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Production and Handling Practices for Safe Produce

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& Justin R. Morris

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Production and Handling Practices for Safe Produce

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Much of the information in this publication was derived from material in “Improving the Safety and Quality of Fresh Fruit and Vegetables – A Training Manual for Trainers.” This manual was prepared by the University of Arkansas FAO Center for Food Quality, Safety, and Nutrition for the Joint Institute of Food Safety and Applied Nutrition/University of Maryland. The purpose of the manual was to provide a teaching tool to train trainers who will conduct courses on the safe production, handling, storage, and transport of produce being grown in other countries for export into the United States and to serve as a resource for the produce industry’s efforts to reduce microbial risks while maintaining market quality. The training manual is available in both English and Spanish online at <http://www.jifsan.umd.edu/gaps.html>.

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Impact Statement

The University of Arkansas Division of Agriculture received a grant from the USDA's Initiative for Future Agriculture and Food Systems program to help small- and medium-sized farms become more profitable and to therefore add stability to the family farm. One approach to doing this is to help farmers growing produce reduce or eliminate safety hazards which may be associated with their products.

There are many activities that take place as fruits and vegetables move from the farm to the table. These include activities related to production, postharvest operations, packaging, transportation, storage, and marketing. Farmers must carefully assess all of the steps they use in handling produce and incorporate systems to ensure the safety and wholesomeness of the fruits and vegetables they grow. This publication looks at three safety systems for producers: Good Agricultural Practices, Good Manufacturing Practices, and the Hazard Analysis Critical Control Points (HACCP) system for producing juice or cider.

Key Words

Produce safety, good agricultural practices (GAPs), good manufacturing practices for produce (GMPs), juice HACCP

INTRODUCTION

In order to avoid health risks due to potential hazards associated with fruits and vegetables, an increasing number of consumers are choosing to buy locally-grown produce. Consumers feel good about buying home-grown produce at farmer's markets, road-side stands, and neighborhood markets, since this allows them to buy directly from people they know and trust. This has opened new markets to small- and medium-sized farms which sell at local outlets.

There are many activities that take place as fruits and vegetables move from the farm to the table. These include activities related to production, post-harvest operations, packaging, transportation, storage, and marketing. Regardless of the size of the farm or the type of marketing system being used, farmers must carefully assess all of the steps they use in handling produce and incorporate systems to ensure the safety and wholesomeness of the fruits and vegetables they produce. Safety systems for produce growers that are discussed in this publication include:

- Good Agricultural Practices (GAPs) – guidelines published by the U. S. Food and Drug Administration (FDA) to reduce or eliminate contamination in the field and in packinghouses;
- Good Manufacturing Practices (GMPs) – FDA regulations for food processing facilities, including fresh-cut operations; and
- Hazard Analysis Critical Control Points (HACCP) – a system that is voluntary for the produce industry, except those producing juice or cider, but is widely used as a component of a comprehensive food safety program.

Although many of the GAPs and GMPs presented in this publication are applicable to organically-grown produce, the Organic Foods Production Act (OFPA) of 1990 and the National Organic Program (NOP) contain specific rules about the production and handling of products that are labeled organic. For example, the regulations require that agricultural products labeled organic must originate from farms or handling operations certified by a state or private organization that has been accredited by the USDA. As a general rule, only all natural substances are allowed in organic production and all synthetic substances are prohibited. The regulations for organic production are not included in this publication. Additional information on organic production of produce can be found at the NOP Website, <http://www.ams.usda.gov/nop/>.

Americans Are Eating More Fruits and Vegetables

Fruit and vegetable consumption is an important part of any healthy diet. A report from the Government Accounting Office (GAO) refers to scientific evidence that suggests that consuming the recommended 5 to 9 servings of fruits and vegetables each day helps protect against heart disease and cancer (GAO, 2002). The report goes on to cite research from the National Institutes of Health showing that people who consume 5 or more servings of fruits and vegetables daily have about one-half the cancer risk of those who eat fewer than 2 servings.

The 2005 Dietary Guidelines for Americans recommend at least four and a half cups (9 servings) of fruits and vegetables a day (HHS and USDA, 2005). The Guidelines encourage consumers to choose a variety of vegetables during the week from each of the major sub-groups (dark green, orange, dried beans, and starchy) and to ensure adequate fiber intake by choosing whole fruits (fresh, frozen, canned, or dried) rather than juice.

In the U.S., fruit and vegetable consumption has grown over the last two decades (Pollack, 2001). There are a number of factors leading to this increase in consumption:

- Americans have become more health conscious and have come to recognize the health benefits of including produce in their diet.
- Because of improvements in transportation and storage systems and greater numbers of imports from other countries, most fruits and vegetables are now available at reasonable prices year-round.
- New fruits and vegetables are now on the market that many Americans did not even know existed in the past.
- Convenience and ease of preparation are characteristics of much of the produce on the market. Many fresh products can be eaten after just washing. The trend toward marketing fresh-cut produce has boosted produce sales by offering items that are prepared and ready-to-eat from the package.

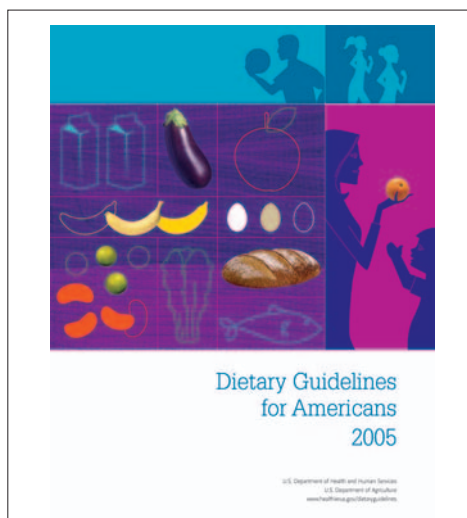


Figure 1. The 2005 Dietary Guidelines for Americans recommend increased consumption of all types of fruits and vegetables (HHS and USDA, 2005).

USDA consumption figures indicate that total fruit and vegetable consumption in the United States averaged 722 pounds per person during 2003 (Tables 1 and 2). This is 11% more than the 644 pounds per person that had been consumed 20 years earlier. In addition to an increase in the amount of produce eaten, between 1983 and 2003 there was a shift in the forms of produce Americans preferred.

The amount of fruit consumed decreased slightly during this period (Table 1). This was primarily due to decreases in the amounts of canned fruit and juice products chosen. Consumption of citrus fruits, a large part of total fruit consumption, was significantly lower in 2003 than in most previous years primarily due to lowered supplies and higher prices resulting from poor weather in the citrus-growing regions.



Figure 2. As awareness of the health benefits of fruits and vegetables has increased, Americans have chosen to eat more of these products. (Photo courtesy of USDA/ARS)

Table 1. Although total annual per person fruit consumption has remained about the same, Americans are choosing more fresh and frozen fruit.

Product Forms	Consumption (pounds per person)				
	1983	1988	1993	1998	2003
Fresh	90.9	97.3	98.5	101.7	100.4
Canning	20.0	20.6	20.5	16.9	17.1
Freezing	3.2	4.0	4.2	4.3	4.5
Juice	133.7	112.5	122.9	127.4	117.9
Dried	11.7	14.9	12.5	12.1	9.9
Total	287.2	277.2	283.6	288.7	278.9
(Citrus)	(137.2)	(108.5)	(115.4)	(122.9)	(106.9)

Source: Perez, A. and Pollack, S. 2004. Fruit and Tree Nut Outlook Yearbook.

Bananas have been the most preferred fruit of Americans for many years. This is interesting since bananas are one of the few fruits that Americans (except Hawaiians) must get totally by importing. Other fresh fruits topping the list of most consumed fruits in 2003 were apples and oranges; however, the fresh forms of fruits like grapes, pears, and strawberries were gaining in popularity. Juice, especially citrus juice, accounted for 42% of all fruits consumed in 2003. Berries accounted for more than half of the 2003 frozen fruit consumption, with strawberries being the most consumed berry. Raisins and prunes made up the bulk of dried fruits consumed by Americans, accounting for 80% of all dried fruit consumption in 2003.

Table 2. Americans are eating more vegetables per person each year, but there have been shifts in the forms selected.

Products	Consumption (pounds per person)				
	1983	1988	1993	1998	2003
Vegetables, except potatoes					
Fresh	114.7	138.5	149.0	157.8	168.4
Canning	92.6	90.9	106.6	102.2	97.2
Freezing	16.5	20.8	21.9	22.3	21.2
Total	223.2	251.9	279.5	283.4	288.2
Potatoes					
Fresh	49.8	49.6	50.1	47.0	47.0
Processing	68.9	72.7	86.6	91.1	91.8
Total potatoes	118.7	122.3	136.7	138.1	138.8
Sweet potatoes	4.6	3.9	3.7	3.8	4.7
Mushrooms	3.4	3.5	3.7	3.9	4.1
Dry peas & lentils	0.4	0.7	0.2	1.5	0.6
Dry edible beans	6.6	7.1	7.4	7.3	6.6
Total, all vegetables	356.9	389.4	431.2	438.0	443.1

Source: Lucier, G, Plummer, C., and Jerardo, A., 2004. Vegetables and Melons Situation Outlook Yearbook.

Although potatoes were the most consumed fresh vegetable in 2003, more potatoes were consumed processed, especially as frozen French fries, than were eaten fresh. There were also increases in consumer demand for other fresh vegetables such as asparagus, broccoli, cauliflower, carrots, onions, and lettuces. In 2003 fresh market spinach consumption reached its highest level since 1949 as consumers came to appreciate this vegetable both as a salad ingredient and as a side dish. While almost all vegetables were available canned, tomatoes were the vegetable canned in the greatest amounts, representing 72% of all canned vegetables.

Produce and Foodborne Disease

Infectious diseases transmitted by foods have become a major public health concern in recent years. Although a majority of the cases of these diseases are mild and cause symptoms which last for only a day or two, some cases result in long-term illnesses and even death.

It is very difficult to pinpoint exactly how many people suffer from foodborne disease each year since the symptoms of these diseases are often mistaken for flu, and the illnesses may never be reported to medical personnel or health authorities. However, the U.S. Centers for Disease Control and Prevention (CDC) have estimated that foodborne illnesses affect at least 76 million persons in the United States each year (Mead et al. 1999). Based on

current population data, this means that approximately one in four Americans annually will be exposed to pathogens (disease-causing microorganisms) that lead to foodborne illness.. The CDC estimates that there are approximately 323,000 hospitalizations and 5,200 deaths related to foodborne diseases each year. The most severe cases tend to occur in the very old, the very young, those who already have an illness that affects their immune system, and in healthy people exposed to very high numbers of the disease organisms.

Table 3. Foodborne illness affects millions of people in the U.S. each year; however, the causes of these illnesses are often never identified.

Pathogen	Illnesses	Hospitalizations	Deaths
Known Pathogens	13,814,924	60,854	1,809
Bacteria	4,175,565	36,466	1,297
Parasites	357,190	3,219	383
Viruses	9,282,170	21,167	129
Unknown Pathogens	62,000,000	263,000	3,400
Total	76,000,000	323,000	5,200

Source: Mead et al., 1999.

Although a relatively small percentage of all foodborne disease outbreaks are associated with produce, the number of cases is increasing. According to the CDC, the number of reported produce-related outbreaks per year in the U.S. doubled between the periods 1973-1987 and 1988-1992 (Buck et al., 2003).

Fresh produce is a particular food safety concern since much of it is eaten without any heat treatment to eliminate or reduce the number of

Table 4. Examples of foodborne illness outbreaks associated with produce or other plant materials.

Year	# of States	# of Cases	Associated food	Pathogen
2003 – 2004	12 + Canada	29	Almonds	Salmonella
2003	4	>550	Green onions	Hepatitis A
2001	4	40	Alfalfa sprouts	Salmonella
2001	6	>40	Cantaloupe	Salmonella
2000	8	86	Tomatoes	Salmonella
1998	3	>400	Parsley	Shigella
1997	14	864	Berries	Cyclospora
1997	3	305	Basil	Cyclospora

Source: Summarized from CDC Morbidity and Mortality Reports. Available on the internet at: <http://www.cdc.gov/mmwr/>

microorganisms present. In addition, several organisms causing foodborne illness have been either newly described or newly associated with fruits and vegetables since the 1980's (Tauxe, 1997). An example of one such organism is *E. coli* O157:H7. When this organism was first identified in 1982, it was associated with hamburger meat. In 1993, an outbreak of disease caused by this organism was attributed to unpasteurized apple juice, proving that plant materials could also be a source of *E. coli*.

Contamination of produce leading to foodborne illness has occurred during production, harvest, processing, and transporting, as well as in retail and foodservice establishments and in the home kitchen (Suslow et al., 2003). Contamination at any point in the food handling chain can be made worse by improper handling and storage of produce by the consumer.

The point of contamination is important because the control measures are most effective if geared towards reducing contamination at the source. However, determining the exact source of an outbreak often proves to be difficult. The actual source may never be determined because product contamination can occur anywhere in the production and marketing chain (Zepp et al., 1998). Identification of the source of a disease outbreak is further complicated by the fact that, by the time an outbreak is traced to a farm, packing-house, or other site, the actual source of contamination may no longer be there. This was the situation in 1991 with a Hepatitis A outbreak associated with frozen strawberries. The berries were grown in Mexico and processed and distributed in the United States. Outbreak investigators were never able to determine if the contamination occurred before the berries entered the United States or during processing and distribution.

Economics of Produce Safety

There are important economic reasons for ensuring that fruits and vegetables remain safe throughout the production and marketing chain. Unsafe fruits and vegetables pose a threat to the health and safety of consumers, and when this happens, consumers lose confidence in the produce and do not buy it. This can lead to losses in revenue for the produce industry. Lost markets and decreased revenues can translate to reduced community services, lower wages, and lost jobs. An example of this was seen with a 1996 outbreak of *Cyclospora*. Preliminary investigations identified strawberries from California as the source of this organism. Although further investigation proved the source was actually imported raspberries, the California Strawberry Commission reported that decreased consumer confidence in the safety of their berries resulted in over \$40 million in lost revenue, five thousand lost jobs, and a 10% reduction in crop acreage the following year (CDFA, 1997).

Costs of Foodborne Illness

Although the difficulty in identifying the actual number of cases of foodborne illness makes it hard to estimate the cost of these diseases, no one can dispute that foodborne illness is very expensive. In 2000, the Economic Research Service (ERS) of the USDA used estimated medical costs, productivity losses, and costs of premature deaths for five of the most common bacterial pathogens as a way to estimate the costs of foodborne diseases (ERS, 2004). The five bacterial pathogens evaluated were: *Campylobacter*, *Salmonella*, *E. coli* O157, *E. coli* non-O157, and *Listeria monocytogenes*. The figures for *Salmonella* were updated in 2003 with revised figures for the distribution of this organism.

