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Food Microbiology/ Foodborne Illness

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Microorganisms in Food

Bacteria, yeasts, and mold are microorganisms associated with foods. The individual microorganism cannot be seen without the aid of a microscope. The size of these microorganisms are measured in microns (1 micron is 1/1000 of a millimeter or 1/25,400 of an inch). More than a thousand microorganisms in a cluster are barely visible to the eye.

Microorganisms may be classified into three groups according to their activity. **Beneficial microorganisms** may be used in the process of making new foods. Cheese is made with microorganisms which convert the milk sugar to an acid. **Spoilage microorganisms** cause food to spoil and are not harmful to humans. A spoilage microorganism is responsible for souring milk. **Pathogenic microorganisms** are disease causing microorganisms. The living microorganism or a toxin (microbial waste product) must be consumed to cause symptoms associated with specific pathogenic microorganisms.

Microorganisms may exist as living cells; referred to as vegetative cells. Vegetative microorganisms are actively growing. Some microorganisms have hairlike appendages called flagella. Flagella allow microorganisms to attach to surfaces.

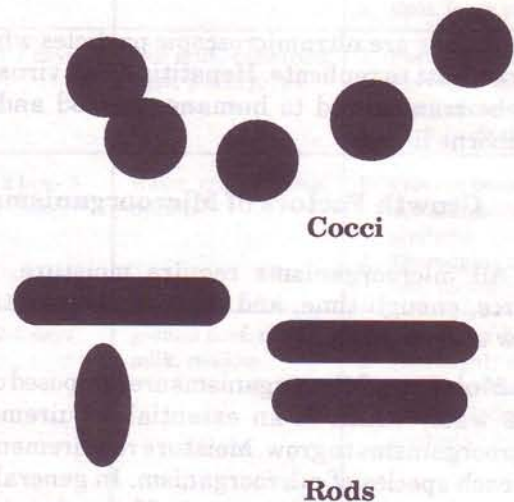
Some microorganisms can exist in a dormant state. These microorganisms produce a spore which may remain dormant for years. Under the proper conditions, spores may develop into vegetative microorganisms.

Microorganisms can be found virtually everywhere. Bacteria and molds are found in the soil and water. Yeasts are found mainly in the soil. Plant and animal food products support the growth of microorganisms. Bacteria have been detected on plants and animals; molds are usually found on fruits and vegetables; yeasts are generally found on fruits. Many bacteria are part of the normal microflora of the intestinal tracts of man and animals.

Microorganisms may be transferred from soil and water to plants and animals. Raw food stuffs contain microorganisms which may be transferred to processed foods by careless handling. Food handlers with poor hygiene practices may transfer microorganisms to food. If suitable conditions exist, some of these microorganisms may grow to create a public health concern. Specific bacterial species are the main causes of foodborne illnesses in humans.

Bacteria

Bacteria are single cell organisms which can be identified on the basis of their cell shape. There are round bacteria called *cocci*, rod shaped cells called *bacilli*, curved bacteria (the *vibrios*), and corkscrew-shaped *spirilla*. Single bacterial cells grow and multiply into chains, clumps or organized clusters. Harmful bacteria may cause food poisoning. Useful bacteria are used to make yogurt and several other fermented foods.



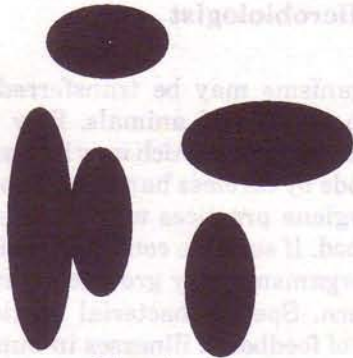
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Yeast

Yeasts are single cell fungi (plants without chlorophyll) with various shapes when viewed under a microscope. Yeasts are undesirable when they cause spoilage in foods such as jams, jellies, honey, sauerkraut, and beverages. However, gas produced by yeast causes bread to rise and the production of beer.



