Handbook of Meat, Poultry and Seafood Quality

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Associate Editors
Terri Boylston
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Patti C. Coggins
Maria Beatriz Gloria
Grethe Hyldig
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Lisa H. McKee
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Contents

List of Contributors, ix
Preface, xv

Part I. General Food Quality Factors
1. Factors Affecting Food Quality: A Primer 3
   Y. H. Hui
2. Hazard Analysis and Critical Control Points and Muscle Food Safety in the United States 7
   Y. H. Hui

Part II. Sensory Attributes of Muscle Foods
3. History, Background, and Objectives of Sensory Evaluation in Muscle Foods 15
   M. W. Schilling
4. Chemical and Biochemical Aspects of Color in Muscle Foods 25
   J. A. Pérez-Alvarez and J. Fernández-López
5. Sensory: Human Biology and Physiology 45
   M. A. Da Silva and F. Cendes
6. Sensory Methodology of Muscle Foods 61
   P. C. Coggins
7. Objective Methods of Sensory Analysis 71
   J. L. Montgomery
8. Attributes of Muscle Foods: Color, Texture, Flavor 89
   P. C. Coggins

Part III. Flavors
9. Sensory Characterization 101
   K. Bett-Garber
10. Chemical Characterization 111
    N. C. Da Costa and S. Eri
11. Chemistry, Technology, and Safety of Synthetic Flavors 127
    R. K. Singh and E. Singh
12. Process Flavors 151
    H. H. Baek
13. Savory Flavors 163
    C. Cerny

14. Natural Flavors 183
H. Kumagai
15. Wood Smoke Flavor 201
K. R. Cadwallader
16. Blended Flavors 211
S. X. Ma, Z. B. Xiao, and F. Chen
17. Off Flavors and Rancidity in Foods 217
R. B. Pegg and F. Shahidi
18. Land Animal Products 229
T. Boylston
19. Marine Animal and Plant Products 243
N. Narain and M. L. Nunes
20. Maillard Reaction in Flavor Generation 259
M. V. Romero and C. Ho
21. Traditional Laboratory Methods 275
E. Mehinagic
22. Recent Developments in Flavor Measurements 293
J-L. Le Quéré

Part IV. Beef Quality
23. Sensory Evaluation of Beef Flavor 311
R. K. Miller
24. Beef Quality and Tainting 327
J. M. Martin
25. Microbiological and Sensory Properties of Beef 333
J. Thomas
26. Quality Measurements in Beef 341
R. S. Chamul
27. Shelf Life of Meats 357
R. S. Chamul
28. Packaging and Freezing of Beef as Related to Sensory Properties 369
R. W. Rogers

Part V. Pork Quality
29. Fresh and Frozen Pork Color 377
D. H. Kropf
30. Microbiological and Sensory Properties of Fresh and Frozen Pork Products 395
L. McKee
31. Pork Taint 405
W. B. Mikel
32. Shelf Life of Fresh and Frozen Pork 417
M. A. Carr

Part VI. Poultry Quality
33. General Attributes of Fresh and Frozen Poultry Meat 429
L. McKee
34. Poultry Meat Flavor 439
P. L. Dawson and N. Spineli

35. Color of Fresh and Frozen Poultry 455
A. Totosaus, M. L. Pérez-Chabela, and I. Guerrero
36. Shelf Life of Fresh and Frozen Poultry 467
M. L. Pérez-Chabela
37. Packaging of Fresh and Frozen Poultry 475
A. Totosaus and V. Kuri
38. Microbiological and Sensory Properties of Fresh and Frozen Poultry 487
L. McKee

Part VII. Seafood Quality
39. Fish and Sensory Analysis in the Fish Chain 499
G. Hyldig, E. Larsen, and D. Green-Petersen
40. Sensory Profiling of Fish, Fish Product, and Shellfish 511
G. Hyldig
41. Quality Index Methods 529
G. Hyldig, A. Bremner, E. Martinsdóttir, and R. Schelvis
42. Texture of Fish, Fish Products, and Shellfish 549
G. Hyldig and D. Nielsen
43. Perception of Sensory Quality of Wild and Farmed Fish by Experts, Consumers, and Chefs or Cooks in the Restaurant Sector 563
G. B. Olsson, M. Carlehög, M. Heide, and J. Luten
44. Quality of Frozen Fish 577
J. Nielsen and F. Jessen

