrange the information in your food safety plan in a progressive manner that clearly explains the thought process for the hazard analysis and the individual steps in the Food Safety Plan. For example:

- Your hazard analysis should contain information to justify:
  - Your identification of each hazard requiring a preventive control; and
  - The types of preventive controls applied;
- You should explain the details for each preventive control.

Other formats are entirely acceptable if they work for your organization. If you use another format, you should ensure that your format provides all of the information that the preventive controls rule requires for each required component of the food safety plan. See 21 CFR 117.126, 117.305, and 117.310.

Each FSPCA form has a form name, but does not have an identifying number. In this Appendix, we number each FSPCA form (Form 2-A, Form 2-B, etc.) to have a concise identifier for each form.

Form 2-A: FSPCA Form for Product Description

In Chapter 2 of this guidance, we recommend that you conduct certain preliminary steps before conducting your hazard analysis. One of these preliminary steps is to describe the product, its distribution, intended use, and consumer or end user of the product. The product description form that is commonly used in the development of HACCP plans can be used to do so. See Form 2-A.

Below, we list the information that you will see on Form 2-A. When appropriate for clarity, we explain what type of information you would include for the listed information. Regardless of whether you use Form 2-A, we recommend that you include such information in any product description that you develop.

- General information such as the name and address of the plant, the issue date of the form and the old version ("supersedes"), the page number (often "Page X of Y").
- Product Name: i.e., the full name of the finished product.
- Product Description, including Important food safety characteristics – i.e., descriptors such as ready-to-eat (RTE), frozen; factors that can influence growth of pathogens, such as whether the food has a low pH or a_w or contains preservatives.
- Ingredients.
- Packaging Used: e.g., type (bottle, box, can); material (plastic, glass, cardboard with liner); reduced oxygen packaging.
- Intended Use: e.g., intended for retail, foodservice, or further processing; whether the food is ready-to-eat or ready-to-cook by the consumers; and what the potential is for mishandling or unintended use.
- Intended Consumers: usually the general public; however, if a food product is intended specifically for susceptible populations such as hospitals, you should say so.
- Shelf Life.
- Labeling Instructions Related to Safety: e.g., "keep refrigerated" or cooking instructions.
- Storage and Distribution: e.g., whether the food is stored and/or distributed refrigerated, frozen or at ambient temperatures.

FORM 2-A PRODUCT DESCRIPTION

PAGE _____

PRODUCTS: _____
PLANT NAME: _____
ADDRESS: _____
ISSUE DATE: (mm/dd/yy)_____
SUPERSEDES: (mm/dd/yy)_____

Product Name(s)	
Product Description, including Important Food Safety Characteristics	
Ingredients	
Packaging Used	
Intended Use	
Intended Consumers	
Shelf Life	
Labeling Instructions related to Safety	
Storage and Distribution	

Approved: (signature or initials)_____

Date: _____

Form 2-B: FSPCA Form for Hazard Analysis

In Chapter 2 of this guidance, we explain how to set up an adaptation of the "Hazard Analysis Worksheet" used in HACCP systems to organize your hazard analysis. See Form 2-B. Note that for brevity Form 2-B uses the term "potential hazard" rather than "known or reasonably foreseeable hazard."

See section 2.2.2 in Chapter 2 for an overview of how to set up columns 1-6 of Form 2-B. See the remainder of Chapter 2 for more detail about how to provide information on Form 2-B. Regardless of whether you use Form 2-B, we recommend that you include such information in your hazard analysis.

FORM 2-B HAZARD ANALYSIS*

PAGE _____

PRODUCTS: _____
PLANT NAME: _____
ADDRESS: _____
ISSUE DATE: (mm/dd/yy)_____
SUPERSEDES: (mm/dd/yy)_____

(1) Ingredient / Processing Step	(2) Identify <u>potential</u> food safety hazards introduced, controlled or enhanced at this step B = biological C = chemical, including radiological P = physical	(3) Are any <u>potential</u> food safety hazards requiring preventive control? (Yes/No)	(4) Justify your decision for column 3	(5) What preventive control measure(s) can be applied to significantly minimize or prevent the food safety hazard? *Process including CCPs, Allergen, Sanitation, Supplier, other preventive control*	(6) Is the preventive control applied at this step? (Yes/No)

* The current FSPCA form includes some additional features, such as a separate column for "Yes" and "No" responses and a separate row at each step for biological, chemical, and physical hazards (labeled B, C, and P, respectively).

