AN INTRODUCTION TO THERMAL PROCESSING OF FOOD PRODUCTS

Donald G. Mercer ¹, Ph.D. and Daryl B. Lund ², Ph.D.

¹ Department of Food Science, University of Guelph
² Professor Emeritus, University of Wisconsin - Madison

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CHAPTER 1: GETTING STARTED

1.1 Learning Objectives

The purpose of this manual is to provide a basic understanding of thermal processing of food products.

In Chapter 1, we will start by explaining what is meant by the term “thermal processing” and then describe a number of reasons why food products are processed in this manner. A brief overview of the process involved and examples of thermally processed products will complete the first chapter. Here, we will also look at “Food Safety and Quality”. A basic knowledge of this topic is essential for understanding the concepts of thermal processing. This should serve as a review for those who have already studied the “Food Safety” module, and will provide essential introductory material for those who have not done so.

Since thermal processing is quite closely linked to the growth of microorganisms in food, Chapter 2 introduces this topic in preparation for the following chapters.

Chapter 3 examines various aspects of basic sanitation and its critical importance throughout the entire food production system.

In Chapter 4, we will look at sterilization and pasteurization, while Chapter 5 deals with blanching of fruits and vegetables. Chapter 6 will show some of the basic calculations associated with the heating (and cooling) of various food products.

Finally, Chapter 7 summarizes the material presented in this Introductory Course and sets the stage for the “Intermediate Course in Thermal Processing of Food Products”. Sources of information are also listed in this chapter.

After completing the “Introduction to Thermal Processing of Food Products”, you will:

- be able to explain the reasons why food is thermally processed and be familiar with the basic concepts that are involved in it.
- be able to describe the risks associated with contaminated food and the impact of thermal processing on food safety and food quality.
- understand the fundamentals of microbial growth in food products and be able to relate them to real-life food processing situations.
- understand the importance of basic sanitation measures in food processing operations and be able to use this knowledge to identify potentially hazardous unsanitary conditions.
- be able to perform basic calculations in the heating (and cooling) of food products.
1.2 Background

1.2.1 What is Thermal Processing?

The concept of “thermal processing” is not really very complicated. It basically involves the application of heat to a food material for a specified period of time.

In most thermal processes, the temperature to which the food must be heated will be given along with the time for which the material must be held at that temperature.

This explanation should become much clearer after you have read the remaining portions of this section.

1.2.2 Why Do We Thermally Process Food?

1.2.2.1 Overview

It is a rather sad fact of life that once a food product is created, grown, or harvested, it begins to age and deteriorate over time. In the case of food products, this aging process is generally associated with spoilage. Spoilage can be caused by a number of factors including:

- physical deterioration
- chemical reactions within the product or reactions with the environment
- microbiological (or biological) contamination

We will examine physical deterioration and chemical reactions briefly in the next section of this chapter.

Contamination by microorganisms is an extremely serious problem. These microorganisms are incredibly small single-celled life-forms that are able to grow almost anywhere. In addition to causing food to spoil, they can also cause diseases in humans and animals. People who eat food contaminated with microorganisms or drink contaminated water often suffer from what we commonly call “food poisoning”. It can have a range of effects from mild illnesses that last only a short time to long-term illnesses, or even death.

Fortunately for us, most spoilage and disease-causing microorganisms can be killed by heating the foods while the foods are still fresh and wholesome and have not yet begun to spoil.

In addition to addressing several key areas of these forms of spoilage, thermal processing also provides a means of changing the texture or form of the food itself. It can also improve the nutritional value of foods, as we shall soon see.

Only a limited number of food products actually improve with age. Fine wines are an example of this, and cheeses will also improve as they ripen or age. However, if not handled and stored under proper conditions, these products can also deteriorate or spoil with time.

Foods that are thermally processed do not stop aging nor deteriorating entirely, but the aging process is usually slowed down significantly. This is particularly important in a number ways.

First, consider countries where only one crop can be grown per year. Fresh fruits and vegetables can only be stored
for a short period of time before they start to spoil. By thermally processing these products as well as packaging them properly and storing them under acceptable conditions, they can be kept much longer. They can then be used by consumers during the “off-season” when fresh fruits and vegetables may not be available (or imported fruits and vegetables may be available at a higher cost).

Next, you may want to consider areas where excessive amounts of a particular crop are grown. The producers of this product may look to distant markets to sell their product and receive money in return for these sales. Thermal processing of their product can increase the distances which the product can be shipped and provide year-round sales to distant customers.

Tomatoes are a good example a seasonal product that can benefit from thermal processing. At harvest time, there is often an abundance of tomatoes available. As a result, the cost for consumers to buy them goes down and the grower receives only a small amount of money in return for the time and labour involved in bringing the product to market. In some places, tomatoes literally rot in the fields since there is no market for them (see Figure 1-1). However, several weeks later, there are no longer many tomatoes available. This means that the price goes up because tomatoes must be imported from other countries or areas. By thermally processing tomatoes, they can be canned and stored for prolonged periods of time and used throughout the off-season in cooked recipes such as soups and stews.

In addition to enhancing the safety of food products by addressing microbial contamination, thermal processing slows the deterioration process from which additional benefits can be obtained.

In order for persons to lead a healthy, productive, and satisfying life, it is absolutely essential to have a reliable supply of “safe” food that nourishes the consumer without causing illness or death. A safe food supply can reduce illness in infants and young children,

Figure 1-1: Tomatoes left unharvested in a field in Equatorial Guinea

1.2.1 Food Safety

1.2.1.1 What is Food Safety?

1.2.1.2 Why is Food Safety Important?

“Food safety” means various things to different people and it is impossible to give a definition that is totally satisfactory to everyone. In general, we consider a food to be “safe” for consumption if it is free of physical, chemical, and microbiological contamination; and if its consumption does not prove injurious to the health of the individual consuming it.
thereby reducing infant deaths and allowing for healthy development during their years of growth to adulthood. We will look at food-borne illnesses later in this course.

1.2.1.3 How is Food Safety Different from Food Quality?

Food safety is often confused with food quality. Although high quality foods are generally “safe”, there are several subtle differences between “food safety” and “food quality” which should be explained.

“Food quality” involves a number of factors which include:

- nutritional value
- appearance
- taste
- colour
- flavour
- aroma
- functional properties
- etc.

Quality is often subjective and depends on the preferences of the consumer. What appeals to one person may not appeal to another person. It may also depend on the intended end use of the product. As an example, a consumer may view firm yellow bananas as desirable for eating when peeled, but may want to have a softer, more ripe, brownish coloured banana for use as an ingredient in a prepared food.

Basically, “quality” is the overall property or set of properties that makes most foods desirable or undesirable to consume.

A food may be of extremely high quality and yet be “unsafe”. Consider an apple that is large, firm, plump, bright red, ripe and fresh looking, free of skin blemishes, sweet and fresh tasting, fragrant, and overall delightful to eat. Anyone seeing this apple, or lucky enough to eat it would feel that this was indeed a high quality apple. However, this apple might not be “safe” to consume, and the person eating it could become terribly ill. As we will see when we look at various forms of food contamination, there may be potential danger lurking on the surface of these apples.

We may even find that what is “safe” for some people to consume is not safe for others to eat. It has happened that people sharing an identical meal of the same food may react differently. Some of the people may become ill afterwards while others may suffer no negative effects whatsoever from exactly the same food.

There are numerous cases of school children who have grown up in cities visiting farms and becoming ill after tasting the fresh milk taken directly from the cow’s udder. However, the family living on the farm may have been drinking the milk for years without any problems. The milk that was of high quality and safe for the farmer’s family to drink was definitely not safe for these visitors to the farm. This is because the milk normally consumed by the children from the city had been heat treated through the process of “pasteurization” to reduce the presence of harmful bacteria in the milk. The farm family was able to consume this untreated milk by building up a tolerance for the microorganisms that were present in it.
We will pursue this further when we discuss microbiological contamination later in this chapter.

As food processors, we must understand that a high quality food product can still be unsafe to consume. We must take every measure and precaution to ensure that the foods we distribute in the marketplace meet the safety and quality needs of everyone who will be consuming our products. In addition, we must be sure that the food remains safe for consumption for an appropriate length of time after it is purchased by the consumer.

1.2.2 Food Spoilage

Most people can look at fruits and vegetables in a marketplace and judge whether they are appealing enough to eat, or if they are spoiled and not suitable for eating. These assessments are based on sense of sight, feel, and perhaps smell. With experience, consumers learn which mangoes, or apples, or melons they should pick.

However, there are other spoilage factors associated with foods that are often not immediately or easily detectable by sight, feel, or smell. This is where the thermal processing of foods becomes important.

There are three basic methods in which food spoilage can occur. These are:

- Physical deterioration
- Chemical reactions
- Microbiological growth

We will now examine each of these three types of spoilage mechanisms as background information for our thermal processing studies.

1.2.2.2 Physical Deterioration of Food

Physical deterioration of food is perhaps the only area of food spoilage that does not benefit greatly from thermal processing.

Physical deterioration of food can occur through the loss of moisture or a gain in moisture. Some products which are supposed to contain a high level of moisture may suffer from a loss of quality if an excessive amount of moisture is lost. Fruits and vegetables may fall into this area. We should not, however, confuse a loss of moisture here with deliberate drying to remove moisture to create dried products that have a desirable place in our food supply.

There is a big difference between removing water from mango slices in a specially designed dryer to produce dried mango slices and having mangoes dry out before they are eaten or processed.

Carrots may lose their moisture and become limp and unappealing if they are left out in the open air after harvesting.

Other products may lose quality or be considered spoiled if they gain moisture. Biscuits and other dry products may pick up moisture from the air and lose their crispness or flakiness. While these changes may not make the product unsafe to eat, the consumer may not find the quality satisfactory.
These are more appropriately addressed by the proper use of packaging and storage conditions.

1.2.2.3 Chemical Reactions in Foods

There are chemical reactions which can proceed within food products that contribute greatly to their spoilage, or make them unappealing for consumption. When you bite into an apple, you may notice that the white fleshy portion of the apple begins to turn brown with time. This is caused by a reaction of the sugars with the oxygen in the air. The reaction is catalyzed by naturally-occurring enzymes which speed up chemical reactions such as oxidation. Enzymes are actually types of proteins which are found in the tissue of all living things.

When some products such as cauliflower are harvested, their white edible portions may turn brown or even black over time. This is caused by enzymes present within the plant that produce dark pigments. As mentioned above, enzymes are really protein molecules in the food that have the ability to make chemical reactions happen faster than they would if no enzymes were present.

Orange juice may also darken on exposure to air due to the reactions between compounds in the orange juice and the oxygen in the air. Heat treatment, or heat treatment in combination with packing can help reduce or almost eliminate these problems.

Chemical deterioration or spoilage can also result from the reaction of oxygen in the air with fats or oils in the product that can create an undesirable rancid flavour.

1.2.2.4 Microbiological Spoilage of Food Products

Microbiological contamination is the final source of food spoilage that we will be discussing. It is also the most serious. We may want to include insects and rodents in this section as well since they contribute greatly to the spread of microbial contaminants and disease.

If you have completed the “Food Safety” module, you may recall that microbiological contamination is caused by the presence of incredibly small microorganisms such as yeasts, molds, and bacteria.

Almost everyone has seen mold growing on fruits, or vegetables, or products such as bread. Molds grow rapidly under suitable conditions and are visible as “fuzzy” colonies on the surface of the spoiled food product (see Figure 1-2). Although most mold colonies seem to be grey in colour, several other colours may also be observed, such as orange, or green.

