Dairy Science and Technology Handbook

Edited by Y.H. Hui

Volume 3: Applications Science, Technology, and Engineering

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PREFACE

Although there are many professional reference books on the science and technology of processing dairy products, this 3-volume set is unique in its coverage (topics selected, emphasis, and latest development) and its authors (experts with diversified background and experience).

Volume I discusses four important properties and applications of milk and dairy ingredients: chemistry and physics, analyses, sensory evaluation, and protein. Each chapter is not a comprehensive treatment of the subject, since more than one reference book has been written on each of the four disciplines. Rather, each chapter discusses the basic information in reasonable details that are supplemented by new research data and advances. This assures that each chapter contributes new information not available in many reference books already published.

Volume II discusses the manufacture technology for yogurt, ice cream, cheese, and dry and concentrated dairy products. The direction of each chapter is carefully designed to provide two types of information. Each chapter details the currently accepted procedures of manufacturing the product and then explores new advances in technology and their potential impact on the processing of such products in the future. The fifth chapter in this volume discusses microbiology and associated health hazards for dairy products. The goal of this chapter is obvious, since there are so much new information on this topic in the last few years. The authors have done an excellent job in reviewing available data on this highly visible field.

Volume III is unique because it covers five topics not commonly found in professional reference books for dairy manufacture: quality assurance, biotechnology, computer application, equipment and supplies, and processing plant designs. The length of each chapter is limited by the size of the book. As a result, I assume full responsibility for any missing details since I assigned a fixed length to each chapter.

The appendix to Volume I alphabetically lists products and services in the dairy industry. Under each product or service, the appendix describes the names of companies that provide those products and services. In Volume III, the appendix provides information for each company listed in Volume I. This includes contact data and the types of products and services for each company. The appendixes for Volumes I and III are not repeated in Volume II in order to assure a reasonable price for the books.

As for the expertise of the authors, you are the best judge since most of them are known among scientists, technologists, and engineers in the dairy discipline.

This three-volume set is a reference book and will benefit dairy professionals in government, industry, and academia. The information is useful to individuals engaged in research, manufacturing, and teaching. In general, the texts form an excellent background source for professionals who just enter the field. For expert dairy professionals, these books serve as a subject review as well as a summary of what is new. Any chapter in the three volumes can be used as a supplement material for a class teaching a specific topic in or an overview of the science and technology of processing dairy products.

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October 1992

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Quality Assurance and Dairy Processing

John E. Stauffer

1.1 Introduction

1.1.1 Definition of Quality

Traditional concepts of quality need to be modified when discussing dairy products. Quality can be thought of as the ''degree or grade of excellence,'' but something more specific should be added to this definition when coping with everyday problems. A survey by the Dairy & Food Industries Supply Association indicated that the primary quality concern of dairy processors is the organoleptic attributes (taste and texture) of their products. Safety issues, that is, bacterial control and sanitation, ranked second among the concerns expressed.[1] This priority undoubtedly reflected the outstanding progress that has been made over the years to ensure product safety.

Consumers also expect and demand convenience, sound value, and, increasingly, good nutrition. The meaning of nutrition, however, has undergone dramatic changes. Whereas at one time quality was equated with the fat content of a dairy product (the richer the better), now consumers are substituting low-fat or ''light'' dairy products into their diets. This switch has been prompted by fears of excessive intake of saturated fat, cholesterol, salt, and sugar, all of which have been shown to contribute to such chronic diseases as hypertension, heart disease, and some cancers.[2]

The new concerns about nutrition have exerted a strong effect on consumer preferences. Skim milk and cheese, for example, have become dominant staples as meal items. At the same time such high-calorie treats as ice cream and sherbet remain popular.[3] In an attempt to have it both ways—good nutrition while being self indulgent—consumers are availing themselves of new introductions of engineered dairy products containing fat substitutes and artificial sweeteners.

1.1.2 Quality Assurance Versus Quality Control

A distinction should be made between quality assurance and quality control. Too often these terms have been used interchangeably with the result that the difference between them has become blurred. Quality assurance can be defined as a strategic management function that establishes policies related to quality, adopts programs to meet the established goals, and provides confidence that these measures are being effectively applied. Quality control is a tactical function that carries out those programs identified by quality assurance to be necessary for the attainment of the quality goals.

Quality assurance covers a wide range of programs. It has oversight responsibility in the areas of product planning, manufacturing, customer service, and distribution. Its duties include the approval of specifications for raw materials, additives, processing aids, finished products, labeling, and packaging. In the preview for a symposium on dairy products, sponsored by the Institute of Food Technologists in June 1989, the point was made that, ''Quality Management now involves all facets of the process of moving milk from the producing farm to the processing plant to the consumer.''[4]

1.1.3 Organization and Management

In order to fulfill their responsibilities, dairy processors need to allocate significant resources in terms of both manpower and funds to quality assurance. Perhaps no other segment of the food industry can match these efforts. Indeed, the dairy industry is considered to be the most regulated. To carry out its mandate to produce safe, wholesome products, each processor requires the services of well trained and experienced personnel. These individuals must be melded into a strong organization that is professional and dedicated to its tasks.