The costs associated with these five organisms totaled \$6.9 billion (Table 5). The actual costs, however, would probably be much greater since these are only estimates and did not look at all costs involved. The Economic Research Service's conservative estimates of the annual costs due to foodborne illnesses (particularly the chronic conditions associated with *Campylobacter*) would be substantially increased if a dollar value could be assigned to a person's willingness to pay to avoid disability, pain, and suffering.

Table 5. Estimated annual costs due to selected foodborne pathogens.

Pathogen	Estimated annual foodborne illnesses ¹			Costs ²
	Cases	Hospitalizations	Deaths	
	Number			Billion 2000 dollars
<i>Campylobacter</i> spp	1,963,141	10,539	99	1.2
<i>Salmonella</i> ³	1,341,873	15,608	553	2.4
<i>E. coli</i> O157:H7	62,458	1,843	52	0.7
<i>E. coli</i> , non-O157	31,229	921	26	0.3
<i>Listeria monocytogenes</i>	2,493	2,298	499	2.3
Total	3,401,194	31,209	1,229	6.9

¹ Data from the Centers for Disease Control and Prevention, Food-Related Illness and Death in the United States.

² The total estimated costs include specific chronic complications in the case of *Campylobacter* (Guillain-Barré syndrome), *E. coli* O157 (hemolytic uremic syndrome), and *Listeria monocytogenes* (congenital and newborn infections resulting in chronic disability or impairment). Estimated costs for *Listeria monocytogenes* exclude less serious cases that do not require hospitalization.

³ The Economic Research Service updated the costs estimates for *Salmonella* in 2003.

In the event of a foodborne illness outbreak, consumers are on the frontline facing health problems and medical bills, lost days of work, etc. Although the most obvious costs are those associated with health care for the afflicted individuals, additional costs related to caring for those who are ill,

absenteeism from work and school, and travel to seek medical care add to the financial burden caused by foodborne illness.

The economic impacts of foodborne illness affect not only the individuals and families involved but also the communities, industries, and nations (Doores, 1999). Even people not directly associated with the contaminated food may pay for unsafe product. Costs to society include lost worker productivity, lost revenue due to business closure and product avoidance, legal costs for litigations related to the illnesses, and costs related to public services for those suffering from chronic disease. If a foodborne illness is traced to a particular product, but not a particular grower, all producers of that food item may feel the effects of decreased demand. The CDC and FDA incur substantial costs investigating and controlling outbreaks, and some level of government often ends up paying for many of the medical costs incurred in an outbreak.

Growers' Benefits and Costs for Added Safety

When produce growers are deciding whether or not to adopt additional food safety practices, they weigh the benefits they hope to receive from these practices against the costs. Benefits growers might expect from adopting safer production practices include higher prices for higher quality product, reduced safety risks, or lower costs of production (Calvin et al., 2004). Additional costs may include investments in new infrastructure such as water purification plants, training for workers to improve hygiene in the fields, upgrades to recordkeeping systems, and use of third-party audits to verify compliance with GAPs in the fields and GMPs in packinghouses.

Generally, growers do not receive higher prices from adopting improved product safety practices (Calvin et al., 2004). Since the costs of these practices are often very high and immediate, some growers choose not to adopt them. However, there are benefits from adopting better safety practices that also should be considered when deciding if these practices are needed. These benefits involve avoiding the risks of drops in sales if contaminated produce is traced to their operations, damage to their reputation, and lawsuits. Because these events only occur as the result of an outbreak, growers may think that the probability of ever experiencing the benefits of the improved safety measures is very low. However, after an outbreak growers may decide these benefits are extremely important. A more immediate benefit of adopting better food safety practices is that many retailers and foodservice buyers now require third party audits of grower food safety practices as a condition of purchase. So, having higher food safety standards gives growers broader market access.

When there are outbreaks of foodborne illness, other groups in the produce industry, marketing chain, or government may try to impose new rules on growers to encourage or force them to implement food safety measures more in line with society's total demand for food safety. For example, grower organizations may put into place voluntary or mandatory practices to reduce the negative impact of one producer with contaminated produce on other producers of the same product. Retailers and foodservice buyers may require growers and packinghouses to obtain third-party audits showing compliance with GAPs and GMPs to reduce the chance that their businesses will be associated with an outbreak. The government may also impose higher standards on producers.

Hazards in Fresh Produce

A hazard is something that could cause harm to the consumer. There are three main types of hazards associated with fresh produce:

- Biological hazards result from microorganisms such as bacteria, viruses, and parasites as well as some fungi that produce toxins (poisons).
- Chemical hazards arise from contamination of produce with harmful or potentially harmful chemicals that may occur naturally in the products or may be added during agricultural production and product handling.
- Physical hazards are particles or fragments of materials that are not meant to be in the food.

Fresh produce is susceptible to contamination during growth, harvest, and distribution. The surfaces of vegetables and fruits are exposed to hazards in the environment, the soil, and water. Recently it was found that hazards on the surface of produce may reach the interiors of products during preparation. Thus products like melons, once considered safe since their edible portions were protected by a hard rind, have been found to be hazardous if not handled appropriately.

Biological Hazards

Microorganisms are small organisms that can only be observed through a microscope. Many of these organisms consist of a single cell and are found everywhere in the environment.

Many microorganisms are beneficial to humans. For example, some are involved in the production of fermented foods such as bread, cheese, wine, beer, and sauerkraut. Others are used by industry to produce products such as

some enzymes, antibiotics, and glycerol. Microorganisms also work to break down organic matter causing enrichment of soils.

Some microorganisms, especially some bacteria, parasites, and viruses, can cause foodborne illnesses. Unfortunately, many of these microorganisms may be found on raw produce, which is of special concern since many fruits and vegetables are eaten raw and do not receive preparation treatments that remove or kill organisms that might be present. Sometimes microorganisms occur on fruits or vegetables due to exposure to soil, dust, and the surroundings. In other instances, organisms are introduced onto produce through poor production and handling practices such as the use of contaminated water for irrigation, washing, or cooling.

There are some basic principles that should be remembered about microbial contamination of fresh produce (FDA, 1998). First, fresh produce can become contaminated at any point along the farm-to-table food chain. Secondly, it is better to prevent microbial contamination of produce than to rely on treatments to eliminate contamination that may have already occurred. Third, to minimize microbial food safety hazards in fresh produce, growers, packers, and shippers should use good agricultural and management practices in those areas over which they have control.

Bacterial Hazards

Because bacteria are everywhere, they can easily contaminate fruit and vegetables when these commodities are not handled properly prior to consumption. A large number of bacterial pathogens have been implicated in foodborne disease outbreaks associated with the consumption of fresh fruits and vegetables (Table 6).

Bacteria such as *Clostridium botulinum*, *Bacillus cereus* and *Listeria monocytogenes* can be found in the soil and may contaminate produce that grow low to the ground, that are dropped, or that have soil splashed on them. Other bacteria such as Salmonella, Shigella, pathogenic *Escherichia coli*, and Campylobacter are found in the intestinal tracts of animals and/or humans. Bacteria can contaminate fruits and vegetables when field workers do not practice good hygiene or when contaminated water is used in the fields, when animals are allowed onto the field, or through inappropriate composting. Contamination can also take place during handling at harvest and packaging, as well as in other steps in the distribution and marketing chain.

Because it takes very low numbers of some bacteria to cause disease, prevention of bacterial contamination is the most important control measure to ensure produce safety. Good Agricultural Practices (GAPs), which will be discussed later, are important measures in the prevention of produce contamination.

Table 6. Examples of bacterial pathogens that have been identified on fresh produce and juice.

Pathogen	Associated Products
<i>Aeromonas</i>	Alfalfa sprouts, asparagus, broccoli, cauliflower, celery, lettuce, pepper, spinach
<i>Bacillus cereus</i>	Alfalfa sprouts, cress sprouts, cucumber, mustard sprouts, soybean sprouts
<i>Campylobacter jejuni</i>	Green onions, lettuce, mushroom, potato, parsley, pepper, spinach
<i>Clostridium botulinum</i>	Cabbage, mushroom, pepper
<i>E. coli O157:H7</i>	Alfalfa sprouts, apple juice, cabbage, celery, cilantro, coriander, cress sprouts, lettuce
<i>Listeria monocytogenes</i>	Bean sprouts, cabbage, chicory, cucumber, eggplant, lettuce, mushroom, potato, radish, salad vegetables, tomato
<i>Salmonella</i>	Alfalfa sprouts, artichoke, beet leaves, celery, cabbage, cantaloupe, cauliflower, chili, cilantro, eggplant, endive, fennel, green onion, lettuce, mungbean sprouts, mustard cress, orange juice, parsley, pepper, salad greens, spinach, strawberry, tomato, watermelon
<i>Shigella</i>	Celery, cantaloupe, lettuce, parsley, scallions
<i>Staphylococcus</i>	Alfalfa sprouts, carrot, lettuce, onion sprouts, parsley, radish
<i>Vibrio cholerae</i>	Cabbage, coconut milk, lettuce

Source: Buck et al., 2003

Parasitic Hazards

Parasites are organisms that live in another living organism, called the host. They are only able to grow in a host; however, they may be passed from one host to another through some non-host means. Parasites most commonly associated with human infections include *Cryptosporidium*, *Cyclospora*, *Giardia*, *Entamoeba*, *Toxoplasma*, *Sarcocystis*, *Isospora*, and nematodes.

Because produce is often eaten raw, it can serve as a vehicle to pass parasites from one host organism to another (Beuchat, 1998). The original source of these parasites is human and animal fecal matter (Isaacson et al., 2004). The toughness of some parasites allows them to survive in the environment, particularly in water, for great lengths of time. However, since not all parasites are waterborne, other places they may exist include feces of livestock animals and wildlife. Thus, infected food handlers, animals in the field, and water contaminated with fecal material may be ways produce can become contaminated with parasites. The produce then passes these organisms on to the humans who consume the raw product.

Viral Hazards

Viruses are very small and unable to reproduce outside of a living cell. Therefore they do not grow in or on foods.

Currently recognized foodborne viruses are known to originate from human feces (Isaacson et al., 2004). Raw fruits and vegetables may become contaminated by exposure to contaminated water or during handling by infected people. The viruses infect susceptible persons eating the raw produce. Because it takes a very small number of virus particles to cause illness, preventing contamination of fruits and vegetables is critical to controlling viral disease.

Chemical Hazards

A chemical hazard arises from the contamination of produce with harmful or potentially harmful chemicals. Chemical contamination of raw fruits and vegetables may occur naturally or during production, handling, transport, and storage (FAO, 1998). Harmful chemicals occurring naturally include allergens and toxins such as mushroom toxins and aflatoxin on grains. Some chemicals, such as fertilizers and pesticides, are used on crops intentionally and are beneficial when used properly; unfortunately, they can become unsafe when misused.

Chemicals like lubricants used on equipment, paint on buildings and equipment, cleaners, pesticides in buildings, and refrigerants are not intended to be used on food products but may accidentally become product contaminants. Prevention of such accidental contamination is critical to ensuring produce safety.



Figure 3. Consumer concerns about chemical hazards in foods offer opportunities for growers who market products produced with no chemicals. (Photo courtesy of USDA Photo Center)

Food Allergens

Undeclared food allergens in produce are chemical hazards that can occur when juice is processed on equipment that has been used to process a potentially allergenic food without adequate cleaning prior to the juice run (FDA, 2004). For example, if juice is processed using equipment that was not thoroughly cleaned after it was used to produce milk or a dairy-based beverage, an individual who is allergic to milk could face a potentially serious and unexpected health risk from drinking the juice containing the milk protein.

The FDA believes there is scientific consensus that the following foods can cause serious allergic reactions in some individuals. These foods account for more than 90% of all food allergies and care should be taken that they do not contaminate fruit or vegetable products:

- Peanuts
- Soybeans
- Milk
- Eggs
- Fish
- Shellfish
- Tree nuts
- Wheat

Physical Hazards

Physical hazards are particles or fragments of materials that are not meant to be in the food. They may be introduced into fresh fruits and vegetables at numerous points in the production chain (Table 7). When physical hazards occur and are consumed, they can cause serious injuries or illness for consumers of fresh produce. Physical hazards may include:

- Glass and stones picked up in the field during harvest.
- Wood or plastic splinters from packing cases.
- Jewelry, hair clips, and other personal items belonging to workers.

Table 7. Physical hazards that have occurred from fruits and vegetables.

Material	Sources	Injury potential
Glass	Bottles, jars, light bulbs, utensils, gauge, covers, etc.	Cuts, bleeding; may require surgery to find or remove
Wood	Field sources, pallets, boxes, building materials	Cuts, infection, choking; may require surgery to remove
Stones	Fields, buildings	Choking, broken teeth
Insulation	Building materials	Choking long-term if asbestos
Plastic	Packaging, pallets, equipment	Choking, cuts, infection; may require surgery to remove
Personal items, such as jewelry, hair clips, pens	Employees	Choking, cuts, broken teeth; may require surgery to remove

Adapted from JIFSAN, 2002.

GOOD AGRICULTURAL PRACTICES (GAPs) HELP ASSURE SAFE PRODUCE

Good Agricultural Practices are guidelines established to ensure a clean and safe working environment for all employees while eliminating the potential for contamination of fresh fruits and vegetables.

Land Choice is First Step to Safe Produce

The first consideration for growers wanting to ensure safe fruits and vegetables is choosing a site for growing their crop. A key factor to consider in selecting a site is its history. Previous use of the land, prior agricultural production practices, and the location of the site relative to potential hazards can all affect the safety of produce grown on the site. Information on a site's history can help identify situations that can increase the risk of fresh produce contamination (FDA, 1998).

Knowing the history of the land's use can help identify potential hazards which may exist in the soil. Agricultural land that has been used for activities other than producing food crops can be contaminated with pathogenic organisms or toxic chemical substances. If the land's prior use is not known, it can often be obtained by talking with previous owners/users of the site or by reviewing records and permits for the land.

Land that was previously used as pasture or as a feedlot may contain pathogenic microorganisms from the animals. The potential for contamination from this source is related to the time that has passed since the land was used for animal production. The degree of contamination risk is also influenced by conditions such as atmospheric temperature, sunlight, and relative humidity.

