DIVISION OF AGRICULTURE
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FOOD INDUSTRY CONCEPTS

FOOD PRESERVATION AND SAFETY

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Anyone thinking of starting a food processing business must be aware of some basic principles that can affect the safety and quality of their product.

WHY PROCESS FOODS?

Before looking at the principles of food safety, it is important to consider just what is meant by the term food processing. Food processing involves changing raw ingredients into food. It may also be changing food into other forms. The goal of food processing is to produce marketable food products with extended shelf-life that can be easily prepared and served by the consumer.

Many producers who market raw products like meats, fruits, and vegetables find that they have more product than they can sell in the fresh state. They are then faced with losing the excess product. Some producers also may find that they have product that is good but, because of some sort of blemish or defect, is not attractive to fresh-market consumers. Food processing offers producers a way to transform their excess or less marketable product into marketable foods.

Perhaps most importantly, food processing helps prevent or delay changes in foods that can make the food unsafe and/or lead to spoilage and loss of quality. These changes are caused by the action of enzymes or the activity of microorganisms. By preventing or delaying enzymatic and microbial changes in food, the food will be of safe to eat and have good quality for much longer periods of time.

PREVENTING ENZYMATIC CHANGES

Enzymes occur naturally in plant and animal tissue. They serve important roles in the development, maintenance, and maturation of the tissue. Once the plant or animal tissue is harvested, continued enzymatic activity can lead to deterioration resulting in loss of quality so it must be stopped.

Since enzymes are readily destroyed by heat, applying heat to a product will stop the enzymes.

While freezing slows enzyme activity it does not stop it. For this reason, many products are given a short heat treatment, called blanching, before freezing to help control enzyme activity.

PREVENTING ACTIVITY OF MICROORGANISMS

Microorganisms are living organisms so small they can only be seen with a microscope. Bacteria, fungi (molds and yeasts), viruses, and some parasites are some of the types of microorganisms which can affect food safety. They may get in food from soil, water, animal feeds, and other sources in the production environment. During processing, microorganisms may be introduced through equipment and utensils, ingredients, and environmental factors like air, dust, and condensation.

Microorganisms are all around us and perform some important roles for our daily living. For example, fermentation, which results in the production of many types of cheese, bread, beer, wine, and some sausages is the result of microbial activity. Microorganisms also aid in digestion of food in the body. They are important to the environment since they help break down waste products.

Unfortunately, microorganisms can also be harmful. Some, called pathogens, can cause diseases in humans, animals and plants. Others cause foods to spoil and become inedible.

BACTERIA

Viruses and parasites may be carried by food and may cause illness but they cannot grow in food and do not cause food to spoil. Molds, yeasts, and bacteria can grow in food and cause spoilage. Because some bacteria also can cause foodborne illness, bacteria are the microorganisms of most concern to food processors.

Bacteria are single-celled living organisms. Some bacteria are capable of forming spores. Spores are a dormant or resting stage of the bacteria that help ensure the survival of the organism in times of environmental stress. Because spores can survive unfavorable conditions like heating, freezing or drying, food processors must take care to assure their product handling prevents spores that survive processing do not return to active bacteria.

Some bacteria cause foodborne illness when the organism is eaten. Depending on the bacteria, it may take as few as 10 organisms to cause illness or as many as several thousand. Other bacteria produce a toxin (poison) in the food which makes people sick. Some toxins are very heat resistant and may be a hazard in food even if it is properly cooked.

Like all living organisms, bacteria the right conditions to live and grow. Although the levels of these may differ for different types of bacteria, there are six basic conditions needed for bacterial growth. Controlling one or more of these will help keep bacteria in food from increasing to dangerous levels and/or from producing harmful toxins. This control is the goal of food processing.

These conditions can be easily remembered by the acronym FAT-TOM: Food, Acidity, Time, Temperature, Oxygen, and Moisture.