Appendix. Standards for Meat, Poultry and Seafood in the United States 589
Y. H. Hui

Index, 695

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Preface

The quality of a food is defined from two perspectives—scientific status and consumer preferences. Scientific factors affecting the quality of a food include: composition, spoilage, colorants, additives, nutrients, flavorants, functional ingredients (affecting health), contamination, general safety, etc. Consumer preferences are linked directly to the human senses—sight, touch, smell, taste, and mouthfeel. Visual factors refer to color, moisture, overall appearance, etc. Tactile factors refer to sliminess, elasticity, softness, hardness, etc. Factors responsible for taste and smell cover many specific chemicals. Mouthfeel refers to texture, softness, tenderness, chewy sensation, and so on. In the last 10 years or so, food quality has been defined by most professionals to include "health" and "safety." The nutrition and safety of foods has always been important, especially since the seventies. The word "health" now includes manipulating certain chemical components in food to increase food's positive impact on our health. "Safety" now refers to a whole spectrum of new legal or recommended requirements for both fresh and processed foods. These requirements are designed to exclude or prevent undesirable agents (biological, chemical, physical, environmental, and extraneous) in our foods.

For ease of reference, we can consider that the quality of a food is the composite picture of many factors. In the last five to ten years, many professional reference books have become available that explore the relationship between such factors and food quality. This book discusses the quality factors of muscle foods (meat, poultry, and seafood). Each professional reference treatise has its characteristics and the users determine which one best suits their purpose. From that perspective, we will describe the major features of our book.

This book provides an initial discussion of basic scientific factors responsible for the quality of muscle foods, with a specific emphasis on sensory attributes and flavors. The remaining sections discuss factors affecting the quality of beef, pork, poultry, and seafood. Under each muscle food, some or all of the following factors affecting the quality will be discussed—additives, aroma, color, contaminants, flavors, microbiology, moisture, mouthfeel, nutrition, packaging, safety, sensory attributes, shelf-life, stability, tainting, texture, and water-activity. Each muscle food discussed may be fresh, frozen, or processed.

This work is the result of the combined efforts of more than 60 professionals from industry, government, and academia worldwide. They represent more than 16 countries with diverse expertise and background in the quality of muscle foods. An international editorial team of 9 members from four countries led these experts. Each contributor or editor was responsible for researching and reviewing subjects of immense depth, breadth, and complexity. Care and attention were paramount to ensure technical accuracy for each topic. It is our sincere hope and expectation that it will serve as an essential reference on the quality of muscle foods for all professionals in government, industry, and academia.

The editorial team wishes to thank all the contributors for sharing their expertise throughout our journey. We also thank the reviewers for giving their valuable comments on how to improve the contents of each chapter. All these professionals are the ones who made this book possible. We trust that you will benefit from the fruits of their labor.

This book is relevant to many professionals in industry, government, and academia and will be most appreciated by the following users:

- All libraries.
- Research units in government, industry, and academia specializing in one or more food quality factors (color, flavor, microbiology, packaging, sensory attributes, and so on).
- Academic institutions: food science, food technology, food engineering, animal science, poultry science, cereal science, marine science, etc.
- Food industries of commodities covered.
- Individuals with expertise in any of the food quality factors discussed in the book.

We know firsthand how hard it is to develop the content of a book. However, we believe that the production of a professional book of this nature is even more difficult. We thank the editorial and production team at Blackwell, Inc. for their time, effort, advice, and expertise. You are the best judge of the quality of this book.

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Handbook of Meat, Poultry and Seafood Quality

Part I
General Food Quality Factors

1
Factors Affecting Food Quality: A Primer

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Introduction
Biology and Genetics
Nutrition
Flavors and Aroma
Color
Microbiology and Safety
Processing
Sensory Attributes and the Consumer
Government Standards and Specifications
Summary