Form 2-C: FSPCA Form for Process Controls

Chapter 5 of this guidance provides an overview of the application of preventive controls to significantly minimize or prevent the occurrence of biological, chemical, and physical hazards in finished foods and the food production environment. Chapter 5 also provides an overview of preventive control management components (i.e., monitoring, corrective actions and corrections, and verification activities (and their associated records)). When the preventive control that you identify is a process control, Form 2-C provides a format for you to specify the process control and the associated preventive control management components.

Below, we list the information that you will see on Form 2-C. When appropriate for clarity, we explain what type of information you would include for the listed information. Regardless of whether you use Form 2-C, we recommend that you include such information in your food safety plan when you will implement a process control.

- General information such as the name and address of the plant, the issue date of the form and the old version ("supersedes"), the page number (often "Page X of Y").
- Process Control: From the Hazard Analysis form, enter the steps identified as requiring a process control
- Hazard(s): From the Hazard Analysis form, enter the hazard requiring a preventive control at each step listed in the "Process Control" column.
- Parameters, values, or critical limits: Enter the parameters, and the associated minimum or maximum value (or critical limits) associated with the parameters.
- Monitoring: In the columns provided, enter what will be monitored, how it will be monitored, the frequency that the monitoring will be done and who will do the monitoring (e.g., the position, such as "operator" or "QA technician").
- Corrective Actions: Describe the corrective actions that will be taken when deviations from the minimum/maximum values (or critical limits) for a parameter occur.
- Verification: List the ongoing verification activities, including calibration (where appropriate) and records review. Although the form was designed to focus on ongoing verification activities, rather than data and information addressing validation, you also can list information such as a validation study on FSPCA Form 2-C if you find it useful to do so.
- Records: List the names of the records that result from implementation of the process controls (e.g., cook log, cooling records, metal detector check log).

FORM 2-C PROCESS CONTROLS

PAGE _____

PRODUCTS: _____
PLANT NAME: _____
ADDRESS: _____
ISSUE DATE: (mm/dd/yy)_____
SUPERSEDES: (mm/dd/yy)_____

Process Control Step	Hazard(s)	Critical Limits	What to Monitor	How to Monitor	Frequency of Monitoring	Who Monitors	Corrective Action	Verification	Records

Process Control Step	Hazard(s)	Critical Limits	What to Monitor	How to Monitor	Frequency of Monitoring	Who Monitors	Corrective Action	Verification	Records

Form 2-D: FSPCA Form for Sanitation Controls

The forthcoming Chapter 10 of this guidance will address sanitation controls, which can vary substantially from facility to facility. When the preventive control that you identify is a sanitation control, Form 2-D provides a format for you to specify the sanitation control and the associated preventive control management components. Although Form 2-D may not always be the most effective way to describe the many sanitation controls that may be employed, you may find Form 2-D helpful to summarize cleaning and sanitizing of a particular piece of equipment or particular locations in your plant where product is exposed to the environment.

Below, we list the information that you will see on Form 2-D. When appropriate for clarity, we explain what type of information you would include for the listed information.

- General information such as the name and address of the plant, the issue date of the form and the old version ("supersedes"), the page number (often "Page X of Y").
- Location: Enter the location(s) in the plant where the sanitation control described on Form 2-D will be used.
- Purpose: e.g., to remove food allergens, to reduce contamination with environmental pathogens
- Frequency: How often the procedure is used (e.g., daily; after each production run; weekly;)
- Who: i.e., the position, such as "sanitation technician" or "sanitation supervisor"
- Procedure: You can write the procedure on the form or refer to a specific Standard Operating Procedure (SOP). Procedures can include cleaning procedures and monitoring procedures, such as measuring sanitizer concentration.
- Corrections (Corrective Actions Where Appropriate) - e.g., recleaning equipment that is not visibly clean prior to production. In most cases, corrections are appropriate. However, you may want to include circumstances that would trigger corrective actions.
- Records: the type of records you will maintain.
- Verification activities (such as records review) and the type of records maintained are listed.