Land that was used as a waste dump could contain high soil microbial loads, harmful chemicals, or toxic contaminants. Former use as an incineration site, for mining or for extraction of oil or gas may have resulted in contamination with heavy metals or hydrocarbons. Even if these sites were located only on a small portion of a farm or even on a neighboring farm, it is important to assess if factors such as rainfall and underground water flow may have spread the contamination. Analysis of toxic substances in the soil and a review of the environmental compliance of the extraction operation are recommended when the ground history indicates a high risk for chemical hazards (JIFSAN, 2002).

Obtaining information about the history of the land should also involve determining if the land has ever been flooded and, if it has, when this flooding occurred. Land that has been flooded may have been exposed to contaminants carried by the floodwaters. Once the floodwaters have receded, there may be no obvious signs of the presence of these contaminants. If flooding has occurred, it may be desirable to have the soil analyzed for the presence of pathogenic organisms and chemical hazards.

Even if an investigation of the prior use of the land indicates that it was used solely for agricultural production, prior production practices should



Figure 4. There may be no visible signs that pathogens and chemical contaminants were left on farm lands after flooding has occurred. (Photo courtesy of USDA/NRCS)

be reviewed. Unless properly composted, animal manure used as fertilizer could result in pathogens in the soil that can remain for extended periods of time and may reappear as contaminants on new crops. Inappropriate use of chemical fertilizers can increase the risk of chemical hazards from future produce crops. It is important to carefully review the records of previous agricultural activities to assure that all agricultural activities were carried out following appropriate safety guidelines.

An ideal site for growing produce has no recent history of use for poultry or livestock production, is not close to an existing poultry or livestock operation, and is not downstream or down slope from sites that house poultry or livestock. The presence of barns, poultry houses, or farm animals a short distance from cultivation sites increases the risk of produce contamination. Assessment of the location of animals and their facilities and evaluation of drainage systems and water currents flowing near these areas will help determine the potential for contamination of produce in the field.

Good Agricultural Practices and Water Resources

During agricultural production of fruits and vegetables, water is used for numerous activities in the field, including irrigation, pesticide and fertilizer application, cooling, and frost protection (FDA, 1998). Water is used during produce handling for purposes such as cooling, washing, waxing, and transportation. In addition to activities where water comes in direct contact with the produce, water also is used by field and packing shed workers for drinking and hand washing.

Water used in the production of fruits and vegetables can be a source of pathogen contamination. The severity of the hazard resulting from poor water quality depends on the type and number of microorganisms in the water and their capacity to survive on the produce.

The amount of water contact with the edible portion of the produce and when the contact occurs, are factors in determining the risk of contamination of produce. Fruits and vegetables with large surface areas, like leafy vegetables, or those with a surface texture that allows pathogens to adhere easily are at a greater risk for contamination from water than those with compact, smooth surfaces. Also, produce that is contaminated early in the growing season is less likely to carry pathogens at harvest than product that is contaminated late in the growing season.



Figure 5. The quality of all water used in the production of fruits and vegetables is critical to assuring the safety of the produce. (Photo courtesy of USDA/NRCS)

Produce Contamination Associated with Water Sources

Among the most common sources of agricultural water are surface waters such as rivers, streams, irrigation ditches, and open canals; impoundments such as ponds, reservoirs, and lakes; groundwater from wells; and, occasionally, public water systems (FDA, 1998).

It is generally assumed that groundwater is less likely to be contaminated with high levels of pathogens than surface water. However, surface and reservoir sources vary considerably in their microbial content. Microbial loads of surface water may range from several thousand organisms per milliliter after a rainfall to a relatively low number after auto purification, a normally-occurring process in smooth waters.

Improperly managed human and animal wastes are one source of contamination for agricultural water. Human contamination may occur from improperly designed or poorly managed septic systems, from sewage treatment discharges, and from sewer system and storm sewer overflows. On-the-farm contamination may result from animal wastes when animals have access to water supplies or are in pastures that are in or near produce-growing areas; from manure storage near crop fields, vineyards, and orchards; from leaking or overflowing manure lagoons; and from high concentrations of birds and other wildlife.

Surface water often flows great distances through a variety of environmental situations that may expose it to contamination. This contamination can come from animal production, manure applied to land, industrial operations, and areas of concentrated human populations. Although there is little a grower can do about contamination to waters from these sources, it is important that the grower is aware of potential problems from up-stream sources of contamination. Every possible step to assure minimum contamination should be taken. In some instances, the best approach to preventing contamination may be to create physical barriers or channels to divert potentially-contaminated water away from growing areas.

Water used for the application of pesticides and foliar fertilizers also can be a source of microbial contamination. For this reason, the microbiological quality of the water used for these activities should be considered.

Hazards Introduced by Irrigation Practices

Irrigation is the controlled application of water to the land or field in order to provide the moisture levels needed for the development of the crops. It plays an important part in ensuring suitable conditions for crop development. Irrigation methods are selected according to the environment, water source, climate, soil characteristics, type of crop, and cost. In order to ensure produce safety, growers should make every effort to protect and maintain the quality of all irrigation water.

Since the amount of contact between irrigation water and the crop has a major role in produce contamination, the type of irrigation system used should be considered when assessing product risk (FDA, 1998). In general, if water is in direct contact with the crop during irrigation, water quality needs to be better than water used in systems with minimal product contact.



Figure 6. Drip irrigation methods (left) offer less contact between produce and water than spray systems (right), however, water quality is important whenever produce is irrigated. (Photos courtesy of USDA/NRCS)

Irrigation methods where the contact between water and plant is minimized, such as a drip system, are generally less likely to lead to fresh produce contamination; however, the use of good quality water is still important.

Sprinklers offer a greater degree of contact between the edible portion of the fruit or vegetable and the water. Therefore, these systems offer a greater risk of produce contamination. With these systems, the use of good quality water and the proper use and maintenance of the equipment is especially important.

Microbiological Testing Procedures for Agricultural Water

Tests of the microbial content of water are time consuming, and so they are not generally used for daily monitoring activities. Instead they are used to track safety trends and to verify that the appropriate preventive measures are in place.

Microbiological analyses may be used as indicators of contamination for purposes such as verification of cleaning programs for tanks and wells or when contamination from a specific source or event is suspected.

Proper records of water's microbiological quality are an important good agricultural practice. It is essential to document the frequency and results of each water test since changes in results may identify problems.

Testing for specific pathogenic bacteria in water may be inappropriate since they could be present in very small amounts and thus not detected. Furthermore, microbiological characteristics of water can vary considerably depending on such factors as the water source, season, and sampling time. Since waterborne disease is usually the result of fecal contamination of water supplies, it is more efficient to determine if fecal contamination is present than to look for the presence of specific pathogens.

Fecal indicator bacteria are used to identify when fecal contamination of water has occurred. In the United States, coliform bacteria serve as the indicator organisms for fecal contamination. Coliforms are naturally present in the environment, as well as in feces. They are not a health threat; however, they are used to indicate whether other potentially harmful bacteria may be present since relatively high numbers of fecal indicator bacteria in water suggest the possibility that pathogens are present. To determine if the water being used in agricultural production is contaminated with fecal material, laboratory tests look for the presence of fecal coliform bacteria, specifically *E. coli*.



Figure 7. Care when collecting and handling water testing samples assures the integrity of the sample, avoids contamination during sampling, and assures changes do not occur in the sample after it is collected. Precise sampling procedures should be obtained from the laboratory that will be running the tests to assure appropriate samples. (Photo courtesy of USDA/NRCS)

Table 8. The type of water source will determine the recommended frequency of testing (CSC, 1998).

Source	Possible Water Testing Frequency
Closed system, under the ground or covered tank	One annual test at the beginning of season
Uncovered well, open canal, water reservoir, collection pond	Every three months during the production season
Municipal/District water system	Keep records from the municipality/district water system (monthly, quarterly or annual report)

The maximum contaminant level (MCL) for drinking water for total coliform/*E. coli* is zero (EPA, 2003). Although an MCL does not exist for agricultural water, growers are urged to minimize sources of microbial contamination over which they have control. If wells or water sources are contaminated with these organisms, possible methods to eliminate them include disinfecting with chlorine or another disinfectant or filtration of the water source.

Chemical Hazards in Water

In addition to biological hazards, water also can contain chemical contaminants. Hazardous chemicals may get into the water when it flows through soils that contain high chemical levels or that have been contaminated. Water washing over road beds, fields and lawns treated with agricultural chemicals, dump sites, or other areas high in potentially-hazardous materials can pick up chemicals which may be deposited on fruits and vegetables.

Chemical contamination can occur when pesticides, lubricants, solvents, or other chemicals are spilled; when rinse water from container or equipment cleaning is dumped on the ground or discharged into surface water; or when improperly cleaned containers are stockpiled or buried (Howard et al., 2000). Pesticide handling in the vicinity of wells may result in chemical contamination of ground water, so the location of wells should be considered when mixing, applying, storing, and disposing of pesticides. Vegetation or other barriers should be established as guard zones to help limit contact between the chemicals and water sources (Nesheim, 1993). The application of pesticides should be delayed if heavy or sustained rain is anticipated since rain runoff can wash newly applied chemicals into water supplies.



Figure 8. Water from washing pesticide application equipment can be a source of contamination for fresh produce. (Photo courtesy of USDA/NRCS)

Arkansas Water Situation

There are approximately 34 million acres of land and water in Arkansas. Of this, 15.1 million acres (44%) are in agricultural production (ADEQ, 2002). Approximately 8.2 million acres of this agricultural land are in crops and 6.9 million acres are used for pasture land and other agricultural uses. There are roughly 17 million acres of forests in the state; however, not all of these acres are managed for timber production. The remaining 1.9 million acres are in state parks and wildlife areas, waterways, highways, roads, urban areas and other nonagricultural lands.

Arkansas has 11,935.9 miles of rivers and streams and a total of 356,254 acres of significant publicly-owned lakes. The Arkansas Department of Environmental Quality (ADEQ) has classified the State's waters by ecoregions (Figure 1). This classification allows not only categorizing the regions by physical, chemical, and biological features, but separates the major pollution problems, most of which are land use-related. A general summary of water quality from the 2002 Integrated Water Quality Monitoring and Assessment Report (ADEQ, 2002) is presented below.



Figure 9. Arkansas' waters can be classified into 6 ecoregions based on physical, chemical, and biological features. This separation allows identification of major pollution problems (map adapted from ADEQ, 2002)

Water quality in the Delta Region (Mississippi Alluvial Plain) was found to be significantly influenced by nonpoint-source runoff from areas with high levels of agricultural production. The vast majority of the waterways within this region were in a network of extensively channelized drainage ditches. Long-term government programs have been used to develop this highly productive agricultural land; however, many of the practices used to make this land more productive actually decreased water quality. Many of the waterways within the Delta Region of Arkansas are not consistently rated as swimmable because of elevated coliform measurements. However, the contaminants are not from human fecal sources. The current standard for rating

the swimming quality of water is based on the fecal coliform test which supposedly indicates the amount of fecal contamination within the water. However, this test also reads positive for numerous soil bacteria which bear no relationship to fecal contamination. The highest incidence of measurable pesticide residue in Arkansas water occurs in this region.

The Gulf Coastal Region of southern Arkansas has site-specific areas of lowered water quality due to extraction of petroleum products, brine, bromine, barite, gypsum, bauxite, gravel and others. Effects on water quality occur due to pollution from extraction sites, from storage and transmission of the extracted products, and from processing facilities. Timber is the crop harvested in this area, and no large scale influences on water quality were detected from activities related to these operations.

The Ouachita Mountains Region is considered a recreational region which possesses exceptionally high quality water. The main land use throughout this region is forestry, both in the operations of private timber companies and in National Forest holdings. Areas of the Ouachita Mountains have been identified in a national study as potentially sensitive to the effects of acid rain; however, data is currently inconclusive concerning any impact on the region due to acid precipitation. Various groups and organizations have expressed concerns about the potential erosion and depositing of silt as a result of management practices used in timber harvest; however, water quality monitoring data has not indicated significant problems with the streams within this region. Occasionally above-normal turbidity (cloudiness due to suspended particles) values have been observed when there was a lot of rainfall. Activities in the area with the potential for affecting water quality include land clearing for pasture without protective zones along the banks of streams and rivers, in-stream gravel removal, and increasing areas of confined animal production.

The Arkansas River Valley Region has distinct seasonal characteristics for its surface waters. During the summer, zero flows are common. During peak runoff events waters are exposed to increased contamination from the predominantly agricultural land use, which is primarily pasture lands with increasing hog, poultry, and dairy production. The fecal coliform bacteria level is a quality parameter of concern since it makes the water unacceptable for swimming. Measurements of water quality during storms routinely show levels of coliform bacteria greater than those in the water quality standards, although the source of the contamination is not from humans. The current exploitation of natural gas deposits has resulted in some site-specific water quality degradation. Most recently, this area has experienced rapid expansion of confined animal activities which can also affect water quality unless these activities are handled appropriately. The soil in much of this area is of types that erode and tend to easily go into colloidal suspension, thus causing long-lasting, high turbidity values.

The Boston Mountains Region, located in north central Arkansas, is a sparsely populated area. The main use of the land is for growing trees, and much of the region is located within the Ozark National Forest. This region is a high-use recreational region with exceptionally high quality water. Major changes in the region which could result in lowered water quality include: 1) conversion of forests to improved pastures, 2) expansion of confined animal operations, 3) even-aged timber management, and 4) localized natural gas production. Periodically elevated levels of turbidity are noted in some waters in this region. This is most likely caused by clearing of timberland adjacent to major streams for conversion to pastures which accelerates stream channel and bank erosion. In addition, road construction and maintenance and in-stream gravel removal are taking place in the region and serve to aggravate turbidity problems.

The Ozark Highlands Region, located in extreme north Arkansas, has mountainous terrain with steep gradients and fast-flowing, spring-fed streams. A large percentage of the streams in this region are designated as extraordinary resource waters (that is, have extremely clean water). The fractured limestone geology of the region allows a direct linkage between surface waters and ground waters. The water quality problems within this region are directly related to land use. Within this region are some of the highest animal production rates in the United States, specifically, chickens, swine, and cattle. The waste generated from these animal production facilities is generally applied to the land and, therefore, has the potential for contaminating both surface and ground waters. The nitrate levels measured from this region are atypically high and are trending upward. The region is experiencing a tremendous population growth that has resulted in increased water contamination both from infrastructure development and increased human waste generation. Removal of gravel from the banks and beds of streams is a very frequent activity. This causes habitat destruction and greatly accelerates silt problems in the streams.

Fertilizers as a Source of Produce Contamination

Properly treated manure and litter from animals and domestic poultry can be effective and safe fertilizers (FDA, 1998). Biosolids, which are the nutrient-rich organic materials resulting from the treatment of sewage sludge, also can be safely recycled and applied as fertilizer to improve and maintain productive soils and stimulate plant growth. However, if untreated, improperly treated, or recontaminated after treatment, manure and biosolids may contain microorganisms that can contaminate produce.