Figure 1-2: Mold growth on a tomato is an obvious indication of spoilage
Fruit juices may become contaminated with various strains of yeasts. These yeasts are present on the skins of many fruits and if proper sanitation procedures are not followed, they can find their way into the final juice products. Once inside the container of juice, the yeasts thrive on the nutrients such as the naturally occurring sugars they find in the juice. As they grow, they may produce an alcohol by-product that provides a highly distinctive odour when the container is opened by the consumer. Yeasts also produce carbon dioxide gas as a by-product of their growth. Carbon dioxide build-up can create pressure inside the juice container which results in swelling of soft, non-rigid containers (such as “drink boxes”), or a rapid release of gas pressure in rigid containers such as metal cans or glass bottles.

Figure 1-3 shows two cans of identical product. The can on the left appears normal in all respects. However, the can on the right is noticeably swollen due to the generation of gases inside it. Shortly after this picture was taken, the swollen can began to leak along the seams. You may be able to see some of the early signs of leakage along the seam at the top of the can on the right in the photo.

Even though yeasts and molds are common food contaminants, it is bacteria which are of most concern to many food processors. Some bacteria are particularly dangerous to the health of consumers. They are capable of causing diseases which can be fatal in certain circumstances. These bacteria are too small to be seen, but fortunately thermal processing provides a means to deal with them.

Microorganisms can contaminate fruits, vegetables, and cereal crops at any point or at any time along the food chain from the time before the seeds of a crop are even put into the ground until the time the food is actually eaten. Similarly, meat, dairy, and poultry products are equally susceptible to microbiological contamination throughout the entire food chain from the time the animal or bird is born right up until the time that it or anything made from it are consumed. If left to grow, these microorganisms will cause the food to spoil and be potentially dangerous to those eating it.

While these microorganisms are growing they can produce by-products which are toxic to humans or animals. If corn is not harvested before the rainy season begins in an area, molds called “fusarium” may start to grow and produce toxins (i.e., afla-toxins) that can be accumulated in the digestive organs of animals like cattle and pigs. When people eat the meat of these animals, they can also be eating the toxins contained in the meat. The results of this a quite serious.

Meat that is not properly cooked or stored can become spoiled through the growth of microorganisms. Pork, for
example, can be contaminated with trichinosis. If humans consume this contaminated meat, they can become seriously ill.

1.2.2.5 Nutritional Benefits

A benefit of thermal processing that is often overlooked is the improvement of nutritional properties of certain food materials, especially cereal grain products (e.g., rice, wheat, etc.), and starchy tubers like potatoes. Most people only consider the negative aspects of heating and say that heating reduces the nutrient values of such things as vitamins. This is true, but it is often not as serious as we are led to believe.

Cereal grains contain starches which are not gelatinized when crops like rice or wheat are first harvested. This is also the case with the starches in potatoes. Humans generally cannot digest ungelatinized starches. By heating the starches, primarily in boiling water, the starch becomes gelatinized and the starchy structure of the material swells. The gelatinized starch is highly digestible and forms the nutritional basis for much of the world’s population.

1.2.3 How is Food Thermally Processed?

The basic approach to thermally processing foods is actually quite simple. However, the methods and equipment used may be quite sophisticated and imaginative. Throughout this module, we will focus mainly on thermal processing to destroy microorganisms that are present in foods.

In order to destroy harmful microorganisms that may be present and reduce degradation through enzymatic reactions etc., food products must be heated to a specified temperature and held at this temperature for an appropriate length of time.

Each contaminating microorganism will have its own set of temperature and time conditions. These temperatures and times will also be dependent on the product which is being processed. Conditions for thermally processing milk are different than those for thermally processing peas or beans. These conditions are in turn different than the conditions for thermally processing fruit juices or tomatoes.

Establishing processing conditions and understanding the various mechanisms associated with the destruction of microorganisms is a complex aspect of thermal processing.

A key factor in thermal processing is to heat the product as rapidly as possible to the desired temperature and then cool it as quickly as possible once the heating period has been completed. It is important to keep the food material separated from the outside environment while it is being processed, and after it is processed to prevent re-contamination. Re-contamination occurs when microorganisms from the outside get back into the thermally processed food and begin to grow.

The easiest way to envision a thermal process is to think of food being boiled
in a pot on a stove or over a fire. Heat from the fire or stove is transferred to the food through the metal pot. The food in the pot picks up heat from the metal surface inside the pot. It is stirred frequently to assist in this heat transfer process. Once the food is at the desired temperature (often this would be its boiling point), the pot can be removed from the heat and the product can be served. During the heating process harmful microorganisms are destroyed and the product is made more appealing for eating.

Industrial thermal processes function in much the same manner as the pot on the stove example mentioned above. The big difference is that industrial processes must be carried out on a much larger scale with bigger quantities and must be done faster than something that is done in the home to make them commercially successful.

In an industrial or commercial process, a jacketed kettle may be used in place of the pot on the stove. In this case, there is a second wall around the large container with a gap between it and the inner wall of the kettle. Steam or hot water is introduced into the space between the two walls, which heats the contents of the kettle. Insulation is often placed on the outer surface of the jacket to prevent the loss of heat to the surrounding air.

Figure 1-4a shows a jacketed kettle using steam as a source of heat. Notice the way in which the steam is introduced at the top of the jacket. This lets the steam condense to give up its heat and allows the condensate water to drain out of the jacket.

In Figure 1-4b, we see how hot water is used with a jacketed kettle. The hot water is introduced into the bottom of the jacket so that the jacket is completely filled before the water drains out the top outlet.

Jacketed kettles are designed for working with batches of product. If we want to have a continuous process, we need to use a different approach.

A common way to heat a product in a continuous process is to pump it through a “heat exchanger” unit. The simplest
A heat exchanger consists of a pipe which is jacketed by a second larger diameter pipe. This is called a tubular heat exchanger.

Steam or hot water can be passed through the region between the two pipe walls. Heat released by the condensing steam (see Figure 1-5a) or lost by the hot water (see Figure 1-5b) is then transferred to the food inside the inner pipe. The length of the jacketed pipe, the temperature of the hot water or steam, and the speed at which the food material passes through the pipe all contribute to the heating efficiency of this device which is known as a "heat exchanger".

Figure 1-5c shows an end view of a tubular heat exchanger to show how the heating (or cooling) medium is contained within the space between the two pipes.

Figure 1-5a: A tubular heat exchanger with steam as the heat source

Figure 1-5b: A tubular heat exchanger with hot water as a heat source. A coolant may also be used in this manner.

Figure 1-5c: An end view of a tubular heat exchanger

Numerous variations of the basic heat exchanger have been developed to accommodate different products with a variety of properties and heating needs. These devices will be explained in more detail in the "Intermediate Course".

If food products are being put into cans, the cans may be filled and sealed prior to being thermally treated. The cans can then be loaded into a pressurized vessel called a "retort". Small retort units may look like a cylindrical tank with a lid that bolts down against the internal pressure. For large industrial-scale
retorts, the cans are stacked onto racks on a cart and pushed into the cylindrical retort which is mounted horizontally. Again, the door must be securely fastened to accommodate the pressure within the vessel. Once fully loaded and securely closed, steam is introduced into the retort at a pressure of approximately 100 kiloPascals (kPa). This raises the boiling point of water inside the chamber to about 121°C. By increasing the temperature, there is an increased level of effectiveness in killing any microorganisms present inside the containers within the retort. By studying the sensitivity of various microorganisms to temperatures, standards have been established for the length of time canned foods must be held inside the retort to complete the desired thermal processing.

It is important to keep in mind that the time is actually the “time at temperature”. This means the process timing starts when the entire contents of the cans reach 121°C. Often, there is considerable time taken for the cans to reach their processing temperature.

Retorts are very similar to a sterilizer used in a hospital or doctor’s office to sterilize medical equipment and surgical tools. The main difference is that they are much larger in their capacity.

A small-scale sterilizer used in a microbiology lab is shown with its door open (Figure 1-6a). When the door is closed (Figure 1-6b), it needs to be securely bolted into place to withstand the pressures generated by the steam inside.
1.2.4 Heating Mechanisms:

Different food products have different rates of heating due to their heating mechanisms.

There are two basic heating mechanisms: one is conduction and the other is convection.

Once again, let’s consider a pot of water on the stove or over a fire.

Heat from the stove or fire warms the outside surface of the metal pot. The molecules in the metal transfer the heat to neighbouring metal molecules, which in turn continue to transfer the heat to other molecules of the metal. This process is referred to as “conduction”.

Some of you may have placed one end of a metal rod in a fire and burnt your hand when you grabbed the end that was not in the fire. Others of you may have reached for the metal handle of a pot on the stove only to find that the handle was too hot to hold. The process by which the metal heated was conduction.

When the water in the pot contacts the hot metal surface on the bottom of the pot, it becomes heated. When water becomes warmer, it expands slightly and becomes less dense. Because of this density change, the water begins to rise to the top of the pot and cooler more dense water flows to the bottom of the pan. This creates a circulation pattern that helps warm the contents of the pot, which is water in this case. The heating process is called “convection” because of the convection currents which occur. If the water is allowed to come to a full boil, the circulation will become extremely rapid and we tend to call this a “rolling boil”. Figure 1-7 shows how convective heat transfer takes place.

![Figure 1-7: A schematic representation of convective heat transfer](image)

Products like fruit juices and broths contain nothing more than liquid ingredients. These tend to heat up by convection and can be stirred to enhance the heating process.

If we have a piece of meat and place it in a frying pan to be cooked, there will be very little heating by convection. This is because the meat is mainly a solid substance. When the meat contacts the surface of the frying pan, its surface is heated. Heat from the surface of the meat is then transferred by conduction to the rest of the meat. If you do not turn the meat over several times while cooking it, you can actually burn the bottom surface of the meat while the top surface will not be cooked at all. By flipping the meat over regularly, you make the heating process on the top and bottom more uniform and reduce the risk of burning it. Figure 1-8a shows a schematic representation of heating by conduction in a metal rod. Figure 1-8b shows how heat is conducted through a metal pot to warm its contents.
Figure 1-8a: A schematic representation of heat transfer by conduction in a metal rod.

Figure 1-8b: Heat transfer by conduction through a metal pot to warm its contents.

Not all food products are completely liquid like the water, or completely solid like the piece of meat. In some cases we have a mixture like peas in water. When heating a mixture of this type, there is a combination of heating by convection and conduction.

The water will heat by convection as it draws heat from the metal surface of the pot. As it begins to circulate, it will transfer some of this heat to the outer surface of the peas. The heat will then be conducted from the surface to the inner portions of the peas by conduction.

Because of the different heating mechanisms, there are different rates at which foods heat up. Let’s take a look at two very different canned materials which are being heated. We have cans of water, and a thick mixture of beans in a tomato sauce. By inserting a thermal probe into the top of each can (see Figure 1-9) we can measure the temperature of the contents during a heating process. For this study, the cans were placed inside a heated oven and the temperature was recorded during the time it took for the contents of the can to reach 100°C. Since the oven was not pressurized, we could not get temperatures above this level.

Figure 1-9: Canned product in an oven with a thermal probe inserted to monitor temperatures

Figure 1-10 shows a graph of temperature versus time for the heating of the water and canned beans in tomato sauce materials. Notice how the water heats more quickly than the thicker beans in tomato sauce. This is largely due to the ability of the water to circulate by convection inside the can. In contrast, the tomato sauce cannot
circulate very well due to its thickness and the fact that the beans prevent any appreciable motion of the sauce.

Figure 1-10: Graph of temperature versus time for canned water and beans in tomato sauce
CHAPTER 2: FOOD SAFETY AND QUALITY

2.1 Introduction

In this chapter, we will look at the way in which microorganisms can create problems with the safety of food through food-borne diseases.