INTRODUCTION

The quality of a food is defined from two perspectives: scientific status and consumer preferences. Scientific factors affecting the quality of a food include composition, spoilage, colorants, additives, nutrients, flavorants, functional ingredients (affecting health), contamination, general safety, etc. Consumer preferences are linked directly to the human senses such as sight, touch, smell, taste, and mouthfeel. Visual factors include color, moisture, overall appearance, etc. Tactile factors include sliminess, elasticity, softness, hardness, etc. Factors responsible for taste and smell cover many specific chemicals. Mouthfeel refers to texture, softness, tenderness, chewy sensation, and so on. In the last 10 years or so, food quality has been defined by most professionals to include "health" and "safety." The nutrition and safety of foods have always been important, especially so since the 1970s. The word "health" now includes manipulating certain chemical components in food to increase the positive impact of food on our health. "Safety" now refers to a whole spectrum of new legal or recommended requirements for both fresh and processed foods. These requirements are designed to exclude or prevent undesirable agents (biological, chemical, physical, environmental, and extraneous) in our foods. For ease of reference, we can consider that the quality of muscle foods (meat, poultry, and seafood) is the composite picture of many factors, and this chapter provides a brief mention of some of them.

BIOLOGY AND GENETICS

Obviously, the quality of any muscle food depends first and foremost on the genetics and biology of the animal. The beef from a young animal is more tender than that from an old animal. Due primarily to biological reasons, muscle from some parts of beef cattle is tastier and more tender than those from another part. Chickens are more tender than turkey. White meat is biologically different from dark meat. Of course, the preference of a consumer varies with regard to the two different kinds of meat. Saltwater fish is different from freshwater fish. Some fish have more bones than others. Western consumers prefer fish with fewer bones while most often the opposite is true for Asians.

NUTRITION

Recently, the nutrition of food has reached an all-time high as far as its impact on our health is concerned. There is no doubt the majority of Americans

consider a quality food as one with high nutritional value. Some salient points follow:

1. Meat and poultry are nutritious because of their high source of protein, vitamins, and minerals.
2. The high content of fat and cholesterol in land muscle foods is undesirable. Thus, "lean" is in.
3. Fish and shellfish are an important part of a healthy diet. Fish and shellfish contain high-quality protein and other essential nutrients, are low in saturated fat, and contain omega-3 fatty acids. A well-balanced diet that includes a variety of fish and shellfish can contribute to heart health and children's proper growth and development.

FLAVORS AND AROMA

One major reason, among many, that we like to eat is because food tastes good, which equates to flavor and aroma. Extensive research over the past 25 to 30 years has identified more than 1,000 flavor compounds in meats. However, a single compound or group of compounds responsible for "meaty flavor" has not and perhaps never will be identified due to the overall complexity of meat flavor. Meat flavor is dependent on the pool of flavor precursors in the meat tissue and the chemical reactions that occur during processing. Processing and subsequent storage contribute to the development of the characteristic flavors of meats. Because the precise flavor precursors vary between and within species, beef, pork, lamb, and poultry each have distinctive flavor characteristics. The quality of meat and poultry is to a large extent defined by its flavor and aroma.

In general, fresh saltwater fish are almost odorless because they contain a small quantity of volatiles while freshwater fish give off pyrrolidine and other earthy-odor compounds.

The compounds responsible for the development of flavor during seafood cooking can be classified in two groups. One, which represents the pleasant cucumber/green, almond/nutty, and potato aroma notes, consists of highly volatile, low molecular weight compounds belonging to various chemical classes such as aldehydes, ketones, alcohols, esters, nitrogen, phenols, and sulfur-containing compounds. The second is due to water soluble, low molecular weight free amino acids (taurine, glutamic acid, glycine), nucleotides (purine derivatives), organic acids (lactic acid), and inorganic salts (Na, K, Cl).

Biogenic amines are nitrogen-containing compounds, which are present at very low levels in fresh fish. However, during storage and deterioration, biogenic amines can be produced by amino acid decarboxylation from bacterial enzymes. Among biogenic amines formed, putrescine and cadaverine have a putrid flavor while histamine and phenylethylamine have a pungent and fishy flavor, respectively. Biogenic amines are thermally stable and, therefore, have been used as indices to determine fish freshness. Volatile amines such as trimethylamine (TMA) or dimethylamine (DMA) are formed from trimethylamine oxide (TMAO), and these compounds also serve as a quality index for marine fish.

COLOR

The first impression that a consumer receives concerning a food product is established visually, and among the properties observed are color, form, and surface characteristics.