Yeast

Mold

Mold growth on foods appears fuzzy or cottony and may be colored. Molds are multicell microorganisms which consist of filaments called **hyphae**. The whole mass of hyphae is called the **mycelium**. Hyphae may be growing below the surface of the food. Some molds do produce toxic substances (mycotoxins). Useful molds allow production of blue cheese.

Virus

Viruses are ultramicroscopic particles which require a host to replicate. Hepatitis A is a virus which can be transmitted to humans via food and cause foodborne illness.

Growth Factors of Microorganisms

All microorganisms require moisture, a food source, enough time, and suitable temperatures to grow and multiply.

Moisture. Microorganisms are composed of about 80% water which is an essential requirement for microorganisms to grow. Moisture requirements vary for each species of microorganism. In general bacteria need more water than yeasts. Yeasts require more water than molds to grow.

If water is not available for microorganisms in a food product, the microorganisms may remain but will not grow and multiply. Certain components in foods will make water unavailable for microorganisms.

Water Activity (A_w) describes the degree of water available in food. Water activity in foods ranges from 0 to 1.0. Water activity for various foods is listed in Table 1.

Table 1. pH values, A_w values of common foods.

| Food | pH range | A_w range |
|--------------------------------------|----------|-------------|
| Fruits, fresh (most) | 2.8-4.6 | 0.97-1.0 |
| Melons | 5.2-6.7 | |
| Juices | 2.2-3.5 | 0.97 |
| Vegetables, fresh, canned (low-acid) | 4.8-7.0 | 0.93-1.0 |
| Tomatoes | 4.1-4.6 | 0.93-1.0 |
| Meats-fresh | 5.3-6.4 | 0.95-1.0 |
| Poultry | 5.5-6.4 | 0.95-1.0 |
| Fish | 6.2-7.1 | 0.95-1.0 |
| Processed meats/fish | | |
| Ham | 5.9-7.0 | 0.85-0.90 |
| Lunch meat | 6.2 | 0.93-0.97 |
| Canned meat | 4.5-5.2 | 0.93-0.97 |
| Tuna | 5.9-6.1 | 0.93-0.97 |
| Eggs | 6.0-9.5 | 0.90 |
| Milk | 6.5-7.0 | 0.98-0.99 |
| Cheese | 4.5-5.4 | 0.68-0.98 |
| Butter | 6.1-6.4 | 9.75-0.84 |
| Yogurt | 3.7-4.4 | 0.95-0.98 |
| Flour | | 0.67-0.84 |
| Pasta | | <0.60 |
| Cake | | 0.90-0.94 |
| Breads | 5.0-6.0 | 0.94-0.96 |
| Cereal/Crackers | | 0.10-0.20 |
| Snack chips | | <0.60 |
| Jams, jellies | 3.0-5.0 | 0.60-0.85 |
| Honey | 3.0-5.0 | 0.60-0.85 |
| Mayonnaise | 3.0-3.8 | |
| Salad dressings | 3.7 | |
| Vinegar | 2.9 | |

Most bacteria cannot grow at a water activity of less than 0.91. Yeasts can grow at water activities as low as 0.87. Molds do not grow at water activities of less than 0.80. Water activity ranges are given for bacteria in Table 2.

Sugar and salt added to foods "tie" up water and lower the water activity. When enough sugar or salt is added to a food, the water activity will be lowered to a level that will prevent microorganisms from growing. In general, bacterial growth is inhibited by the addition of 5-15% salt. Yeasts and molds can tolerate up to 15% salt. To inhibit mold growth, 65-70% sugar must be added. The addition of up to 50% sugar will inhibit bacteria and yeast growth.

Some microorganisms are tolerant of certain conditions. *Halophilic* (salt-liking) microorganisms require salt to be present for the organism to grow. *Osmiophilic* (sugar-liking) microorganisms, usually yeasts, grow best at high concentrations of sugar. *Xerophilic* (dry-liking) microorganisms can grow with limited moisture.