Food (nutrients) – every living organism requires food to grow. If the food supply is removed, bacteria will not reproduce. Unfortunately, since bacteria require the same nutrients we do, it is difficult to eliminate their food supply.

Acidity – acidity levels, measured as pH, range from a pH of 0 (very acid) to 14 (very alkaline). All bacteria have an ideal acid level for growth. This level is generally somewhere between mildly acid (pH 4.6) and neutral (pH 7). The pH of most foods is in the range of 3.0 to 7.5 (Figure 1) but can be adjusted to help control bacterial growth.

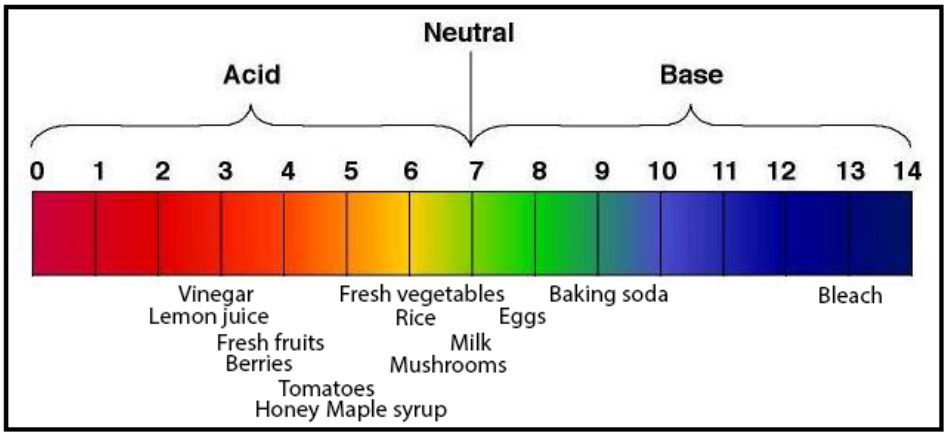
Time – the more time bacteria spend in favorable growth conditions, the higher the rate of reproduction.

Temperature – all bacteria have an ideal temperature where they reproduce the fastest. Above and below this ideal temperature, growth is slowed or even stopped. When the temperature is high enough, the bacteria are killed. Extremely low temperatures, will slow the growth of bacteria but generally do not kill them so they may begin to reproduce and/or produce toxins when the food is warmed. Figure 2 shows temperatures important for food safety.

Oxygen – bacteria differ in their need for oxygen. Some, called aerobes, need oxygen to survive. Others, called anaerobes, cannot grow if free oxygen is present. Still others, facultative anaerobes, use oxygen if it is present but don't require it.

Moisture – because bacteria get their nutrients by absorbing it through their cell walls, water must be present to dissolve the nutrients so they can be absorbed. The measure of the amount of water available to dissolve nutrients is called water activity or a_w. The a_w scale ranges from 0 which is no water available to 1, pure water. Most bacteria need an a_w greater than or equal to 0.95 for growth. It is important to note that a_w is the amount of water available, not the total water content of the food. Some water may be tied up by the presence of sub-

Figure 1. pH values of some common products used by food processors.