2.2.1 Microorganisms Present in Food Products

Microorganisms are everywhere around us. They are even present inside our bodies. Some beneficial microorganisms live in our digestive tract to break down the food we eat into its nutritional components. There are also disease-causing microorganisms which might invade our body and overcome our body’s natural defences against them. We are continuously striving to maintain levels of the beneficial microorganisms and keep out those that are harmful to us.

One way that harmful microorganisms, which we often hear referred to as “germs”, get into our bodies is through the food we eat. We have all seen food that has spoiled and looks absolutely disgusting and totally unattractive to eat. However, before we see these obvious signs of spoilage, the microorganisms may still be there growing within the food.

One of the questions that this might prompt you to ask is, “How did the microorganisms get into the food in the first place?”

2.2.2 How Microorganisms Get There

There are many ways which microorganisms can get into our food supply. Generally, the first thing that occurs is the contamination of the food surface. Fruit may fall from a tree and land on the ground below where cattle or other animals are being pastured. Cattle droppings (i.e., feces) in the grass contain harmful bacteria that can get on the surface of the fruit. If the fruit is not properly washed before it is prepared for eating, these bacteria can spread to the entire fruit and be eaten. When the fruit is cut, the knife blade may come in contact with harmful microorganisms on the surface of the fruit. The blade of the knife will then draw these microorganisms into the centre of the fruit, thereby contaminating the entire fruit.

A large piece of meat will often be carved into smaller cuts for home use. If the meat is placed on an unclean surface for carving, microorganisms on this surface will become transferred to the surface of the meat. The knives used to cut the meat will then transfer the “germs” to the surfaces of every piece of meat that is cut from the larger piece of meat. Each time the meat is cut into smaller pieces, the contaminating surface bacteria get spread to the newly exposed surfaces.

Since most of the foods we eat contain high amounts of moisture, the
microorganisms have a wonderful environment in which to grow. The sugars, starches, and proteins in the food act as a food supply for them and the moisture allows them to grow and spread even more throughout the entire mass of the food material.

Rodents and insects spread microorganisms and disease. Rats and flies may feed on decaying food in one area and then travel to another area where they find fresh uncontaminated food. As soon as they touch the surface of this newly found food, it will become contaminated due to the microorganisms on their bodies and in their mouths. Rats and mice have been responsible for the spread of some of the greatest disease outbreaks in history. The “Great Plague” or “Black Plague” that swept across Europe in the 1600's and killed approximately one-third of the entire population was spread by rats. Although this was not a food-borne incident, it does illustrate the dangers associated with rodents and other pests.

Bird droppings are another source of microbial contamination. These droppings may land on the food itself or on surfaces where food will contact them. In this case, the fruit does not have to fall to the ground to become contaminated. It can be contaminated while still on the tree or bush.

Unsanitary on-farm practices may also help microorganisms enter the food chain. Spreading animal manure onto fields is an acceptable way of putting nutrients back into the soil, if it is done properly. However, it can also create problems. Consider manure spread around leafy vegetable crops. As the crops grow, their leaves are only a few centimetres from the manure on the ground around them. When rains come, the water droplets may splash small bits of manure up onto the leaves of the vegetables. When the water droplets dry, the harmful microorganisms from the manure are left sticking to the leaves. From here, the leaves are picked, as in the case of lettuce or cabbage and the bacteria etc. travel to the consumer along with the leaves. It is only through careful washing and other sanitary measures that such contamination can be removed. There are also cases where the microorganisms can actually get into the pores of the plants and create contamination problems that cannot be removed by surface washing.

Dairy farmers may be concerned about mastitis in their herd and use a disinfectant solution to wash the udder of each cow before milking. However, the cloth they use to wipe the udder may be filthy and the level of disinfectant in the solution may become reduced over time. The combination of the low disinfectant level and the dirty cloth used to apply it may actually spread the disease from one cow to the next. Similar things can happen when unclean cloths and insufficient disinfectant concentrations are used to wipe down surfaces where food is being prepared. The dirty cloth may spread microorganisms, which are then picked up by foods prepared on those surfaces.

Unclean surfaces in processing facilities are other sources of contamination for foods which pick up any microorganisms as they contact the surfaces. Workers
who are ill and handle food can introduce harmful, disease-causing microorganisms, as can people sneezing or not washing their hands after using the washroom facilities.

There are numerous cases of harmful microorganisms getting into food and being spread through human carelessness. In one case, customers at a market purchased cheese made by a local farmer. Within a few days, illnesses were reported in the area. Health authorities interviewed the victims of this “food poisoning” incident and found that all had bought cheese from the same farmer. They then inspected the entire cheese-making process, the storage conditions used, and the handling of the cheese on its way to the market.

The inspectors found that several days before taking the cheese to market, the farmer had prepared a chicken and had soaked it in a pail. He then carried the cheese to market in the same pail without properly cleaning it. Microorganisms from the chicken were transferred to the water where they grew until the pail was emptied. However, the inner surface of the pail remained contaminated with the microorganisms which were then transferred to the cheese and eaten by the unsuspecting customers.

Fortunately, all those affected by the contaminated cheese recovered with no long-lasting problems.

Our bodies have a natural resistance to many of the microorganisms that occur around us. However, there are numerous ones to which the body has no defence that can be particularly worrisome. In addition, microorganisms may adapt or mutate to suit the growing conditions in a new environment. These mutated microorganisms may be a major threat to human health and may contaminate the food that is shipped to consumers around a country, or even the world.

2.3.1 How Microorganisms Grow

The information presented here is included to serve as a lead-in to the material on preservation and sterilization. A basic appreciation of microbial growth goes a long way to understanding preservation methods.

In general, any factors which reduce or slow microbial growth will have a positive effect on increasing a product’s shelf-life.

2.3.2 Doubling Times of Microorganisms:

Doubling times (based on the time required for the mass of a microorganism or number of microorganisms to double) are affected by a great many factors. These include:

- temperature
- availability of nutrients
- types of nutrients
- general environment
- various other factors

As a general approximation, under ideal conditions (20°C to 37°C):

bacteria can double in 45 minutes
yeast can double in 90 minutes 
molds can double in 180 minutes 
The doubling time of a microorganism 
has a profound effect on the rate of 
spoilage of a food product and on their 
impact on the health of humans eating 
any contaminated foods.

2.3.3 The Power of Doubling:

In order to appreciate the power of 
doubling let’s consider a totally made-up 
story.

There once was a very wealthy man 
who had twin sons. For their eighteenth 
birthday, the father decided to give each 
son a monthly allowance of money so 
that they might enjoy a share of his 
wealth. The first son said that he would 
like one-hundred thousand dollars 
($100,000) each month. Being so 
wealthy, the father instantly agreed and 
the first son smiled with joy at his good 
fortune.

The second son asked his father to start 
his allowance on the first day of each 
month with one cent ($0.01). The 
second son then asked that the father 
double this amount every day for the 
rest of the month. On the final day of 
the month, the second son would then 
come and collect his allowance.

The father looked at his second son and 
laughed at this apparent foolishness. At 
the end of the first week, the second 
son’s allowance had grown to only sixty-
four cents, which made the father and 
the first son ridicule the second son’s 
decision even more. However, they 
were not laughing at all on the thirty-first 

day of the month when the second son 
showed up to collect over ten-million 
dollars!

Table 2-1 shows how the power of 
doubling increased the value of the 
second son’s initial one cent.

<table>
<thead>
<tr>
<th>Day</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
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<td>$0.02</td>
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<tr>
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<tr>
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<td>$5,368,709.12</td>
</tr>
<tr>
<td>31</td>
<td>$10,737,418.24</td>
</tr>
</tbody>
</table>
Table 2-1: Doubling of money each day for 1 month

2.3.4 Microbial Growth in Food Systems:

Many types of microorganisms also grow by a doubling process. By drawing similarities between the doubling of cells of microorganisms, and the doubling of the money in our example, we can see that it will not take long for a single cell to reproduce to dangerous levels. If bacteria can double in number in less than one hour, it will not take long for a few bacteria contaminating our food to reach numbers that are sufficient to cause illnesses to occur.

This should be kept in mind when you are tempted to taste just a little bit of something which you suspect might be spoiled. Even the smallest number of contaminating microorganisms may grow to problematic levels. For some microorganisms, only a few thousand cells in our bodies can be harmful.

Not only are microorganisms potentially harmful at low levels, but they are so small we cannot detect them at low numbers without the aid of a microscope. It is estimated that about 1 million (i.e., 1,000,000) microorganisms must be present in one millilitre of water before the water becomes cloudy enough to indicate that they are present. This is well beyond the number of such microorganisms that are required to cause severe illness!

2.3.5 Illnesses from Microorganisms:

There are two separate processes by which microorganisms can make you sick. On the one hand, the growth of microorganisms can cause an infection, and your immune system must fight off the further growth of the microorganisms. If the body's own self-defense processes are not able to quell the growth, the ultimate consequence may be death. The severity of the infection is in direct proportion to the number of microorganisms, and, generally, to produce these severe symptoms takes several days to allow growth of the microorganism. On the other hand, some microorganisms produce a chemical for self-protection. These chemicals, called toxins, can be ingested and result in severe illness or even death. If the dose of the toxin is sufficient, the symptoms from an ingested toxin can occur in a matter of hours. In thermal processing we must identify the target microorganism of the process so that it can be destroyed so as not to cause an infection or intoxication. The basis of the process will be discussed in the Intermediate Thermal Processing Course.
2.4 Effects of Temperature on Growth Rates:

If you are not familiar with the following terms, please do not worry about it. They are included here to show the wide range of temperatures (and other conditions) under which microorganisms can grow.

**Psychrophiles**: Able to grow at 0°C (and below freezing in some cases)

**Mesophiles**: Optimal growth around physiological temperatures (i.e., body temperatures of warm-blooded animals). Typically this is 37°C.

**Thermophiles**: Optimal growth between 45°C and 70°C. Extreme thermophiles can grow at temperatures as high as 115°C, with an optimum temperature of 80°C.

Temperatures are an important consideration in the growth of microorganisms. Many of them grow best at temperatures around 37°C, which is the normal body temperature for humans, and of course, the temperature of our stomachs. Any microorganisms present in the food we eat will find themselves at very suitable temperature. Thankfully, our digestive systems are acidic enough to reduce many of the risks.

Not only are some microorganisms able to withstand extremes in temperatures, but others can even grow where there are high salt concentrations. They are called **halophiles**. This is particularly troublesome since there are preservation processes for fish and various meat products that rely on salt as the main preservative.

Other microorganisms can grow in environments where the water content is very low. These are called **xerophiles** (pronounced “zero-FILES”).

2.5 Typical Growth Patterns:

Under “ideal” conditions (such as during a controlled fermentation), the general growth pattern consists of three distinct phases (see Figure 2-1)

The **Lag Phase** is the period of adjustment of microorganisms to a new environment or change in nutrients on which they are growing. The microorganism is essentially “getting its act together” and is reorganizing itself. The duration of the lag time can vary from quite short to appreciably long. The cell mass can change slightly without a change in the cell number (the cells are “fattening up”).

The **Log Phase** is the period of exponential growth of microorganism. This is when the most rapid growth or “doubling” occurs. The log phase ends when any of the essential nutrients for cell growth are used up, or when the concentration of any products the cells produce reach such a level as to halt growth.

The **Stationary Phase** occurs when the cells stop reproducing, or when the growth rate of living cells becomes equal to the death rate of cells in the system. Reaction products may continue to be produced by the viable cells that still remain. Spores may form...
in response to a non-favourable environment. These spores can remain dormant (not growing) for long periods of time and begin to grow once there are conditions favourable for them to begin to grow.