Color is the main aspect that defines a food's quality, and a product may be rejected simply because of its color, even before other properties, such as aroma, texture, and taste, can be evaluated. This is why the appearance (optical properties, physical form, and presentation) of meat and poultry products at the point of sale is of such importance for the industry. Regarding the specific characteristics that contribute to the physical appearance of meat and poultry, color is the quality that most influences consumer choice.

Food technologists have a special interest in the color of food for several reasons. First, because of the need to maintain a uniform color throughout processing; second, to prevent any external or internal agent from acting on the product during processing, storage, and display; third, to improve or optimize a product's color and appearance; and, last, to attempt to bring the product's color into line with what the consumer expects.

Put simply, the color of meat is determined by the pigments present. These can be classified into the following four types:

- Biological (carotenes and haemopigments), which are accumulated or synthesized in the organism antemortem

- Pigments produced as a result of damage during manipulation or inadequate processing conditions
- Pigments produced postmortem (through enzymatic or nonenzymatic reactions)
- Those resulting from the addition of natural or artificial colorants

As a quality parameter, color has been widely studied in fresh meat and cooked products. Dry-cured meat products have received less attention because in this type of product, color formation takes place during the different processing stages. Recently, new haempigment has been identified in this type of product.

From a practical point of view, color plays a fundamental role in the animal production sector, especially in meat production (primarily beef and poultry,) since in many countries of the European Union, paleness receives a wholesale premium.

MICROBIOLOGY AND SAFETY

All foods contain microorganisms, some beneficial to and some with potential harm for mankind. With muscle foods, the beneficial ones are responsible for fermented meat and fish. Those potential pathogens are of concern. In the last 25 years, government records show that pathogenic organisms in meat, poultry, and seafood have been responsible for many deaths and injuries. Also, marine toxins pose big threats to our well-being considering that most of us enjoy eating fish and shellfish. It is not surprising that a quality muscle food must also be a safe one.

In view of potential hazards from the consumption of muscle foods, state and federal agencies have developed and implemented stringent safety requirements in the processing of meat, poultry, and seafood.

PROCESSING

The quality of any muscle food is obviously affected by the way it is processed.

Why do we want to process food? At present, there are many modern reasons why foods are processed, e.g., adding value to a food, improving the visual appeal, convenience. However, traditionally, the single most important reason that we wish to process food is to make them last longer without spoiling. Probably the oldest methods of achieving this goal are the salting of meat and fish, fermenting of milk, and pickling of vegetables.

Foods are made from natural materials, and like any living matter, will deteriorate in time. The deterioration of food, or food spoilage, is the natural way of recycling, restoring carbon, phosphorus, and nitrogenous matters to the good earth. However, putrefaction (spoilage) will modify the quality of foods resulting in poor appearance (discoloration), offensive smell, and inferior taste. Food spoilage can be caused by a number of factors, chiefly by biological factors, but also by chemical and physical factors. Consumption of spoiled foods can cause sickness and even death. There is no doubt none of us consider spoiled foods as having quality.

Selected examples will illustrate how food processing can affect the quality of a food product:

- Heat application. All of us know that overheating tender meat and chicken usually means toughness. The same is especially true for seafood.
- Heat removal or cold preservation. Freezing is a good example. Most of us are familiar with freezer-burn of meat, chicken, fish, shellfish, or other products left in the freezer over extended periods of time.
- Evaporation and dehydration. Food drying has been popular since the beginning of time. Destruction of nutrients, especially vitamins, is one drawback to this method of preservation.
- Fermentation. In general, of meat, poultry, and fish products, fermented meat such as sausages is most popular. The quality of a sausage is to a large extent determined by the consumer, e.g., dry, sweet, salty, and pickled. Each method affects the quality in terms of nutrients, hardness, tenderness, and flavor.
- New technology. There are numerous new technologies in food processing such as irradiation, microwaving, and ohmic heating. Each method affects the quality of a food in various ways.

The finished product requires packaging. The obvious reason for packaging a food product, muscle foods or other, is to protect the food so it will not be exposed to the elements until it is ready to be prepared and consumed. The quality and shelf life of a

food, especially a muscle food, depends very much on the way it is packaged.