Management structure can best be illustrated by an organizational chart. Although each company will favor its own management style, certain practices are widely accepted throughout the industry. Foremost among these practices is the need to have the individual responsible for directing the quality assurance function report directly to senior management.[5] By this means senior management will have ready access to operational data, and line supervisors will have an open line of communication. Nothing can be more important to quality assurance than defining individual responsibilities and establishing clear channels of communication.

1.2 Hazard Analysis and Critical Control Points

1.2.1 Basic Concepts

Process controls are necessary to produce a dairy product that is safe and acceptable to the consumer. The means by which such controls can be established is a methodology known as Hazard Analysis and Critical Control Points (HACCP). The effectiveness of this procedure is so widely documented that it has received general acceptance throughout the food industry. Therefore, HACCP is the basis for most discussions of quality assurance including this treatment of the subject.

Several steps are required during a HACCP review of a process. First, all the potential hazards associated with the process are analyzed. These hazards will include microbiological dangers, possible chemical contamination, and the potential inclusion of extraneous matter. Next, process parameters or control points that have a direct bearing on the hazards in question are identified. Through practical experience, it has been found that lack of control at any one of these points, for example, ingredient inspection, pasteurization, or finished product analysis, may cause, allow, or contribute to a hazard in the final product. Thus, these control points are deemed to be critical to the successful operation of the process.

A complete description of a critical control point must include the following five specifications:

- Location of the control point and its parameter(s)
- Monitoring procedure for each parameter
- Frequency of monitoring
- Decision criteria for acceptable and unacceptable control
- Action to be taken if the control is unacceptable.[6]

Such a formalized procedure will ensure that proper attention will be given to the control of a given hazard.

1.2.2 Food Hazards

The hazards that plague the dairy processor are legion. For convenience, most of them can be grouped into the categories that follow. A further advantage of listing hazards by type is that the grouping helps in their identification and suggests means for their control. Because milk is such an excellent medium for the growth of microorganisms, dairy products are most susceptible to microbiological hazards.

1.2.2.1 Microbiological Hazards

The dairy industry, much like the canners, was driven to microbiological control by outbreaks of disease. Dating from the 19th century, such milkborne diseases as typhoid fever, diphtheria, septic sore throat, brucellosis, and tuberculosis were widespread. By 1939 these dangers led health authorities in the United States to establish requirements covering animal health, sanitation, pasteurization, refrigeration, and microbiological standards.[7]

Modern methods for the control of foodborne disease depend on the detection of the causative microorganism. The more significant bacteria responsible for food poisoning have been covered in several excellent reviews.[8–10] Below are summarized the principal microorganisms of interest.

Clostridium botulinum is responsible for the most feared form of food poisoning. Under low-acid, anaerobic conditions this microbe will produce a toxin that is one of the most poisonous substances known. The optimum temperature for growth and toxin production is about 35°C (95°F). Even in minute quantities the toxin will cause sudden death. Control of *C. botulinum* is made difficult because it forms spores that are heat resistant. Any viable spores remaining in improperly canned foods will germinate and multiply, producing their deadly toxin. A wide variety of foods including dairy products are susceptible to contamination. Although the toxin is heat labile and can be made innocuous by boiling, in all instances where botulism is suspected, the food should be discarded.

Clostridium perfringens has been implicated in many outbreaks of food poisoning in the food service industry, particularly at catered events. It is most common when food is prepared in advance and kept warm for hours before serving. Illness is caused by a foodborne infection that results from exposure to live pathogens. With symptoms of nausea, intestinal gas, and diarrhea, the sickness is discomforting but not especially serious. *C. perfringens* is an anaerobic, spore-forming bacteria. Although it is commonly associated with meat and poultry products, this pathogen has been found in virtually all types of processed foods.

Staphylococcus aureus is an ubiquitous organism. People are carriers of this pathogen, which occurs in boils, skin lesions, and nasal passages. Under unsanitary conditions, food can be contaminated with this organism which will then multiply, producing a powerful enterotoxin that causes vomiting, cramps, and diarrhea. Because the toxin is heat stable and may be present after the organism is destroyed, diagnosis of the illness can be complicated. It is important to avoid contamination with this bacteria by maintaining personal cleanliness and adhering to recognized sanitation procedures in the handling of foods. Refrigeration of foods below 4.4°C (40°F) inhibits the growth of this organism. Typical foods that can be adulterated with *S. aureus* are pastries and foods of animal origin such as meats and dairy products.