Crops that grow in or near the soil are most susceptible to contamination by pathogens from manure or biosolids which may survive in the soil.

Low growing crops that may be splashed with soil during irrigation or heavy rainfall are also at risk if pathogens remain in the soil. Fruits and vegetables that are produced so that they have no contact with the soil are not exposed to contaminants in the soil unless they are dropped on the ground. As was the case with agricultural water, characteristics of produce that contribute to microorganisms attaching to their surface increase the potential for produce contamination.

Using Biosolids as Fertilizer

Requirements for the use of biosolids as fertilizers are in Title 40 of the Code of Federal Regulations, part 503 (40 CFR part 503). By these requirements, biosolids applied to the land must meet risk-based pollutant limits specified in Part 503 (EPA, 1994). Procedures to control disease-causing organisms and to reduce the attraction of flies, mosquitoes, and other potential disease-carrying organisms to the biosolids must also be met. In addition, there are general requirements, management practices, and frequency of monitoring, recordkeeping, and reporting requirements that must be met.

Rules for using biosolids as fertilizers are discussed in the EPA publication, “A Plain English Guide to the EPA Part 503 Biosolids Rule” (Walker et al., 1994). Since animal manure may contain levels of certain pathogens equal to or higher than those in biosolids, growers may want to consider some of the principles behind the Part 503 requirements and consider the appropriateness of adapting these practices to the land application of manure (FDA, 1998).

Using Animal Wastes as Fertilizers

The large volumes of animal manure generated by livestock feedlots, dairy barns, poultry farms, and other areas of highly concentrated animal production are a concern because animal wastes such as manure and litter can be an important source of pathogens. One particularly dangerous pathogen, *Escherichia coli* O157:H7, originates primarily from ruminants such as cattle, sheep, and deer, which shed it through their feces (FDA, 1998). In addition, animal and human fecal matter is known to harbor *Salmonella* and *Cryptosporidium*, as well as other pathogens.



Figure 10. Large scale animal operations like feedlots, dairy farms and poultry houses generate large volumes of wastes and litter which can be a source of pathogens for fresh produce. (Photo courtesy of USDA/NRCS)

Animal manure can pose a safety threat to the environment and to human health (Smith, 2002). If not properly contained or treated, it can lead to waterborne and foodborne illnesses (Figure 2). Waterborne illness may result when contaminated water reaches water municipal systems or is used for crop irrigation or for washing produce. Foodborne illness can occur when improperly aged or treated manure is used as fertilizer on fresh fruits and vegetables. Therefore, the use of manures, including solid manure, manure slurries, and manure tea, must be closely managed to limit the potential for pathogen contamination.

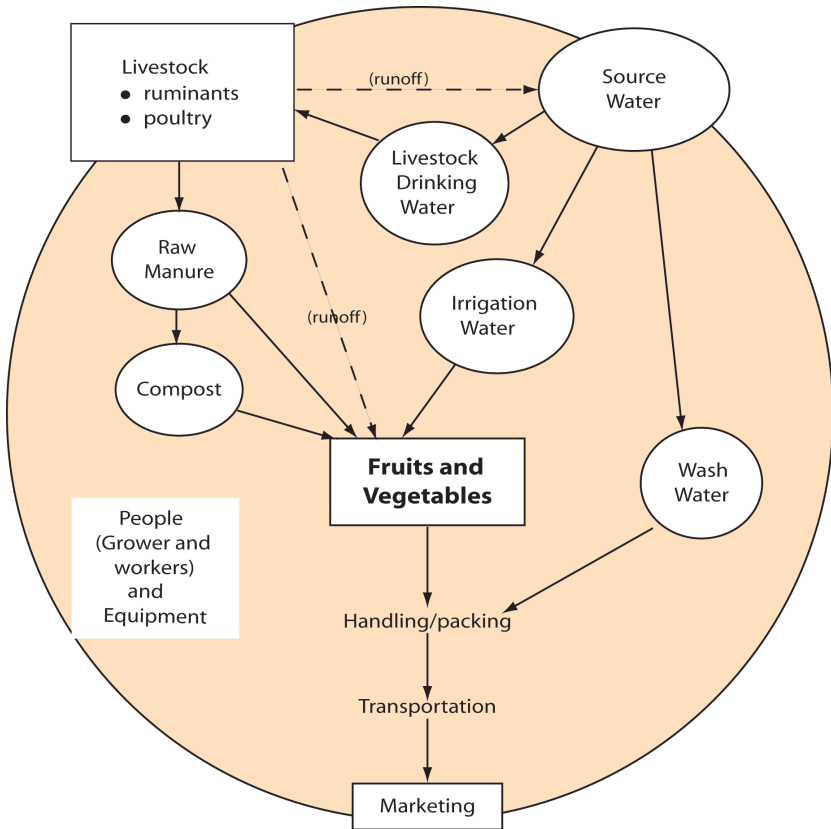


Figure 11. If not managed properly, animal manure can be a source of contamination for fruits and vegetables (Adapted from Gast et al., 2000)

The use of raw (untreated) manure on food crops carries a greater risk of contaminating the crops than the use of treated manure. For this reason, growers should not use raw manure unless it is:

- Applied to land used for a crop not intended for human consumption;
- Incorporated into the soil not less than 120 days prior to harvest of a product whose edible portion has direct contact with the soil surface or soil particles; or
- Incorporated into the soil not less than 90 days prior to harvest of a product whose edible portion does not have direct contact with the soil surface or soil particles (Ferguson and Ziegler, 2004).

Where it is not possible to maximize the time between application of raw manure and harvest, such as when growing a crop that is harvested throughout most of the year, raw manure should not be used (FDA, 1998).

A variety of treatments may be used to reduce pathogens in manure and other organic materials (FDA, 1998). The choice of treatment will depend on the needs and resources of the individual grower or supplier. Treatments may be divided into two groups, passive and active.

- Passive treatments rely primarily on the passage of time, in conjunction with environmental factors such as natural temperature and moisture fluctuations and ultraviolet (UV) irradiation to reduce pathogens. To minimize microbial hazards, growers relying on passive treatments should ensure manure is well aged and decomposed before applying it to production areas. Holding times for passive treatments vary depending on regional and seasonal climatic factors and on the type and source of manure.
- Active treatments include pasteurization, heat drying, anaerobic digestion, alkali stabilization, aerobic digestion, or combinations of these. Composting is an active treatment commonly used to reduce the microbial hazards of raw manure. It is a controlled and managed process in which organic materials are broken down by microbial action. Because this breakdown process generates a great deal of heat, it reduces or eliminates pathogens in the composted material. Thus, the risk of microbial contamination from composted manure is reduced compared to untreated manure. County extension offices can provide procedures to use when composting manure and poultry litter.

Additional good agricultural practices to reduce the potential for contamination of fresh produce when using animal wastes as fertilizers include the following:

- Avoid contamination of fresh produce from manure that is in the process of being composted or otherwise treated. Manure

storage and treatment sites should be located as far as possible from fresh produce production and handling areas. The minimum distance necessary will depend on many factors, including farm layout and the slope of the land, what runoff controls are in place, the likelihood of wind-spread or heavy rainfall, and the quantity of manure and how it is contained.

- If there is a possibility of runoff, leaching, or wind spread, consider barriers or physical containment to secure manure storage or treatment areas. This might involve storing manure being treated on a concrete slab or in clay-lined pits or lagoons.
- Because rainfall onto a manure pile can result in runoff which may carry pathogens, growers should consider storing manure under a roof or covering piles with an appropriate covering. Alternatively, growers may decide to collect water that leaches through manure that is being stored or treated. Collecting the leachate allows the grower to control its disposal (e.g., on a vegetative grassway) or use (e.g., to control moisture during composting).

Equipment, such as tractors, that come into contact with untreated or partially treated manure and are then used in produce fields can be a source of contamination (FDA, 1998). Equipment used to turn compost and other multiple use equipment that contacts manure should be cleaned with high pressure water or steam sprays before it contacts fresh produce. Growers also should be aware of factors such as farm layout and traffic flow that may allow a tractor to drive through manure before entering a produce field.

Organic fertilizers should not be applied when the produce is nearing maturity or ready to harvest. Growers should allow as much time as possible between the application of organic fertilizers and harvest.

Growers must also be alert to the presence of human or animal fecal matter that may be unintentionally introduced into the produce growing and handling environments. Potential sources of contamination include the use of improperly prepared animal wastes in fields near the production area; nearby composting or manure storage areas; nearby livestock, or poultry operations; near-



Figure 12. Properly treated organic fertilizer should be applied to fields before planting or in the early stages of plant growth. It should be applied near the roots and covered with soil. (Photo courtesy USDA/NRCS)

by municipal wastewater or biosolids storage, treatment, or disposal areas; and high concentrations of wildlife in the growing and harvesting environment (for example: birds nesting in a packing shed or heavy concentrations of migratory birds, bats, or deer in production areas).

Keeping complete records of organic fertilizer preparation and use is an important part of a Good Agricultural Practices program. Information that should be recorded includes:

- Source and physical make-up of the composted material
- Date compost process started
- Compost treatment applied
- Conditions during composting, such as dates of turnings of windrows (minimum 5 times) and daily temperature measurements
- Amount of composting material used on production field
- Site(s) of application
- Date of application
- Method of application
- Person applying the fertilizer
- Results of any microbial testing done on compost

Inorganic Fertilizers

Inorganic fertilizers are generally produced by commercial chemical processes. Although the products themselves are generally not a source of microbial contamination, care should be taken to assure that they are not contaminated due to the use of unclean water to mix them or contaminated equipment used to apply them.

Using Fertilizers in Arkansas

In 2003, the Arkansas legislature enacted three laws designed to ensure that decisions are made regarding the ways in which nutrients are applied to meet crop requirements so that water quality in the state is preserved (Goodwin et al., 2003; Daniels et al., 2004). These laws (Acts 1059, 1060, and 1061), which became effective January 1, 2004, affect Arkansas' commercial poultry farmers as well as any livestock, forage, and crop production operations using poultry litter as fertilizer. Others affected by the regulations are agricultural operators and landowners of more than 2.5 acres that are operating in designated nutrient surplus areas and any agricultural producers using state or federal funds for creating or implementing nutrient management plans, whether or not they are within designated nutrient surplus areas. The Arkansas Soil and Water Conservation Commission (ASWCC) was given the power to impose penalties on those who fail to comply with the regulations developed under these acts.

Specifically, the new regulations require:

- Certifying all those who apply nutrients to crops or pasture land
- Certifying nutrient management plan writers
- Registering all poultry feeding operations
- Developing and implementing nutrient management and poultry litter management plans for those operating in nutrient surplus areas. Areas designated as nutrient surplus areas include: the Illinois watershed; the Spavinaw Creek watershed; the Honey Creek watershed; the Little Sugar Creek watershed; the upper Arkansas River watershed which includes Lee Creek and Massard Creek; the Poteau River watershed; the Mountain Fork of the Little River watershed; the upper White River watershed above its confluence with the Buffalo River.

For more details on these laws, contact your county extension office or visit www.uaex.edu to obtain the factsheets FSA29, “New Arkansas Laws Regulate Use and Management of Poultry Litter and Other Nutrients” and FSA 9515, “Nutrient Management Planning for Livestock Operations: An Overview.”

Animal Exclusion and Pest Control

All animals, both domestic and wild, are potential sources of pathogenic organisms. These organisms are usually contained in the feces from the animals. However, since animals are in contact with soil, manure, and water, pathogens from these sources can easily become attached to their hair, feathers, hides, etc. In addition, microorganisms native to the respiratory and digestive tracts of some animals may be pathogenic to humans. While it is not possible to keep all animals out of produce production areas, efforts to exclude as much animal life as possible not only improve the safety of fruits and vegetables but also aid in preventing damage to crops which can lower crop value.

Domestic animals, such as pets and livestock, should be kept out of produce fields, vineyards, and orchards during the growing season. Workers should not be allowed to bring dogs, cats, or other domestic animals into production fields, packing houses, or storage facilities. Physical barriers such as



Figure 13. Birds, deer, and other wildlife can contaminate fresh produce and should be kept out of production areas as much as possible. (Photo courtesy of USDA/ARS)

fences should be used to keep livestock from entering areas where produce is grown.

High concentrations of wildlife, such as deer or birds, in a field may increase the risk for microbial contamination (FDA, 1998); however, control of wild animal populations in a crop production area may be difficult, especially where these areas are adjacent to wooded areas, open meadows, or waterways. In addition, federal, state, or local animal protection requirements may affect the kinds of exclusion practices that can be used. To the extent possible, where high concentrations of wildlife are a concern, growers should consider establishing good agricultural practices to keep wildlife away from produce growing areas or to redirect wildlife to areas with crops that are not destined for the fresh produce market.

Pest Control

Insects and rodents are the pests most commonly found in production and handling areas. Not only can they carry pathogens that contaminate fruits and vegetables, they also may damage packaging materials, other supplies, and buildings.

Since pests are attracted to areas where they have food, water, and materials for nesting, cleaning is an important step in controlling them. Removal of weeds and standing water in the fields, vineyards, and orchards, and careful cleaning of packing and storage facilities eliminates food supplies, destroys insect eggs, and reduces the number of places where pests can take shelter.

In addition to cleaning, it also is important to implement a pest control program. In-house pest control programs are critical to identifying when pests are present and implementing measures to control them. In addition, however, many fruit and vegetable producers have found it is desirable to work with a professional pest control operator to solve and prevent pest problems, especially in packing houses and storage buildings. A licensed, certified pest control operator is able to take an integrated approach to pest control using both chemical and non-chemical control measures. This will help control pests with a minimum usage of potentially hazardous chemicals. Professional pest control operators stay up-to-date on the latest equipment and prevention products and will maintain the appropriate records regarding their usage for you.

Pesticides in Produce Production

Pesticides have a long history of use in the United States. Farmers have traditionally used them to increase crop production and to produce fruits and vegetables that are free of insects and blemishes. These chemicals

have helped to increase agricultural production with reduced labor. Improper use of pesticides, however, can result in chemical contamination of fresh fruits and vegetables.

The amount of pesticides used in the United States in both 2000 and 2001 exceeded 1.2 billion pounds. Pesticides are an important component of total farm expenditures totaling more than \$11 billion in both 2000 and 2001. This represented 3.9% of total farm expenditures in 2000 and 3.7% in 2001 (Kiely et al., 2004). Over half of all money spent for pesticides went to purchase herbicides (Table 9). Expenditures for insecticides were next but were less than half what was spent for herbicides. Expenditures for all other types of pesticide products totaled just over half those for insecticides.