Table 2. pH and A_w of bacteria.

| Bacteria | pH range | Minimum A_w |
|---------------------------------|------------|---------------|
| <i>Staphylococcus aureus</i> | 4.3 - 9.0 | 0.83 |
| <i>Salmonella</i> | 3.8 - 9.0 | 0.95 |
| <i>Clostridium perfringens</i> | 5.0 - 8.9 | 0.96 |
| <i>Clostridium botulinum</i> | 4.8 - 8.5 | 0.95 |
| <i>Bacillus cereus</i> | 4.4 - 9.3 | 0.93 |
| <i>Listeria monocytogenes</i> | 4.5 - 8.0 | unknown |
| <i>Yersinia enterocolitica</i> | 4.4 - 9.6 | 0.97 |
| <i>Campylobacter jejuni</i> | 4.9 - 9.0 | unknown |
| <i>Vibrio cholerae</i> | 6.0 - 11.0 | 0.97 |
| <i>Escherichia coli</i> O157:H7 | unknown | unknown |

Food. Microorganisms need a source of nutrients to grow and multiply. Individual microorganisms have specific requirements. All microorganisms need an energy source. Carbohydrates provide the main source of energy. Protein is also required by microorganisms for growth. Other nutrients vary according to the species. Food from plants and animals provide these nutrients for microorganisms to grow.

Time. When microorganisms have suitable conditions, reproductive growth will occur. Microorganisms reproduce by dividing into two parts. Under favorable conditions (enough moisture and food available with the desired temperature), this division may occur every 20 to 30 minutes. The time for a microbial cell to double is called the **generation time**. Table 3 illustrates the large numbers which can result from one microbial cell under ideal conditions multiplying ever 20 minutes.

Table 3. Bacterial multiplication.

| Time in minutes | Number microorganisms |
|-----------------|-----------------------|
| 0 | 1 |
| 20 | 2 |
| 40 | 4 |
| 60 (1 hour) | 8 |
| 80 | 16 |
| 100 | 32 |
| 120 (2 hours) | 64 |
| 140 | 128 |
| 160 | 256 |
| 180 (3 hours) | 512 |
| 200 | 1024 |
| 220 | 2048 |
| 420 (7 hours) | 2,097,152 |

Microorganisms do not grow at a constant rate. Figure 1 illustrates the growth curve for a microorganism. Initially the microbial cells grow in size

MICROBIAL GROWTH CURVE

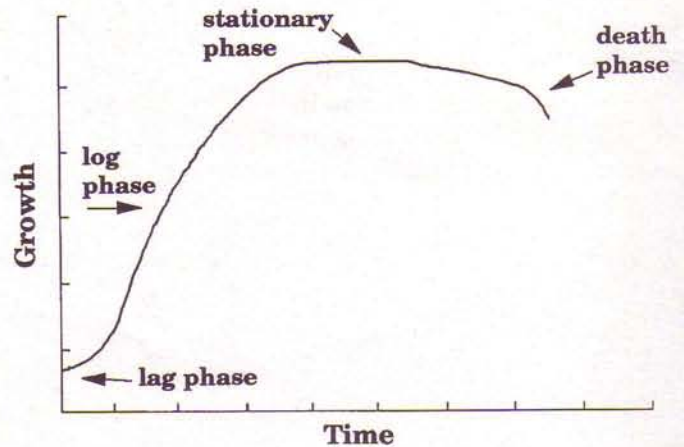


Figure 1. Bacterial growth curve.

rather than number. This is called the **lag phase**. The next phase is the **log phase** where growth is rapid. The third phase is called the **stationary phase**. During this phase the number of microbial cells produced equal the number of microbial cells that are dying; the total number of microorganisms remain the same. When the nutrients are depleted, the growth rate decreases. This is the **death phase**.

Temperature. Microorganisms grow best within certain temperature ranges. Bacteria are classified into three groups, depending on the temperature at which the bacteria grows best.

- * *Psychrophilic* (cold-liking) bacteria
 - Growth range 32-77°F
 - Optimum temperature 68-77°F
- * *Mesophilic* (middle-liking) bacteria
 - Growth range 68-110°F
 - Optimum temperature 68-113°F
- * *Thermophilic* (heat-liking) bacteria
 - Growth range 113-158°F
 - Optimum temperature 122-131°F

The bacteria which cause foodborne illness in humans grow best at body temperature (98.6°F - mesophilic bacteria). Psychrophilic bacteria are responsible for food spoilage in the refrigerator. *Psychrotrophic* bacteria can grow at refrigerated temperatures and grow rapidly at room temperatures. Another type of bacteria is *thermoduric* (heat tolerant) bacteria. These bacteria can survive but do not grow and multiply at high temperatures.