Occasionally, there may be a secondary growth phase after many of the microorganisms have died. This is due to new microorganisms growing on the nutrients from those that have died.

Figure 2-1: Typical growth pattern for microorganisms
2.6 Using Microbial Growth Information in Food Processing Applications:

Simply knowing a lot of information about a lot of microorganisms in a lot of growth environments is of little use, if we cannot apply this knowledge to a particular situation.

In food processing and preservation, we are trying to:

1. Reduce the number of living or “viable” microorganisms at the time of packaging a product.

2. Create an environment during storage that is not attractive for microbial growth.

3. Reduce the number of viable organisms at the time the product is consumed.

If we do a good job of reducing the number of microorganisms initially present in the food through our processing, we will have fewer microorganisms present for growth in the subsequent time of a product’s life.

We can take our knowledge of microbial growth and formulate a product to incorporate ingredients that inhibit growth (i.e., halt or slow the growth) and essentially prevent the microorganism from ever getting into a logarithmic growth phase. If we can keep the microorganism in its lag phase, the population will never take off. Similarly, we may impose conditions on the microorganism that put it into a stationary phase, even though the cell population is at a very low level.

We may impose temperature constraints on a product (chilling or freezing) to exploit the growth rate factors of a microorganism under less than ideal growth conditions.

We may stress the microorganism by reducing moisture levels to sub-optimal levels.

We can alter the pH of a product to deliver the desired attributes while impeding growth.

We may combine our knowledge of growth factor attributes to create a number of hurdles to discourage microbial growth.

2.7 Hurdle Technology

While each preservation technology may be effective on its own, using several techniques in combination can be even more effective. This approach is referred to as “hurdle technology”.

Picture a runner ready to begin a long race. At the sound of the starter’s pistol, the runner breaks from the starting line and sets off at the desired pace. Under ideal conditions and little exertion, the runner may seemingly be able to go on forever without stopping or faltering. However, if we place obstacles in the path of the runner, such as hurdles of varying heights, this could seriously upset the runner and have a negative impact on the pace. A very large hurdle could ultimately end the runner’s progress.
The same can be said for contaminating microorganisms. If enough “hurdles” are in place, the microorganisms may not be able to grow to the point of spoiling the food product.

Some of you may be familiar with aseptically packaged beverages (i.e., drink boxes). Here, the juice is formulated to have enough acidity to prevent the growth of molds. In addition, before packaging in a sterilized packaging material, the beverage is subjected to a high-temperature short-time heating process designed to destroy most, if not all microorganisms that may be present. The growth of any mold spores that may make it past the heating process hurdle should be stopped by the acidic nature of the beverage formulation itself.

Another example of hurdle technology could be in the preparation of home-made apple sauce.

An important part of this process is boiling the apples. Not only does this provide the heat necessary to change the texture of the apples, but heating also reduces the microbial load that is initially present, even on the most thoroughly washed apples. Heating is the first “hurdle” to microbial spoilage.

It has been shown that cinnamon has a degree of preservative activity. Adding cinnamon to the apple sauce could create a second “hurdle” that a microorganism weakened by the first hurdle (i.e., the heating step) might not be able to overcome. Freezing the apple sauce would create a third “hurdle”, all but blocking the spoilage of the apple sauce.

Figure 2-2 shows how hurdles can be used in the development of food products and in food processing to prevent the growth of unwanted microorganisms that create spoilage or cause illnesses and disease.

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**Figure 2-2:** Diagram showing the hurdle technology concept with heat treatment and high acidity to reduce microbial growth
2.8 Foodborne Diseases

2.8.1 Examples of Foodborne Diseases

Here are some examples of foodborne illnesses taken from newspaper articles and various internet sources. In order to respect the privacy of individuals and companies, some of the details have been omitted. The main purpose of including these accounts is to give you an idea of how serious food safety is in our everyday lives.

You may hear foodborne illnesses referred to as “food poisoning”. This is an acceptable term, but it can cause confusion when discussing cases where food contains residual pesticides or other harmful chemicals that are actually poisonous to animals and humans. We must be careful not to confuse the two different causes of illness.

Example 1: In May, 2011, 26 people were hospitalized in Rwanda after they drank milk from a local restaurant and a school canteen. About three hours after drinking the milk, a number of the individuals became weak, suffered nausea and terrible headaches, and then developed stomach pain and diarrhoea. Fortunately all recovered. Dirty containers which had been exposed to house flies were suspected as being the cause of the problem.

Example 2: In late November 2010, two tourists vacationing at a resort in Kenya began suffering from vomiting, diarrhoea, stomach cramps, and a high fever. When they returned to their home country, tests showed that they had been exposed to Campylobacter bacteria. They were hospitalized for treatment. According to accounts of the event, conditions at the resort were quite undesirable. Fish and meat was raw and uncooked, and was left uncovered for long periods of time. The two individuals recovered, but a lawsuit against the resort was being considered. Based on the news article, the reputation of the resort would also have suffered greatly from the unfavourable events.

Example 3: According to a review article published in 2011, Staphylococcus was found in almost one-quarter of 200 samples of cottage cheese which were tested over a seven month period. The authors of the study in Ethiopia pointed out the serious health risks to the consumer and the need for processors to adopt strict control measures for sanitation during the manufacturing, handling, storage, and distribution of these perishable products. (Reference: Mekonnen Addis, Mahinda Pal, and Moses N. Kyule “Isolation and Identification of Staphylococcus Species from Ethiopian Cottage Cheese in Debra Zeit, Ethiopia: Veterinary Research 4, 13-17, 2011).

Example 4: In November 2009, about 40 patrons of a salad bar in Ghana were treated at hospital for abdominal cramps, diarrhoea, and vomiting. It was found that cabbage used to make the salad had not been properly washed and stored. Temperature controls were poor which allowed Clostridium perfringens (a bacteria) to reach levels of over 100 microorganisms per gram of food. The owner of the establishment received training in the washing and
storage of vegetables and in the importance of frequent hand washing.

Example 5: In June 2011, 10 Nigerian school teachers died and numerous others were hospitalized after eating lunch at a weekend workshop. There was no indication as to the exact cause of the “food poisoning”, but the seriousness of this tragedy is quite evident.

Example 6: In February 2011, about 400 students at a high school in South Africa were struck with a foodborne illness which caused stomach cramps and diarrhoea. Some students even collapsed. Health authorities suspected that a workshop being used as a kitchen facility was cause of the problem. They said that conditions in the workshop were so bad that the workshop should never have been used as a kitchen and that regulations for the preparation of food were not met.

Example 7: In another example from South Africa, 151 persons required treatment for “food poisoning” in a January 2011 incident. According to reports, a person hired to dispose of some expired food products distributed the cookies, cakes, jams, and juice to a group of people, instead of taking them to the proper dump site. It was reported that the expiry dates were in 2007 and that the food should not have been consumed.

Example 8: In an older account of “food poisoning” (January 1994), students at a college in Ethiopia suffered abdominal cramps and mild diarrhoea after eating unpeeled, undercooked eggs at breakfast. A strain of Salmonella was found to be the cause of the ailments which affected 79 students.

Example 9: In May 2007, dozens of students from two schools in Ghana were hospitalized after eating rice balls and groundnut soup at their schools. It was noted that the person preparing the food had done so without incident for several years. It was also reported that a group of students eating the same food earlier in the day had no ill effects. However, the children who ate the same food in the afternoon did suffer the ill-effects. Based on this observation, the cause of the outbreak was attributed to improper handling of the food during the period between the two meals.

Example 10: In 1986, 20 people died in Nigeria after eating sandwiches consumed one day after they were prepared. The sandwiches were stored without refrigeration and were found to contain extremely high levels of Salmonella in the fillings.

2.8.2 Impact of Foodborne Disease

The listings in the previous section are only a few examples of foodborne illnesses and how they can impact unsuspecting consumers of foods and beverages. While these incidents are all from African countries, it is very easy to find reports from all around the world that indicate how widespread the problem of “food poisoning” really is.

Here are three examples of the impact of foodborne diseases that appeared in
newspapers and on the internet in the late 1990’s. These somewhat outdated accounts are included to illustrate just how little has changed since then in spite of efforts to educate food processors, food distributors and vendors, and the general public. Sadly, the very young, the elderly, and those with weakened immune systems and poor health, still die from these illnesses.

**Example 1: United States:**

“According to the Centers for Disease Control and Prevention, 7 million illnesses and 7,000 deaths occur each year from food poisoning in the United States. Of these, 5 million illnesses and 4,000 deaths come from contaminated meat and poultry.

But these are just the reported cases. Many people who get sick aren’t aware that food-borne illness is the culprit.”


**Example 2: Worldwide:**

“Annually, at least 1,500 million (i.e., 1.5 billion) episodes of diarrhoea occur in children under the age of five. An estimated 4 million children die each year as a result. Diarrhoea removes essential body fluids and vital nutrients, producing dehydration and malnutrition. Difficulty in obtaining an adequate supply of clean water and safe food, and the lack of basic sanitation, are the major causes of diarrhoea in young children.

Up to 90% of these deaths can be prevented by standard case management. This includes oral rehydration therapy, feeding during and after the diarrhoea episode, and the use of an antibiotic in the case of dysentery.”


**Example 3: Australia:**

“The incidence of salmonella poisoning has doubled in Victoria in the past year, according to federal Health Department figures.

For the first six months of 1997, Victoria recorded 1,111 salmonella outbreaks, compared with 906 for the whole of 1996.

Nationwide, cases of food poisoning have also increased dramatically in the past 12 months.”

“The Food Safety Campaign Group chairman, Mr. Bruce Bevan, said food poisoning cases were costing Australia about $2 billion a year.”

ref. The Sunday Age, “State’s salmonella cases double”, August 24, 1997
2.8.3 Addressing Foodborne Disease Problems

In the remaining sections of this manual, we will examine the ways in which food processing can help reduce the occurrences of foodborne illnesses, or “food poisoning”, through the use of heating.

You should also keep in mind that it is important to maintain proper storage and handling conditions throughout the entire food chain. In the case of fruits and vegetables, this covers the time from which the seeds are first put in the ground or the time the fruit begins to appear on the tree until they are prepared and eaten by the consumer. In the case of meat, this covers the entire life of the animal, including the health and general well-being of the mother, until the meat is prepared and eaten.

The actual thermal processing is only one step in this long and complicated process.

It should also be remembered that most cases of “food poisoning” are not reported to the health authorities. For every case that is reported, there may be ten or more that are unreported.

Some countries are better than others at tracking and reporting outbreaks of foodborne diseases. Therefore, it should not be assumed that just because you cannot find a large number of reports for a given country that the problem is not serious or does not exist at all.

2.9 Practice Exercise: Microbial Growth:

2.9.1 Background:

Many clear liquid beverages such as fruit juices become cloudy when the concentration of microorganisms reaches one million microorganisms per millilitre (i.e., 1,000,000 per mL)! Such populations may also be referred to as “cells / mL” or “colony forming units per millilitre” or “cfu’s / mL”.

In a purely imaginary case, you have produced an apple juice-based beverage at 8:00 a.m. one morning and do not store it properly. At the time the beverage was made, there were 30 microbial cells per millilitre. Since the beverage is warm and there is an abundant source of sugar for the microorganism to use as a food supply, the population may double every 30 minutes (i.e., every half-hour).
2.9.2 Your Task:

Calculate the time it takes for the population of microorganisms to reach the level where the beverage turns cloudy and determine what time of day this happens.

If the microorganism growing in the beverage can be harmful to humans when its population is over 1,000 microorganisms / mL, how long after production, and at what time of the day will the beverage pose a threat to human health?

Use the chart on the following page to assist you. The initial population and the first time interval have been provided to get you started.