Table 9. Pesticide expenditures, by type of product, in the United States in 2001.

Type	Expenditure (Million \$)	% of Total Expenditures
Herbicides ¹	6,410	58
Insecticides ²	3,124	28
Fungicides ²	835	8
Other ³	721	7
Total	11,090	100

Source: Kiely et al., 2004

¹“Herbicides” include herbicides and plant growth regulators

²“Insecticides” and “fungicides” exclude sulfur and petroleum oil

³“Other” includes nematocides, rodenticides, molluscicides, aquatic and fish/bird pesticides, other miscellaneous conventional pesticides, plus other chemicals used as pesticides

Agriculture was the market segment spending the greatest amount on pesticides in both 2000 and 2001 (Table 10). Home and garden users spent slightly more than industry/commercial/government users but these two segments together represented less than half of the agricultural usage. Agricultural expenditures were greatest for all pesticide types, except insecticide/miticides where home & garden levels of usage were similar to those of agricultural users.

Agricultural pesticides are applied to work on specific targets such as weeds or insects. Ideally, pesticides should be applied at just the right time to control pests and should then degrade into harmless compounds in the soil, air, or water without contaminating the environment (EPA, 2004). However, this timing is often difficult to attain.

Pesticides have the potential to harm the environment by injuring nontarget plants and animals, leaving harmful residues, or moving from the application site into the surrounding environment. Some pesticides may reach ground or surface water causing an environmental hazard.

Table 10. 2001 U.S. pesticide expenditures (and percent of total for type) by pesticide type and market sector.

Pesticide Type	Market Sector			
	Agriculture	Industry/ Commercial/ Government	Home & Garden	Total
	Mil \$ (%)	Mil \$ (%)	Mil \$ (%)	Mil \$ (%)
Herbicides/Plant growth regulators	4,987 (78%)	792 (12%)	631 (10%)	6,410 (100)
Insecticides/Miticides	1,326 (42%)	510 (16%)	1,288 (41%)	3,124 (100)
Fungicides	615 (74%)	172 (21%)	48 (6%)	835 (100)
Other ¹	476 (66%)	61 (8%)	184 (26%)	721 (100)
Total	7,404 (67%)	1,535 (14%)	2,151 (19%)	11,090 (100)

Adapted from: Kiely et al., 2004

¹ "Other" includes nematocides, rodenticides, molluscicides, aquatic and fish/bird pesticides, other miscellaneous conventional pesticides, plus other chemicals used as pesticides

In order to reduce hazards to humans caused by pesticides, the EPA has set limits on how much of a pesticide may be used on food during growing and processing. They also set limits, called tolerances that are the maximum amount of a pesticide that may remain in or on a food treated with the pesticide. Information on tolerances is available in the Code of Federal Regulations. The EPA's web site also has a search page that can be used to view tolerances for particular foods. Government inspectors monitor food in interstate commerce to ensure that these tolerances are not exceeded. The EPA has also set standards to protect workers from exposure to pesticides on the job.

Farmers have a variety of options for fighting pests. These include applying biological pesticides, introducing natural predators such as bats, removing pests' breeding grounds, and applying chemical pesticides. Exploring alternative methods for pest control and using a variety of methods are referred to as Integrated Pest Management (IPM). IPM techniques can reduce pesticide use to the minimum amount necessary to produce high quality food, while maximizing profits.

IPM combines chemical control with cultural and biological practices to form a comprehensive program for managing pests. This approach emphasizes preventive measures to keep levels of pests below the economic threshold while using the minimum amount of pesticide necessary. However, using the proper pesticide at the time of maximum pest susceptibility is often critical to an effective IPM program (Waskom, 1995). IPM includes practices

such as the following:

- Monitoring pest and predator populations.
- Selecting crops and varieties that are resistant to pest pressures.
- Timing planting and harvest dates to minimize pest damage.
- Rotating crops.
- Employing beneficial insects and other biological controls.

Changing a pest management strategy to an IPM program may involve modifying tillage, fertility, cropping sequence, and sanitation practices. This may require some experimentation and perhaps even professional help. When pesticides are required to control pests, it is important to use application techniques which minimize the possibility of contaminating water with the pesticides. All pesticide applicators should become certified and remain current in new developments in pest management.

Pesticide registration is a process in which the EPA examines the ingredients of a pesticide, the site or crop on which it is to be used, the amount, frequency and timing of its use, and storage and disposal practices in order to ensure that the pesticide will not have unreasonable adverse effects on humans, the environment, and non-target species.

The EPA registers pesticides and their use on specific pests and under specific circumstances. For example, "Pesticide A," registered for use on apples, may not be used legally on grapes, or an insecticide registered for "outdoor use" may not legally be used inside a building. In some circumstances, use of a registered pesticide may be restricted to pesticide applicators with special training. Certification and training regulations require pesticide applicators to meet certain training and/or testing requirements before they use or supervise the use of pesticides labeled "restricted use."

Using Pesticides in Arkansas

In Arkansas, the licensing of pesticide applicators and the enforcement of pesticide laws and regulations are primarily the responsibility of the Arkansas State Plant Board. Before a pesticide can be sold in Arkansas, it must first be registered with the Plant Board in accordance with the Arkansas Pesticide Control Act and Regulations. This allows the Plant Board to confirm that the product meets all State and Federal requirements to provide for both human and environmental protection.

Dealers who want to sell or distribute pesticides designated by the Environmental Protection Agency as "Restricted Use Products" must first obtain a license from the Plant Board. Both "users" and "applicators" of restricted use pesticides must be trained in the proper handling of such pesticides and then licensed by the Plant Board in accordance with the Arkansas Pesticide Use and Application Act and Regulations. Those applicators that will

apply pesticides commercially must also be tested before a license can be issued. The required safety training, also known as Certification or Recertification, is provided by the Cooperative Extension Service, University of Arkansas.

The Pesticide Division of the Plant Board is also responsible for enforcement of the Arkansas Worker Protection Standard as it applies to the use of pesticides. The Division is also involved in monitoring ground water for contamination by pesticides and determining the impact of pesticides on endangered species in the State. The Arkansas Department of Pollution Control and Ecology is responsible for certain pesticide regulations concerning transportation and disposal.

Worker Health and Safety

It is important that individuals handling produce at every stage, from field to table have a good understanding of proper hygiene practices to prevent product contamination. Training of workers at every level of the production chain and education of consumers in proper handling of fresh fruits and vegetables have been identified as key elements to reduce foodborne illnesses associated with fresh fruits and vegetables (Beuchat, 1998).

Growers can provide education to workers, but, in the end, it is the workers' health, hygiene, and safety practices that will reduce the risks of product contamination. Therefore, employers should provide workers with all the necessary information about acceptable hygiene practices, ensure that it is understood, and send a clear signal to workers about the importance of following these practices.

An infected person may or may not show symptoms of illness but they can easily contaminate fresh produce with microbial pathogens. When infected workers handle fresh produce, the pathogens in their bodies can then be passed to the fruits and vegetables. Consumers who handle or eat the contaminated produce may then become infected.

Workers with gastrointestinal illnesses or open wounds can contaminate fresh fruits and vegetables



Figure 14. The responsibility for reducing or avoiding contamination during production of crops falls mostly on the workers since they have the greatest amount of contact with the product. (Photo courtesy of USDA/NRCS)

through handling. General symptoms that indicate a worker may have an illness that can lead to fruit and vegetable contamination include diarrhea, vomiting, dizziness, abdominal cramps, exposed or open wounds or sores, and jaundice (yellowing of the skin). Persons showing these symptoms should be prevented from handling fresh produce.

Supervisors should train workers to recognize disease symptoms and to report them before beginning work. Affected workers should be assigned to activities that do not involve contact with the produce. Supervisors should be trained to make judgments about when to keep employees from handling produce. If workers are assured that reporting illness will not mean loss of work or reduction in pay they may be more likely to report problems.

Workers removed from produce handling jobs because of illness should not be returned to these jobs until one of the following conditions has been satisfied:

- They provide documentation from a licensed healthcare provider stating that they are free from the infectious agent that was suspected of causing their symptoms.
- They provide documentation from a licensed healthcare provider stating that the symptoms experienced resulted from a chronic, noninfectious condition.

Any worker with exposed wounds or lesions like boils that contain pus should have these wounds properly disinfected and covered before participating in fruit or vegetable production and handling activities. If the lesion cannot be effectively covered to prevent contact with fresh produce or produce handling equipment, the worker should not be allowed to work with anything that might contact the produce. A first-aid kit, with supplies for treating worker injuries, should be readily available at the work site. The procedures involved in disinfecting and covering a wound should be included in employee training.

Unfortunately, people with no symptoms of disease also can transmit microbial pathogens to produce, water, and other employees because many microorganisms can reside in the human body without producing signs of disease. Therefore, it is also important for employers to provide fruit and vegetable handlers with a training program on good food handling and hygiene practices. This training is important for all employees, including supervisors, full time, part time, and seasonal personnel. A good training program for workers is one of the best ways to reduce the risk of produce contamination.

Proper hygiene procedures should be established and included in training programs. If a formal training program is not appropriate, such as for part-time and seasonal workers, the person in charge (grower, foreman, etc.) should verbally instruct and demonstrate to newly hired workers proper health and hygiene prac-

tices and stress that all employees are expected to follow these procedures.

Proper records should be kept detailing training activities, employee medical conditions, and any incidents of gastrointestinal disease. This makes it possible to assess the health of personnel and take corrective action to minimize the risk of contaminating produce. Such records are also useful should there be a need to trace the cause of a disease outbreak.

Employees should be provided with water for drinking and sanitary needs. Water for human consumption should be potable - that is, free from microorganisms and/or chemical substances that can adversely affect the health of the person consuming it. Contaminated drinking water can easily cause intestinal disorders in the workers. To prevent contamination, it is also important that water used for handwashing is drinking water quality. Ensuring the availability of potable water for use by field workers reduces the risk of waterborne diseases and the consequent contamination of fresh produce.

When providing drinking water in growing fields and packing areas growers should assure that:

- Water supply systems are in good condition and operating properly;
- Water storage vessels are clean and closed at all times;
- Individual water vessels are cleaned and disinfected on a daily basis;
- Water containers are kept closed and out of the sun and excessive heat until required for use; and
- Disposable cups are provided and each person uses a different cup.

Some basic hygiene practices that should be used by agricultural workers to minimize contamination of fresh fruits and vegetables include:

- Regular bathing;
- Using toilets, even in the fields (Portable units should be provided in locations without a municipal sewage system. Units should be maintained in a good condition to encourage their use.);
- Washing hands after any possible contamination and in the correct manner;
- Wearing clean clothes; and
- Keeping nails clean and short.

Handwashing is considered a simple procedure and it is generally assumed most people learn to wash their hands as young children. However, individuals come from different backgrounds and may have different concepts of proper handwashing. Therefore, workers should be instructed in proper



Figure 15. Workers' hands are frequently the source of produce contamination. (Photo courtesy of USDA/NRCS)

handwashing practices, no matter how basic this instruction may seem. The proper technique for washing hands is as follows:

1. Wet hands with warm water then vigorously apply soap, rubbing hands together for 20 seconds. Scrub the whole surface of the hand, including the back, wrists, between fingers, and under nails
2. Rinse thoroughly with warm, running water
3. Dry hands with paper towels
4. Turn off water tap using a paper towel
5. Open the exit door with the same paper towel then dispose of the towel in the container provided

When nails contain accumulated dirt, they should be scrubbed with a nail brush.

Hands should be washed after using the restroom, smoking or eating, taking a break, covering coughs or sneezes, touching skin or wounds, touching hair, shoes, floors, or other dirty surfaces, or handling agricultural chemicals or cleaning materials. Signs reminding workers to wash their hands should be posted in toilet facilities and other places where hand contamination might occur.

Toilets and handwashing stations should be inspected frequently to ensure their cleanliness and the availability of soap and paper products. Keeping the facilities neat and clean will encourage their use. Supervisors and the workers themselves should be instructed to report any dirty sanitary facilities or other possible sources of contamination. Cleanliness programs for these facilities should be accurately documented.

Areas should be designated for workers to smoke and eat, and workers should be told that these activities should only take place in the designated areas. Workers should be instructed to deposit trash and any unwanted food items in the appropriate garbage cans.

It is important that visitors to the produce production and handling areas, such as produce inspectors and buyers, follow the established hygiene and safety practices. Signs indicating proper handwashing and trash disposal procedures are recommended to prevent contamination of doorknobs and other surfaces by visitors.

Toilet facilities should be easily accessible from the work areas and should be available to the workers on a continuous basis, not just during break periods. This will reduce the possibility of workers relieving themselves in convenient places near the production area or behind packing sheds or storage buildings.

Toilets located in the fields should not be placed close to water sources or where rain can spread contaminants or cause flooding. Any inadequate toilet facility increases the risk of contaminating water, soil, produce,

and personnel working in the field. Maintenance and servicing of toilets should be performed away from the field to protect soil, water, and workers, in case leaks or spillages occur. A plan should be made to handle problems with toilet facilities located near production areas.

Toilets and hand-washing stations should be cleaned and inspected regularly and periodically checked for adequate supplies. Provision should be made to dispose of handwashing water away from the growing field to avoid contamination of produce. Containers used for water transport and storage should be periodically emptied (preferably daily), cleaned, and disinfected. Bottles for potable water should be replaced regularly.

Harvesting and Cooling Fresh Produce

Since most fresh fruits and vegetables are extremely perishable, a major factor in determining the safety and quality of produce at market is its safety and quality at harvest. Also important in determining market safety and quality is the treatment the produce receives during harvesting, handling, storage, and transportation.

Harvesting

The selection of a harvest procedure will depend on the characteristics of the produce and its proposed use. Because appearance and freedom from defects are important for commodities destined for the fresh market, manual harvesting is generally used since it allows for selection of the material to be harvested and generally results in less damage to the product during harvest. This is especially true for commodities such as lettuce, berries, grapes, peppers, and apples that are to be sold fresh. With manual harvest, worker hygiene is important since there is extensive hand contact with the product that can lead to produce contamination.

Mechanization has proven extremely useful in harvesting many types of produce for processing and for produce that can withstand physical handling (i.e., carrots, potatoes, and radishes) (Morris, 2002). For processing, harvesting by machine may improve quality over that obtained with hand harvesting because of the faster rate of harvesting and the reduced holding time in the field before processing. However, for some products, the once-over nature of mechanical harvesting results in lower quality than the more selective hand harvesting.

