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**Foodservice Systems:
Product Flow and Microbial Quality
and Safety of Foods**

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Foodservice Systems: Product Flow and Microbial Quality and Safety of Foods

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NC-120 Regional Project

Quality and Safety of Foods Served in Households and Mass Feeding Systems

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FOREWORD

One purpose of the NC-120 regional committee is to conduct regional research involving microbial safety, nutritive value and sensory quality of foods served in mass feeding systems. To achieve this objective, members of the committee recognized the need for a reference base which delineates food product flow and presents the current status of microbial quality and safety of foods served within foodservice systems. This bulletin was written to fulfill that need and stimulate both needed research and systematic implementation of research findings. Potential users of this bulletin include:

1. Researchers who can contribute to solving problems of the foodservice industry
2. Foodservice industry educators
3. Trade and professional groups concerned with the foodservice industry
4. Sanitarians concerned with surveillance of foodservice facilities and practices
5. University students concerned with foodservice programs

The concepts of the foodservice industry presented in this bulletin focus on a limited segment of the food industry, namely the interrelationships between food processing industries and foodservice operations. Although agricultural production and economics, and food marketing and distribution are not discussed, their functions are implied. Without cooperative research efforts among scientists throughout the food industry, effective foodservice establishments could not operate. A glossary of terms is provided to assist those unfamiliar with the foodservice discipline.

Glossary

Food processing:

A commercial industry in which food is processed, prepared, packaged or distributed for consumption in the home or foodservice operation.

Food product flow:

The alternate paths within foodservice operations which food components and menu items may follow, initiating with receipt of food items and ending with service of food to the client.

Foodservice resources:

The food, supplies, space, equipment, energy, personnel, money and time required to serve a nutritious meal that meets the quality standards established for the foodservice operation.

Foodservice system:

A facility where large quantities of food intended for individual service and consumption are routinely provided, completely prepared. The term includes any such place regardless of whether consumption is on or off the premises and regardless of whether or not there is a charge for the food.

Heat processing:

Application of heat to either uncooked or cooked and chilled menu items in a foodservice system to achieve the desired level of cooking of the components and/or the appropriate food product internal temperature for service.

Managerial control points:

The time-temperature relationships for food components and menu items when foods located within the foodservice system require precise managerial monitoring to maintain microbial and sensory quality.

Microbial quality:

Sensory attributes of each specific food influenced by the presence of microorganisms.

Microbial safety:

The amount of pathogenic microorganisms or amount of toxins of microbial origin in foods are sufficiently low to prevent the onset of a foodborne disease outbreak after the food is consumed.

Sensory evaluation:

A scientific discipline used to evoke, measure, analyze, and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, smell, taste, touch and hearing.

Introduction

Personnel in the foodservice industry assume responsibility for serving high quality, nutritious meals to a large segment of the population of the United States. Current societal changes including decreased family size, increased number of persons residing alone, increased number of females employed outside of the home and substantial disposable incomes are factors encouraging increased patronage of foodservice operations (Raskin, 1975). Foodservice administrators should respond to the growing challenge to optimize food quality and safety, and minimize costs of food served to the consumer.

This bulletin was developed to identify (1) food product flow through various forms of foodservice systems and (2) critical areas for managerial control or monitoring of time-temperature relationships for microbial quality and safety. The need for this information was recognized through observation of recent developments in foodservice systems. Current changes in foodservice systems have been aimed primarily at either increasing productivity or decreasing food costs. Sensory quality and microbial quality and safety have not received adequate emphasis during these developments.

Changes in foodservice systems have occurred by applying innovative managerial concepts and developments in food technology. For example, the assembly-serve foodservice system was specifically established in response to recent developments in the frozen food industry. The availability of innovative foodservice equipment for thermal processing has increased the number of potential techniques for materials handling available to the foodservice industry.

With the evolution of foodservice operations, the interdependence between food processing and foodservice industries has become more apparent and their functions should be coordinated. The five conceptual diagrams for foodservice operations presented throughout this bulletin illustrate how food procurement decisions by the foodservice administrator affect food product flow within foodservice operations. A multi-disciplinary approach including foodservice administrators, food scientists, food microbiologists, food engineers and economists is necessary for research on food quality and safety. Identification of time-temperature relationships or sequences involved with the handling of food products in each foodservice operation is necessary for adequate managerial controls of food quality and safety.

Complex managerial decisions are required to execute appropriate foodservice systems to serve quality food at minimal costs. The foodservice administrator assumes primary responsibility for food safety and quality regardless of the type of foodservice system. This professional must be able to apply knowledge of food standards to control quality within each different system. The physical, chemical and microbiological changes occurring in food throughout all stages of procurement, production and service must be monitored and appropriate managerial decisions made to ensure the quality and safety of the finished product. Clearly, the managerial competence of a foodservice administrator is a crucial input to the successful management of each type of foodservice operation. To serve food products which meet consumer needs, the foodservice administrator should consider the appropriate food product flow for each menu item.

Food Processing/Foodservice Interface

With the evolution of foodservice systems at the present time, the interdependence between the food processing and the foodservice industries has become more apparent. Many highly processed foods are available for use in foodservice operations. The type of food products procured from food distributors for foodservice operations tends to identify the interface between the two industries. Figure 1 gives a schematic diagram of this interface.

Within the food processing industry, the food processing continuum represents the amount of processing which food items receive. At the far left side of this diagrammatic continuum, food items receive little or no processing; at the far right side, the food products have undergone complete processing operations. Figure 1 represents a foodservice operation which tends to procure food items with either no processing or a limited amount of processing.

To illustrate this concept, a ready-to-cook, whole chicken carcass which is chilled in ice slush receives little processing before distribution. If the bird is cut-up, packaged and frozen, this product receives some food processing relative to chicken products. However, if the poultry meat was diced, frozen, incorporated into chicken cacciatore, portioned, and frozen before distribution, these handling techniques would represent complete food processing for that menu item.

The interdependence of food processing and foodservice industries emphasizes the importance for foodservice administrators to have a close working relationship with the food processors. Based upon their foodservice operation and products available, foodservice administrators make procurement decisions about the type of food products desirable.

Microbial Quality and Safety of Foods

During the past few years approximately 300 outbreaks of foodborne illnesses have been reported annually. (See Table 1.) The range in numbers of individuals involved per outbreak was from one to more than 10,000 people. However, because most outbreaks are not reported, estimates state the actual incidence to be 10 to 100 times greater than reported figures (CDC, 1974). The physiological effects from foodborne diseases have been thoroughly delineated by Longree (1972) and others.

The number of organisms in most foods is commonly taken as an indication of the quality of the food. It is generally recognized that the number of organisms required per gram of food to produce sensory spoilage is 10^7 - 10^8 (Punch et al. 1965). A comparable number per square centimeter on the surface of meats causes spoilage (Thornley et al. 1960). Nevertheless, depending upon the food and the types of organisms present, populations of greater than 10^8 per gram may occur in foods without any deleterious effect. In fact, some microorganisms are used to produce such foods as cheese and fermented sausage.