FORM 2-D SANITATION CONTROLS

PAGE _____

PRODUCTS: _____
PLANT NAME: _____
ADDRESS: _____
ISSUE DATE: (mm/dd/yy)_____
SUPERSEDES: (mm/dd/yy)_____

Location	
Purpose	
Frequency	
Who	
Procedure	
Monitoring	
Corrections (Corrective actions where necessary)	
Records	

Verification: (signature or initials) _____

Date: _____

FSPCA Food Allergen Control Forms

Chapter 5 of this guidance provides an overview of the application of preventive controls to significantly minimize or prevent the occurrence of biological, chemical, and physical hazards in finished foods and the food production environment. Chapter 5 also provides an overview of preventive control management components (i.e., monitoring, corrective actions and corrections, and verification activities (and their associated records)). Our forthcoming Chapter 11 - Food Allergen Controls will provide a comprehensive guide to food allergen control.

When the preventive control that you identify is an allergen control, the FSPCA forms that we identify as Forms 2-E, 2-F, 2-G, and 2-H provide a format for you to specify the allergen control and the associated preventive control management components.

- Form 2-E: FSPCA form for Food Allergen Ingredient Analysis. Use for conducting an allergen-specific hazard analysis of food ingredients.
- Form 2-F: FSPCA form for Food Allergen Label Verification List. Use to list the specific allergens to be listed in the "Contains" declaration on the product label.
- Form 2-G: FSPCA form for Production Line Food Allergen Assessment. Use to identify common and unique food allergens for products produced on a production line for the purpose of making decisions on scheduling (e.g., run unique allergens last) and allergen cleaning information (e.g., conduct a full allergen cleaning before running products without the allergen)
- Form 2-H: FSPCA form for Food Allergen Controls. Use to describe any food allergen controls and associated preventive control management components.

Regardless of whether you use these FSPCA Food Allergen forms, we recommend that you conduct a food allergen ingredient analysis and include information such as you see in Form 2-E in your food safety plan. if your food allergen ingredient analysis identifies food allergens that will be (or may be) in your products, we recommend that you include information such as you see in the remaining FSPCA forms in your food safety plan.

Form 2-E: FSPCA Form for Food Allergen Ingredient Analysis

Below, we list the information that you will see on Form 2-E. When appropriate for clarity, we explain what type of information you would include for the listed information.

- General information such as the name and address of the plant, the issue date of the form and the old version ("supersedes"), the page number (often "Page X of Y").
- Raw Material Name: List all raw materials received in the facility
- Supplier: Identify the supplier for each raw material
- Food Allergens in Ingredient Formulation: Identify any food allergens in each listed raw material – e.g., by reviewing ingredient labels or contacting the manufacturer
- Food Allergens in Precautionary Labeling: List any allergens listed in precautionary labeling (such as a "May Contain" statement) in raw materials that you receive

FORM 2-E FOOD ALLERGEN INGREDIENT ANALYSIS

PAGE _____

PRODUCTS: _____
PLANT NAME: _____
ADDRESS: _____
ISSUE DATE: (mm/dd/yy)_____
SUPERSEDES: (mm/dd/yy)_____

Food Allergens in Ingredient Formulation or in Precautionary Labeling

Raw Material Name	**Supplier**	**Egg**	**Milk**	**Soy**	**Wheat**	**Tree Nut** (market name)	**Peanut**	**Fish** (market name)	**Shellfish** (market name)	**Food Allergens in Precautionary Labeling**

Form 2-F: FSPCA Form for Food Allergen Label Verification List

Below, we list the information that you will see on Form 2-F. When appropriate for clarity, we explain what type of information you would include for the listed information.

- General information such as the name and address of the plant, the issue date of the form and the old version ("supersedes"), the page number (often "Page X of Y").
- Product: List each product that will contain (or may contain) a major food allergen
- Allergen Statement: Specify the "Contains" statement that you will include on the product label for that product.

FORM 2-F FOOD ALLERGEN LABEL VERIFICATION LIST

PAGE _____

PRODUCTS: _____
PLANT NAME: _____
ADDRESS: _____
ISSUE DATE: (mm/dd/yy)_____
SUPERSEDES: (mm/dd/yy)_____

Product	**Allergen Statement**
	Contains:
	Contains:
	Contains:
	Contains:

Form 2-G: FSPCA Form for Production Line Food Allergen Assessment

Below, we list the information that you will see on Form 2-G. When appropriate for clarity, we explain what type of information you would include for the listed information.

- General information such as the name and address of the plant, the issue date of the form and the old version ("supersedes"), the page number (often "Page X of Y").
- Product Name: List each product made in the plant
- Production Line: Identify the production line used for each listed product
- List the allergens that you will add to the listed product, including any allergens listed in precautionary labeling if you determine there is the potential for these to contaminate the line.