Microbial contamination of fresh produce can occur easily during harvest. This contamination may result not only from contact with field workers but also from environmental contaminants such as soil, water, and air

and from unclean or contaminated equipment and harvest containers. Produce that is damaged during harvest is especially susceptible to contamination since surface breaks can allow pathogens to enter the flesh of the product. Once in the product, pathogens are much more difficult to remove by washing, which is the only pathogen reduction step for most fresh produce.

Harvest equipment, including machinery, knives, containers, baskets, buckets, pallets, and lugs, should be cleaned and sanitized before use, used appropriately, and kept as clean as possible. It should never be used to haul things like garbage, manure, or other debris, nor should these things be allowed to contact containers or pallets used for fresh produce.



Figure 16. Proper handling and sanitation of harvest equipment is critical to produce safety. (Photo courtesy of USDA Photo Library)

In-field Packaging Operations

Some products like grapes and strawberries are not cooled or washed after harvest. Instead, they are packed in the field immediately after harvest, where contamination can easily occur.

All workers involved in field packing operations should be encouraged to follow good hygiene and sanitation practices. Also, containers and packing materials should be handled with care and kept clean and free from dirt and contaminants.

Postharvest Water Quality

Water is used in a number of postharvest operations. It is used in dump tanks to reduce injury to the produce when field containers are emptied onto a packing line, and it may be used for rinsing on the packing line. Cold water may be used to remove field heat from fruits and vegetables. Water is needed for mixing solutions of waxes and/or fungicides, and hot water treatments can be used as a means of insect control in some commodities.

Water used for postharvest operations should be potable and free of disease-causing organisms (FDA, 1998). Since the quality of the processing water should be such that it does not contaminate produce, water quality consistent with EPA requirements for drinking water is recommended.

Even healthy-looking produce coming from the field can carry large populations of pathogens, particularly during warm, rainy weather (Sargent et

al., 2000). Water used in post-harvest operations may become contaminated by contact with contaminated fruits and vegetables and then spread the pathogens to uncontaminated produce.

Maintaining water quality usually involves the addition of an approved sanitizer to the water. Sanitizers such as sodium hypochlorite, calcium hypochlorite, or liquid chlorine are frequently used to aid in maintaining water quality, and many packers routinely add chlorine to their water handling systems. A 50-200 parts per million (ppm) chlorine concentration can destroy most microorganisms. However, higher concentrations are needed to kill microbial spores. Failure to follow appropriate guidelines regarding the use of chlorine sanitizers can reduce or eliminate the effectiveness of this treatment for reducing produce contamination.

If chlorine is used to sanitize water used for fresh fruits and vegetables, it is important to monitor the free (unreacted) chlorine concentration in the water. Water samples should be taken at least on an hourly basis and tested for chlorine concentration. All recirculated water should be changed daily or more frequently if the water becomes extremely dirty due to a build-up of waste matter from the produce since this reduces the effectiveness of the chlorine treatment. Local environmental codes must be consulted for the proper disposal of chlorinated water.

Water used in produce handling operations should be changed as often as necessary to maintain sanitary conditions. The actual frequency for changing the water will vary depending on the operation, the product being handled, how dirty it is, etc. All equipment surfaces that the water contacts should be cleaned and sanitized to prevent contamination of the water and subsequent produce contamination. Procedures such as the use of backflow devices and legal air gaps should be used to prevent contamination of clean water with potentially contaminated water. All equipment designed to assist in maintaining water quality, such as chlorine injectors, filtration systems, and backflow devices should be routinely inspected and maintained.

Cooling Considerations

Good temperature management is a critical factor in determining the ultimate quality of fresh fruits and vegetables (Morris and Brady, 2005). All fresh produce are living organisms and, for optimum quality, must remain alive and healthy until processed or consumed. Temperature also influences the rate of spore germination and pathogen growth. Recommendations for cooling methods and optimum storage conditions for a variety of fruits and vegetables are presented in Appendix B.

In order to maintain the highest produce quality, it is necessary to slow product deterioration as much as possible and as quickly as possible (Mitchell, 1991). One way to do this is to lower the temperature of the product, generally within 24 hours after harvest. As a general rule, each 18°F reduction in temperature lowers respiration rate by a factor of 2 to 4. This can have a significant effect on the keeping-quality of produce. For example, an apple or a pear will ripen as much in a day at 70°F as it will in a week at 32°F.

Temperature control of produce begins in the field. At harvest, the temperature of fruits and vegetables is close to that of the air which, depending on the location and the time of the year, may be over 100°F (Wills et al., 1981). In order to ensure the lowest possible temperature at harvest, it is generally recommended that most fruits and vegetables should be harvested in the coolest part of the day, which is usually early morning. An exception to this recommendation occurs in situations when fruit is harvested late in the afternoon so that it can be transported to a local market during the cooler night hours (Thompson, 2002).

After harvest, produce should be handled to keep it as cool as possible until it is removed from the field. Exposing picked produce to direct sun can result in a significant rise in product temperature. For example, Nelson (1985) reported that the temperature of grapes held in the sun was as much as 12°F above air temperature while that of shaded fruit remained at least 5°F below air temperature. This temperature range can mean the difference between produce that is acceptable and produce that has lost a significant amount of quality. However, care should be taken to avoid contamination during shading. For example, if shading is achieved by placing produce under a tree, care must be taken to prevent produce contamination by droppings from birds sitting in that tree.

It is critical that produce is cooled to storage temperatures as quickly as possible (Appendix B). Rapid cooling is beneficial because lower temperatures lead to less development of pathogens, reduced metabolic rates, and decreased water loss from the products. As a general rule, more quality is lost in one hour at 68°F than in 24 hours at 32°F (Lurie, 2002).

Consider the results of an experiment in which apples were cooled at different rates and held in storage at different temperatures (Figure 17). The apples cooled quickly kept longer than both the fruit cooled more slowly and the fruit cooled in stages. Apples stored at lower temperatures also kept longer than those stored at warmer temperatures.

Pre-cooling is the term commonly used to refer to any cooling treatment before shipping, storage, or processing (Wills et al., 1981). A number of methods are used for pre-cooling fruits and vegetables; however, the two most commonly used methods are cold air cooling and hydrocooling.

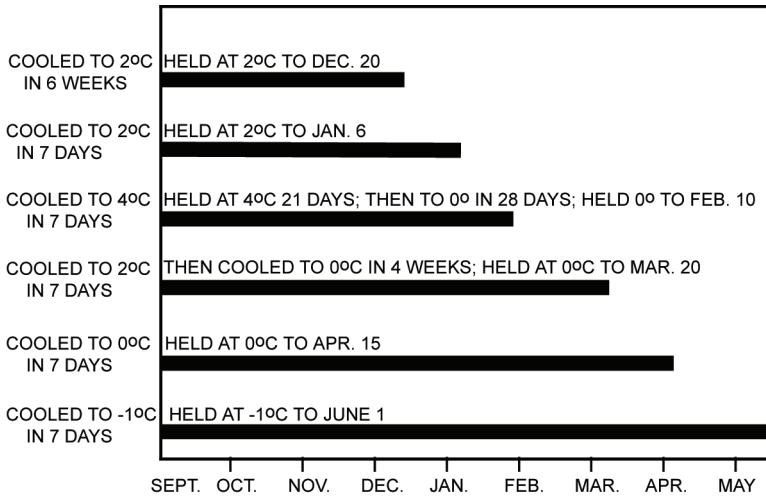


Figure 17. Normal life expectancy of apples cooled at different rates and stored at different temperatures. (Adapted from Bramlage and Morris, 1985)

The nature of the product is a major factor in the selection of a cooling method (Boyette et al., 1989). Different types of produce have different cooling requirements. For example, strawberries and broccoli require near freezing temperatures while these low temperatures may damage summer squash and tomatoes. Because some products are damaged by exposure to water used as the cooling medium in some cooling methods, these products must be air cooled.

Cold air cooling, in the forms of room cooling or forced-air cooling, is the most widely adaptable method of precooling and is commonly used for many fruits and vegetables (Morris et al., 1974). In this cooling method the cooling medium, refrigerated air, surrounds the produce packed in boxes or pallet bins. Cold air cooling is the least energy-efficient type of cooling but is widely used because it is adaptable to a wide range of products and packaging systems.

Room cooling is most commonly used for products with a relatively long storage life that will be cooled and stored in the same room (Mitchell, 1991). Examples of such products include potatoes, sweet potatoes, and controlled-atmosphere stored apples. Room cooling is generally sufficient for keeping produce at a low temperature once it has been cooled, but it often does not remove field heat rapidly enough to maintain the quality of highly perishable crops. For example, some types of produce, such as strawberries,

must be cooled as quickly as possible after harvesting to preserve fresh quality. Even a delay of several hours may be enough to reduce quality considerably. In such cases, room cooling is not fast enough to prevent serious damage.

The rate of cooling is significantly increased if the air is forced through the packages and around each piece of produce (Wills et al., 1981). Forced-air cooling is accomplished by exposing packages of produce in a cooling room to higher air pressure on one side than on the other. This pressure difference forces the cool air through the packages and past the individual units of produce, greatly increasing the rate of heat transfer. Depending on the temperature, airflow rate, and type of produce being cooled, forced-air cooling can be from 4 to 10 times faster than room cooling (Figure 18).

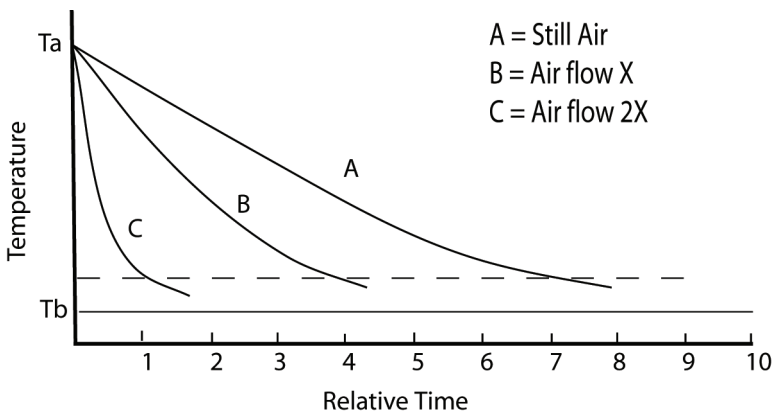


Figure 18. Response of a typical commodity to airflow rate during cooling. T_a is the beginning temperature of the product; T_b is the air temperature in the cooling room. (Adapted from: Boyette et al., 1989)

When using an air-based cooling system, it is important to maintain sanitary conditions in the facility. Special attention should be given to the air source. The air system should be properly maintained and the filters changed regularly. Animals should be excluded from the areas surrounding the air source, compost storage deposits should be located far from air sources, and any other pathogen sources that could potentially contaminate the air used in cooling systems should be eliminated.

Hydrocooling is accomplished by moving cold water around the produce either in a shower system or by immersing the produce directly in the cold water (Thompson, 2002). Because water is a better heat transfer medium than air, hydrocoolers reduce produce temperature faster than forced air coolers; however, hydrocoolers are not appropriate for use with fruits and vegetables that can be damaged by exposure to water. For most products, cooling

water is kept at 32° to 33°F since this temperature is low enough to cool product quickly but not so low that it will damage most produce (Lurie, 2002). If the produce is simply immersed in the cold water, the water in contact with the produce will start to heat up and cooling will be slowed. Therefore, to be effective, a hydrocooler must be designed so that the water moves around the produce. Since there is direct contact between the produce and the water, the water must be free of disease-causing organisms.

Package icing involves packing the product in crushed or flaked ice. Ice not only removes heat rapidly when first applied to produce but, unlike other cooling methods, continues to absorb heat as it melts (Thompson, 2002; Boyette, et al., 1989). This cooling method has the advantage of maintaining a high humidity around the product, thereby reducing moisture loss. This method is best used on commodities that can tolerate contact with ice, e.g. root and stem vegetables, broccoli, and Brussels sprouts. Disadvantages of package icing include its high capital and operating costs, added package weight due to the ice, the necessity that the product package be capable of withstanding constant water contact, and melting ice which may damage or contaminate other products in a shipment of mixed commodities.

Cooling methods using water and ice as the cooling mediums have the greatest potential for contamination of fruits and vegetables. Cooling water can become a contamination problem, therefore the water should be replaced regularly (at least once a day, depending on the amount used and produce conditions). It is essential that ice used in cooling be produced from chlorinated, potable water and stored in a sanitary manner, so that it doesn't contaminate the produce during the cooling process (Sargent et al., 2000). It is important to perform microbiological tests on water used in cooling and ice-cooling systems. The most commonly used tests are for total coliforms, fecal coliforms, and *E. coli* since these tests are good indicators of water contamination.

The addition of chlorine to cooling water is a common practice and the use of chlorinated water to make the ice is recommended. Because chlorine loses effectiveness when it reacts with organic compounds, its concentration should be monitored frequently. A 50-200 ppm chlorine concentration can destroy most viable microorganisms. However higher concentrations are needed to kill spores. It is important to place a water settling and filtration device in the cooling water treatment system to remove organic material since these materials can react with the chlorine and lower its efficiency as a sanitation agent.

Cooling equipment should be cleaned and inspected frequently. Maintenance of equipment and use of appropriate sanitary procedures is critical to ensuring the safety of the produce.

GOOD MANUFACTURING PRACTICES FOR FRESH PRODUCE

The packing process has been identified as the point in the field-to-table chain where fresh produce is at the greatest risk of contamination (Castillo and Rodriguez-Garcia, 2004). The use of Good Manufacturing Practices (GMPs) will help reduce the risk of contamination of fresh produce during handling, packing, storage, and transportation.

Produce Cleaning and Treatment

Because microorganisms are everywhere in the growth environment of produce, it is inevitable that fresh fruits and vegetables will have microorganisms on their surface, even when produce operations used recommended GAPs. Once produce is contaminated with human pathogens, there are currently no available agents or processes, other than thorough cooking, that can ensure complete elimination of the pathogens. This is why preventing contamination in the first place is so important.

As discussed earlier, surface microorganisms on fresh produce vary widely and the ones present vary with the type of commodity and the agricultural practices used. Natural microflora on fresh produce is usually harmless. However, soil, water, sewage, and air, as well as humans and animals, can contaminate the external surfaces of produce with pathogenic organisms. During and after harvest, many conditions come together that can favor the growth of microorganisms. Some of these conditions include handling, cross-contamination, temperature abuse, and increases in product respiration rates leading to heat production.