Salmonella, of which there are more than 2000 different serotypes, is transmitted primarily by farm animals which pass the organisms on to such foods as eggs, meat products, poultry, and raw milk. The symptoms of salmonellosis include diarrhea, abdominal cramps, vomiting, and fever usually within 24 h after consuming the contaminated food. Consequences, however, may be more severe for the very young, the elderly, and those already weakened by disease. *Salmonella* is very heat sensitive, and therefore it is readily destroyed by normal cooking of food and proper pasteurization of milk. Nevertheless cross-contamination of foods after heat treatment must be guarded against. Because *Salmonella* is so pervasive in nature, complete control of this organism has remained elusive.

Listeria monocytogenes is characterized by its ability to grow even under refrigeration temperatures. It is heat sensitive, however, and the preponderance of evidence indicates that the microorganism is destroyed by pasteurization. Most healthy people can survive infection, but certain individuals such as newborns, pregnant women, and persons with impaired immune systems are particularly susceptible to listeriosis. The mortality rate among sensitive individuals can be as high as 30 to 40%. Raw milk and soft cheese are the dairy products most commonly associated with listeriosis.

Campylobacter jejuni has been reported on a number of occasions when raw milk was consumed. These incidents occurred usually under special circumstances, such as during visits by school children to dairy farms. This organism can be controlled by proper pasteurization.

Yersinia enterocolitica has been the cause of serious outbreaks of food poisoning. Such dairy products as pasteurized milk, reconstituted dry milk, and chocolate milk were thought to have been contaminated through unsanitary handling. The afflicted persons, many of them children, developed symptoms of intense abdominal pain often misdiagnosed as apendicitis. These errors resulted in a number of unnecessary appendectomies.

Escherichia coli is common in the intestinal tract of humans and animals. As a result it has long been used as an "indicator" organism, the presence of which in a food product would suggest insanitation. More recent evidence indicates that certain strains of *E. coli* are pathogenic. There have been several reports of cheese contaminated with this organism.

Molds produce mycotoxins which may have adverse effects on humans. Therefore care should be taken to avoid eating molds except such intentional ones as veined in Roquefort and other blue cheeses. These organisms are capable of growth on a variety of substrates, notably cheese among dairy products. Conditions of high humidity and warm temperatures favor the growth of molds.

One toxin that has received much attention is aflatoxin, produced by the mold *Aspergillus flavus*. This toxin is highly poisonous and potently carcinogenic. The commodities peanuts, corn, and cottonseed, are most susceptible to aflatoxin contamination. When contaminated feeds have been included in the rations of dairy cows, the milk produced by these animals has been found to be adulterated with the toxin.

Moldy cheese is a common occurrence and a problem that must be faced by consumers. The normal reaction of most persons is to discard such food, but by careful trimming, good cheese can often be recovered. Some guidelines have been suggested for this practice:

1. Trim only cheese that has been kept properly refrigerated.
2. If the mold growth is extensive, do not attempt to recover the cheese.
3. Consider trimming only solid cheeses; do not try to recover semisolid or soft cheese, such as cream cheese or Brie.
4. To minimize mold growth, practice good sanitation in the handling of the cheese, keep it well wrapped and stored under adequate refrigeration, and consume it within a reasonable time span.
5. Keep in mind that manufacturers' use of mold inhibitors (preservatives) such as potassium sorbate and calcium proprionate will delay mold growth but not prevent it indefinitely.[11]

Viruses are not a major problem with dairy products. Until the 1940s poliomyelitis was the only viral disease known to be foodborne. This foodborne disease was largely associated with unpasteurized or recontaminated milk. It should be noted that viruses cannot multiply in foods, and even the modest heat treatments of milk pasteurization will inactivate foreseeable quantities of most viruses that might be present.[12]

Somatic cells are not microbes, but their presence in milk is significant from a health standpoint. Somatic cells are white blood cells or body defense cells whose primary function is to eliminate infections and repair tissue damage. Increasing numbers of these cells will be detected in milk from cows that are fighting off mastitis infections. These cells are an indication of the overall health of the herd and the quality of milk that is being produced. Thus, the goal of producers should be to supply milk with the lowest possible somatic cell count (SCC).[13]

1.2.2.2 Chemical Contamination

Animal drug residues found in milk are a continuing health and regulatory concern. These drugs include the sulfa drug, sulfamethazine, and such antibiotics as penicillin and tetracycline. Concern arises because sulfa drugs have been found to cause cancer in test animals and antibiotics may cause allergic reactions in people. A report by the General Accounting Office, an investigative agency of Congress, was critical of regulatory efforts and called upon the Food and Drug Administration (FDA) to take a more active role in enforcement.[14]