FORM 2-G PRODUCTION LINE FOOD ALLERGEN ASSESSMENT

PAGE _____

PRODUCTS: _____
PLANT NAME: _____
ADDRESS: _____
ISSUE DATE: (mm/dd/yy)_____
SUPERSEDES: (mm/dd/yy)_____

Product Name	**Production Line**	**Egg**	**Milk**	**Soy**	**Wheat**	**Tree Nut** (market name)	**Peanut**	**Fish** (market name)	**Shellfish** (market name)

Form 2-H: FSPCA Form for Food Allergen Controls

The FSPCA Food Allergen Control Form (Form 2-H) is modeled after the FSPCA Process Controls Form (Form 2-C). Below, we list the information that you will see on Form 2-H. When appropriate for clarity, we explain what type of information you would include for the listed information.

- General information such as the name and address of the plant, the issue date of the form and the old version ("supersedes"), the page number (often "Page X of Y").
- Allergen Control Step: Describe the step at which the allergen control is being applied e.g., at label receipt or label application for label controls; at post-production sanitation for equipment cleaning.
- Hazard: e.g., undeclared allergen due to incorrect label; undeclared allergen due to cross-contact.
- Criterion: Specify the criterion you are trying to meet, e.g., all finished product labels declare the allergens in the product.
- Monitoring; In the columns provided, enter what will be monitored (e.g., the label ingredient declaration), how it will be monitored (e.g., the label will be visually checked and compared to the product formulation), the frequency that the monitoring will be done (e.g., each new order of labels before they are released to production), and who will do the monitoring (e.g., label coordinator).
- Corrective Actions: In some cases, corrections will be appropriate. However, you should include circumstances that would trigger corrective actions.
- Verification: List the verification activities, such as records review.
- Records: List the names of the records that result from implementation of the food allergen controls (e.g., label review log).

FORM 2-H FOOD ALLERGEN CONTROLS

PAGE _____

PRODUCTS: _____
PLANT NAME: _____
ADDRESS: _____
ISSUE DATE: (mm/dd/yy)_____
SUPERSEDES: (mm/dd/yy)_____

Allergen Control Step	Hazard(s)	Criterion	What to Monitor	How to Monitor	Frequency of Monitoring	Who Monitors	Corrective Action	Verification	Records

Allergen Control Step	Hazard(s)	Criterion	What to Monitor	How to Monitor	Frequency of Monitoring	Who Monitors	Corrective Action	Verification	Records

Form 2-I: FSPCA Form for Supply-chain-applied Preventive Controls Program

Chapter 5 of this guidance provides an overview of the application of preventive controls to significantly minimize or prevent the occurrence of biological, chemical, and physical hazards in finished foods and the food production environment. Chapter 5 also provides an overview of preventive control management components (i.e., monitoring, corrective actions and corrections, and verification activities (and their associated records)). Our forthcoming Guidance for Industry, Supply-Chain Programs, Draft Guidance, will provide a comprehensive guide to supply-chain controls.

When the preventive control that you identify is a supply-chain control, Form 2-I provides a format for you to specify the preventive control and the associated preventive control management components appropriate for a supply-chain program. You would use a separate form for each ingredient that would have a supply-chain program control. Below, we list the information that you will see on Form 2-I. When appropriate for clarity, we explain what type of information you would include for the listed information. Regardless of whether you use Form 2-I, we recommend that you include such information in your food safety plan when you will implement a supplier control.

- General information such as the name and address of the plant, the issue date of the form and the old version ("supersedes"), the page number (often "Page X of Y").
- Hazards requiring a supply-chain-applied control: List each hazard requiring a preventive control
- Preventive controls applied by the supplier: When applicable, list any preventive controls applied by the supplier
- Verification activities: List the verification activities you will conduct – i.e., onsite audits; sampling and testing of the raw material or other ingredient; review of the supplier's relevant food safety records; and other appropriate supplier verification activities based on supplier performance and the risk associated with the raw material or other ingredient.
- Verification procedures: e.g., procedures for receiving raw materials and other ingredients; audit procedures
- Records: e.g., records documenting receipt from an approved supplier, records documenting review of supplier verification activities

Form 2-I: Supply-chain-applied Preventive Controls Program

PAGE _____

PRODUCTS: _____
PLANT NAME: _____
ADDRESS: _____
ISSUE DATE: (mm/dd/yy)_____
SUPERSEDES: (mm/dd/yy)_____

Determination of Verification Procedures

Ingredient:

Hazards requiring a supply-chain-applied control	
Preventive controls applied by the supplier	
Verification activities	
Verification procedures	
Records	

Approved Suppliers for Ingredients Requiring a Supply-chain-applied Control

Ingredient (requiring supply-chain-applied control)	**Approved Supplier**	**Hazard(s) requiring supply-chain-applied control**	**Date of Approval**	**Verification method**	**Verification records**

Receiving Procedure for Ingredients Requiring a Supply-chain-applied Control

[Document procedures used for receiving ingredients requiring a supply-chain-applied control.]