2.9.3 Results:

From Table 2-2 on the following page, enter your results below.

It took approximately _____ hours for the microbial population to reach 1,000 cells / mL

If the beverage was made at 8:00 a.m., it posed a health risk by _____ a.m. / p.m.

It took approximately _____ hours for the population to reach 1,000,000 cells / mL

If the beverage was made at 8:00 a.m., it became cloudy by _____ a.m. / p.m.
Table 2-2: Chart for Determining the Population of a Microorganism with a Doubling Time of One-Half Hour and an Initial Population of 30 Microorganisms per Millilitre

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<th>Time</th>
<th>Population (microorganisms/mL)</th>
</tr>
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</tbody>
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Time to Reach 1,000 cells per mL = _____ hours: Time of day =

Time to Reach 1,000,000 cells per mL = _____ hours: Time of day =
3.1 Introduction

Cleanliness is one of the most critical aspects of food preparation, yet it is often overlooked by those studying food processing. Perhaps it is just assumed that everyone will instinctively know to keep things clean and how to go about it. In actual fact, this assumption is incredibly wrong.

As children, most of us were taught to wash our hands with soap and water before eating a meal. However, this basic skill is often forgotten in the working environment of a food processing plant or a food service facility such as a restaurant or cafeteria. Food preparation facilities such as kitchens in hospitals and hotels also require the same attention to cleanliness.

In this chapter, we will look at some of the ways in which a lack of cleanliness can affect food products. We will also discuss how sanitation can be improved in the food processing workplace and in our everyday lives.

As you read through the material presented here, please keep in mind that much of this is common sense and may not seem all that complicated. However, failing to maintain a high level of sanitation may have costly or disastrous results.

3.2 Why is Cleanliness Important?

It seems like everyone is always saying that you need to keep everything absolutely clean and spotless in areas where food is being prepared or processed. For those who are not familiar with food processing, an honest question would be, “Why?”

To answer this question, let’s take a look at what happens to food when we eat it. Once we have thoroughly chewed and swallowed our food, it travels to the stomach where the process of digestion begins. It then continues along through our digestive system where millions of beneficial microorganisms break the food down so that our bodies may extract the nutrients from it.

Many of the foods we eat are starch-based such as rice, cassava, potatoes, maize, and cereal grains such as wheat. These are very easy for the microorganisms in our digestive system to break down into sugars which our bodies use for energy.

If these foods are easily broken down by the good microorganisms in our bodies, then they can be broken down just as easily by microorganisms outside our bodies. When this happens, it is usually by non-beneficial microorganisms which cause the food to spoil.

Because most foods contain a lot of water, it is not hard for spoilage to
occur. All it takes is for a few unwanted spoilage microorganisms to come into contact with the food and eventually the food will not be edible. In hot, humid climates, spoilage may occur literally overnight. Sliced fruit or vegetables that are left unprotected from spoilage microorganisms floating in the air can show signs of fluffy mold growth within a day.

The really scary thing about food spoilage is that most of the microorganisms are not visible. We may eat food thinking that it is safe to do so but in reality, there may be some harmful bacteria or other microorganisms growing in its surfaces or within it.

In order to reduce the chances of introducing harmful microorganisms into our food every effort must be made to keep things as clean as absolutely possible.

Although the question as to why we need to emphasize cleanliness is really not all that difficult to answer, creating a clean processing environment is much more challenging.

### 3.3 Keeping Things in Perspective

In the following sections, you will come across numerous examples of how foods can become spoiled and how harmful microorganisms may be lurking in various foods.

It is important to keep things in their proper perspective and not become excessively alarmed or overly anxious about this situation. Remember that with proper care, most food-borne disease problems can be avoided and you can stay healthy. Your body has some natural defences against many of the harmful bacteria that are around us. However, we must do everything possible to ensure that the food we all eat is as safe as possible. This means that it needs to be free of spoilage microorganisms and any other harmful things.

Proper sanitation and food preparation will go a long way towards keeping you safe.

### 3.4 Contamination

When spoilage microorganisms are introduced into food products, they may begin to grow. If they reach a point, where they pose a threat to the health of the consumer, we may say that the food is “contaminated”.

It is the purpose of thermal processing to “kill” any of these microorganisms which may have found their way into a food product. After processing, the food must be kept free from these microorganisms as it goes through the distribution and sales sequences before being purchased and consumed.

There are many ways in which harmful spoilage microorganisms can come into contact with foods. From the time crops begin growing in the field or even before animals are born, they are under a constant threat of potential contamination.

To better understand how foods may be contaminated, let’s follow two examples through the food chain.
Example 1: Apples

Let's begin by looking at apples growing on a tree. They may eventually be used to make apple sauce, pie filling, or apple juice (see Figure 3-1). As they develop, the apples may be attacked by insects which bore small holes through the peels. In addition to the contamination brought by the insects themselves, these holes can allow other potential contaminants to penetrate into the apple. Flies carrying disease-causing microorganisms can also enter the apple through the holes. If there was no hole present, it would be more difficult for contaminants to enter the fleshy portion of the apple.

Figure 3-1: Care must be taken in handling fruits such as apples

Birds sitting in the tree branches can contaminate the surface of the apples with their droppings. Dried bird-droppings can cling to the apple peels and create health problems later if they are not removed by a thorough washing before the apples are cut open or mashed.

Often cattle or other animals are allowed to graze in apple orchards. If apples fall from the trees, they may be contaminated by harmful microorganisms present in the cattle droppings. One of the main sources of *E. coli* contamination is the use of "windfall" apples that have come in contact with fecal material from cattle.

Even the air around the apples contains harmful bacteria and mold spores.

Once any of these microorganisms come into contact with the fleshy part of the apple, they are in an ideal growth environment. Apples contain about 84% water and just over 10% sugar on a weight basis. The sugar which is dissolved in the juice of the apple provides everything the microorganisms need to grow quite well.

During harvesting and shipping to the processing facility, the apples may be bruised by rough handling and road vibration. Damaged peels can no longer protect the fleshy part of the apple from moisture loss or invasion by microorganisms which are floating in the air or are already on the apple surface. As a result, there is an opportunity for spoilage.

Once in the processing facility, the problems are not over. Before doing anything, the apples need to be washed to rid them of any surface contaminants. If this is not done, the microorganisms on the apple surfaces could contaminate the entire processing plant.

When processing the apples, all cutting tools, cooking kettles, strainers, and other food contact surfaces must be completely free of contaminants that could otherwise get into the apples. This is true even though the apples
themselves might contain contaminating microorganisms.

The apples can then be made into apple sauce, pie filling, or apple juice through the appropriate processing steps. Any contaminants inside the apple will then be transferred to the processing equipment surfaces. At this point, the products are probably not safe to consume.

The apple products can be thermally processed by heating to a specified temperature and holding them there for the prescribed period of time. After cooling, the product can be packaged and should be safe to eat. However, if care is not taken, the processed products can be contaminated once again and the thermal processing steps will have been done in vain.

Immediately after the apples are processed, all equipment and food contact surfaces must be cleaned to a high standard. The equipment cannot be allowed to sit uncleaned for any period of time, since this will allow an opportunity for microbial growth to take place.

The finished product must be handled properly as it is distributed to stores to be sold. If the packages are damaged, microbial contaminants may enter and cause spoilage or create a health hazard. Lids on glass jars must be tight and hold an air-tight seal. Cans must be free of dents and rust. Sealed bags must not be torn or have damaged seams. All of these could allow for contamination of the finished product.

When the consumer opens the package and prepares the food for the table, there are still opportunities for contamination. Unclean utensils and dishes; dirty counter-tops and food preparation surfaces; flies and other insects; and unseen microorganisms in the air can all contribute to food safety problems in the home.

Example 2: Lettuce

We will not go into as much detail with this example as we did with the apples. Many of the problems are the same for other fruits and vegetables as they were for the apples. However, lettuce may offer a few additional problems not previously discussed.

Lettuce is commonly used in salads and can be grown as either leaf lettuce or head lettuce (see Figure 3-2). There are very few foods that contain more water than lettuce. Over 95% of the lettuce is water! Because of its high water content, lettuce requires abundant watering while it is being grown. It also requires nutrients typically applied as fertilizers - often in the form of animal manure. Manure is really the droppings from cattle or other farm animals and contains fecal microorganisms that are potentially dangerous to human health. Among these is *E. coli*. 
Figure 3-2: Although not thermally processed, head lettuce offers some interesting challenges.

When manure (either in dried or liquid form) is spread around the base of the lettuce plants, it brings with it the fecal microbes that are left lying on the soil surface. When it rains, or when water is sprayed onto the fields, the water droplets striking the ground splash mud up onto the leaves of the lettuce. These droplets carry the microbial contaminants along with them and deposit them on the lettuce. In addition, contaminated water may actually be taken into the root system in some cases.

When the lettuce is harvested, E. coli and the other harmful microbes are left clinging to its surface. Extremely thorough washing is required to remove these microorganisms.

While we do not tend to thermally process lettuce, it is an excellent example of how foods can become contaminated and bring these contaminants into our homes.

3.5 Cross-Contamination
Cross-contamination occurs when a thermally processed food is re-contaminated by coming into contact with unprocessed foods or contaminated surfaces.

A common example of cross-contamination occurs frequently in many homes. Consider this simple situation. Someone is about to cook some meat and places it on a plate before frying it. Once the meat is cooked, the person then places it back on the same plate to cut it.

Now, let’s think about what happened. Raw meat usually contains microorganisms that can create digestive problems or cause food-borne illnesses. By cooking the meat thoroughly, the vast majority of these microorganisms are killed, which makes the meat safe to eat. When the raw meat was placed on the plate, some of the harmful microorganisms were transferred to the plate surface. After being cooked, the meat was safe to eat because the heating process had killed the harmful microorganisms it contained. However, when the meat was placed back on the contaminated plate, it once again picked up some of the harmful microorganisms.

Even though the number of microorganisms picked up by the meat from the plate may have been small, there could still be enough to cause problems if they began to grow in number in the digestive system of the person eating the meat.

Utensils such as knives used to cut raw meat, cutting boards, and other work
surfaces are all potential sources of cross-contamination.

Cross-contamination also occurs in the meat packing industry. When animals are brought into the plant to be slaughtered, they carry with them a host of microorganisms on their hair. More importantly, the manure in their bodies is an incredible source of potential contaminants. This is called “paunch manure” and must be removed from the processing plant without contaminating other areas. Most meat packing facilities do everything possible to separate the “clean side” of the plant (where the cut meat is handled) from the “dirty side” of the plant (where the animals are slaughtered). If harmful bacteria or other microorganisms are carried from the “dirty side” to the “clean side”, the cut meat may become contaminated. This has happened numerous times in many parts of the world. In many cases, lives were lost due to the production of toxins by microorganisms such as *E. coli*.

This is a further reminder to be careful when handling food. It also reminds us to be sure and cook meats thoroughly until the juices in the centre of the meat are clear and the blood-red colour has disappeared.

We will examine ways to clean surfaces later in this chapter.

### 3.6 Your Health is in Your Hands

One of the main ways in which illnesses or diseases are spread is through human contact - generally by hands.

When greeting someone, we have absolutely no idea what that person has touched before shaking our hand (see Figure 3-3). Any microorganisms (commonly called “germs”) that were on their hands will be transferred to your hands through this simple gesture. If you then place your fingers to your mouth or touch food that you are about to eat, these germs can find their way into your digestive system.

![Figure 3-3: Even a friendly greeting can spread “germs”](image)

If a person sneezes and covers their mouth and nose with their hand, germs can be deposited on their hands by the tiny droplets of moisture that are expelled during each sneeze. Once on their hands, the germs can be spread to door-knobs and other surfaces where they can be picked up by others.