The problem of drug residues is compounded by "extra-label" drug use to treat several common diseases in dairy animals. There are few approved drugs for lactating dairy animals because pharmaceutical manufacturers do not have an economic incentive to obtain such registrations. Under the circumstances, veterinarians will prescribe and producers will make use of drugs that are not labeled for such use. Generally these extralegal acts will not be prosecuted so long as certain precautions are taken, for example, the drug is withdrawn in sufficient time before resumption of milking so as to avoid residue contamination. With the increasing sensitivity of new testing methods, however, residues are being found in milk that previously escaped detection.[15]

Chemical contaminants are not limited to animal drug residues but cover a multitude of other substances. These compounds include such pesticides used on crops as dieldrin, chlordane, and heptachlor. Surveillance of Florida's milk supply has disclosed in addition to drug residues the following chemical contaminants: vinyl chloride, 2-4D, cyanide, lead and other heavy metals, volatile organic solvents, chlorine, and acid sanitizers.[16] Although some of these contaminants can be traced to specific infractions; others are the result of an increasing background of synthetic substances that have pervaded our environment.

Another group of contaminants is chemical germicidals: iodophores, hypochlorites, and strong ionic surfactants. These substances are used in formulations for udder hygiene, including teat dips and washes, to control the spread of bovine mastitis. The same germicidals are also applied to sanitize dairy process equipment. These substances can leave toxic residues in milk.[17]

1.2.2.3 Extraneous Matter

Foreign bodies such as metal filings, wooden splinters, and paint chips may be introduced into the product through ingredients or during plant operations. Sediment (dirt, soil) is commonly found in milk supplies and is routinely evaluated by the disk filtration method. Means for the detection and removal of extraneous matter will depend on the handling characteristics of the product: whether it is in a divided state, such as fluid and powder milk, or it is in bulk form like cheese. It is advisable to use a combination of detection methods throughout a process.[18]

1.2.2.4 Functional Hazards

Functional hazards may not pose the same dangers encountered with other hazards but are extremely important to the dairy processor. If a product has a poor taste, a container is slack filled, or appearance is unappetizing, the manufacturer will surely hear from irate customers. More to the point, sales will turn downward. Misbranding errors will catch the attention of regulatory authorities.

1.2.3 Critical Control Points

The identification of critical control points requires a thorough familiarity with the food process, including each step in the operation from the receiving of raw materials to the shipping of finished product. A flow diagram showing all of the processing streams is indispensable for understanding the key elements of the process. With this knowledge at hand, a systematic search can then be made to identify the potential entry points of each hazard. Many of these entry locations are obvious, for example, raw materials, but others are less apparent, such as open vats, exposed conveyor lines, and even the equipment itself. The latter may be a source of hazards because of broken parts or unclean surfaces.

1.2.3.1 Blended Products

It is instructive to take a look at a process for blended products in order to appreciate how the critical control points are identified. Figure 1.1 shows a milk replacer process.[19] The critical control points are indicated by numbered diamonds and the other control points by numbered circles. Complete agreement does not exist among professionals concerning the distinction between critical control ponts and all other control points. Some people, for example, would include as critical control points only those control points which monitor microbiological hazards.

Referring still to Figure 1.1, the differences between the control points can be illustrated. Control point No. 2 might test for the protein content of the soy flour whereas critical control point No. 2 would test for *Salmonella*. Critical control points 4, 6, and 7 are established to check for tramp metal and other foreign objects. Critical control point 5 monitors product uniformity whereas No. 8 is for final product testing. Finally, critical control point 9 records the filled weights of containers.

1.2.3.2 Raw Milk Quality

Inasmuch as milk is the common ingredient of all dairy products, its quality is key to these products. It has been said that a milk product can be no better than the quality of the raw materials that go into it. Because the quality of the raw milk cannot be improved through processing, dairy farms must provide the highest quality raw milk from the beginning. The following controls are routinely used to evaluate the quality of raw milk supplies.[20,21]

Flavor, including odor, taste, mouthfeel, color, and appearance, is the most critical attribute of raw milk. There is a consensus that flavor is the most important yardstick for consumer acceptance of milk. Because milk flavor is so bland and mild, the presence of any off-flavor can easily overshadow its pleasant, slightly sweet taste. Flavor can be affected not only by the health of the dairy herd but also by the feed composition. In spite of extensive efforts to develop instrumental analyses for flavor testing, the only reliable method is sensory evaluation. These screens must be conducted by experienced individuals and under proper conditions, for example, the milk sample should be tempered to 15.6 to 21.1°C (60 to 70°F).

Standard Plate Count (SPC) is a standardized procedure to estimate the total aerobic, viable bacterial cell count in a sample of raw milk. Historically this test is required by public health authorities. It also gives a good general idea of the milk quality. Although maximum regulatory values for SPC may range from 50,000