Hazard Analysis and Risk-Based Preventive Controls for Human Food: Draft Guidance for Industry[16]

This draft guidance, when finalized, will represent the current thinking of the Food and Drug Administration (FDA or we) on this topic. It does not establish any rights for any person and is not binding on FDA or the public. You can use an alternative approach if it satisfies the requirements of the applicable statutes and regulations. To discuss an alternative approach, contact FDA's Technical Assistance Network by submitting the form available at http://www.fda.gov/Food/GuidanceRegulation/FSMA/ucm459719.htm.

Appendix 3: Bacterial Pathogen Growth and Inactivation

This appendix contains information on the growth and inactivation of bacterial pathogens. The tables in this appendix derive from our guidance entitled "Fish and Fishery Products Hazards and Controls Guidance." In these tables, and our discussion of these tables, we use the technical terms "D-value" and "z-value," which we briefly describe immediately below. For additional information about what these terms mean and how you can use the information in these tables to determine appropriate processing conditions for your product, you should consult standard food processing books and technical information.

- D-value: The relationship between the duration of a thermal treatment and the percentage of microorganisms surviving the treatment is generally logarithmic, and the results of such studies are usually presented in a plot that represents the log of the percent of surviving vegetative cells or spores versus time at a given temperature. The time required to destroy 90 percent of the vegetative cells or spores at a given temperature is called the decimal reduction time, usually referred to as the "D-value" (Larousse and Brown, 1997). The D-value usually varies inversely with temperature.
- z-value: In general, the slope of a plot of the log of the D-value versus temperature is approximately linear. A "z-value" is derived from the reciprocal of the slope of the best straight line and is equal to the increase in the number of degrees (from a given starting temperature) that results in a 90 percent reduction in the D-value (Larousse and Brown, 1997). The D-value and z-value for the vegetative cells or spores of a microbial strain at a specified temperature characterize its thermal resistance at that temperature. Therefore, D-values and z-values provide a means to compare the thermal resistance of different microorganisms, or different strains of the same microorganism, at one or more temperatures.

Table 3-A contains information on the minimum water activity (a_w), minimum and maximum pH, and minimum and maximum temperatures that limit growth for the bacterial pathogens that are of greatest concern in food processing. Table 3-A also provides data on the maximum water phase salt that limits growth and the oxygen requirements for the pathogens listed. The data shown in Table 3-A are the extreme limits reported among the references cited. These values may not apply to your food or processing conditions.

[16] This guidance has been prepared by the Office of Food Safety in the Center for Food Safety and Applied Nutrition at the U.S. Food and Drug Administration.

Table 3-B contains information on maximum cumulative exposure time at internal product temperature ranges for exposure of foods that, under ordinary circumstances, will be safe for the bacterial pathogens that are of greatest concern in food processing. These maximum, cumulative exposure times are derived from published scientific information.

Table 3-C is a Quick Reference Guide based on Table 3-B.

Because the nature of bacterial growth is logarithmic, linear interpolation using the time and temperature guidance may not be appropriate. Furthermore, the food matrix affects bacterial growth (e.g., presence of competing microorganisms, available nutrients, growth-restrictive agents). You should consider such attributes when using the information in Tables 3-A, 3-B, and 3-C.

Table 3-D contains information on the destruction of *Listeria monocytogenes* (*L. monocytogenes*). Lethal rate, as used in Table 3-D, is the relative lethality of 1 minute at the designated internal product temperature as compared with the lethality of 1 minute at the reference internal product temperature of 158°F (70°C) (using a z = 13.5°F (7.5°C)). For example, 1 minute at 145°F (63°C) is 0.117 times as lethal as 1 minute at 158°F (70°C). The times provided are the length of time at the designated internal product temperature necessary to deliver a "6D" process for *L. monocytogenes* (i.e., a process that will accomplish a 6 logarithm (factor of 1,000,000) reduction in the number of *L. monocytogenes*).