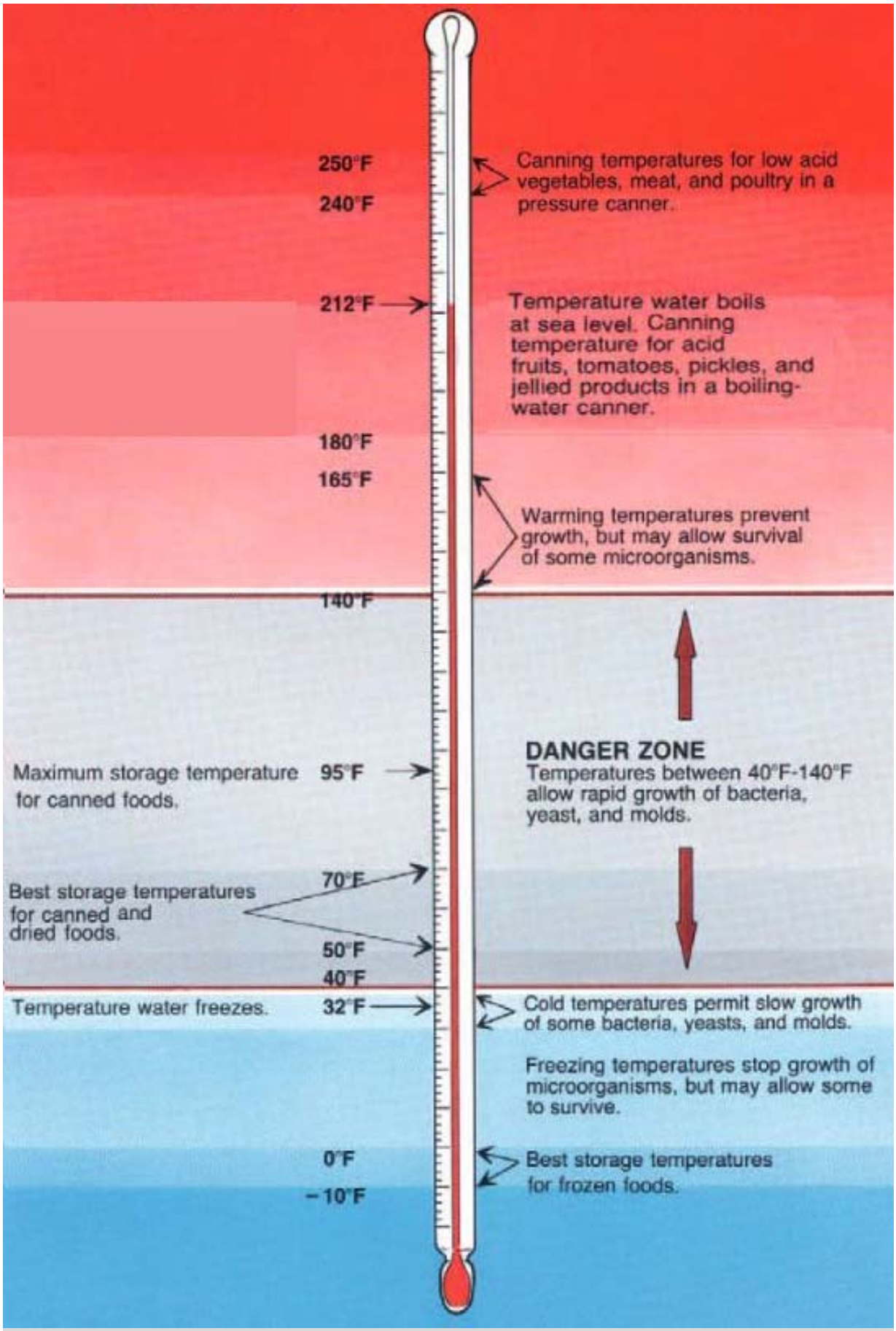


Figure 2. Temperatures important in food processing

(*Adapted from: USDA. 2009. Complete Guide to Home Canning, Guide 1*)

stances, like sugar or salt, so not available for use by bacteria.

PROCESSING/PRESERVATION METHODS

As mentioned previously, preservation methods extend the safety and shelf-life of food by

- preventing or delaying enzyme activity and/or
- preventing changes due to microorganisms by controlling one or more of the conditions required for the organisms to grow.

Let's take a look at some food processing methods to see how they function to control undesirable changes in the food.

CANNING

In canning, food is sealed in a container and heated. The container may be metal cans, glass jars, or flexible pouches made of foil or plastic. The sealed container serves to keep out air. It also prevents the processed food from being recontaminated. Enough heat is applied to the container to kill microorganisms present in the food and inactivate enzymes.