Municipal and state health departments as well as the Division of Food Service of the U.S. Food and Drug Administration (FDA) are concerned with food safety wherever food is offered to consumers. Although improved technology over the past 40 years has

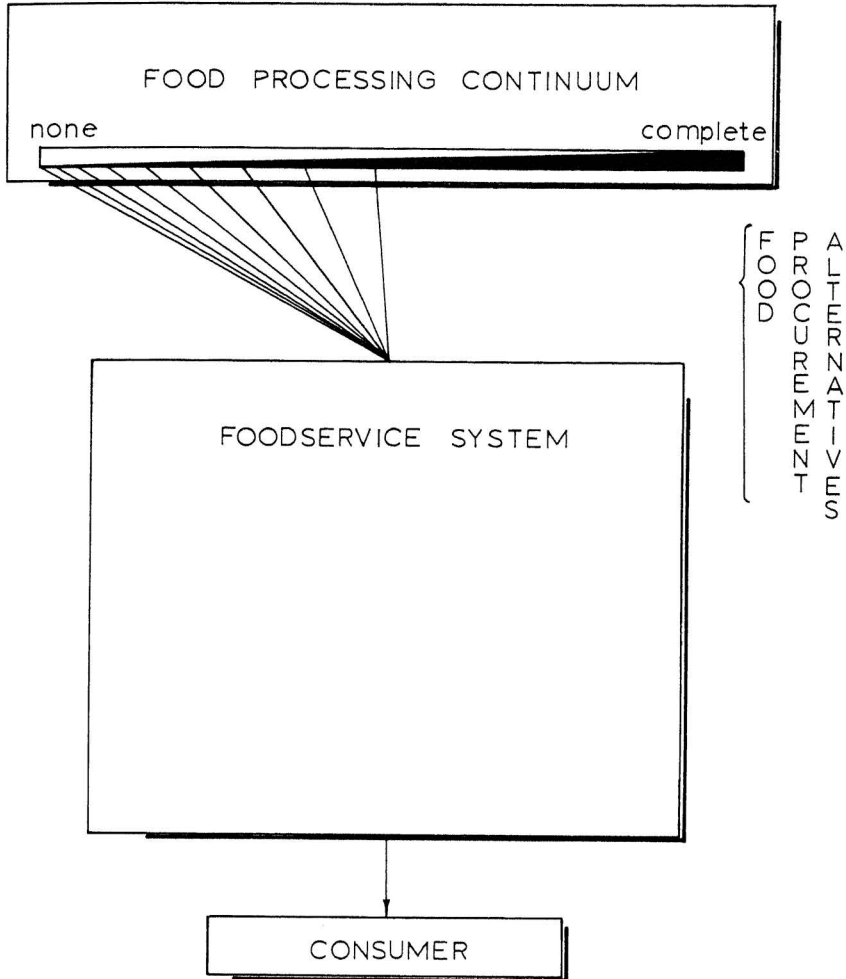


Figure 1. Food Processing/Foodservice Interface

identified and corrected a number of hazards associated with foods, a large number of foodborne disease outbreaks are reported annually. (See Table 1.) Because the incidence of foodborne illness can be reduced by effective preservation methods and sanitation practices, regulations dealing with these items are prevalent throughout the industry. For example, in 1974, proposed foodservice sanitation regulations were published by the FDA. Following responses to 353 separate letters and memoranda containing approximately 3,300 comments, the revised regulations were published and recommended for adoption by state and local regulatory officials (F.D.A. 1976). Because regulations do not state all the critical control points in various foodservice systems which require monitoring, this bulletin will emphasize key areas for the control of microbial quality and safety.

Food Product Flow in Foodservice Systems

To provide a basic conceptual framework of the foodservice industry, four major categories of foodservice systems represent the current industry. In some foodservice establishments, a combination of two or more of these categories may be used to prepare different menu items. Although variations within each category occur, the four major categories of foodservice systems define the foodservice industry. There is no concrete evidence in the literature that cost effectiveness has been adequately substantiated for any of the four categories of foodservice systems. For each foodservice system, operational objectives and definition, food product flow, and rationale for use is detailed.

Commissary Foodservice Systems

The evolution of commissary foodservice systems has been made possible by technological developments for sophisticated foodservice equipment.

Operational Objectives and Definition. Foodservice administrators adopting these foodservice systems emphasize objectives for the effective utilization of all resources by employing economies-of-scale in food production. Alternate names have been given to these operations: Satellite (O'Hara et al. 1973), Central commissary (Balsley, 1973), Commissariat (Morgan, 1973a), and Food factory (Williamson, 1975). Commissary foodservice systems have centralized food procurement and production functions with distribution of prepared menu items to several remote areas for final preparation and service.

Food Product Flow. The actual food product flow may vary with different commissary adaptations; however, the distinct feature of all commissaries is that the food production center and service areas are located in separate facilities. Therefore, the function of food distribution must receive considerable emphasis for the effective operation of these foodservice systems.

1. Food Procurement Trends. Commissary operations tend to acquire food products which have received no processing or limited processing. (See Figure 2.) Economies of large scale purchasing and production realized from utilizing one central facility often justify procurement of expensive multi-function foodservice equipment which has been developed and may be automated for preparation of foods from the unprocessed state. Consequently, food may be procured before processing expenditures within the food industry have occurred.

2. Description of Food Product Flow. Following procurement, food supplies are received and held under appropriate environmental conditions for frozen, chilled or dry storage. Most food items are completely processed in the central facility. These menu items may be held either in bulk or portioned before storage. Three alternatives for storage following food production are currently available—frozen, chilled, or hot-hold (Balsley, 1973). The type of storage used depends upon the time lag necessary between food production and service.

To serve food items at desirable temperatures, some frozen or chilled food items require an additional thermal process. Innovative foodservice equipment may be used to

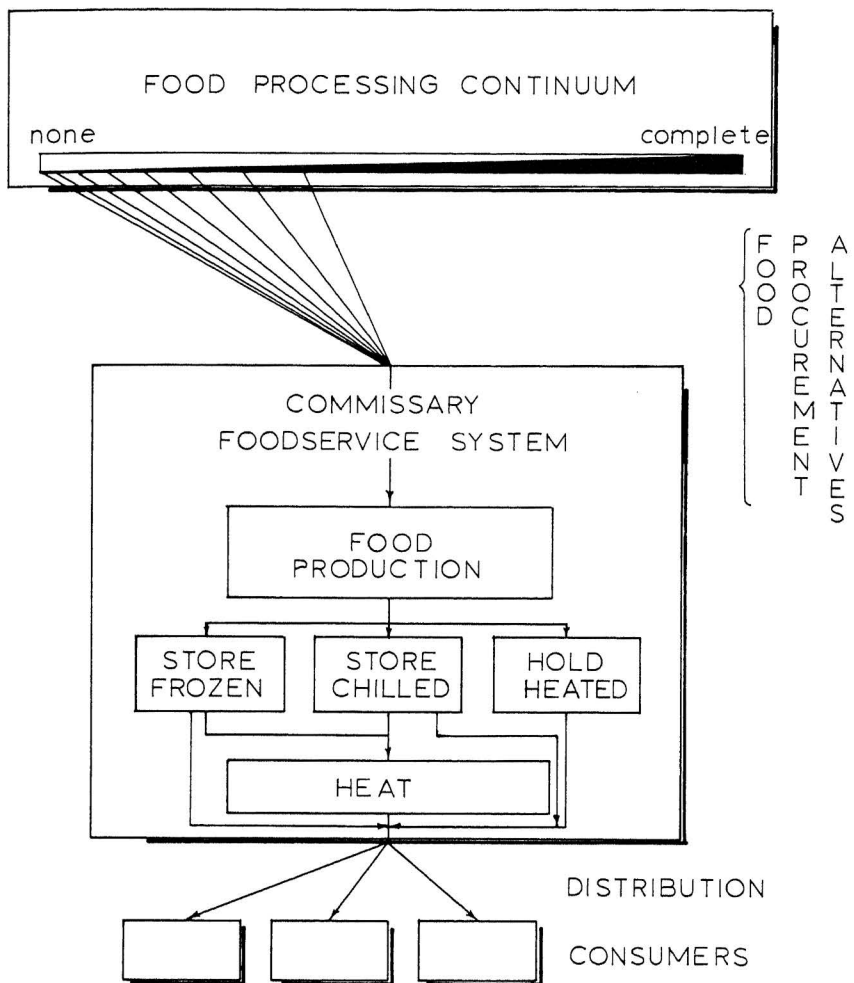


Figure 2. Food Processing/Foodservice Interface for Commissary Systems

temper and heat food products without excessive handling.