Reduction in the numbers of pathogens on produce is important to reduce foodborne illness, to decrease spoilage, and to improve appearance and nutritive value. The washing and sanitizing of fruits and vegetables are commonly used to reduce surface contamination. However, the application of such treatments is dependent on the ability of the commodity to tolerate water since the shelf life of some delicate produce is reduced after wetting. This is especially true for commodities with large surface areas that readily hold water, like strawberries, other berries, and grapes. For these products, another cleaning media, air, may be needed for removal of dust and debris.

For produce that can tolerate handling, surface dirt should be removed by dry cleaning, brushing, air blowers, or vacuuming before washing.

This step is especially important with commodities that cannot tolerate being wet. Subsequent washing steps then reduce remaining surface dirt. Generally, a thorough spray wash with chlorinated water or multiple washes are more effective than a single soaking wash.

Water used for produce washing must be potable and free of pathogenic organisms. The initial wash to remove surface dirt can be with hot water alone or with water containing food grade detergents or permanganate salts (Beuchat, 1998).

Washing equipment should be selected based on the characteristics of the produce. Soft fruits are generally washed on conveyor belts using water sprayers. More solid fruits like apples and pears may be washed in rotating devices or on flumes. Root crops are typically cleaned with brush washers which contain cylindrical rotating brushes. Brushes must be cleaned and disinfected often because they can easily spread contaminants.

A sanitizing step, generally using chemical agents, usually follows washing. Sanitizing means treating clean produce to destroy or substantially reduce the numbers of microorganisms of public health concern, as well as other undesirable microorganisms, without adversely affecting the quality of the product or its safety to the consumer (FDA, 1998). It is important to apply the sanitation step to produce that has already been washed since dirt can interfere with the effectiveness of sanitizing agents on microorganisms.

A chlorine solution is the most common sanitizer, but there are many other sanitizing agents on the market. The effectiveness of each individual sanitizer is influenced by factors such as water temperature, pH, contact time, organic matter content, and the surface structure of the fruit or vegetable. Produce sanitizers can reduce the number of surface organisms but do not destroy all organisms. Manufacturer's instructions should always be strictly followed when using sanitizers. When in doubt about proper sanitizer use or for new applications of a product, contact the manufacturer.

There is a debate among food safety experts about the best temperature for washing and sanitizing fresh fruits and vegetables. It is generally agreed that washing and sanitizing produce in cold water results in a higher quality product since low temperatures slow the respiration rate of fresh commodities which, in turn, slows changes in texture and other quality factors. However, for some commodities (e.g. apples, celery, mangoes and tomatoes), it has been observed that when the warm fruit or vegetable is placed in cold water, a pressure differential develops. This creates a suction effect that results in the cold water being pulled into the fruit. Contaminants in the water are then inside the fruit where they are protected from being washed off.

It has been proposed that if microorganisms can be internalized in wash water, sanitizers in this water should also be pulled into the produce and

be active against the organisms (Castillo and Rodriguez-Garcia, 2004). In a study testing this theory, tomatoes which had internalized several species of microorganism were treated with sprays of water, chlorine, or lactic acid. Only the lactic acid was effective in reducing the contamination levels. The researchers proposed that the organic matter in the tomatoes inactivated the chlorine but did not affect the lactic acid.

One recommendation to reduce the risk of produce contamination associated with water infiltration is to adjust cooling/wash water temperature to 9°F above the temperature of the flesh of the fruit (Showalter, 1993; Zhuang et al., 1995). This could be an important precaution for washing systems; however, for cooling systems it interferes with the removal of field heat. Therefore, for commodities that can have this problem, it is recommended that they should be cooled with air or by other cooling methods that don't use water. If hydrocooling is used, it should be combined with an initial air cooling step to minimize the temperature difference between the produce and the cooling water. The use of disinfectants such as chlorine in the cooling water could also help to reduce the risks associated with pathogen internalization.

For those commodities such as berries that cannot be exposed to water, prevention of contamination is the only way of controlling microorganisms on the surface of the fresh produce.

Packing and Storage

Many of the sanitation considerations discussed for the production field can be extended to the packing facility. During packing it is important to consider GMPs for packing and storage facilities, equipment, containers, trash handling, worker health and hygiene, and storage of produce and packing material.

Packing Facilities

Packing and storage facilities will vary depending on the produce being processed and the size of the operation. The packinghouse can be a small shed near the field or a large building with many processing and storage areas. Regardless of the size of the operation, good manufacturing practices are essential to prevent the physical facility from becoming a source of microbial, physical, or chemical contamination and to ensure consistent produce quality.

Sanitary construction considerations for packing and storage facilities include the following:

- Facilities should be designed and constructed for easy cleaning

and sanitation.

- Buildings should be well screened with barriers designed to exclude pests, domestic and wild animals, birds, and insects.
- Windows should be closed or covered with mesh.
- Walls, floors, and ceilings should be in good condition and easy to clean and sanitize.
- Lamps and bulb lights should be covered so that, if they should break, the product and the work area will not be contaminated with broken glass.
- The floor should be constructed with a slight slope to avoid water accumulation in production areas.
- The sewage system should be constructed to prevent water back-up into packing and storage rooms.

Packing and storage areas should be separated. Ideally, different personnel should handle tasks in each of these areas to avoid cross-contamination. It is important to keep all packing and storage areas free from chemicals, trash, machinery, harvest residues, and waste materials in order to discourage pests and prevent produce contamination. Comprehensive sanitation and maintenance programs should be implemented, and pest control and monitoring should be in place.

All equipment used for handling fresh produce should be designed for easy cleaning and properly maintained to prevent contamination. If possible, all equipment and containers that come in direct contact with produce or ingredients should be stainless steel or plastic since these materials are easy to clean and disinfect. Equipment should have smooth surfaces and be easily cleaned. All equipment should be placed so cleaning around it is easy. Within the packing facility, it is a good practice to color code or label containers that are used for transporting the product before and after washing and keep them well separated to avoid cross-contamination.

Prevention of physical contamination of the produce is important. Handling equipment should have no loose bolts, knobs, or movable parts that could accidentally fall off into the product. If the equipment has any paint on it, the paint should be approved for food processing equipment and should not chip easily. Rust should be removed so it will not flake off onto the product. Only food grade oil and lubricants should be used, and oil leaks and over-lubrication must be avoided.

A complete equipment cleaning and maintenance program should be designed and implemented. Such a program will prevent hazards to the operator and the consumer. Equipment malfunctions should be reported as soon as they start to develop, so that the necessary precautions can be taken before a small problem can become something more serious. It is often a good idea

to assign a single individual to operate each piece of equipment so that person can become familiar with the equipment and its proper operation.

Containers for holding and transporting fruits and vegetables should be cleaned and sanitized thoroughly before use. Damaged containers with cracks, chips, or breaks that could harbor microorganisms should be discarded to prevent contamination of the produce.

Containers should be designed so that air flow around the product is sufficient to prevent heat from building up.

Trash and fruit or vegetable waste can be sources of microbial contaminants. Decomposing waste materials can spread microorganisms, create offensive odors, and attract insects and other pests which may carry pathogens. Trash and waste materials should be stored in designated locations that are easy to clean. Trash should be placed in closed containers located so that odors do not affect the production and packing facilities or the surrounding neighborhood. Trash should be removed daily. Separation of organic and inorganic wastes with appropriate recycling is recommended.

Cardboard boxes, plastic bags, and other materials to be used for packaging fresh produce must be stored in a place designated for this purpose. This storage area should be clean, dry, and free of trash, insects, and animals. Packaging materials should be kept away from any sources of contamination.

During packing operations it is important to avoid damage to packing containers. Boxes should not be stapled since staples can damage produce and packages in the boxes and staples can become physical contaminants in the produce. Always use new boxes and bags, as well as food-grade plastic bags and contact surfaces to prevent contamination of the fresh produce.

Storage of Fresh Produce

All fresh fruits and vegetables should be stored in clean locations using an organized system. Codes to identify the contents and packing information about boxes of produce as well as inventory rotation are important to minimize the time that the commodity is stored and to facilitate recall in case of problems later in the food chain. Boxes of product should be placed on pallets to avoid direct contact with floors. Pallets should be placed away from the walls and from each other to allow air flow and to make it easier to clean and



Figure 19. Containers for handling and transporting produce must be clean, sanitized, and free of damage. (Photo courtesy UA Grape Research Program)

inspect for rodents and insects. Chemicals, trash, waste, or odorous material must not be stored near fresh fruits and vegetables. Walls, floors, and ceilings must be systematically and periodically cleaned to avoid accumulation of dirt or other contaminants.

Fruit and vegetable storage areas should have accurate, recorded temperature and humidity control to prevent or delay microbial growth and to maintain produce quality. The proper storage temperature and relative humidity will vary considerably depending on the commodity and its specific requirements (Appendix B).

Transportation

Several modes of transportation are used to move harvested fruits and vegetables from production areas to packing or processing facilities, to shipping points, and to markets (Suslow, 2004). Proper handling of fruits and vegetables during transportation is critical to the safety of fresh fruits and vegetables. All of the time and effort taken to minimize microbial contamination and to monitor quality during field production, harvest, washing, and packing are wasted if the conditions during product transportation are not appropriate.

Temperature control during transport is critical to ensuring produce safety. The ability to maintain product temperature is affected by the condition of the transit vehicle. Transportation vehicles need intact side walls and insulation, appropriate air-delivery chutes, and tight, undamaged doors and seals. If trucks are refrigerated, cooling units should be properly serviced, maintained, and calibrated.

Because shipments frequently include several types of produce, factors such as temperature, ethylene, and moisture product compatibility must also be considered in order to ensure safety and quality when the product reaches its destination. If all or part of a load is packed in ice, care must be taken to ensure the drip from the melting ice does not contaminate other items in the shipment. Care must also be taken to ensure that melting ice does not damage packaging of other products or raise humidity levels so that mold growth becomes a problem.

Ideally the transportation vehicle would be sanitized after each load; however, this is not always feasible. It is important to remember that these vehicles also haul other materials. If the previous load included live animals, raw foods such as fish, meat or eggs, or chemical substances, then the produce should not be placed in the vehicle until appropriate cleaning and sanitizing measures have been taken. The trailer or transport container should be

washed and decontaminated using procedures similar to those described for food processing equipment.

Trucks, trailers and transportation containers must be free of visible filth and food particles. Odors are a sign that the transportation equipment needs additional cleaning since bad smells can be an indication of microbiological contamination and/or poor cleaning. Many of the cleaning and sanitizing chemicals described for use in disinfecting produce can be used as long as they don't cause corrosion of the transportation equipment.

JUICE HACCP

In the last few years there have been a number of foodborne illness outbreaks associated with juice products (HHS, 2001). A 1996 *E. coli* O157:H7 outbreak associated with apple juice sickened 70 people in the western United States and Canada, including a child who died from hemolytic uremic syndrome caused by the infection. A *Salmonella enteritidis* outbreak in 2000 was caused by unpasteurized orange juice and resulted in 88 illnesses in six western states. The previous year, a *Salmonella muenchen* outbreak was caused by unpasteurized orange juice and resulted in 423 illnesses in the U.S. and Canada and contributed to one death. The FDA estimates that there are between 16,000 and 48,000 cases of juice-related illnesses each year.

As a result of the number and severity of juice-related foodborne illness outbreaks, the FDA implemented a rule requiring juice processors to use Hazard Analysis and Critical Control Point (HACCP) principles for juice processing (HHS, 2001). HACCP

involves processors evaluating manufacturing processes to determine whether there are any microbiological, chemical, or physical hazards that could contaminate products. If a potential hazard is identified, processors are required to implement control measures to prevent, reduce, or eliminate those hazards.

Implementation of a HACCP system increases the protection of consumers from illness-causing microbes and other hazards in juices. The juice HACCP regulation applies to juice products in both interstate and intrastate commerce. It is estimated that action taken due to the rule will prevent at least 6,000 illnesses per year.

HACCP is a science-based system designed to prevent, reduce, or eliminate hazards in food products through appropriate controls during production and processing (HHS, 2004). HACCP involves seven principles, each of which must be backed by sound scientific knowledge (for example, pub-



Figure 20. Firms that grow their fruit, produce and package juice from that fruit, and sell the juice exclusively to the public, often right from their farm site, are not subject to the juice HACCP rule. Instead, these firms are required to place a warning label on the container if the juice has not been pasteurized or otherwise processed to ensure its safety (FDA, 2003).

lished microbiological studies on time and temperature factors for controlling foodborne pathogens). The seven HACCP principles are as follows:

1. Analyze hazards. This step identifies potential biological, chemical, or physical hazards associated with the juice and also determines measures to control these hazards. For each of the hazards identified the producer should assess the likelihood of occurrence and the severity of health consequences if it does occur. Then, based on the information gathered, determine whether each hazard is reasonably likely to occur in the juice. Hazards that are not reasonably likely to occur do not have to be included in a HACCP plan.
2. Identify critical control points (CCPs). A CCP is a point in the production of the juice—from its raw state through processing and shipping to consumption by the consumer—at which the potential hazard can be controlled or eliminated. Examples of control measures for juice production include thermal processing of the juice and culling produce to eliminate visibly moldy, rotten, or damaged fruit.
3. Establish preventive measures with critical limits for each control point. The regulation states that juice producers must treat juice using a process that will achieve at least a 100,000 fold (5-log) decrease in the number of the most resistant microorganism of public health concern that may occur in the juice. This microorganism may vary with the type of juice and the type of treatment used, although typically it would be *Salmonella* or *Escherichia coli* O157:H7. Juice processors may use microbial reduction methods other than pasteurization (heat), including approved alternative technologies (such as the recently approved UV irradiation technology), or a combination of techniques. Preventative measures might involve setting the temperature and time required to pasteurize the juice or establishing the requirements for another control process (or processes).
4. Establish procedures to monitor the critical control points. Such procedures might include determining how and by whom pasteurization time and temperature should be monitored.
5. Establish corrective actions to be taken when monitoring shows that a critical limit has not been met. This allows the juice producer to ensure that no product that might injure consumers enters the market. Examples of corrective actions include reprocessing or disposing of juice if the minimum cooking temperature is not met.

6. Establish procedures to verify that the system is working properly. An example of verification would be testing time-and-temperature recording devices to verify that a cooking unit is working properly.
7. Establish effective recordkeeping to document the HACCP system. This would include records of hazards and their control methods, and monitoring of safety requirements and actions taken to correct potential problems.

The above discussion focuses on microbial hazards. However, in conducting a hazard analysis, a juice processor must consider all potential hazards and determine whether any of these hazards are reasonably likely to occur (HHS, 2004). If a hazard is reasonably likely to occur, a processor must include controls for that hazard in the HACCP plan. Therefore, HACCP controls for chemical and physical hazards are required when a processor determines that there is a possibility of these types of hazards in the juice.