SENSORY ATTRIBUTES AND THE CONSUMER

The sensory attributes of muscle foods are related to the senses of taste, smell, sight, feel, and sound. Of all the foods consumed, muscle foods have the lowest tolerance for complete sensorial acceptability. A muscle food is either acceptable or unacceptable with little in between. Predominately, the consumer visually assesses the color and surface texture of the muscle. The preparation technique of consumer choice is utilized, thereby altering the sensory attributes (usually completely). The consumer cooks or prepares the muscle food as they prefer, changing the surface color, appearance, and texture. The internal altering of texture and flavor is a result of the preparation or cooking process as well. This will vary depending on the many methods applied. For instance, the muscle may be grilled, baked, broiled, or otherwise prepared, all with different fluctuating end results. Consumption of muscle foods is one of the most pleasurable eating experiences. The satiety value applied by the consumption of a muscle food is great when comparing the satisfying effect of foods in general. This is why the sensorial properties of muscle foods can be viewed as often more important than that of other foods.

GOVERNMENT STANDARDS AND SPECIFICATIONS

The technical information in this book is applicable to food scientists and technologists worldwide. However, users from the United States will be very interested in the current government standards and specifications for muscle foods (meat, poultry, and seafood) since such documents usually include quality factors. Since many countries use the United States as an example in formulating their standards and specifications for muscle foods, scientists, technologists, and engineers from the international community may also benefit from information included in the appendix.

SUMMARY

This chapter provides a short introduction to the factors affecting the quality of foods, especially muscle foods. More details on most of the factors will be provided throughout the book.

2
Hazard Analysis and Critical Control Points and Muscle Food Safety in the United States

Y. H. Hui

Introduction
Current Good Manufacturing Practice Regulations
Hazard Analysis Critical Control Points Regulations or Programs
- What is HACCP?
- The Need for HACCP
- Advantages and Plans
- Hazard Analysis
- The HACCP Plan
  - The Contents of the HACCP Plan
  - Signing and Dating the HACCP Plan
- Sanitation
- Implementation

References

INTRODUCTION

Nearly 25 years ago, the United States Food and Drug Administration (FDA) started the approach of using umbrella regulations to help the food industries to produce wholesome food as required by the Federal Food, Drug, Cosmetic Act (The Act). In 1986, the FDA promulgated the first umbrella regulations under the title of Good Manufacturing Practice Regulations (GMPR). Since then, many aspects of the regulations have been revised.

Traditionally, industry and regulators have depended on spot-checks of manufacturing conditions and random sampling of final products to ensure safe food. The Current Good Manufacturing Practice Regulations (CGMPR) form the basis on which the FDA will inform a food manufacturer about deficiencies in its operations. This approach, however, tends to be reactive, rather than preventive, and can definitely be improved.

For more than 35 years, FDA has been regulating the low-acid canned food (LACF) industries with a special set of regulations, many of which are preventive in nature. This action aims at preventing botulism. In the last 35 years, threats from other biological pathogens have increased tremendously. Between 1980 and 1995, the FDA studied the approach of using Hazard Analysis and Critical Control Points (HACCP) programs.

For this approach, FDA uses the LACF regulations as a partial guide. Since 1995, the FDA has issued HACCP regulations (HACCPR) for the manufacture or production of seafood, among others.

In the last two decades, increasing death and injuries associated with contaminated meat and poultry have prompted new safety measures for these two muscle foods. Currently, the Food Safety and Inspection Service (FSIS) of the United States Department of Agriculture (USDA) have issued regulations implementing HACCP for the processing of meat and poultry.

CURRENT GOOD MANUFACTURING PRACTICE REGULATIONS

The Current Good Manufacturing Practice Regulations (CGMPR) cover the topics listed in Table 2.1.

These regulations cover essential practices to prevent food from being contaminated with biological, chemical and physical hazards, and foreign objects, such as the following:

Personnel: Use a hair net.
Plants and grounds: Use proper containers and locations for garbage.
Sanitation operations: Keep processed ingredients away from raw ingredients.
Sanitary facilities and controls: Maintain rest rooms and remove water that collects on the floor of processing areas.
Equipment and utensils: Clean vats daily.
Warehouse and distribution: Reduce the presence of rodents; do not transport food ingredients in a truck that has not been sanitized after transporting pesticides.