Yeasts thrive best at room temperatures, but are capable of survival for many weeks at temperatures well below freezing. Moderate heat (140°F) for a few minutes will destroy yeast.

Molds will flourish at room temperatures, but can grow from 32-108°F.

Many microorganisms can survive freezing temperatures but cannot grow or multiply at low temperatures.

Oxygen. Microorganisms differ in their requirements for oxygen. **Aerobic** bacteria require oxygen to survive. **Anaerobic** bacteria grow in the absence of oxygen. Oxygen is toxic to these types of bacteria. **Facultative anaerobes** grow in the presence or the absence of oxygen, preferring oxygen but capable of growth without oxygen.

Yeasts grow in the absence of oxygen, but multiply faster in the presence of oxygen. Molds are aerobic and require an abundant source of oxygen to grow.

pH. The acidity or alkalinity of a food affects the ability of a microorganism to survive and grow. pH is a measure of the acidity or alkalinity of a food. Most microorganisms prefer a pH near neutral (pH = 7.0). A list of foods with their pH range is given in Table 1. The general pH range of microorganisms is given in Table 2.

Light. Microorganisms usually grow best in the dark, although it is not a requirement. Ultraviolet light is lethal to microorganisms and may be used in some sterilization processes.

Foodborne Illnesses

"I must have the flu bug," is a common explanation for gastrointestinal upset. Flu-like symptoms are characteristic of many foodborne illnesses. Instead of the flu, food contaminated with pathogenic microorganisms may have been the cause of many stomach upsets.

It is estimated that more than 81 million cases of foodborne illnesses occur each year in the United States. Many of these illnesses are misdiagnosed as the flu and are not reported. Pathogenic (disease causing) microorganisms in food are the prime cause of foodborne illnesses.

Microorganisms that cause disease are found naturally in the environment. Foods contaminated with pathogenic microorganisms usually do not look bad, taste bad, or smell bad. It is impossible to determine whether a food is contaminated with pathogenic microorganisms without microbiological testing. To avoid potential problems in foods, it is very important to control or eliminate these microorganisms in food products.

Pathogenic microorganisms can be transmitted to humans by a number of routes. These routes include air, water, direct person-to-person contact, and food. Some pathogenic microorganisms can be transmitted to food by animals, or by contact with the soil, or by contact with contaminated surfaces and equipment.

Diseases which result from pathogenic microorganisms are of two types: infection and intoxication. **Foodborne infection** is caused by the ingestion of

food containing live bacteria which grow and establish themselves in the human intestinal tract. **Foodborne intoxication** is caused by ingesting food containing toxins formed by bacteria which resulted from the bacterial growth in the food item. The live microorganism does not have to be consumed.

For a foodborne illness to occur, the following conditions must be present:

- The microorganism or its toxin must be present in food.
- The food must be suitable for the microorganism to grow.
- The temperature must be suitable for the microorganism to grow.
- Enough time must be given for the microorganism to grow (and to produce a toxin).
- The food must be eaten.

The most common symptom associated with foodborne illnesses is diarrhea. Each pathogenic microorganism has its set of characteristic symptoms. Table 4 lists most of the pathogenic microorganisms with their growth ranges, nature of the illness each causes, and the time required for the symptoms to occur (incubation period). The table also lists the foods commonly associated with each pathogenic microorganism and control measures to prevent or eliminate growth of that microorganism in food.

The severity of the foodborne illness depends on the pathogenic microorganism or toxin ingested, the amount of food consumed (dose), and the health status of the individual. For individuals who have immunocompromised health conditions, or for the aged, children, or pregnant women, any foodborne illness may be life-threatening.