In food processing facilities, workers’ hands are also responsible for much of the spread of food-borne contaminants. People going into an area of the plant which is not clean can bring
microorganisms back into the processing areas on their hands and even on their clothes. Hand-washing can reduce much of this problem.

In order to reduce the spread of infectious diseases, hand-washing should be a top priority on everyone’s list. Your health is ultimately in (or perhaps “on”) your hands.

Hand-washing is not simply dipping your hands in a stream of water coming out of a faucet and shaking off the water droplets. There are steps that need to be followed to do the job properly. Many washrooms have signs posted in them telling employees to wash their hands before leaving. Detailed instructions may also be printed on the signs.

To adequately wash your hands, you need to thoroughly rinse your hands under warm running water. The water must be “potable” (i.e., drinkable). Once wet, you need to apply soap and work it into a lather which you should spread over the entire surface of your hands, including between your fingers and on the backs of your hands. Once this is complete, you must rinse the soap from your hands and dry them on a clean towel.

In order not to re-contaminate your hands, use the paper towel on which you dried your hands to turn off the water faucet. You may also want to open the door out of the washroom with this towel.

Many washrooms have levers on the water supplies that you can push with your elbow to turn the water off. Others may have foot pedals or automated sensors to activate the water supply. Some washrooms also have a “dog-leg” entry in which a corridor with several turns in it allows employees to enter and exit the room without the need to pass through a doorway, while still maintaining the users’ privacy.

The use of warm water sometimes raises questions. Warm water is not meant to be hot enough to thermally destroy any microorganisms on your hands. These temperatures would need to be so high that they would scald your skin. The purpose of warm water is to soften any grease and oil that is on your hands and make it easier for the soap to remove. If the water is cold, the grease and oils would be harder to remove.

3.7 Sanitation in a Food Processing Area

3.7.1 Basic Sanitation:

We have already looked at the problems of cross-contamination and the need to keep our hands clean in order not to spread microorganisms around the food processing facility. In addition to these procedures, we must also keep all food contact surfaces as clean as possible. This does not mean that they simply look clean - they must be totally free of deposits of food residue and other materials which can support the growth of microorganisms. Sticky surfaces indicate the presence of sugars which are ideal to support the growth of microorganisms. Slippery surfaces may be caused by grease or oils from food remaining there. Surfaces which feel rough to the touch but should be smooth can indicate that
there is a build-up of waste material - even if we cannot easily see it.

The easiest way to clean a surface is to wash it thoroughly with potable (drinkable) water and a soap or detergent solution. Such washings do much to reduce deposits on surfaces and remove films of grease or oil. However, there may still be harmful microorganisms lingering there. For this reason, it is recommended that all surfaces be washed with a chlorine solution followed by a rinse with potable water. Instructions on preparing sanitizing solutions are usually available on the label of the chlorine bleach from which the solution is prepared.

All cleaning cloths must be kept as clean as possible. They should be washed and dried after use so as not to be sources of re-contamination when they come into contact with clean surfaces. Microorganisms can grow in damp, dirty cloths left on counter tops. If allowed to remain for a sufficient period of time, they may also start to develop a distinctly unpleasant odour.

Warning: Some companies use chlorine bleach to clean equipment and may also use ammonia solutions for other cleaning tasks. Never use ammonia and chlorine solutions in the same areas at the same time. The two chemicals can react with each other to produce a very toxic and irritating cloud of ammonium chloride. This is dangerous to your health.

You must also be sure to use all cleaning solutions in accordance with the suppliers’ safety instructions. In all cases, the area should be well-ventilated.

3.7.2 Sanitizing Equipment:

In addition to your work surfaces, it is important to sanitize all of the equipment used in any food preparation steps.

Knives and other utensils can be thoroughly washed and rinsed with a chlorine solution; followed by a rinse with clean water. The sanitized utensils should then be stored in a suitable location awaiting their next use. It is often a good idea to re-wash these utensils prior to their next use to ensure their cleanliness.

Equipment with moving parts should be disassembled in a safe manner according to the manufacturer’s instructions. Once taken apart, the individual pieces of the equipment should be washed in a detergent solution, rinsed with chlorine (if allowed by the manufacturer), and rinsed in potable water.

Once cleaned and dried, the equipment may be re-assembled or left apart until just prior to its next use.

Every effort must be made to clean every small crevice, seam, or joint where food particles may be clinging. Failure to remove all traces of food debris from processing equipment has resulted in contamination of processed foods. Serious illnesses and death have occurred among those who have consumed food contaminated by unclean equipment.

Some equipment cannot be disassembled easily and needs to be cleaned as a complete unit. For this, we
use a procedure called clean-in-place. Instead of washing the pieces of equipment by hand and scrubbing them with a brush etc., cleaning solutions are pumped through the processing equipment.

Clean-in-place (also called CIP) procedures are something that should be left to the experts to establish. Often the equipment manufacturer will work closely with the supplier of cleaning chemicals to set up the proper CIP procedures. In other cases, chemical suppliers may be called in by the company owning the equipment to develop a procedure to meet their special needs.

For cleaning-in-place, solutions of acids and detergent may be pumped through the equipment at a high rate to dissolve and sweep away all traces of food residue from the inside walls of pipes and equipment. These solutions are frequently heated to make them even more effective cleaning agents.

Once the chemical cleaning steps have been completed, the equipment is washed with potable water before it is shut down. A modified shortened version of the CIP procedure may be used before using the process for the next processing runs. In this way, any problems that might arise from contaminants getting into the equipment between uses can be reduced.

Although the equipment may be difficult to dis-assemble, regular shut-downs should be scheduled to allow the equipment to be taken apart, cleaned, and re-assembled. In this way, it can be inspected for signs of wear and possible contamination sites while also giving it a very thorough and deep cleaning.

3.7.3 Biofilms:

A serious problem that can arise when equipment is not properly cleaned is the build-up of layers of film on various surfaces. When this happens, microorganisms will begin to grow and form what is known as a “biofilm”. This is literally a film of biological material that is living and growing on surfaces within the equipment.

As the film grows, pieces of it may break off and enter the products that are being processed. This contaminates the product with the microorganisms growing in the biofilm. As time passes, these microorganisms will grow in numbers and become hazardous to the health of those consuming the product.

With proper cleaning, the formation of biofilms can be reduced significantly or even eliminated.
4.1 Introduction:

Before going on to study canning and processing of various other food products, we will examine the basics of “sterilization” and “pasteurization".

We will begin by taking a look at the sterilization of liquid products. Then we can continue onwards and include solid particles and larger solid pieces.

Before going any further, it is necessary to establish some definitions of terms that are often used in dealing with thermal treatment of foods (including beverages).

4.2 Definitions:

Sterilization or “Absolute Sterility”:

This is the term used to describe the complete destruction of all microorganisms within a product. To achieve sterility in most foods, a temperature of 121°C must be maintained for at least 15 minutes (or equivalent conditions). However, exposing many foodstuffs to such treatment can significantly alter their properties and reduce quality.

Food used in the space program is sterilized to remove all traces of microorganisms which may cause illness. Suffering from food poisoning while in space is definitely something to be avoided, if at all possible.

Another good example of a sterility, although not related to a food, is medical and surgical equipment which is placed in a heating chamber called an “autoclave” to destroy any microorganisms which may be present on them.

Commercial Sterility:

This term should not be confused with “sterilization” or “absolute sterility”. Commercial sterility describes the situation where the growth of microorganisms is halted under a specific set of conditions. In general, all pathogenic and toxin-forming microorganisms have been destroyed. In addition, all other types of organisms that could grow in the foodstuff and cause spoilage at those conditions have been destroyed as well.

There may be some heat resistant bacterial spores remaining after the heat treatment which cannot grow under the prevailing conditions. However, if these spores were isolated and transferred to a more favourable environment, their growth would proceed. Most frequently in food systems, the combination of heat treatment and the low pH of the food itself is sufficient to promote commercial sterility. The shelf-life of such foods (e.g., canned goods) is frequently several years.

Pasteurization:

Pasteurization is a more gentle thermal
process than sterilization. The temperature and time of exposure are dependent on the food itself. For milk, fruit juices, and liquid egg products, the treatment is designed to destroy pathogenic microorganisms which pose a health threat to the consumer.

Products such as beer and wine may be pasteurized to prevent the growth of microorganisms which can cause the products to spoil.

Pasteurization also increases product shelf life by reducing microbial populations and enzymatic activities that lessen food quality. Pasteurized foods still contain living or "viable" microorganisms, but their numbers are significantly lower than those in the unprocessed products. The storage life of pasteurized dairy products is on the order of several weeks under refrigerated conditions.

Pasteurization has "evolved" over the years from simple batch heating in a vat to more sophisticated high temperature-short time (HTST) processing. In all cases, the objectives are the same; to destroy spoilage organisms, pathogenic organisms, and degradative enzymes, in order to enhance quality, safety, and storage life.

4.3 Pasteurization Overview:

4.3.1 Historical Development:

(based on "Milk Pasteurization" by C.W. Hall and G.M. Trout, AVI Publishing Co. Inc., 1968)

As many of you may know, the process of "pasteurization" took its name from Louis Pasteur (1822 - 1895), the noted French scientist who studied the application of heat in controlling fermentations and preserving the liquid product.

Pasteur cannot be credited with discovering that heat treatment reduced food spoilage, however. That knowledge goes back to pre-recorded history when heat from fires was used to preserve food and enhance flavours.

The application of heat to liquid products is a more recent development which is believed to have started around 1782 when a Swedish scientist named Scheele used heat in the preservation of vinegar. In 1765, Spallanzini had demonstrated that meat extracts could be preserved in sealed flasks by boiling them for about 1 hour.

In 1804, Nicholas Appert published a treatise on "The Art of Preserving Animal and Vegetable Substances". At this time, France was at war and Napoleon's supply lines were stressed to the point that his armies were doing poorly on inadequate rations that were often spoiled, unwholesome, or generally unpalatable. Similarly, the sailors in the navy and on merchant ships were suffering the ill effects of poor diets, including scurvy, a disease caused by inadequate consumption of Vitamin C (found in citrus fruits like oranges, lemons, and limes). Appert found that if foods were sealed inside containers and sufficiently heated, the product would not spoil as long as the container remained closed. Appert's processing technology won him 12,000 francs as a prize for developing a useful method of preserving food. At about the same time, in England, Durrant heated products in tin cans, which resulted in extended shelf-life. From his process
came the term “canning”. This was the beginning of canning as we now know it.

In 1824, William Dewees, a professor of obstetrics at the University of Pennsylvania, recommended that milk should be heated to near boiling and cooled prior to using the milk for babies. He had observed that the tendency of milk to decompose in hot weather was diminished by boiling the milk.

From 1860 to 1864, Louis Pasteur worked on preventing the problem of wine spoilage that was plaguing the nation. He found that if the wine was heated to a sufficiently high temperature, and if it was held there for a suitable length of time, the contaminating microorganisms would be inactivated while the characteristics of the wine would still be retained. He used temperatures in the range of 50°C to 60°C.

Pasteur later applied his process of “par-boiling” or “under-boiling” to the treatment of beer (at temperatures of 50°C to 55°C). In spite of the fact that Pasteur’s process is so widely applied to milk, there do not seem to be any references in Pasteur’s records that he ever applied his principles to milk himself.

In 1881, the first commercial milk pasteurizer was introduced in Germany.

In 1889, the world’s first dispensary for the provision of heat-treated milk for infants was established in New York City by Dr. Henry Koplik, a pediatrician.

At the start of the 20th Century, many people felt that pasteurization of milk was undesirable and unnecessary. It was the growth of cities that changed all this by increasing the distance milk had to be transported and the time it took to reach the consumer. Heat treatment reduced this spoilage problem.