It is obvious that a careful food processor will become familiar with these regulations to make sure that their products are safe for public consumption. With this understanding, this chapter will not provide more details on this topic. Rather, our discussion will concentrate on HACCP because one of its objectives is to make sure that food processors implement CGMPR.

HAZARD ANALYSIS CRITICAL CONTROL POINTS REGULATIONS OR PROGRAMS

In 1997, the FDA adopted a food safety program that was developed nearly 30 years ago for astronauts and is now applying it to seafood, and fruit and vegetable juices. The agency intends to eventually use it for much of the U.S. food supply. The program for the astronauts focuses on preventing hazards that could cause food-borne illnesses by applying science-based controls, from raw material to finished products. The FDA's new system will do the same.

Many principles of this new system now called (HACCP) are already in place in the FDA-regulated LACF industry. Since 1997, the FDA has mandated HACCP for the processing of seafood, among others. The FDA has also incorporated HACCP into its *Food Code*, a document that gives guidance to and serves as model legislation for state and territorial agencies that license and inspect food service establishments, retail food stores, and food vending operations in the United States.

Table 2.1. Current good manufacturing practices regulations as stated in 21 CFR 110 (Title 21, United States Code of Federal Regulations, Part 110).

21 CFR 110.3	Definitions.
21 CFR 110.5	Current good manufacturing practice.
21 CFR 110.10	Personnel.
21 CFR 110.19	Exclusions.
21 CFR 110.20	Plant and grounds.
21 CFR 110.35	Sanitary operations.
21 CFR 110.37	Sanitary facilities and controls.
21 CFR 110.40	Equipment and utensils.
21 CFR 110.80	Processes and controls.
21 CFR 110.93	Warehousing and distribution.

The USDA has developed HACCP programs for meat, poultry, and other land muscle foods. It is important to realize that the underlying principles are the same, no matter what the manufacturing process. The same principles apply to the processing of meat, poultry, and seafood. The details vary. The discussion in this chapter will concentrate on the principles, citing specific examples for meat, poultry, and seafood.

Please note that the word "shall" in a legal document means mandatory and is used routinely in USDA FDA regulations published in the U.S. In this chapter, the words "should" and "must" are used to make for smoother reading. However, this in no way diminishes the legal impact of the original regulations.

WHAT IS HACCP?

HACCP involves the following seven principles:

1. Analyze hazards. Potential hazards associated with a food and measures to control those hazards are identified. The hazard could be biological, such as a microbe; chemical, such as a toxin; or physical, such as ground glass or metal fragments.
2. Identify critical control points. These are points in a food's production—from its raw state through processing and shipping to consumption by the consumer—at which the potential hazard can be controlled or eliminated. Examples are cooking, cooling, packaging, and metal detection.

3. Establish preventive measures with critical limits for each control point. For a cooked food, for example, this might include setting the minimum cooking temperature and time required to ensure the elimination of any harmful microbes.
4. Establish procedures to monitor the critical control points. Such procedures might include determining how and by whom cooking time and temperature should be monitored.
5. Establish corrective actions to be taken when monitoring shows that a critical limit has not been met—for example, reprocessing or disposing of food if the minimum cooking temperature is not met.
6. Establish procedures to verify that the system is working properly—for example, testing time and temperature recording devices to verify that a cooking unit is working properly.
7. Establish effective record keeping to document the HACCP system. This would include records of hazards and their control methods, the monitoring of safety requirements and action taken to correct potential problems.

Each of these principles must be backed by sound scientific knowledge such as published microbiological studies on time and temperature factors for controlling food-borne pathogens.

The Need for HACCP

New challenges to the U.S. food supply have prompted the USDA and FDA to consider adopting an HACCP-based food safety system on a wider basis. One of the most important challenges is the increasing number of new food pathogens. There also is increasing public health concern about chemical contamination of food, for example, the effects of lead in food on the nervous system.

Another important factor is that the size of the food industry and the diversity of products and processes have grown tremendously, in the amount of domestic food manufactured and the number and kinds of foods imported. At the same time, federal, state, and local agencies have the same limited level of resources to ensure food safety. The need for HACCP in the United States, particularly in the MUSCLE food industries, is further fueled by the growing trend in international trade for worldwide equivalence of food products and the Codex Alimentarius Commission's adoption of HACCP as the international standard for food safety.