Rationale for Commissary Foodservice Systems. The commissary foodservice principles have been adopted in systems where service areas are remote from, yet accessible to, the production center. This concept can be applied to reduce the duplication of production labor and equipment which occurs if production centers are located at each foodservice site. Space requirements at the service sites are minimized because limited production equipment is required. By centralizing food procurement and production, the economies of volume purchasing may be realized. Commissary foodservice concepts are employed to meet various operational objectives related to effective use of resources.

Conventional Foodservice Systems

Conventional foodservice systems have evolved from traditional foodservice operations which were labor intensive. Because of increasing labor costs, foodservice administrators with conventional systems have gradually made changes to assist with the reduction of the labor component for meals served. One exception is conventional foodservices in correctional facilities where labor is abundant. These correctional foodservice operations have their own meat processing, baking and vegetable preparation areas.

Operational Objectives and Definition. The operational objective of foodservice administrators who manage conventional foodservice systems is to produce and serve quality food within one foodservice operation while effectively utilizing all renewable and non-renewable resources.

Food Product Flow. Following receipt and appropriate storage of food items and ingredients, menu items should be prepared as near to the service time as possible. Considerable labor is required before and during the foodservice periods. Pinkert (1972) enumerated several considerations about managing time-temperature relationships in conventional foodservice systems.

1. Food Procurement Trends. Foodservice administrators generally procure food products from all points along the food processing continuum. Currently, most foodservice operators procure some pre-portioned cuts of meat, frozen potatoes, vegetables and desserts, confectionery mixes and prepared fresh salads when accessible (Rappole, 1973). Because the procurement mix includes foods with various levels of processing, time-temperature relationships must be considered for the entire food processing continuum for each menu item.

2. Description of Food Product Flow. Figure 3 illustrates the food product flow for conventional foodservice systems. When food is subjected to hot-holding conditions, quality can be affected by both temperature, humidity and length of holding period. The effect upon the product during the holding stage must be considered when managerial decisions are made concerning scheduling food production. Prolonged holding at 71°C (160°F) has an adverse effect upon nutritional and sensory quality. Batch cooking of food in quantities to supply the service line for approximately a 15 minute interval is an effective production technique to use for vegetables. Although menu items may be prepared and chilled before service, effects upon microbial and sensory quality must be considered when the length of refrigerated storage is determined.

Rationale for Conventional Foodservice Systems. Traditionally, effective foodservice administrators with conventional foodservice systems have utilized a skilled labor force for food production 13-14 hours per day. Given adequate food production equipment and available skilled labor, foods may be procured with limited amounts of processing. However, with constantly rising labor costs within the foodservice industry, the current trend in conventional foodservice systems is to procure more extensively processed foods.

Ready-Prepared Foodservice Systems

Ready-prepared foodservice systems were developed in response to a critical shortage of skilled food production personnel and increased labor costs. Generally, foodservice

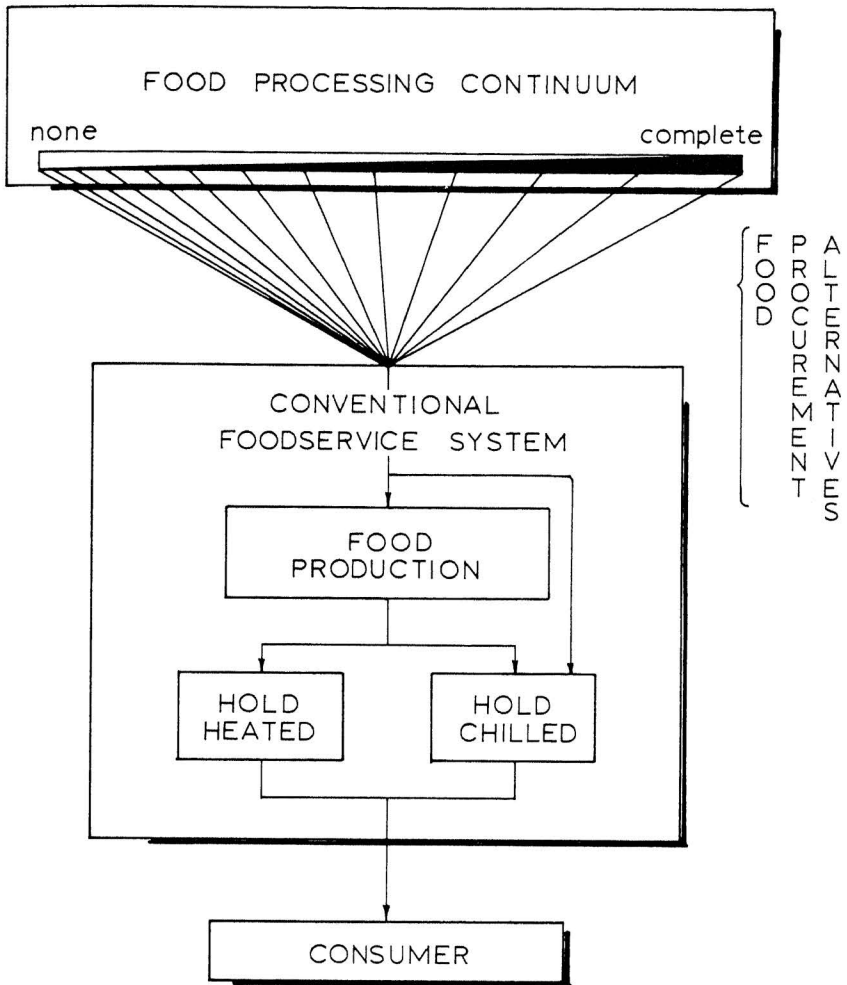


Figure 3. Food Processing/Foodservice Interface for Conventional Systems

administrators who adopted these systems found that completely prepared foods available on the market did not meet their organizational objectives.

Operational Objectives and Definition. The objective of ready-prepared foodservice systems is to effectively use all resources by preparing menu items for storage. The distinct feature of ready-prepared foodservice systems is that prepared menu items are always stored and ready for final assembly and/or heating. Thus, menu items such as entrees and hot vegetables undergo two stages of heat processing. The first heating occurs in quantity production, the second heating occurs after storage and is a preservice heating at the point of service to the consumer.

Food Product Flow. Two main variations of the ready-prepared foodservice concept are

the cook-chill and the cook-freeze foodservice systems. These systems vary in the method of food storage after production. In cook-chill foodservice operations, food is maintained in the chilled state for various periods. With the cook-freeze system, appropriate storage in the frozen state ranges from one to three months (Longree, 1972).

1. Food Procurement Trends. Food items for both variations of the ready prepared foodservice system may be procured from all points along the food processing continuum. (See Figure 4.) However, if adequate skilled labor is available in the foodservice operation, there should be a tendency to procure more partially prepared than completely prepared menu items.