In 1908, Chicago became the first city in the world to require the pasteurization of the city’s milk supply. In 1909, the city passed the first compulsory pasteurization law in the United States.

There have been many significant developments in technology and processing equipment design over the years that have enhanced the reliability and economics of the pasteurization process, as well as improving product quality.

These include:

- HTST (high temperature short time) procedures
  (standards established in 1919, present form developed in 1927)
- heat recovery from pasteurization processes by means of specially designed pasteurizers (early 1900’s).
- UHT (ultra high temperature) processing (introduced in 1948)

There have also been many accompanying developments in packaging and distribution that have contributed to the quality and shelf-life of dairy-based products over these years.
4.3.2 Basic Processing Principles:

4.3.2.1 Batch Processing:

Batch pasteurization of milk was one of the earliest thermal processes for liquid food products. It was originally applied to milk. The milk was placed in a jacketed kettle and heated to 63°C (145°F) and held for 30 minutes. After being rapidly cooled, the milk was packaged.

The original pasteurization process for milk was designed to ensure the destruction of Mycobacterium tuberculosis. This is a highly-heat resistant type of bacteria that is capable to transmitting tuberculosis to humans. The heat treatment required for this process is 62°C (143°F) for 30 minutes. Alternate temperatures and times giving an equivalent amount of destruction of microorganisms (or “equivalent lethality”) could also be used.

It has been discovered more recently that Coxiella burnetii, the microorganism responsible for causing Q fever, can be present in milk. This requires a temperature of 63°C (145°F) for 30 minutes to ensure its destruction. Alternate temperatures and times yielding equivalent lethality may also be used.

It should be noted that processing times of 30 minutes are primarily for batch processes. These excessively long times can lower the quality of liquids such as milk and give them an undesirable “cooked” flavour. In addition, retention times of 30 minutes are not suitable to modern processing techniques which work on a continuous basis rather than a slower batch process.

4.3.2.2 Continuous Processing:

High temperature-short time (HTST) processing is a newer continuous process recognizing the benefits of rapid heating and short holding of a liquid food product versus slower batch pasteurization. The process uses a temperature of at least 72°C (161°F) for a minimum of 15 seconds. This is the thermal equivalent of the 30 minute hold at 63C in the batch kettle process.

Typically, a plate heat exchanger is used in the dairy industry. Actual times and temperatures vary for each individual liquid product and also depend on the microbial load present.

Although milk is the most commonly pasteurized food product, liquid egg is also pasteurized. Liquid whole eggs or egg whites can be pasteurized at 60°C to 62°C for 3.5 to 4.0 minutes. Such processing is designed to reduce the risk of salmonella, however, when using liquid egg products (or even fresh shell eggs), it is necessary to ensure that they are adequately cooked. Listeria monocytogenes is also becoming a concern in egg products.

4.3.2.3 Ultra-High Temperature Processing:

In UHT processing, ultra-high temperatures of 150°C (302°F) are used for a holding time of 1 to 2 seconds. This creates conditions that are equivalent to the batch processing and HTST thermal processing conditions. When a liquid such as milk is processed at this temperature, it may develop a “cooked” flavour. Special processes
have been developed to minimize off-tastes.

Since water boils at about 100°C, processes involving temperatures higher than this must be done in pressurized systems.

### 4.3.3 Pasteurization Systems:

Pasteurization is not commonly done in batch processes. Batch processing tends to be labour-intensive and slow. In addition, it can create unpleasant off-flavours in the milk due to the long exposure to heat.

Batch pasteurization has been replaced by continuous HTST (high temperature short time) processing. Modern dairies use sophisticated state-of-the-art computerized equipment with elaborate built-in safety features. We will examine the processing equipment in the Intermediate Thermal Processing Course.

In addition to heating the milk, these processes cool the milk prior to sending it to refrigerated storage tanks where it is held briefly before being sent to the filling lines where it is packaged in containers for distribution and sale to consumers.

Since milk is not sterilized, it must be kept refrigerated through all steps in the distribution chain. Refrigeration is a “hurdle” to extend the shelf-life of the milk. Pasteurized milk may have a shelf-life of up to approximately two weeks. Therefore, it must be monitored to ensure that it is sold within a short period of time. If milk is not sold before its “best before” date then it should be removed from the distribution system and “disposed of” in a responsible manner.

The “best before” date is a date placed on products that indicates to the consumer the expected usable life of a product. Some products such as canned goods are considered to be acceptable for one or two years following processing. Dairy products and meats have a much shorter storage life before they are considered to be unsuitable for consumption.
CHAPTER 5: BLANCHING

5.1 Introduction:
Blanching might best be described as the equivalent of pasteurization for fruits and vegetables. Its primary aim is to destroy enzymes present in the foodstuff that would cause quality degradation under refrigerated or frozen storage conditions.

Some microorganisms will be destroyed during the blanching process. Fruits or vegetables that are to be canned, rather than frozen, would need to be sterilized to a commercial level, rather than being blanched.

5.2 Reasons for Blanching:
While one of the primary reasons for blanching is to reduce the occurrence of enzymatic reactions, this is not the only reason. You may also be wondering why certain fruits and vegetables need to be blanched when they are going to be thermally processed anyway. Let’s deal with this question first.

Between the time a product is harvested and the time it is canned and thermally processed, there can be a loss of quality due to enzymatic degradation. By blanching the product as soon as possible after harvesting, it is possible to reduce spoilage and nutrient loss that might have occurred before the product undergoes its full heat processing.

Sometimes, there may be gases trapped within the tissues of the fruits or vegetables. These gases are from the product’s respiration. Blanching releases these gases before the product is canned and heated. If the respiratory gases were not removed prior to canning, they could actually be released in the can with negative results such as the reduction in vacuum and product spoilage.

Blanching may also soften the product and cause it to shrink in size. This permits easier filling of cans and allows processors to get more product into a given sized can.

A very significant effect of blanching is that it cleans the surface of the product and may destroy any surface microorganisms that are present.

Blanching also adds water to some products. This hydration can improve the quality of the product.

5.3 An Example of Blanching:
Probably one of the most striking examples for examining blanching would be cauliflower.

For those who may be unfamiliar with cauliflower, it is a type of vegetable with a white head surrounded by green leaves. The edible white head consists of many smaller portions often called “florets”. These florets are cooked by boiling them in water until they are soft and tender. Once the excess water has been drained away, the cooked florets
can be served with a cheese sauce or eaten plain with a light coating of butter. A fresh cauliflower is shown in Figure 5-1. Notice its creamy white colour which contrasts well in the photo with the darker leaves.

Figure 5-1: A fresh cauliflower

Unfortunately, there is a naturally-occurring enzyme which is present in the tissue of cauliflower called “polyphenol oxidase”. As the cauliflower ages after harvesting, this enzyme reacts with certain compounds within the cauliflower to create undesirable products with a dark colour. The cauliflower head will begin to turn a light brown colour and then darken to deep purple or black. Figure 5-2 shows the same cauliflower as shown in Figure 1 after it has been kept at room temperature. The previously appealing white florets have now darkened to an unpleasant brown colour.

Cauliflower florets can be frozen for later use. However, even with freezing, the enzyme can still cause the unwanted colour change. One way to reduce or eliminate the action of the polyphenol oxidase enzyme is through blanching, which is a mild thermal treatment designed to destroy or denature the offending enzyme.

Figure 5-2: The same cauliflower with dark brown discolouration after aging

To blanch cauliflower, the florets are broken apart from the main head of the cauliflower. The pieces should be small enough to allow rapid penetration of heat but not allow the florets to become overly soft or mushy. In Figure 5-3, we can see how a larger portion of the cauliflower has been broken down into smaller florets which have been placed in a wire-mesh strainer.

Figure 5-3: Florets of cauliflower ready for blanching
Some of the florets in the photo are already showing signs of browning due to delays in blanching the fresh cauliflower.

The strainer is then lowered into a large pot of boiling water to immerse the florets (see Figure 5-4). Due to the cooling effect, the water may stop boiling. Once boiling has resumed, timing of the blanching process can begin. Typically about two minutes are required for a blanching process such as this. By blanching small amounts of product, the time taken for the water to resume boiling can be reduced from the time taken for larger batches.

To stop the heating of the cauliflower, the strainer can be easily removed from the boiling water (see Figure 5-5) and the hot cauliflower can be plunged into cold water. After removal from the cold water, the blanched florets can be gently blotted with a clean paper towel to remove any excess water on their surfaces. They can then be spread on a tray and frozen. Once frozen, the florets can be transferred to plastic bags or other appropriate containers and be kept frozen until required for use.

It is not only cauliflower that requires blanching. Most fruits and vegetables are blanched prior to freezing or drying for the reasons discussed previously.

5.4 Industrial Blanching Processes:

The blanching process we have just examined is a small-scale operation designed for use in the home. For applications where commercial-scale quantities of product must be processed in a relatively short period of time, a much larger scale operation would be required.

Commercial blanching can be done with water or steam.

For hot water blanching, the product can be placed on a moving wire-mesh belt and moved through a hot water bath. Typically, the water is maintained at temperatures in the range of 90°C to 95°C. In other processes, the product may be conveyed by a screw device through a rotating drum which is partially filled with hot water. This keeps the...
product in contact with the water while controlling the time during which it is exposed to the blanching process. In yet another hot water process, the product may be pumped through a pipe by a stream of hot water. Steam is injected into the pipe at regular intervals to maintain the desired temperature and to keep the product circulating in the pipe.

One of the problems associated with hot water blanching is the large quantities of water and heat required. There can be nutrient losses from the product into the water or small pieces of broken product may get into the water. This creates a problem in dealing with the effluent, which is the water leaving the process.

Continuous steam blanchers are a good alternative to hot water blanchers. In continuous steam blanchers, the product is generally placed on a wire-mesh conveyor and moved through a steam chamber into which steam is injected through a system of nozzles. This process is generally not energy efficient as a great deal of heat is lost to the surroundings and excessive amounts of steam are used during the time that it takes for the heat to penetrate to the innermost parts of the food being blanched.

In 1974, Drs. Mel Lazar and Daryl Lund were granted a patent (U.S. Patent No. 3,794,500) for their process of deactivating enzymes at the inner core of foods by using a retained heat method of blanching. This was a significant advance in the approach to blanching since steam was no longer applied during the entire blanching process. ABCO Industries Limited of Lunenburg, Nova Scotia, Canada developed a patented blancher which combines a steaming chamber with a holding chamber. The idea here is to heat vegetables such as corn (i.e., maize) either on the cob or off the cob in a well-insulated steam chamber until the surface reaches a desired temperature. The product is then conveyed to a second chamber where it is held until the heat at the surface can penetrate to the centre of the product. In this manner, significant efficiencies are realized when compared to conventional steam blanchers. Not only is the amount of steam reduced, but the effluent from the ABCO Blancher is about one-sixth that from other blanching systems. The ABCO Blancher can be viewed on the company website at: www.abco.ca/blanchers.html

The ABCO approach is essentially a modification of a method known as I QB (Individual Quick Blanch). This involves subjecting each particle of food to an atmosphere of steam for a relatively short period of time and then holding a large amount of product in a deep bed until the heat has been evenly distributed throughout the entire product.

5.5 Summary Comments:

Different fruits and vegetables have different blanching requirements. In addition, different processors may have their own specific procedures for blanching. The description of the blanching process presented here is intended to be general in nature. Your
blanching process may not be exactly the same as those presented here.

