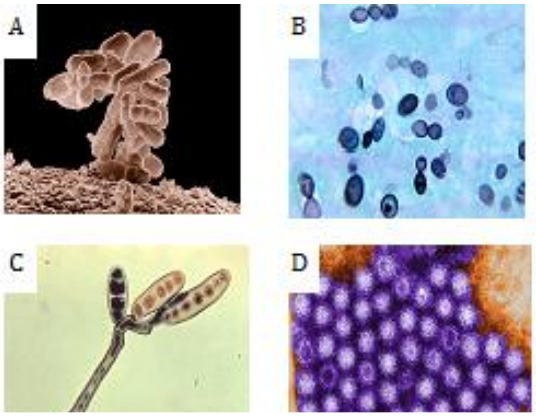
How Microorganisms Affect Food Safety and Quality

All raw food items contain microorganisms. These microorganisms can eventually lead to food spoilage or even foodborne illness. In order to prevent food from spoiling or causing illness, we use different methods of food preservation to control the growth of microorganisms associated with food. With an understanding of how food microorganisms grow and survive, we can more effectively preserve food and increase the safety of the foods we eat.

Each year, nearly 1 in 6 Americans suffer from foodborne illness. These illnesses cause approximately 128,000 hospitalizations and 3,000 deaths. Most foodborne illness can be prevented through proper food processing and handling techniques. Food regulations are focused on keeping the food supply safe, and the requirements put in place are established with food safety, rather than quality, in mind. However, with a sound understanding of how food microorganisms grow and survive, the food processor can control or destroy microorganisms and even improve food quality.

Microorganisms that are the primary concern to food processors include bacteria, yeasts, molds, and viruses. Bacteria are associated with both food spoilage and foodborne illness. Yeasts and molds are most often associated with food spoilage. Viruses are a food safety issue. Microorganisms that cause food spoilage and degrade food quality are not the same microorganisms that cause foodborne illness. You cannot look at a food and know that it is not safe to eat.



Microscopic images of A) Bacteria B) Yeast C) Mold and D) Virus particles

Food spoilage microorganisms cause food to look, smell, taste, and/or feel different, but will not cause illness. Foodborne pathogens will not alter the look, taste, smell, or feel of a food, but WILL cause illness. Therefore, it is of utmost importance that food is properly processed and preserved to prevent foodborne illness, because there are no obvious signs that foods are not safe to eat.

Not all food microorganisms are bad. In fact, they can be beneficial. Microorganisms are used in the food industry to make bread rise, ferment beer and wine, and to make pickles and sauerkraut. Many yogurt and dairy products contain probiotics, which are bacteria that promote healthy digestion.

Knowing that there are microorganisms that are desirable in food, as well as those that cause spoilage, and some that cause illness, it is important as a food processor to understand the conditions that affect how these microorganisms grow and survive. An understanding of the growth requirements of the different types of microorganisms will allow the food processor to better control microorganisms in food.

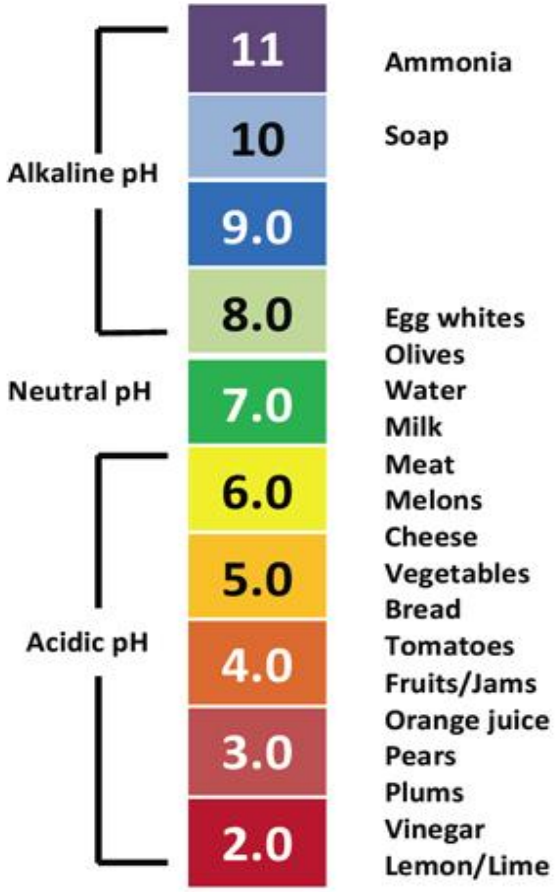
The following factors will influence the growth of bacteria: **food**, **acidity**, **temperature**, **time**, **oxygen**, and **moisture**.