2. Description of Food Product Flow. Following receipt, procured foods are placed in appropriate storage conditions. In the cook-chill system, menu items are removed from storage, processed, chilled and heated before service. When foods are processed for storage the initial heat treatment should be minimal to avoid overcooking and losses of sensory quality during the final heating before service. Hospital foodservices with this system are able to portion chilled food and serve it to patients one day after production. The menu items may be heated in areas near the patient. Thus, prolonged holding of heated menu items is avoided.

Extensive research on the cook-freeze system conducted at the University of Leeds, England (Glew, 1972) revealed some interesting considerations about food quality. When food is frozen, structural and textural changes occur such as cell damage and protein coagulation. In addition, off-flavors may develop in meats and vegetables. Much of this damage can be reduced or eliminated by substituting more stable ingredients, adding stabilizers and exercising greater control of storage time, temperature and packaging. Thus, recipe formulation is one of the problem areas in the processing, freezing and reheating of foods (Hill and Glew, 1974).

Heating before service is required in both variations of the ready-prepared foodservice system. Clagg and Crowley (1972) and Armstrong et al. (1974) outlined factors to consider for procurement decisions about foodservice equipment for heating prepared foods. The objective is to heat the food product to service temperature and to retain nutrient content, microbial safety and sensory quality. Prolonged holding should be avoided (Armstrong et al. 1974). The equipment used affects the rate of heat transfer. Microwave ovens, immersion techniques and convection ovens have been proven effective. Microwave ovens allow the most rapid heating of portioned foods and are used in the cook-chill and cook-freeze foodservice systems. Although the microwave heating process is well established in foodservice systems, the process and its effect on portioned food during heating is still under study (Bernstsen and David, 1975; Ringle and David, 1975; and Bobeng and David, 1975). The capacity for heating items in most microwave ovens is limited to one or two meals per cycle; however, variations of the microwave oven are being developed. Both the tunnel microwave oven and the combination microwave-convection oven have possible applications for these systems (Brown and Doyen, 1973).

Immersion of pouches in boiling water or steamers may be used to reheat moist food items. Convection ovens are effective when reheating a large quantity of food. Because foods may be covered when placed in a convection oven, moist and crisp foods may be heated simultaneously and maintain their desirable quality characteristics. In addition,

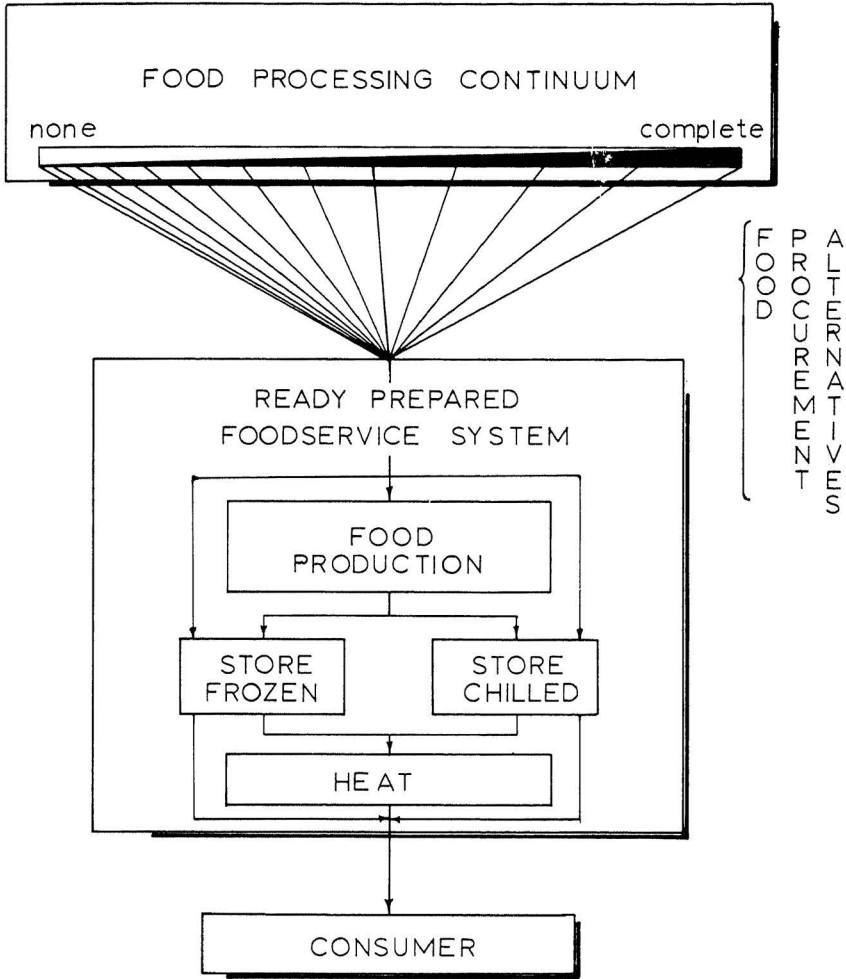


Figure 4. Food Processing/Foodservice Interface for Ready-Prepared Systems

convection ovens get up to temperature rapidly after they are loaded with frozen items.

Rationale for Ready-Prepared Foodservice Systems. Mass producing and freezing food may reduce labor expenditures by more effective use of labor in selected situations. Peak demands for labor may be removed because production is designed to meet future rather than daily needs. Furthermore, fewer skilled employees can be trained to heat and serve menu items thus reducing the number of highly skilled workers required by the system. Food procurement in volume may decrease food costs for the system. A foodservice system based on ready prepared products is contraindicated if additional expenditures for storage facilities, equipment and food inventory cannot be absorbed by the organization.

Assembly-Serve Foodservice Systems

Assembly-serve foodservice systems evolved in response to 1) the chronic shortage in skilled personnel available for food production in foodservice operations, 2) technological changes within the food processing industry which made feasible the production of quality, frozen food products, and 3) the extensive marketing and distribution system for frozen food products. Currently, products processed by aseptic techniques are being developed for assembly-serve foodservice systems.

Operational Objectives and Definition. The primary objective of foodservice administrators who manage assembly-serve systems is to provide optimal quality while minimizing the amount of labor resources employed within the foodservice operation. Food products are procured after a considerable degree of processing; only storage, assembly, heating and service functions are commonly done within the foodservice operation (Figure 5). Among the most prevalent synonymous terms for assembly-serve systems are convenience foodservice systems and minimal cooking concepts (Merrick and Sutton, 1972).

Flow Product Flow. Foodservice systems based on the assembly-serve concept require food products which have undergone extensive processing. Three market forms of completely processed frozen food products predominate: 1) bulk, 2) pre-portioned, and 3) pre-plated. Following receipt and appropriate storage within the foodservice operation, the bulk form requires portioning before or after heating within the foodservice operation. The pre-portioned market form requires assembly and heating. However, the pre-plated product requires heating only before distribution and service. Glew (1972) projected that the absolute use of completely processed foods would probably be more cost-effective than if these foods were used in conjunction with foods requiring more preparation in the foodservice system.

1. Food Procurement Trends. Merrick and Sutton (1972) described three types of food products used in assembly-service systems: 1) completely prepared foods; ready-to-serve, 2) completely prepared foods; ready-to-serve after a single production process such as heating, and 3) partially prepared foods; ready to combine with one or more ingredients before heating or chilling. These food products tend to be relatively compact and more uniform in size than food products which have received lesser degrees of processing (Litman, 1971). Thus, product uniformity facilitates effective storage and materials handling procedures.