The length of time at a particular internal product temperature needed to accomplish a 6D reduction in the number of *L. monocytogenes* depends, in part, upon the food that is being heated. The values in the table are generally conservative and apply to all foods. You may be able to establish a shorter process time for your food by conducting scientific thermal death time studies. Additionally, lower degrees of destruction may be acceptable in your food if supported by a scientific study of the normal initial levels in the food. It is also possible that higher levels of destruction may be necessary in some foods, if you anticipate relatively high initial levels in the food you are processing.

Table 3-E contains information on the destruction of *Clostridium botulinum* (*C. botulinum*) type B (the most heat- resistant form of non-proteolytic *C. botulinum*). (The non-proteolytic strains of *C. botulinum* can grow at refrigeration temperatures and may be a hazard requiring a preventive control in some foods intended to be held refrigerated for extended periods of time.) Lethal rate, as used in this table, is the relative lethality of 1 minute at the designated internal product temperature as compared with the lethality of 1 minute at the reference product internal temperature of 194°F (90°C) (for temperatures less than 194°F (90°C), z = 12.6°F (7.0°C); for temperatures above 194°F (90°C), z = 18°F (10°C)). The times provided are the length of time at the designated internal product temperature necessary to deliver a 6D process for *C. botulinum.* The values in the table are generally conservative. You may be able to establish a shorter process time for your food by conducting scientific thermal death time studies.

Table 3-A Limiting Conditions for Pathogen Growth

Pathogen	Min. a_w (using salt)	Min. pH	Max. pH	Max. % Water Phase Salt	Min. Temp.	Max. Temp.	Oxygen Requirement
Bacillus cereus	0.92	4.3	9.3	10	39.2°F 4°C	131°F[1] 55°C	facultative anaerobe[4]
Campylo-bacter jejuni	0.987	4.9	9.5	1.7	86°F 30°C	113°F 45°C	micro-aerophile[2]
Clostridium botulinum, type A, and proteolytic types B and F	0.935	4.6	9	10	50°F 10°C	118.4°F 48°C	anaerobe[3]
Clostridium botulinum, type E, and non-proteolytic types B and F	0.97	5	9	5	37.9°F 3.3°C	113°F 45°C	anaerobe[3]
Clostridium perfringens	0.93	5	9	7	50°F 10°C	125.6°F 52°C	anaerobe[3]
Pathogenic strains of *Escherichia coli*	0.95	4	10	6.5	43.7°F 6.5°C	120.9°F 49.4°C	facultative anaerobe[4]
Listeria monocyto-genes	0.92	4.4	9.4	10	31.3°F -0.4°C	113°F 45°C	facultative anaerobe[4]
Salmonella spp.	0.94	3.7	9.5	8	41.4°F 5.2°C	115.2°F 46.2°C	facultative anaerobe[4]
Shigella spp.	0.96	4.8	9.3	5.2	43°F 6.1°C	116.8°F 47.1°C	facultative anaerobe[4]
Staphylo-coccus aureus growth	0.83	4	10	20	44.6°F 7°C	122°F 50°C	facultative anaerobe[4]

Pathogen	Min. a_w (using salt)	Min. pH	Max. pH	Max. % Water Phase Salt	Min. Temp.	Max. Temp.	Oxygen Requirement
Staphylo-coccus aureus toxin formation	0.85	4	9.8	10	50°F 10°C	118°F 48°C	facultative anaerobe[4]
Vibrio cholerae	0.97	5	10	6	50°F 10°C	109.4°F 43°C	facultative anaerobe[4]
Vibrio parahaemo-lyticus	0.94	4.8	11	10	41°F 5°C	113.5°F 45.3°C	facultative anaerobe[4]
Vibrio vulnificus	0.96	5	10	5	46.4°F 8°C	109.4°F 43°C	facultative anaerobe[4]
Yersinia enterocoliti-ca	0.945	4.2	10	7	29.7°F -1.3°C	107.6°F 42°C	facultative anaerobe[4]

[1]Has significantly delayed growth (>24 hours) at 131°F (55°C).
[2]Requires limited levels of oxygen.
[3]Requires the absence of oxygen.
[4]Grows either with or without oxygen.