There are numerous sources of information available in textbooks and on the internet. In addition, individual processors will have their own preferences.
6.1 Introduction:

One of the things that you need to do in thermally processing foods is calculate the specific time and temperature relationship in thermal processing. Similarly, you may need to calculate the amount of heat that must be removed to cool a food product. Even if you do not have the responsibility for doing these calculations, having a good understanding of the principles involved will assist you greatly in understanding the reasoning behind certain practices.

6.2 Water - The Basic Ingredient:

Most of the food we eat, especially fruits and vegetables, have a high water content. Apples contain about 84% water by weight, which means that for every kilogram of apples there will be 840 grams of water and 160 grams of dry solids. Tomatoes may contain up to 95% water by weight. One kilogram of tomatoes will contain 950 grams of water and only 50 grams of dry solids.

From these two examples, it is quite obvious that water will have a major impact on the properties of food products.

Let's take a look at some of the properties of water.

Water can exist as a solid, liquid, and gas at temperatures which can be easily achieved in food processing facilities. At temperatures below 0°C, pure water freezes and becomes ice. At approximately 100°C, water boils and changes from its liquid form into steam. At temperatures between its freezing point and boiling point, water is in its liquid form. In addition to this, water can also be present as a vapour (i.e., a gas) at these temperatures.

Water is known as the “universal solvent” since many different compounds will dissolve in it. Sugars are very soluble in water and are used to form sweet syrups. Sugars are present in the juice of apples which gives them their characteristic sweetness.

When compounds are dissolved in water, the properties of the water are changed. Fruit juices with their naturally-occurring sugars freeze at temperatures below the normal freezing point of pure water. They also boil at temperatures above the boiling point of pure water.

When heat is applied to water, it takes a certain amount of heat to raise the temperature of one kilogram of water by one degree on the Celsius scale. We call this the specific heat of water. It is also referred to as heat capacity.

It takes 4.187 kilojoules of heat energy to raise the temperature of one kilogram of water by one Celsius degree.

When the water and other components in a food are considered together, these other components tend to lower the
specific heat capacity of the food. For example, the sugars and other solids present in an apple give it a specific heat capacity of 3.651 kJ / kg / °C.

This means that 3.651 kiloJoules of heat energy must be added to one kilogram of apples to raise the temperature by one Celsius degree. Similarly, 3.651 kiloJoules of heat would need to be removed from one kilogram of apples to lower the temperature by one Celsius degree.

We will examine an equation to calculate the specific heat capacity of food products in the Intermediate Thermal Processing Course. In the meantime, we will simply use some values from literature sources.

### 6-3: Example Thermal Properties

Thermal properties of some food products are listed in Table 6-1. These include specific heat capacities above and below the freezing points of the products, and latent heats of fusion. They have been calculated based on the relationships presented here using representative moisture levels (see reference source below Table 6-1).

To convert one kilogram of liquid water to steam at 100°C requires 2,259 kiloJoules of heat energy. This heat is referred to as the “heat of vaporization”. Similarly, to produce one kilogram of ice at 0°C from one kilogram of water requires the removal of 334 kiloJoules of heat energy. The conversion from liquid water to solid ice is referred to as “heat of fusion”.

<table>
<thead>
<tr>
<th>Material</th>
<th>Moisture Content (by weight)</th>
<th>Specific Heat Above Freezing (kJ / kg C˚)</th>
<th>Specific Heat Below Freezing (kJ / kg C˚)</th>
<th>Freezing Point (°C)</th>
<th>Latent Heat of Fusion (kJ / kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apples</td>
<td>84%</td>
<td>3.651</td>
<td>1.892</td>
<td>-1.1</td>
<td>280.18</td>
</tr>
<tr>
<td>Dried Apple</td>
<td>24%</td>
<td>1.641</td>
<td>1.139</td>
<td>not available</td>
<td>not available</td>
</tr>
<tr>
<td>Bananas</td>
<td>75%</td>
<td>3.349</td>
<td>1.779</td>
<td>-0.8</td>
<td>250.16</td>
</tr>
<tr>
<td>Grapes</td>
<td>82%</td>
<td>3.584</td>
<td>1.867</td>
<td>-1.6</td>
<td>273.51</td>
</tr>
<tr>
<td>Peaches</td>
<td>89%</td>
<td>3.818</td>
<td>1.955</td>
<td>-0.9</td>
<td>296.86</td>
</tr>
<tr>
<td>Dried Peach</td>
<td>25%</td>
<td>1.675</td>
<td>1.151</td>
<td>not available</td>
<td>not available</td>
</tr>
<tr>
<td>Bread</td>
<td>34%</td>
<td>1.993</td>
<td>1.271</td>
<td>-2.2</td>
<td>106.74</td>
</tr>
<tr>
<td>Water</td>
<td>100%</td>
<td>4.187</td>
<td>2.050</td>
<td>0</td>
<td>333</td>
</tr>
</tbody>
</table>

Based on information from the American Society of Heating, Refrigerating, and Air-Conditioning Engineers from the 1986 ASHRAE Handbook - Refrigeration
The reverse of “heat of vaporization” is “heat of condensation” (when steam condenses to liquid water). This will be important when we discuss using steam as a heat source for thermal processing.

6-4: Practice Problems with Solutions

Question 1:

How much heat must be added to 25 kg of mashed bananas to raise their temperature from 20°C to 75°C?

Solution: For this problem, we need to use the equation:

\[
\text{Heat} = Q = m \cdot C_p \cdot \Delta T
\]

Where:
- \( Q \) = heat required in kiloJoules (kJ)
- \( m \) = mass of the material in kilograms (kg)
- \( C_p \) = heat capacity of the material in kiloJoules per kilogram of material per Celsius degree of temperature change. (kJ / kg °C)
- \( \Delta T \) = change in temperature of the material in Celsius degrees (°C)

The weight of the bananas is given as being 25 kg, so: \( m = 25 \) kg

Based on information in Table 6-1, the heat capacity of bananas is 3.349 kJ/kg °C. Since the initial temperature is 20°C and bananas freeze at -0.8°C, we know that we should use the \( C_p \) value above the freezing point.

The one remaining item to calculate is the change in temperature (i.e., \( \Delta T \)):

\[
\Delta T = 75°C - 20°C = 55°C
\]

Heat to be added = \( m \cdot C_p \cdot \Delta T \)

\[
= \frac{25 \text{ kg}}{\text{kg}} \cdot 3.349 \text{ kJ/cm} \cdot 55 \text{ cm°C} \cdot \frac{1}{\text{kg°C}} \cdot \frac{1}{\text{cm°C}}
= 4,604.9 \text{ kJ}
\]

Therefore, approximately 4,605 kJ of heat must be added.
Question 2:

1,500 kg of milk is stored at 4°C and must be pasteurized at 73°C for 15 to 30 seconds. How much heat would be used to pasteurize the milk if the heat capacity of the milk is 3.751 kJ / kg C?

Solution: Once again, we need to use the equation:

\[ \text{Heat} = Q = m C_p \Delta T \]

Everything is given except the value of \( \Delta T \), which must be calculated.

\[ \Delta T = 73°C - 4°C = 69°C \]

Heat to be added = \( m C_p \Delta T \)

\[ = \frac{1,500 \text{ kg}}{} \cdot \frac{3.751 \text{ kJ}}{} \cdot \frac{69 \text{ C}^°}{\text{ kg C}^°} \]

\[ = 388,228.5 \text{ kJ} \]

Therefore, approximately 388,229 kJ of heat must be added.

The pasteurization time is not used in this calculation. It is just extra information.
Question 3:

A grower picks 75 kg of ripe apples from his orchard on a day when the temperature is 29°C. In order to reduce the risk of spoilage, he needs to cool the apples as quickly as possible. If the apples are cooled to 10°C, how much heat must be removed?

Solution: In this case we are removing heat to cool the apples, but the equation is the same as that used to calculate the heat that must be added.

Recall: \[ \text{Heat} = Q = m \cdot C_p \cdot \Delta T \]

In order to avoid confusion with positive and negative signs, we will always use a positive \( \Delta T \). We will then say that the heat is either being added or removed. This will convey the direction in which the heat is going.

The first thing to do is calculate the value of \( \Delta T \):

\[ \Delta T = 29°C - 10°C = 19°C \] (note this is kept as a positive value)

From Table 6-1, the \( C_p \) for apples is 3.651 kJ/kg°C.

Heat to be removed = \( m \cdot C_p \cdot \Delta T \)

\[
= \frac{75 \text{ kg}}{} \cdot \frac{3.651 \text{ kJ}}{} \cdot \frac{19 \text{ °C}}{} \\
= 5,202.7 \text{ kJ}
\]

Therefore, approximately 5,203 kJ of heat must be removed. (The answer could be rounded off to 5,200 kJ, if desired).
**Question 4:**

What would the final temperature be if 1,500 kJ of heat were added to 15.6 kg of fresh peaches having an initial temperature of 8°C?

**Solution:** As usual, the equation to use for heating and cooling is:

\[
\text{Heat} = Q = m \cdot C_p \cdot \Delta T
\]

In this case, we know:
- \( Q \) which is the amount of heat added
- \( m \) which is the weight (or mass) of the peaches
- \( C_p \), which is the heat capacity of the peaches, can be found in Table 6-1. It is 3.818 kJ/kg°C

We know the initial temperature, so if we find the value of \( \Delta T \), we can calculate the final temperature of the peaches.

By re-arranging the equation, we can find the value of \( \Delta T \):

\[
\Delta T = \frac{Q}{C_p \cdot m} = \frac{1,500 \text{ kJ}}{3.818 \text{ kJ/kg°C} \cdot 15.6 \text{ kg}} = 25.18 \text{ °C}
\]

The \( \Delta T \) value is approximately 25°C.

The final temperature is equal to the initial temperature plus the temperature change.

Final temperature = 8°C + 25°C = 33°C
CHAPTER 7: SUMMARY

7.1 Closing Comments:

This concludes the “Introduction to Thermal Processing of Food Products” course. We have covered a great deal of material in the previous five chapters. Hopefully your understanding of the basics of thermal processing will permit you to move on to the "Intermediate Course in Thermal Processing of Foods". There, you will become involved in more of the calculations relating to thermal processing and will apply much of the material presented in this Introductory Course.

As you may have noticed, thermal processing has many close ties to Food Microbiology. It is the presence of undesirable microorganisms which causes food products to spoil and may lead to more serious problems such as food-borne diseases.

In today’s global economy, food products are transported across continents and around the world. Food produced improperly in a small processing facility in one country can cause illness and death in another country thousands of kilometres away. For this reason, most countries have strict rules about how foods should be processed.

If a processor in Africa wishes to sell a thermally processed product in Europe or North America, then the processor must provide documentation that the products being shipped to those destinations have been produced in accordance with the regulations of the country in which they will be sold. Food inspectors may conduct tests on the food products to ensure that they meet the standards of the country in which they will be sold. Failure to meet these standards may result in the product being destroyed or sent back to its country of origin - both at the expense of the company that manufactured the below-standard product. This now brings “Food Laws” into the picture.

We hope that you have enjoyed this course and have learned from it. We look forward to having you continue by progressing to the “Intermediate Course in Thermal Processing of Foods”.

7.2 Sources of Information:

Numerous textbooks have been written on the subject of Thermal Processing. While they may not be readily available, or their cost may be excessive, the Internet can provide an alternate source of valuable information.

When using internet sources, please be sure to check the reliability of the information contained in the articles. This can be done by examining the background of the author or authors.

One extremely good source of information is available through a “web edition” on the internet. Through the kind generosity of Dr. Richard (Dick) and Dr. Mary Earle of New Zealand, the
book entitled “Unit Operations in Food Processing” has been made freely available to anyone wishing to access it. This is truly a classic textbook originally written by Dr. Richard Earle in 1966. The Food Science Community is grateful to the Earles for their kindness.