2. Description of Food Product Flow. Following procurement, food items are stored dry, refrigerated or frozen. After frozen storage, products are thawed or tempered under controlled conditions so that the product surface temperature does not rise above 4°C (40°F). Controlled temperature cabinets which range from -17°C to 4°C (0°F to 40°F) may be used for tempering. Manufactured roll-in refrigerator systems designed for rapid chilling of bulk food products from 92°C (180°F) to 4°C (40°F) within a few hours appeared on the commercial market during 1975. Performance data based on adequate field testing are not yet available for these innovative refrigeration units.

When menu items are heated in either bulk or pre-portioned form, factors similar to those for reheating products in ready-prepared foodservice systems should be considered.

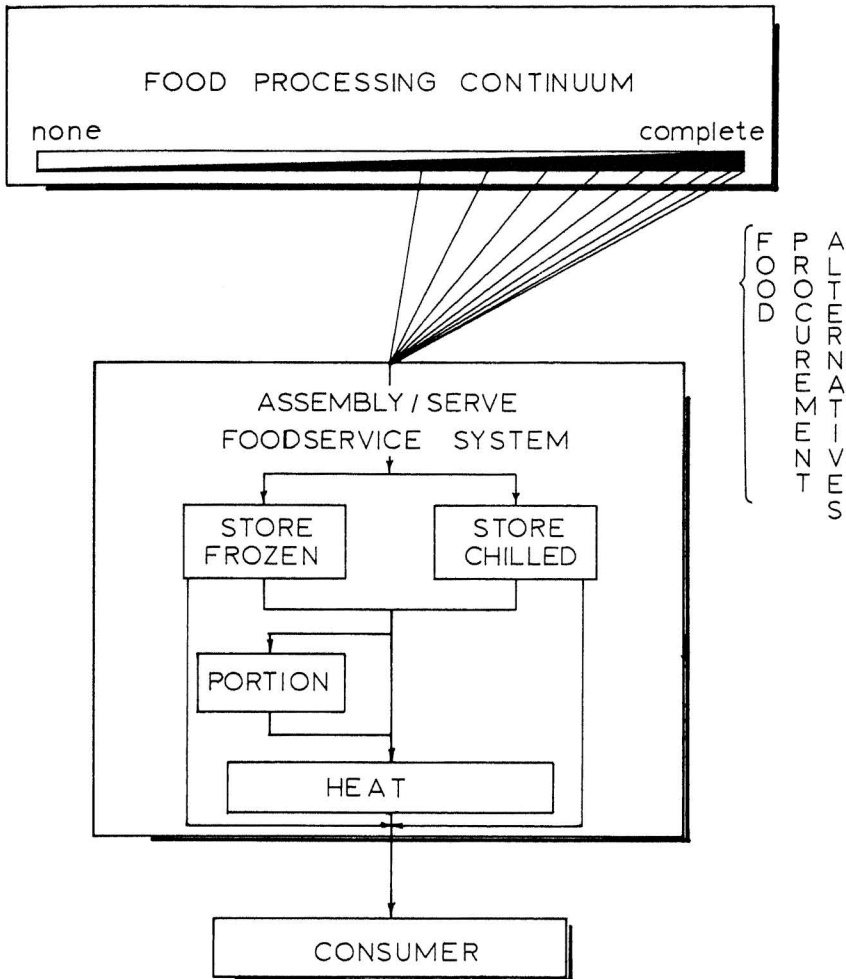


Figure 5. Food Processing/Foodservice Interface for Assembly-Serve Systems

In addition, three effective options are currently available for heating frozen pre-plated meals: 1) convection oven, 2) microwave oven, and 3) integral heat systems. Some special considerations for methodology and efficiency when using the integral heating systems have been emphasized (Fries and Graham, 1972). With the integral heating system, the plating procedures and moisture content of the meals must be carefully monitored (Kubach, 1973).

Rationale for Assembly-Serve Foodservice Systems. Assuming a lack of skilled food production employees, and an available supply of highly processed, quality food products, an assembly-serve foodservice operation may achieve operational objectives to provide client satisfaction. Managerial decisions to adopt this form of foodservice system should consider the availability of these resources to the foodservice operation.

Microbial Growth and Foodservice Systems

There is public concern about foodborne disease outbreaks from foods served in each type of foodservice system previously described (CDC, 1974). Each food product flow has inherent microbiological problems; the challenge to foodservice administrators is to control these problems. Fundamental knowledge of microbial growth and death is required for managerial control in foodservice systems to minimize hazards from microbial contamination and growth. The purpose of this section is to describe factors influencing microbial growth and identify critical points for the control of microbial quality and assurance of microbial safety.

Factors Influencing Microbial Growth

Microbial growth in every foodservice system is influenced by numerous factors including temperature, available water, acidity and available oxygen which enhance or inhibit microbial growth.

Temperature Components of the diverse microflora found in foods can grow at temperatures in the range from below freezing to 70°C (158°F). However, growth of individual microorganisms is limited to a much narrower range of temperatures. Given that all other environmental factors are acceptable for growth, selected microorganisms dominate at certain temperatures. The limits for growth of microorganisms of public health significance are from 7°C (45°F) to 60°C (140°F); foods with exterior and interior product temperatures in this range are considered to be in the "danger zone" (Longree, 1972).

Growth of microorganisms, expressed as an increase in numbers, occurs most rapidly near their maximum temperature for growth. Conversely, microorganisms reproduce slowly at their minimum temperature for growth.

High temperatures destroy many microorganisms. For example, heating to 74°C (165°F) destroys most vegetative cells present in food products. Although such heating does not destroy bacterial spores, the viable population of bacteria is reduced and thus the possibility of food borne illness is minimized.

Water Activity Microorganisms require water for growth because their system of gaining nutrients is by absorption and their excretion of by-products occurs via mediated dialysis. Available water is related inversely to the presence of dissolved substances, such as sugars and salt, and to the extent of binding of food constituents, such as proteins. The approximate water activity values below which growth of organisms does not usually occur are given in Table 2. The water activity of most foods served in foodservice establishments does not inhibit microbial growth. See Table 3. However, the relatively low water activities of some foods and food components does affect storage stability. For example, if cereals were exposed to moist environments, an increased rate of spoilage would result. Thus, the water activity of foods is an important factor to be considered during packaging operations before distribution to foodservices and after cooking in ready prepared foodservice systems.

Certain groups of microorganisms are markedly more sensitive than others to

differences in water activity. Molds and yeasts are usually responsible for spoilage of foods with relatively low water activities (Table 3). Staphylococci are capable of growth at much lower water activities than salmonella and *Clostridium perfringens*.

Acidity Microorganisms are sensitive to the pH of their environment. The most favorable conditions for both growth and resistance to destructive agents is near neutrality (pH 7.0). Acid foods such as citrus fruits and vinegar have sufficiently low pH to inhibit all pathogenic and most other microorganisms. Molds may grow even in these high-acid foods when the products are grossly mishandled. A list of the pH values for common foods was given by Longree (1972).

Oxygen Availability The availability of oxygen in a food influences the types of microorganisms that grow. Certain bacteria require an environment containing essentially no dissolved oxygen, while other bacteria thrive in the presence of oxygen. Bacteria of public health significance may grow at either extreme of oxygen availability.

Food production techniques within foodservice operations may alter the availability of oxygen. Heat processing or conditions which allow growth of other microorganisms in food may reduce the free oxygen and create a favorable environment for growth of clostridia which produce toxins injurious or deadly to man.