Food

Bacteria must have access to nutrients in order to survive and grow. Often they find their source of nutrients in the same place that we do: in our food. Bacteria need sugars, proteins, and some other materials such as calcium and phosphate to survive. Since removing the food from our food product would leave us empty handed, we must look to other ways to control microorganisms.

Acidity

Much like there is a scale to measure how hot or cold a substance is (temperature), there is also a scale to measure the acidity of a product: **pH**. Acidity is perhaps the most important component of food preservation that can be manipulated in food. The pH scale ranges from 0 to 14. Acidity increases as pH values decrease. Below pH 7, foods are considered acidic. At pH of 7, the acidity is neutral. Above 7, foods are considered basic. Almost all food falls into the acidic category (pH below 7). Egg whites are one of the few foods that fall into the basic category (pH ~ 8).



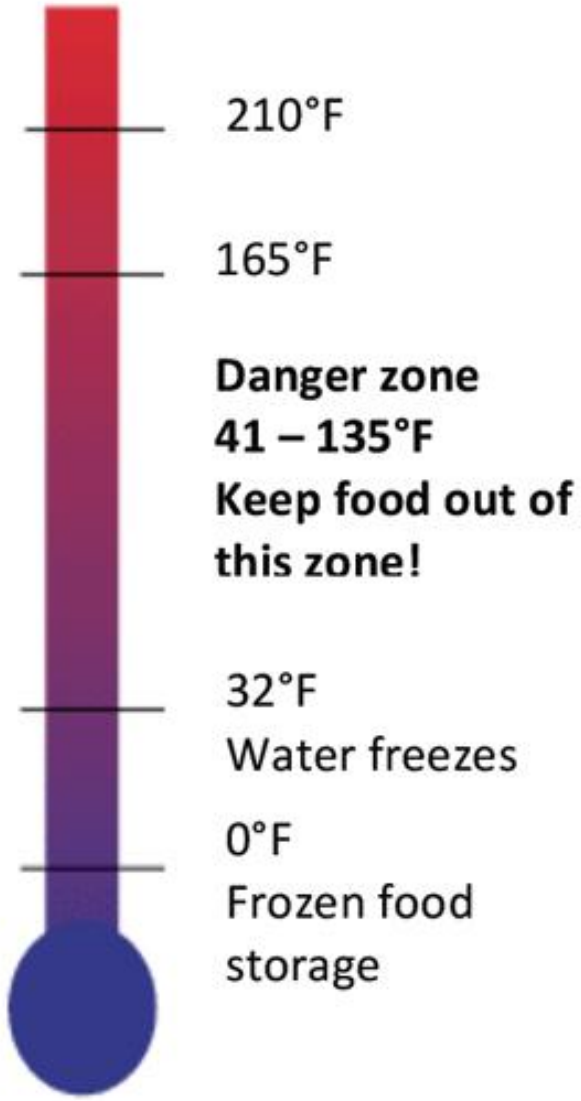
Beyond acidic and basic, we classify foods as **acid** or **low acid**. As mentioned above, almost all foods are acidic. But, in order for it to be considered an acid food, the pH must be 4.6 or below. These foods have enough acidity to prevent most pathogenic microorganisms from growing.

Acid foods include most fruits and fruit juices, vinegar, jams, jellies, and honey. Products may be naturally high in acid or you might acidify products by adding acid (e.g., vinegar, wine, Worcestershire sauce, or lemon juice) to lower the pH. Pickling foods (by adding acid or through natural fermentation) lowers the pH enough to discourage many microorganisms.