The amount of heat needed to assure safety depends on the nature of the food. For foods that are acid, that is that have a pH of 4.6 or lower, the acid helps control growth of bacteria. This means less heat is needed for bacterial control. Heating the food to boiling, 212^{o}F, is hot enough to safely process these foods. This type of processing is referred to as waterbath canning.

Fruits naturally have enough acid to be processed in boiling water (Figure 1). Pickled products are acid due to the pickling process (see below) so can be processed in boiling water. Jams, jellies, and other sweet spreads are often made from fruits. In addition, making these types of products from any kind of produce involves adding high levels of sugar. Since high sugar levels reduce the a_w of the sweet spread, thus helping control bacterial growth, the spreads can be processed in boiling water.

Foods that have a low acidity, like vegetables and meats, do not have enough acid present to help control bacterial growth. These foods need a more severe heat treatment, so must be heated to a temperature greater than 212^{o}F. To reach temperatures higher than boiling, it is necessary to process under pressure. This type of processing is done in a pressure canner, called a retort.

FREEZING

Freezing preserves foods by lowering the temperature to a point too low for microorganisms to grow or enzymes to work. Freezing also causes the water in the food to become ice. Water in the form of ice is unavailable for microorganisms.

Although freezing slows the activity of microorganisms and enzymes it does not stop it completely. Once the temperature is raised by thawing the product, microorganisms and enzymes can become active again. In order to prevent this from happening, many foods are given a mild heat treatment before freezing. This treatment, referred to as blanching, is not severe enough to cook the food but does reduce the number of microorganisms and inactivates enzymes. It has an additional benefit of reducing the level of oxygen in the product which not only helps control microbial activity but also limits other chemical reactions that need oxygen. A final benefit of blanching before freezing is that it helps soften the tissue, making it easier to pack into containers. When blanching, it is important to cool the food as soon as the required blanching time is over to prevent the food from cooking.

There are several factors in addition to blanching that affect the quality of frozen food. One of these is the rate of freezing. Faster freezing leads to the formation of smaller ice crystals in the food. Smaller ice crystals do less damage to the structure of the food so foods frozen quickly will be less mushy when thawed than those frozen slowly.

Packaging of frozen foods is also important. Because the cold air in freezers is very dry, food tends to lose moisture to this dry air. Moisture-vapor proof packaging keeps food from drying out in the freezer.

PICKLING

Preserving foods by lowering their pH to a point that prevents microbial growth is the principle behind pickling. The pH of pickled foods is generally 4.6 or lower. pH levels may be lowered by:

- Adding an acid, like vinegar, to the

product. Often the formula (recipe) for pickles made in this way also includes spices and herbs like mustard seed, cinnamon, and cloves, since these have natural antimicrobial activity and help preserve the product.

- Fermentation is another way to increase the acidity (lower the pH) of a product. When increasing acidity by fermenting, specific microorganisms are allowed to grow in the product. These organisms produce the desired acidity. The addition of salt is a common way to control which organisms will grow. For products like sauerkraut and kimchi, dry salt is added to the raw vegetables. The salt pulls water out of the product, making a brine in which only the acid-producing microorganisms can grow. For brined pickles, salt is mixed with water to make a brine that is then poured over the product being pickled.

DRYING/DEHYDRATION

Controlling bacterial growth by reducing the a_w, the amount of water available, is the goal of drying, also called dehydration. As discussed above, the a_w can be reduced by physically removing the water or by making the water unavailable through the addition of ingredients like sugar or salt.

Physically removing water from a product is usually done in a food dehydrator. These devices blow warm air over a food causing the water in the food to evaporate. Because this drying is rather slow and at temperature ideal for enzymatic activity, foods are often blanched before being placed in a dehydrator.

In sweet spreads like jams, jellies, and preserves, high levels of sugar bind the water, making it unavailable for use by microorganisms. Products like jerky and cured meats use high levels of salt to make water unavailable.

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