Pathogens Associated with Foodborne Disease Outbreaks

The microflora of foods resulting from food handling consists mostly of non-pathogenic types which may contribute to deterioration of sensory quality. While a number of pathogenic bacteria may be transmitted via foods (Longree, 1972), salmonellae, staphylococci, and *Clostridium perfringens* are responsible for most foodborne disease outbreaks. Foodborne disease outbreaks caused by these three microorganisms are primarily associated with foods of animal origin. Interestingly, these organisms have been identified for many years as agents of foodborne disease, and methods for controlling their growth in food are known. Yet, due to gross negligence and ignorance of these relatively simple methods for control within foodservice systems, these organisms are annually responsible for large numbers of foodborne disease outbreaks. The nature of these bacteria and the problems they present will be considered to exemplify microorganisms of public health significance.

Salmonellae

Salmonellae have been a prominent cause of foodborne disease in recent years. Ingestion of foods containing salmonellae results in a foodborne infection accompanied by typical gastrointestinal upset and fever. The salmonellae are relatively heat sensitive. Elimination of all salmonellae is assured by heating foods to 74°C (165°F) or higher. Thus, the presence of salmonellae in foods which received such heat processing indicates the organisms entered the food after cooking.

Salmonellae are widely scattered in nature and are primarily found in raw meat

products. Humans and domesticated animals transmit salmonellae. Employees who are infected with salmonellae can readily contaminate food in foodservice establishments. Cross-contamination between contaminated raw foods and foods which require no further cooking is responsible for many foodborne disease outbreaks caused by salmonellae. In contrast to the staphylococci and *Clostridium perfringens*, salmonellae can grow in a variety of foods and food environments. They grow rapidly on the surface of foods at room temperature. Fortunately, their growth is inhibited by temperatures below 6°C (44°F). Proper personal hygiene, prevention of cross-contamination, proper cooking procedures and refrigeration temperatures below 6°C (44°F) are important in controlling salmonellae in foodservice operations.

Staphylococci

To produce foodborne disease outbreaks, staphylococci must grow and produce enterotoxin before food is ingested (Casman and Bennett, 1965; Minor and Marth, 1976). While staphylococci are destroyed by relatively mild heat treatments, their enterotoxins are heat-stable. Once enterotoxins are produced in food, they are not destroyed at 100°C (212°F) or by other heating processes commonly associated with food production. Humans and products of animal origin are the primary sources of these bacteria. Open sores, boils and the mucous membrane of the nose are frequent sources of human contamination. High protein foods such as meats, poultry, fish, eggs and dairy products and products involving human handling are usually associated with staphylococcal food poisoning (Minor and Marth, 1976). Since staphylococci cannot grow at temperatures below 6°C (44°F), the fluctuation of refrigeration temperatures above 6°C (44°F) is a major factor contributing to staphylococcal food poisoning. Thus, proper refrigeration and handling practices are important in controlling staphylococci in foodservice operations.

Clostridium perfringens

To produce foodborne illness, large numbers of viable vegetative cells of *Clostridium perfringens* must be consumed (Hauschild, 1973). This microorganism multiplies exponentially in large masses of foods, particularly after heating has reduced the oxygen content and decreased the number of competing organisms. Thus, *Clostridium perfringens* is particularly adapted to certain conditions which exist in most foodservice establishments.

Bryan (1969) reported the optimal temperature for the growth of *Clostridium perfringens* is 43-47°C (109-115°F). Thus, inadequate temperatures for holding foods before service may provide excellent conditions for rapid growth of this organism. In meat loaves supplemented with soy protein, generation times for *Clostridium perfringens* of less than 10 minutes have been reported (Schroder and Busta, 1971).

Normal cooking procedures at atmospheric pressure destroy vegetative cells of *Clostridium perfringens* but do not destroy spores. However, after cooking, spores may germinate and form vegetative cells. Thus, destruction of vegetative cells of *Clostridium perfringens* by reheating to 74°C (165°F) is considered to be essential in some products such

as turkey stock because they cook slowly and hence there is an opportunity for bacterial growth (Bryan and McKinley, 1974). Control of *Clostridium perfringens* in foodservice operations is accomplished by adequate monitoring of procedures for refrigerating, cooking and holding foods.

Other Microorganisms

While the three microorganisms previously discussed cause the majority of foodborne outbreaks each year, other microorganisms may cause foodborne diseases. *Clostridium botulinum* produces a potent and sometimes deadly neurotoxin which causes botulism, a rare disease usually associated with under-processed home-canned foods. *Vibrio parahaemolyticus* occasionally causes a mild gastrointestinal illness associated with consumption of some sea foods. *Bacillus cereus*, *Escherichia coli*, *Shigella* and *streptococci* are occasionally implicated as the causes of foodborne disease outbreaks. In addition, there may be other microorganisms which cause foodborne disease which are yet to be identified.

Managerial Control Points

In each foodservice system, the potential survival of pathogens must be considered for foods served without cooking, for menu items inadequately cooked and for food items and components subject to post-cooking contamination. With the development of current foodservice systems, time between initial handling and heat processing and service has increased. All food components are handled and processed according to various time-temperature relationships. Therefore, raw and processed foods are often handled simultaneously and provide opportunities for cross-contamination. Based on the food product flow adopted, each foodservice system has critical control points. Considerable managerial competence in areas of procurement, production, distribution, quality and safety of foods and in decision making is required to monitor time-temperature relationships of food products during the alternate paths from procurement to consumption. Nine areas requiring monitoring within foodservice operations will be presented. The type of foodservice system adopted influences the number of areas requiring precise monitoring in a particular foodservice operation.

Food Procurement

With the exception of cultured foods such as cheese and yogurt, the objective of all foodservice administrators should be to procure pathogen-free ingredients with low levels of microbial counts (Rappole, 1969). Food components may be procured according to microbiological specifications. Longree (1972) recommended specifying a standard plate count of 100,000 per gram for total viable aerobes in frozen precooked foods for assembly/serve foodservice systems. This recommended specification might be useful as a starting point for the further development of recommended microbiological limits.

Food Storage

Tables 4 and 5 outline storage conditions recommended by Longree (1972) and Rowley et al. (1972), respectively. Conventional and assembly-serve foodservice systems involve storing foods immediately after receipt. Commissary and ready-prepared foodservice systems have a storage period both before and after food production. Thus, foodservice administrators should establish and monitor controls for food product temperature and length of storage for each storage period.

Highly perishable foods such as meat and milk products which commonly contain thousands and may contain millions of microorganisms per gram are major inputs of microorganisms (Weiser et al. 1971). Leafy vegetables are examples of fresh foods which harbor numerous microorganisms even before harvest. In many foods, harvesting terminates the inherent defense mechanisms which protect them from invasion by additional microorganisms. Thus, if microbial growth is not arrested by a system such as refrigeration, microbial spoilage may be rapid. Specialty products such as spices may also contain large numbers of microorganisms (Julseth and Deibel, 1974).

Food Packaging

With the increased role of packaging of foods prepared in commissary and ready-prepared foodservice systems, the importance of increased managerial controls for product temperature and storage life should be acknowledged by the foodservice administrator. Foods are packaged both for convenience in handling and distribution as well as for protection from contaminants. Packaging systems can have a great influence on the storage stability and safety of foods. In many dry foods, packaging materials provide an effective moisture barrier; a physical break in the barrier of hygroscopic foods could lead to absorption of moisture and microbial spoilage. The availability of oxygen can also be controlled by the type of packaging system. When oxygen is excluded, the resultant anaerobic conditions should be considered with respect to the possible development of anaerobic bacteria, e.g. *Clostridium perfringens*.