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Table 4. Pathogenic Microorganisms and Foodborne Illness

| Organism | Growth range | Foodborne illness | Symptoms of illness | Incubation period | Implicated foods | Control measures |
|--|--|---|---|-------------------|--|---|
| <i>Staphylococcus aureus</i> (Staph) | 45 - 118°F (7 - 48°C) | Staphylococcal Intoxication | abdominal pain, nausea, vomiting, diarrhea | 1-6 hrs | salads, cream filled pastry | 1. Proper hand washing 2. Prompt refrigeration in shallow containers |
| <i>Salmonella</i> | 43 - 115°F (6 - 46°C) | Salmonellosis Infection | abdominal pain, diarrhea, nausea, chills, fever | 6-48 hrs | raw or undercooked meats and poultry, eggs, unpasteurized milk | 1. Thoroughly cooked meat, poultry, eggs 2. Pasteurize milk 3. Prevent cross-contamination |
| <i>Clostridium perfringens</i> | 60 - 122°F (15 - 50°C) | Clostridium Perfringens Infection/ Intoxication | diarrhea, abdominal pain | 8-22 hrs | meat, meat products & poultry | 1. Keep hot foods above 140°F 2. Keep cold foods below 40°F 3. Properly cook meat and poultry products 4. Reheat to 165°F thoroughly |
| <i>Clostridium botulinum</i> types A & B | 50 - 122°F (10 - 50°C) | Botulism Intoxication | double vision, difficulty in speaking, swallowing, and breathing (can be fatal) | 12-48 hrs | canned foods | 1. Properly processed canned foods |
| <i>type E</i> | 38 - 113°F (3.3 - 45°C) | | | | fish | 1. Properly processed fish |
| <i>Bacillus cereus</i> | 42 - 122°F (5 - 50°C) | Bacillus cereus Intoxication | diarrhea, abdominal pain, nausea, vomiting | 8-16 hrs | rice & rice dishes; meat & meat products; seasonings, spices | 1. Cook food properly 2. Cool foods quickly 3. Prevent cross-contamination |
| <i>Listeria monocytogenes</i> | 34° - 113°F (1° - 45°C) | Listeriosis | meningitis, abortion, fever, headache, nausea, vomiting | 2 days - 3 weeks | vegetables, milk, cheeses, fermented meats | 1. Pasteurize milk 2. Prevent cross-contamination 3. Cook foods properly |
| <i>Yersinia enterocolitica</i> | 32° - 113°F (0° - 45°C) | Yersiniosis | enterocolitis; may mimic acute appendicitis | 1-3 days | raw milk, chocolate milk, water, pork and other raw meats | 1. Pasteurize milk 2. Prevent cross-contamination with raw products 3. Cook foods properly |
| <i>Campylobacter jejuni</i> | 86° - 117°F (30° - 47°C) | Campylobacteriosis | diarrhea, abdominal cramping, fever | 1-7 days | raw milk, cake icing, eggs, poultry, raw beef, water | 1. Pasteurize milk 2. Prevent cross-contamination 3. Cook foods properly |
| <i>Vibrio cholerae</i> | 59° - 108°F (15° - 42°C) | Vibrio Infection | watery diarrhea, vomiting, chills, fever | 12 hrs - 5 days | water, crab, shrimp, oysters | 1. Prevent cross-contamination with raw products 2. Thoroughly cook shellfish, including oysters |
| <i>Escherichia coli</i> 0157:H7 | unknown* 113°F (unknown - 45°C *No growth when incubated at 50°F (10°C) for 48 hrs | | severe abdominal cramps, bloody diarrhea, vomiting, nausea | 2-4 days | ground beef, raw milk, chicken | 1. Pasteurize milk 2. Thoroughly cook meat 3. Prevent cross-contamination with raw products |
| <i>Trichinella spiralis</i> | | Trichinosis | fever, muscular pain, weakness, swelling around eyes | 8-15 days | pork, wild game | 1. Thoroughly cook to 160°F |
| <i>Hepatitis A</i> | | Hepatitis | lethargy, loss of appetite, nausea, vomiting, fever, jaundice | 2-6 weeks | any food | 1. Proper hand washing 2. Personal hygiene practices |