Table 3-B. Time and Temperature Guidance for Controlling Pathogen Growth and Toxin Formation in Food Products

Potentially Hazardous Condition	Product Temperature	Maximum Cumulative Exposure Time
Growth and toxin formation by ***Bacillus cereus***	39.2-43°F (4-6°C) 44-59°F (7-15°C) 60-70°F (16-21°C) Above 70°F (21°C)	5 days 1 day 6 hours 3 hours
Growth of ***Campylobacter jejuni***	86-93°F (30-34°C) Above 93°F (34°C)	48 hours 12 hours
Germination, growth, and toxin formation by ***Clostridium botulinum*** type A, and proteolytic types B and F	50-70°F (10-21°C) Above 70°F (21°C)	11 hours 2 hours
Germination, growth, and toxin formation by ***Clostridium botulinum*** type E, and non-proteolytic types B and F	37.9-41°F (3.3-5°C) 42-50°F (6-10°C) 51-70°F (11-21°C) Above 70°F (21°C)	7 days 2 days 11 hours 6 hours
Growth of ***Clostridium perfringens***	50-54°F (10-12°C) 55-57°F (13-14 °C) 58-70°F (15-21°C) Above 70°F (21°C)	21 days 1 day 6 hours[1] 2 hours
Growth of pathogenic strains of ***Escherichia coli***	43.7-50°F (6.6-10°C) 51-70°F (11-21°C) Above 70°F (21°C)	2 days 5 hours 2 hours
Growth of ***Listeria monocytogenes***	31.3-41°F (-0.4-5°C) 42-50°F (6-10°C) 51-70°F (11-21°C) 71-86°F (22-30°C) Above 86°F (30°C)	7 days 1 day 7 hours 3 hours 1 hour
Growth of ***Salmonella*** species	41.4-50°F (5.2-10°C) 51-70°F (11-21°C) Above 70°F (21°C)	2 days 5 hours 2 hours
Growth of ***Shigella*** species	43-50°F (6.1-10°C) 51-70°F (11-21°C) Above 70°F (21°C)	2 days 5 hours 2 hours
Growth and toxin formation by ***Staphylococcus aureus***	50°F (7-10°C) 51-70°F (11-21°C) Above 70°F (21°C)	14 days 12 hours[1] 3 hours

Potentially Hazardous Condition	Product Temperature	Maximum Cumulative Exposure Time
Growth of ***Vibrio cholerae***	50°F (10°C) 51-70°F (11-21°C) 71-80°F (22-27°C) Above 80ºF (27ºC)	21 days 6 hours 2 hours 1 hour[2]
Growth of ***Vibrio parahaemolyticus***	41-50°F (5-10°C) 51-70°F (11-21°C) 71-80°F (22-27°C) Above 80ºF (27ºC)	21 days 6 hours 2 hours 1 hour[2]
Growth of ***Vibrio vulnificus***	46.4-50°F (8-10°C) 51-70°F (11-21°C) 71-80°F (22-27°C) Above 80ºF (27ºC)	21 days 6 hours 2 hours 1 hour[2]
Growth of ***Yersinia enterocolitica***	29.7-50°F (-1.3-10°C) 51-70°F (11-21°C) Above 70°F (21°C)	1 day 6 hours 2.5 hours

[1] Additional data needed.
[2]Applies to cooked, ready-to-eat foods only.

Table 3-C is a Quick Reference Guide derived from Table 3-B:

Table 3-C Quick Reference Guide for Time and Temperature Guidance for Controlling Pathogen Growth and Toxin Formation in Food Products (for Internal Temperatures above 50°F (10°C) but below 135ºF (57.2ºC))

If the food is a …	And the food is held at an internal temperature …	Then you should limit the exposure time to …	Or, if *Staphylococcus aureus* (*S. aureus*) is the only pathogen of concern, then you should limit the exposure time to …	As long as …
Raw, RTE ingredient or food product	Above 70°F (21.1°C)	2 hours	3 hours	N/A
Raw, RTE ingredient or food product	Above 70°F (21.1°C)	4 hours	N/A	No more than 2 of those hours are between 70°F (21.1°C) and 135ºF (57.2ºC)
Raw, RTE ingredient or food product	At any time above 50°F (10°C) but never above 70°F (21.1°C)	5 hours	12 hours	N/A