When packaging materials are used, controls are needed to assure that the entire mass of food product is sufficiently chilled in a short time. Many of the packaging materials used in ready-prepared foodservice systems have excellent insulating qualities which are desirable to minimize unintentional warming of cold foods (Hobbs and Christian, 1973).

Pre-Processing

In commissary, conventional and ready-prepared foodservice systems, pre-preparation activities such as trimming and washing eliminate gross contamination. However, opportunities for cross contamination between raw and processed food products are prevalent. Managerial policies should be established and monitored to physically separate pre-processing activities from those of food processing and holding.

Heat Processing

During the preparation of foods in commissary, conventional and ready-prepared

foodservice systems, effectiveness of heat processing is influenced by the food mass and capacity and type of equipment used. Heat processing may substantially reduce the microbial content of foods. For example, Maxcy (1976) reported that meat loaf containing nearly one million microorganisms per gram before cooking to an internal temperature of 82°C (180°F) had less than 200 per gram after cooking. The surviving organisms of such a heat treatment require considerable time to initiate growth and, if they can produce toxin, to multiply sufficiently to produce enough toxin for illness. To maintain sensory quality in ready-prepared systems, the initial heat processing should raise the internal temperature of the menu item to 60°C (140°F). Thus, the microbial growth is not sufficiently destroyed and products should be stored at or below 4°C (40°F) to retard microbial growth. The second heat processing to at least 73°C (165°F) substantially reduces the microbial content before ingestion.

Silverman et al. (1975a and 1975b) listed time-temperature profiles of food during preparation and service in conventional foodservice systems and reported results from microbiological analyses of meat, entrees, raw and cooked salads, potatoes, cooked vegetables and cold sandwiches. They demonstrated that some modifications made to the system improved the microbial quality of the cooked items. They emphasized the need for quantitative, evaluation procedures to monitor foods during heat processing.

Food Storage Following Heat Processing

According to the foodservice system requirements and quality attributes of menu items, foods may be stored in heated, chilled or frozen environments.

1. *Heated Food.* In commissary and conventional foodservice systems the hot-holding period should be as short as feasible given the system constraints; sensory quality of heated food deteriorates rapidly.

2. *Chilled Food.* Limited data are available for foodservice systems which utilize the chill storage concept. Tuomi et al. (1974a and 1974b) stressed the need for determining the safety of precooked foods during chill storage and determined counts of *Clostridium perfringens* at intervals during cooling, holding and reheating ground beef gravy. Bacteriological tests indicated the greatest increase in aerobic plate counts of gravy occurred during cooling rather than holding (Table 6). The number of viable cells after 16 hours of refrigeration at 5°C (42°F) was influenced by the first 6 hours of cooling when the temperature of the gravy was in the range that permitted growth of *Clostridium perfringens* 18°C - 50°C (65°F - 122°F).

Rowley et al. (1972) gave results from bacteriological tests for menu items during refrigerated storage at 4°C (40°F) from zero to nine days. Generally, cooked or baked menu items withstood refrigerated storage for nine days without spoilage or excessive microbial growth. However, during storage of chilled prepared foods, refrigerators must be operating properly and closely monitored.

Bunch et al. (1976) prepared beef-soy loaves which were baked to 60°C (140°F) in a convection oven; held chilled at $5 \pm 3^\circ\text{C}$ (36 - 46°F) for 24, 48 or 72 hours; portioned into three ounce servings; and then heated in a microwave oven for 55 sec to achieve an internal temperature of 80°C (176°F). After each of the three periods of chilled storage, viable

bacteria remained in the center of the loaves. (See Table 7.) This result was expected since spores survive heating to 80°C (176°F).

Sufficient microbial data for precooked foods during chilled storage in commissary and ready-prepared foodservice systems has not yet been reported in the literature. However, some descriptions of food quality and safety of foods served in cook-chill foodservice systems are beginning to appear (Zallen et al. 1975); more information is required to establish effective time and temperature controls for the prevention of foodborne disease outbreaks.

3. *Frozen Food.* In ready-prepared foodservice systems based upon cook-freeze concepts, the cumulative time food is held between 4° - 60°C (40° - 140°F) may be substantial throughout the food product flow. (See Figure 4.) Therefore, heat processed menu items must be frozen as rapidly as possible, given system constraints. Rowley et al. (1972) indicated cooked foods should not be held for more than 24 hours in the chilled state before frozen storage. (See Table 5.)

With single portion packs, Rappole (1969) stated that conventional freezers were adequate for the food product flow from the heat processed to the frozen state. However, when foods are frozen in bulk (e.g. 18 lbs, 2½ - 3" deep), a blast freezer -45°C (-50°F) was required to bring the food through the danger zone of 60°C (140°F) to 7°C (45°F) rapidly enough.

Cook-freeze systems in England have been planned to minimize the time food is kept between 20° - 50°C (68° - 122°F) before consumption (Millross et al. 1974). In addition, these researchers recommended the use of materials handling techniques which facilitated food product flow for rapid freezing of menu items.

Although there is a gradual decline in the numbers of viable cells during storage, many microorganisms found in frozen foods are preserved. Therefore, precautions must be taken to control microbial growth during freezing and thawing. Refrigerator temperatures of 4°C (40°F) should be used.

Heat Processing of Precooked Menu Items

Foods should be reheated rapidly to an internal temperature above 73°C (165°F) (Rowley et al. 1972). (See Table 5.) Frozen foods can be thawed and heated rapidly in microwave ovens. However, reheating viscous foods to 73°C (165°F) in microwave ovens may not destroy all the vegetative bacterial cells if uneven heating patterns occur. In addition, reheating foods in microwave ovens will not inactivate staphylococcal enterotoxins if they are present. Effective managerial monitoring of all product temperatures and storage times is required to ensure the sensory quality of reheated foods when served.

Food Product Distribution

Foodservices within health care facilities frequently transport chilled and heated menu items to remote locations. The opportunity for exposure to fomites and vectors which can cause contamination of public health significance and also subsequent microbial growth is increased during food distribution. In commissary foodservice

systems, food distribution requires complex managerial controls for time-temperature relationships involved in food handling and transportation. Rowley et al. (1972) recommended distributing chilled menu items at 7°C (45°F) or below (Table 5).

According to Bryan (1974), food should be held either above 60°C (140°F) or below 7°C (45°F) during distribution. It should be emphasized that inadequate refrigeration is the most common factor responsible for foodborne disease outbreaks.

Foodservice

Although the recommended serving temperature for heated menu items is above 60°C (140°F), foods are often held and served at lower temperatures (Bryan, 1972). Dehydration is one excuse often given by foodservice personnel for not maintaining internal temperatures of products above 60°C (140°F). At this temperature, large roasts can be kept without surface dehydration if adequate equipment is used (Berry and Dickerson, 1975). Protection of food by covering is important in minimizing microbial contamination and retarding evaporation and surface cooling. Clearly, if managerial monitoring is not effective at the point of service, the effectiveness of all previous managerial controls throughout the flow of food products from procurement to consumption may be nullified.

Summary: Directions for Future Research

Four types of foodservice systems which will likely be used for the foreseeable future were identified in this bulletin. Foodservice designers and equipment manufacturers want information about which of these systems is the most effective one. This review revealed to members of the NC-120 Committee that available data are too limited to make such a determination. There is little published data available on the effects of the changing methods of preparation and storage systems and service systems on the sensory and microbial quality of meals prepared and served in these alternate foodservice systems. Therefore, members of the NC-120 Committee intend to use information given in this bulletin as a reference base for coordinating regional research about food quality and safety in each alternate foodservice system.