Low acid foods have a pH of above 4.6. These foods do not have enough acidity to prevent the growth of pathogenic organisms. Examples of low-acid foods include beans, vegetables, meat, and milk.

Time and Temperature

Bacteria grow through binary fission, meaning that they replicate by dividing in two. Most bacteria replicate, or divide in two, every 15 to 20 minutes under ideal conditions. Ideal conditions for pathogenic bacteria are between 41°F and 135°F. This range is often referred to as the "Temperature Danger Zone". Pathogenic bacteria can proliferate quickly in the Temperature Danger Zone, to the point where they can cause foodborne illness if allowed to grow for long enough time. Therefore, it is important to hold potentially dangerous food below 41°F (refrigeration or freezing) or above 135°F (hot-holding), to keep it out of the Temperature Danger Zone. If a potentially dangerous food is exposed to the Temperature Danger Zone, it may only be there for 4 hours or less. Once it has been exposed to the Temperature Danger Zone for more than 4 hours, it must be thrown out.



Oxygen

Different microorganisms have different oxygen requirements to survive and grow. One group needs the same amount of oxygen that is present in the atmosphere. These are known as aerobic microorganisms. Aerobic microorganisms commonly include yeasts, molds, and spoilage bacteria.

Some microorganisms need oxygen to be absent in order to grow. These microorganisms are known as anaerobes. Anaerobic microorganisms can grow when oxygen is removed, like in vacuum packaged foods, or in canned foods. *Clostridium botulinum*, the bacteria that causes the foodborne illness botulism, is an anaerobic bacteria. Therefore if you have a situation where your food has no oxygen present (canned or vacuum packaged foods), other factors need to be in place to prevent the growth of *Clostridium botulinum*.

A third category of microorganisms are known as facultative anaerobes, which are capable of growth in the presence or absence of oxygen. Most foodborne pathogens are facultative anaerobes. Since aerobic microorganisms need oxygen to grow, their growth can be stopped or delayed by reducing oxygen levels. This is often employed to delay food spoilage. However, reducing oxygen levels may create environments ideal for pathogenic bacteria. Therefore, other growth conditions need to be controlled if oxygen is removed or reduced.

Moisture

In foods, the moisture content is typically measured using water activity (a_w). Water activity is a measurement of the amount of free water that is available in a food for microorganisms to use for growth. In food, water can interact with other components of food, such as salt and sugar. When water binds to these components, it is no longer available for microorganisms to use for growth. Water activity is measured on a scale of 0.0 to 1.0. Pure water has an a_w of 1.0.

Pathogenic bacteria cannot grow when a_w is 0.85 or below. Therefore, a_w can be used to safely preserve foods. There are several ways to lower a_w in food. One way is to add ingredients to bind water, like salt or sugar. Another way is to remove water, as is often done with dehydration. Once the a_w of a food is brought to 0.85 or below, the food is considered shelf stable and may be stored at room temperature. Water activity is often the method used to keep foods such as jams, jellies, bread, and cookies safe and shelf stable.

a_w	Microorganisms that can grow
0.95	*Salmonella*, *E. coli*, *Bacillus cereus*
0.90	*C. botulinum*, *Listeria monocytogenes*
0.87	Yeasts, *Staphylococcus aureus*
0.80	Molds, *Saccharomyces* spp.
0.60	Some yeasts and molds

Now that you have a basic understanding of how the conditions in food can affect the way microorganisms grow, you can manipulate your food to create a safe product. The main methods of preservation for shelf-stable foods are controlling the water activity or lowering the pH. Factors are often combined, like lowering pH AND using refrigeration. Understanding how food supports the growth of microorganisms can help improve both food safety AND food quality.

Even with a strong understanding of how certain properties of your food effect safety and quality, it is often necessary to seek assistance to ensure a safe product. Often, the critical values which must be met in order to ensure the safety of food cannot be determined without laboratory tests. If you ever have concerns about the safety of your food or the conditions your food must meet in order to be a safe and wholesome product, please contact the Virginia Tech Food Innovation Program (www.ext.vt.edu/foodinnovations).

More information on keeping food safe can be found at: http://pubs.ext.vt.edu/FST/FST-9/FST-9.html