If the food is a …	And the food is held at an internal temperature …	Then you should limit the exposure time to …	Or, if *Staphylococcus aureus* (*S. aureus*) is the only pathogen of concern, then you should limit the exposure time to …	As long as …
Raw, RTE ingredient or food product	At internal temperatures (or at ambient air temperatures) below 50°F (10°C) throughout processing	N/A	N/A	N/A
Cooked, RTE ingredient or food product	At any time above 80°F (26.7°C)	1 hour	3 hours	N/A
Cooked, RTE ingredient or food product	At any time above 80°F (26.7°C)	4 hours	N/A	No more than 1 of those hours is above 70°F (21.1°C)
Cooked, RTE ingredient or food product	At any time above 70°F (21.1°C) but never above 80°F (26.7°C)	2 hours	3 hours	N/A
Cooked, RTE ingredient or food product	Never held above 80°F (26.7°C)	4 hours	N/A	No more than 2 of those hours are above 70°F (21.1°C)
Cooked, RTE ingredient or food product	At any time above 50°F (10°C) but never above 70°F (21.1°C)	5 hours	12 hours	N/A
Cooked, RTE ingredient or food product	At internal temperatures (or ambient air temperatures) below 50°F (10°C) throughout processing	N/A	N/A	N/A

Note that the preceding recommended critical limits do not address internal product temperatures between 40°F (4.4°C), which is the recommended maximum storage temperature for refrigerated food products, and 50°F (10°C). That is because growth of foodborne pathogenic bacteria is very slow at these temperatures and the time necessary for significant growth is longer than would be reasonably likely to occur in most food processing steps. However, if you have processing steps that occur at these temperatures that approach the maximum cumulative exposure times listed in Table 3-B for the pathogenic bacteria of concern in your product, you should consider development of a critical limit for control at these temperatures.

It is not possible to furnish recommendations for each pathogenic bacterium, process, type of food product, and temperature or combination of temperatures. Programmable models to predict growth rates for certain pathogens associated with various foods under differing conditions have been developed by the U.S. Department of Agriculture' (the Pathogen Modeling Program (PMP)) and by an international consortium of the Institute of Food Research (UK), the USDA Agricultural Research Service (USDA-ARS) and the University of Tasmania Food Safety Centre (CombBase database and Predictor). These programs can provide growth curves for selected pathogens. To use these models, you indicate the conditions, such as pH, temperature, and salt concentration that you are interested in and the models provide pathogen growth predictions (e.g., growth curve, time of doubling, time of lag phase, and generation time). FDA does not endorse or require the use of such modeling programs, but recognizes that the predictive growth information they provide may be helpful to some processors. However, you should be aware that significant deviations between actual microbiological data in specific products and the predictions may occur, including those for the lag phase of growth. Therefore, you should validate the time and temperature limits derived from such predictive models if growth of pathogens during processing requires a preventive control.

Table 3-D Inactivation of *Listeria monocytogenes*

Internal Product Temperature (°F)	Internal Product Temperature (°C)	Lethal Rate	Time for 6D Process (minutes)
145	63	0.117	17.0
147	64	0.158	12.7
149	65	0.215	9.3
151	66	0.293	6.8
153	67	0.398	5.0
154	68	0.541	3.7
156	69	0.736	2.7
158	70	1.000	2.0
160	71	1.359	1.5
162	72	1.848	1.0
163	73	2.512	0.8
165	74	3.415	0.6
167	75	4.642	0.4
169	76	6.310	0.3
171	77	8.577	0.2
172	78	11.659	0.2
174	79	15.849	0.1
176	80	21.544	0.09
178	81	29.286	0.07
180	82	39.810	0.05
182	83	54.116	0.03
183	84	73.564	0.03
185	85	100.000	0.02

Note: z = 13.5°F (7.5°C).

Table 3-E Inactivation of Non-Proteolytic *Clostridium botulinum* Type B

Internal Product Temperature (°F)	Internal Product Temperature (°C)	Lethal Rate*	Time for 6D Process (minutes)
185	85	0.193	51.8
187	86	0.270	37.0
189	87	0.370	27.0
190	88	0.520	19.2
192	89	0.720	13.9
194	90	1.000	10.0
196	91	1.260	7.9
198	92	1.600	6.3
199	93	2.000	5.0
201	94	2.510	4.0
203	95	3.160	3.2
205	96	3.980	2.5
207	97	5.010	2.0
208	98	6.310	1.6
210	99	7.940	1.3
212	100	10.000	1.0

Note: For temperatures less than 194°F (90°C), z = 12.6°F (7.0°C); for temperatures above 194°F (90°C), z = 18°F (10°C).

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