There is a strong need to direct future regional research toward:

1. Investigating the effects of alternate methods of food procurement, storage, preparation, and service upon the microbial, nutritional and sensory qualities of selected menu items in foodservice operations.
2. Determining the effects of innovative materials handling techniques and/or foodservice equipment in each type of foodservice system upon the growth and survival of pathogenic microorganisms of public health significance.
3. Formulating procedures to be used as managerial tools for decision making about preparing and serving quality menu items within each of the foodservice systems.
4. Identifying factors within the physical environment of the foodservice system that directly affect food quality and safety, and correlating the effect of the interrelationships

among these influential factors with food quality.

5. Determining methods through which the systematic control of food quality and safety can be achieved by automated and computerized methods.

Data obtained on a regional basis will be compiled, statistically analyzed, interpreted and used as a basis for making feasible recommendations for the safe preparation and handling of food in alternate foodservice systems. Nine managerial control points were identified in this bulletin for foodservice systems; operational tools in the form of standardized procedures, initial and end-heating temperature controls, microbial controls and training manuals are required for effective managerial monitoring at each of these critical points. Once sufficient data are available, they can be used to enhance the development of this vital information.

In summary, the constant development of new techniques for food processing and distribution, the increasing use of engineered foods and the refinement of analytical methods have resulted in the need for extensive data about food product flow and microbial quality and safety of foods available for use in alternate foodservice systems. While many scientific articles have been cited in this bulletin about microbial quality and safety of foods, there are many areas within the dynamic foodservice industry where research information is limited.

While foodservice administrators attempt to minimize costs, food quality should be maximized by using current knowledge concerning factors which affect food quality and safety. The multi-disciplinary team of food-related professionals must continually provide information concerning the potential effects of new procedures and innovations in alternate foodservice operations. Thus, it is imperative for the health of our population that foodservice personnel and research scientists cooperate to serve safe and nutritious food.

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**TABLE 1. OUTBREAKS OF FOODBORNE
ILLNESS IN THE U. S. 1969-1974***

	1969	1970	1971	1972	1973	1974
Outbreaks	371	366	320	301	307	456
Individual Cases	28,563	23,348	13,453	14,559	12,447	15,489

*Adapted from CDC (1976).

**TABLE 2. APPROXIMATE WATER ACTIVITY
VALUES BELOW WHICH GROWTH OF
ORGANISMS USUALLY DOES NOT OCCUR.***

Organism	A_w
Bacteria	0.90
Yeasts	0.88
Molds	0.80
Halophilic bacteria	0.75
Xerophilic molds	0.65
Osmophilic yeasts	0.61

*Adapted from Mossel and Ingram. (1955).

TABLE 3. MOISTURE CONTENTS AND WATER ACTIVITIES FOR FOODS SERVED IN FOODSERVICE OPERATIONS. *

Food	Water activity (A_w)
Fruits	0.97
Vegetables	0.97
Juices	0.97
Eggs	0.97
Meat	0.97
Cheese	0.96
Bread	0.96
Jams and Jellies	0.82-0.94
Maple Syrup	0.90
Dried Fruit	0.72-0.80
Honey	0.75
Crackers, Cereal	0.10

*From Kaslow (1970).

TABLE 4. RECOMMENDED STORAGE CONDITIONS FOR FOODS IN FOODSERVICE SYSTEMS*

Food Product	Temperature	Relative Humidity
Frozen foods	-18°C or below (0°F or below)	-
Ice cream	-14°C - -12°C (6-10°F)	-
Dairy products	2°C - 4°C (36-40°F)	75-85%
Eggs	2°C - 4°C (36-40°F)	80-85%
Meat and poultry	- 1°C - 2°C (30-36°F)	75-85%
Fish	- 1°C - 0°C (30-32°F)	-
Fruits and vegetables	2°C - 7°C (35-45°F)	85-95%

*From Longree (1972).

**TABLE 5. TIME-TEMPERATURE
RELATIONSHIPS FOR POTENTIALLY
HAZARDOUS FOODS IN COMMISSARY
FOODSERVICE SYSTEMS***

Stages of food product flow	Food Product Internal Temperature	Maximum Time**
Internal temperature of heat processed menu items for immediate consumption		
a. poultry and stuffing	73°C (165°F)	
b. pork (for safety)	65°C (150°F)	
c. pork (for acceptability)	76°C (170°F)	
d. rare roast beef	60°C (140°F)	
Chilled storage of processed menu items	7°C (45°F) 4°C (40°F)	36 h 5 days
Storage of processed menu items before freezing	4°C (40°F)	24 h
Tempering of frozen menu items		
a. refrigeration	4°C (40°F)	
b. potable running water	21°C (70°F)	
Distribution of chilled processed menu items	7°C (45°F)	2 h
Distribution of hot processed menu items	60°C (140°F)	
Internal temperature of reheated menu items	73°C (165°F)	
Storage of pre-fried bacon	4°C (40°F) -17°C (0°F)	5 days 15 days
Storage of prefried bacon after heating	4°C (40°F)	24 h

*Adapted from Rowley et al. (1972).

**Given when applicable.

TABLE 6. NUMBERS OF AEROBIC PLATE COUNTS OF GROUND BEEF GRAVY DURING HOLDING AT 27°C (82°F) and 5°C (42°F) AND HEATING IN A COMPARTMENT STEAMER AT 7 LB/IN² PRESSURE*

Sampling Stage	Total aerobic plate count (cells/g) ^a in ground beef gravy	
	27°C (82°F)	5°C (42°F)
After cooking	50	50
After cooling	320	480
After holding for 2 h	210	410
After holding for 5 h	1530	440
After heating for 20 min	640	510
After heating for 35 min	820	830

^aMean counts from two trials, total of six samples after cooking, and total of eight samples at all other sampling stages.

*From Tuomi, et al. (1974a).

TABLE 7. AEROBIC PLATE COUNTS OF BEEF-SOY LOAVES DURING THREE SAMPLING STAGES IN A CHILL FOODSERVICE SIMULATION.*

Sampling stage and location	Aerobic plate counts (No./g)		
	Length of chilled storage		
	24 h ^a	48 h ^b	72 h ^c
Trial One			
After cooking, corner of loaf 1 ^d	2,700	2,700	2,100
After cooking, center of loaf 3 ^e	59,000	57,000	50,000
After chilled storage, center of loaf 3	110,000	110,000	150,000
After microwave heating, center of loaf 3	5,100	5,100	8,100
Trial Two			
After cooking, corner of loaf 1	4,400	3,600	3,500
After cooking, center of loaf 3	70,000	65,000	59,000
After chilled storage, center of loaf 3	100,000	120,000	130,000
After microwave heating, center of loaf 3	4,000	4,500	6,700
Trial Three			
After cooking, corner of loaf 1	4,200	3,900	2,900
After cooking, center of loaf 3	65,000	68,000	55,000
After chilled storage, center of loaf 3	110,000	120,000	140,000
After microwave heating, center of loaf 3	4,900	5,200	6,900

^aRaw ground beef was held at $5 \pm 3^{\circ}\text{C}$ for 48 h.

^bRaw ground beef was held at $5 \pm 3^{\circ}\text{C}$ for 24 h.

^cRaw ground beef was used day purchased.

^dLoaf 1 (side of pan).

^eLoaf 3 (center of pan).

*From Bunch *et al.* (1976).