Advantages and Plans

HACCP offers a number of advantages over previous systems. Most importantly, HACCP:

1. focuses on identifying and preventing hazards from contaminating food.
2. is based on sound science.
3. permits more efficient and effective government oversight, primarily because the record keeping allows investigators to see how well a firm is complying with food safety laws over a period rather than how well it is doing on any given day.
4. places responsibility for ensuring food safety appropriately on the food manufacturer or distributor.
5. helps food companies compete more effectively in the world market.
6. reduces barriers to international trade.

The seven steps used in HACCP plan development follow:

1. Preliminary Steps
    a. General information
    b. Describe the food
    c. Describe the method of distribution and storage
    d. Identify the intended use and consumer
    e. Develop a flow diagram
2. Hazard Analysis Worksheet
    a. Set up the Hazard Analysis Worksheet
    b. Identify the potential species-related hazards
    c. Identify the potential process-related hazards
    d. Complete the Hazard Analysis Worksheet
    e. Understand the potential hazard
    f. Determine if the potential hazard is significant
    g. Identify the critical control points (CCP)
3. HACCP Plan Form
    a. Complete the HACCP Plan Form
    b. Set the critical limits (CL)

4. Establish Monitoring Procedures
    a. What
    b. How
    c. Frequency
    d. Who
5. Establish Corrective Action Procedures
6. Establish a Record Keeping System
7. Establish Verification Procedures

It is important to remember that apart from HACCPR promulgated for seafood and juices, the implementation of HACCP by other categories of food processing is voluntary. However, the FDA and various types of food processors are working together so that eventually HACCPR will become available for many other food processing systems under FDA jurisdiction. Using the HACCPR for seafood processing as a guide, the following discussion for an HACCP plan applies to all categories of food products being processed in the United States.

Hazard Analysis

Every processor should conduct a hazard analysis to determine whether there are food safety hazards that are reasonably likely to occur for each kind of product processed by that processor and to identify the preventive measures that the processor can apply to control those hazards. Such food safety hazards can be introduced both within and outside the processing plant environment, including food safety hazards that can occur before, during, and after harvest. A food safety hazard that is reasonably likely to occur is one for which a prudent processor would establish controls because experience, illness data, scientific reports, or other information provide a basis to conclude that there is a reasonable possibility that it will occur in the particular type of product being processed in the absence of those controls.

The HACCP Plan

Every processor should have and implement a written HACCP plan whenever a hazard analysis reveals one or more food safety hazards that are reasonably likely to occur. An HACCP plan should be specific to the following:

1. Each location where products are processed by that processor.
2. Each kind of product processed by the processor.

The plan may group kinds of products together, or group kinds of production methods together, if the food safety hazards, CCPs, CLs, and procedures that are required to be identified and performed are identical for all products so grouped or for all production methods so grouped.

The Contents of the HACCP Plan

The HACCP plan should, at a minimum:

> List the food safety hazards that are reasonably likely to occur, as identified, and that thus must be controlled for each product. Consideration should be given to whether any food safety hazards are reasonably likely to occur as a result of the following: natural toxins; microbiological contamination; chemical contamination; pesticides; drug residues; decomposition in products where a food safety hazard has been associated with decomposition; parasites, where the processor has knowledge that the parasite-containing product will be consumed without a process sufficient to kill the parasites; unapproved use of direct or indirect food or color additives; and physical hazards;
>
> List the critical control points for each of the identified food safety hazards, including as appropriate: critical control points designed to control food safety hazards that could be introduced in the processing plant environment; and critical control points designed to control food safety hazards introduced outside the processing plant environment, including food safety hazards that occur before, during, and after harvest;
>
> List the critical limits that must be met at each of the critical control points;
>
> List the procedures, and frequency thereof, that will be used to monitor each of the critical control points to ensure compliance with the critical limits;
>
> Include any corrective action plans that have been developed to be followed in response to deviations from critical limits at critical control points;
>
> List the verification procedures, and frequency thereof, that the processor will use;
>
> Provide for a record keeping system that documents the monitoring of the critical control points. The records should contain the actual values and observations obtained during monitoring.

Signing and Dating the HACCP Plan

The HACCP plan should be signed and dated either by the most responsible individual on site at the processing facility or by a higher-level official of the