Training in applying the principles of HACCP is required for all individuals who have significant safety-related responsibilities in juice processing (Kashtock, 2003). The First Edition of the Juice HACCP Alliance curriculum has been defined as the standardized curriculum for juice HACCP training purposes. Juice processors are not required to use the Juice HACCP Alliance curriculum for training their personnel. If another curriculum is used it should be equivalent in its coverage of the following key components of HACCP:

- Biological, chemical, and physical hazards;
- Applicability of current Good Manufacturing Practices (cGMPs) and Sanitation Standard Operating Procedures (SSOPs);
- The Five Preliminary Steps of HACCP with application to juice processing;
- The Seven Principles of HACCP with application to juice processing; and
- The FDA's juice HACCP Regulation (21 CFR Part 120) and related FDA guidance documents.

Additional information on juice HACCP is available at www.cfsan.fda.gov under "Program Areas" and "HACCP." The information available at this website includes the juice HACCP regulation, two publications entitled "The Juice HACCP Regulation Questions and Answers," and guidance documents that the FDA has issued related to the implementation of the juice HACCP regulation.

FOOD TERRORISM

The potential for terrorist attacks against agricultural targets (agroterrorism) is increasingly recognized as a national security threat, especially after the events of September 11, 2001 (Monke, 2004). In this context, agroterrorism is defined as the deliberate introduction of an animal or plant disease with the goal of generating fear, causing economic losses, and/or undermining stability. Terrorist threats to food are particularly worrisome, as their effects may be felt beyond the site of the original attack (Isaacson et al., 2004).

Farms are viewed by many experts as being particularly vulnerable to terrorist attacks (Monke, 2004). Reasons for this vulnerability include the following:

- Agricultural production is geographically disbursed in unsecured environments such as open fields and pastures throughout the countryside. This makes it extremely difficult to monitor all locations all of the time.
- Produce is routinely combined in the transportation, production, and processing system. Thus a small amount of contaminated product can easily affect a much larger amount, and natural barriers to the spread of contamination are circumnavigated.
- The presence (or rumor) of certain pests or diseases in produce from a particular country can quickly stop all exports of that product, thereby affecting the economy of that country. It can take months or years to resume exports and overcome this economic impact.
- The past success of keeping many diseases out of the United States means that many veterinarians and scientists lack direct experience with foreign diseases. This may delay recognition of symptoms in case of an outbreak.
- The number of lethal and contagious biological agents is greater for plants and animals than for humans. Most of these diseases are environmentally resilient, common in foreign countries, and not harmful to humans, so it is easy for terrorists to acquire, handle, and spread the pathogens.

Once a product is contaminated, it can easily reach supermarkets and homes undetected, causing large numbers of people to be affected. In addition, farms surrounding the targeted area can be vulnerable to the spread of contagious plant or animal pathogens.

A widely accepted view among scientists is that livestock herds are much more susceptible to agroterrorism than crop plants (Monke, 2004). Much of this has to do with the success of efforts to systematically eliminate

animal diseases from U.S. herds. This has left current herds either unvaccinated or relatively unmonitored for many diseases. In contrast, a number of plant pathogens continue to exist in small areas of the United States and continue to infect limited areas of plants each year, making outbreaks and control efforts more routine. Moreover, plant pathogens are generally more technically difficult to manipulate since some plant pathogens may require special environmental conditions of humidity, temperature, or wind to take hold or spread. In addition, most plant diseases take a longer time than an animal disease to become established or achieve destruction on the scale that a terrorist may desire.

An attack on the food supply does not necessarily have to sicken people to have an effect (Isaacson et al., 2004). Simply interrupting the food supply would be enough to spread terror in a targeted nation and impact its economy. Currently, there is little that can be done to stop someone with the goal of committing a terrorist act from targeting the food supply by attacking it at the farm level. Although some measures have been put into place to improve farm security, farmers, scientists, public health officials, and regulators should continue to prepare themselves to manage the consequences of such an attack.

Outbreaks of both unintentional and deliberate foodborne diseases can be managed by the same mechanisms. Prevention, although never completely effective, is the first line of defense. The key to preventing food terrorism is the establishment and enhancement of existing food safety management programs and implementation of reasonable security measures. Prevention is best achieved through a cooperative effort between government and industry, given that the primary means for minimizing food risks lie with the food industry.

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Appendix A

Glossary

Aerobic – requiring oxygen.

Agricultural water – water used in the growing environment for irrigation, transpiration control (cooling), frost protection, or as carrier for fertilizers or pesticides. Typical sources of agricultural water include flowing surface waters from rivers, streams, irrigation ditches, open canals, impoundments (such as ponds, reservoirs, and lakes), wells, and municipal supplies.

Agroterrorism – terrorist attacks against agricultural targets.

Allergen – a substance that causes the immune system to trigger and fight against it. The most common food allergens are peanuts, soybeans, milk, eggs, fish, shellfish, tree nuts, and wheat.

Anaerobic – not requiring oxygen.

Air Gap – air-filled space in a drain allowing contaminated water to discharge freely while preventing the contaminated water from ever siphoning back into the potable water supply.

Backflow – a reverse flow condition, created by a difference in water pressures, which causes water to flow back into the distribution pipes of a potable water supply from any source or sources other than an intended source. A backflow device may be installed in the water system to prevent backflow from occurring since it can result in contamination of the water supply.

Bacteria – single-celled microorganism that can cause food spoilage and illness. Some bacteria form spores that are resistant to adverse conditions like freezing and high temperatures.

Biosolids – the nutrient-rich organic materials resulting from the treatment of sewage sludge.

Centers for Disease Control and Prevention (CDC) – agency of the U.S. Public Health Service that investigates foodborne disease outbreaks, studies the causes and control of disease, and publishes statistical data on disease.

Clean – free of visible soil.

Composting – an active treatment commonly used to reduce the microbial hazards of raw manure. Composting is a controlled and managed process in which organic materials are broken down by microbial action. Because this breakdown process generates a great deal of heat, it reduces or eliminates pathogens in the composted material. Thus, the risk of microbial contamination from composted manure is reduced compared to untreated manure.

Critical control point – a step or procedure at which control can be applied and a food-safety hazard can be prevented, eliminated, or reduced to acceptable levels.

Cross-contamination – the transfer of microorganisms from one surface or food to another.

Drip/trickle irrigation – watering plants so that only soil in the plant's immediate vicinity is moistened. Water is supplied from a thin plastic tube at a low flow rate. It is the most efficient use of water for irrigation and also reduces the chance of pathogens because the entire plant is not wetted, thereby denying moisture to the microorganisms.

Field packing – packing produce directly from the field into market containers for commercial distribution and sale.

Food and Drug Administration (FDA) – an agency of the U.S. government responsible for the safety of the human food supply.

Foodborne disease – disease carried or transmitted to people by food.

Foodborne disease outbreak – the occurrence of two or more cases of a similar illness after ingestion of a common food.

Good Agricultural Practice (GAP) – guidelines established to ensure a clean and safe working environment for all employees while eliminating the potential for contamination of fresh fruits and vegetables.

Good Manufacturing Practice (GMP) – a set of guidelines that ensures products are consistently produced and controlled to the quality standards appropriate for their intended use.

Groundwater – fresh water found beneath the Earth's surface, usually in aquifers, which supplies wells and springs.

Hazard – something that could cause harm to the consumer. There are three main types of hazards associated with fresh produce:

Σ• *Biological hazards* result from microorganisms such as bacteria, viruses, and parasites as well as some fungi that produce toxins (poisons).

Σ• *Chemical hazards* arise from contamination of produce with harmful or potentially harmful chemicals which may occur naturally in the products or may be added during agricultural production and product handling.

Σ• *Physical hazards* are particles or fragments of materials that are not supposed to be in the food. Examples include rocks, glass, or other foreign matter which may be introduced into fresh fruit and vegetable products at numerous points in the production chain.

Hazard Analysis Critical Control Point (HACCP) – a science-based system designed to prevent, reduce, or eliminate hazards in food products through appropriate controls during production and processing.

Integrated Pest Management (IPM) – a system incorporating a range of methods of pest control to produce healthy crops economically and to reduce or minimize risks to human health and the environment.

Irrigation – the controlled application of water to the land or field to provide the moisture levels needed for the development of the crops.

Maximum contaminant level (MCL) – maximum permissible level of a contaminant in water that is delivered to any user of a public water system. MCLs are enforceable standards established by the US Environmental Protection Agency. The MCL for total coliform/E. coli is zero.

Microorganism – any organism that can only be seen with a microscope; protozoa, bacteria, fungi, and viruses are examples of microorganisms.

Nonpoint source pollution – pollution that cannot be traced to a specific point because it comes from many individual places or a widespread area (such as agricultural sites).

Overhead sprinkler system – overhead application of water to a crop by any of a wide range of systems so that water falls onto the plant and the entire plant is wetted.

Packing facility – a facility for cleaning produce and packing it into market containers. Fresh produce is often harvested in one location and transported to a central packing facility. The size of the packing facility can range from a small on-farm shed to a large commercial plant.

Parasite – organisms that live in another living organism, called the host. They are only able to grow in a host; however, they may be passed from one host to another through some non-host means.

Pathogen – microorganism that causes disease.

Pesticide – chemical used to control pests.

Herbicide – a chemical compound used to kill unwanted plants.

Insecticide – a compound specifically used to kill or prevent the growth of insects.

Fungicide – a pesticide used for control of fungi.

Point source pollution – pollution discharged from a single point such as pipes, ditches, wells, vessels, and containers.

Potable water – water that is safe to drink.

Pre-cooling – any cooling treatment before shipping, storage, or processing.

Sanitizing – reducing the number of microorganisms on a clean surface to safe levels.

Spore – inactive or dormant form of some bacteria; organisms in spore-form are protected from adverse conditions such as high and low temperatures, low moisture, and high acidity. Spores may return to vegetative (active) bacteria when conditions become favorable.

Surface water – water that is on the Earth's surface, such as in a stream, river, lake, or reservoir.

Tolerance – limits for the maximum amount of a pesticide that may remain in or on a food treated with pesticide.

Toxin – poisons produced by pathogens, plants, or animals.

U.S. Department of Agriculture (USDA) – a Cabinet department of the United States government. Its purpose is to develop and execute policy on farming, agriculture, and food. It aims to meet the needs of farmers and ranchers, promote agricultural trade and production, work to assure food safety, protect natural resources, foster rural communities, and end hunger in America and abroad.

Virus – very small microorganisms that are unable to reproduce outside of a living cell.

Appendix B

Recommended Cooling and Storage Conditions for Some Fruits and Vegetables

Commodity	Precooling method ¹	Recommended Storage Conditions		Storage Life (at recommended conditions)
		Temperature (°C)	RH (%)	
Apples	R, F, H	-1 to 4	90 to 95	2 to 4 months
Apricots	R, H	-0.5 to 0	90 to 95	1 to 2 weeks (3 to 4 weeks some cultivars)
Asparagus	H	0 to 2	95 to 99	14 to 21 days
Beans, Snap	H	5 to 7.5	95 to 100	8 to 12 days
Beets				
With tops	H, F, PI	0	98	10 to 14 days
Topped	F	1 to 2	98	
Berries				
Blackberry	F to 5° w/in 4 hrs.	-0.5 to 0	>90	2 to 14 days
Blueberry	F to <10° w/in 1hr.	-0.5 to 0	>90	2 weeks
Raspberry	F to 1° w/in 12 hrs.	-0.5 to 0	>90	2 to 5 days
Strawberry	F, R	0	90-95	7 days
Broccoli	I (liquid), H, F	0	98 to 100	2 to 3 weeks
Brussel sprouts	V, H, I, F	0	95 to 100	3 to 5 weeks
Cabbage	H, F	0	98 to 100	3 to 6 months
Carrots	H	0	98 to 100	7 to 9 months
Cauliflower	V, H, F	0	95 to 98	3 weeks
Celery	H, HV, V	0	> 95	5 to 7 weeks
Cherries (Sweet)	R, F, H to <5 in 4 hrs.	-1 to 0	>95	2 to 4 weeks
Corn, sweet	V with top icing, H	0	95 to 98	4 to 6 days
Cucumbers	H, F	10 to 12.5	95	< 14 days
Eggplant	H, F, R	10 to 12	90 to 95	14 days
Endive	V, H	0	95 to 100	2 to 3 weeks
Figs	F	-1 to 0	90 to 95	1 to 2 weeks
Garlic (bulbs)	cured	-1 to 0	60 to 70	9 months
Grapes				
Vinifera	F	-1 to 0	90 to 95	1 to 4 weeks
Rotundifolia	F to ≤2° w/in 12 hrs. F to <2° w/in 24 hrs.	-0.5 to 0	>90	
Labrusca		-0.5 to 0	85 to 90	
Greens for cooking	H, HV, I (liquid, top, or package)	0	95 to 98	2 weeks
Kohlrabi	H, I, F	0	98 to 100	Topped: 2 to 3 months W/tops: 2 to 4 weeks
Leeks	H, I, V	0	95 to 100	2 to 3 months
Lettuce	V, HydroV, H for non-heading types	0	98 to 100	< 4 weeks

Melons Casaba, Crenshaw, and Canary Honeydew Watermelon	H, F	10 7 10 to 15	90 to 95 95 90	3 weeks 7 to 10 days 2 to 3 weeks
Mushrooms	H, F, V to 2 to 4 ^o	0 to 1	95	7 to 9 days
Okra	H, F	7 to 10	>90	7 to 14 days
Onions Bulb Green	A to 0 after drying H, F, V to <4 ^o in 4 to 6 hrs.	0 0	65 to 75 95 to 98	1 to 9 months 3 to 4 weeks
Peaches	F, H	-1 to 0	90 to 95	14 to 28 days
Pears		-1	90 to 94	60 to 90 days
Peas, green and with edible pods	F, H, V	0	95 to 98	1 to 2 weeks
Peppers	F, H, V	7	90 to 95	2 to 3 weeks
Persimmons		-1 to 1	90 to 95	3 mo
Plums and fresh prunes	F, H, R	-1 to 0	90 to 95	14 to 28 days
Potatoes	Cure at 20 ^o C, RH 80 to 100%	7 to 10 (eating) 10 to 15 (frying) 15 to 20 (chipping)	95 to 99 at all temps	2 to 12 months
Pumpkin and Winter Squash	R	10 to 13	50 to 70	2 to 3 months
Radishes	H at 0 to 4.5 ^o C	0	90 to 95	3 to 4 weeks
Rutabagas	R, F, H, I	0	98 to 100	4 to 6 mo
Southern peas Unshelled Shelled	F H	4 to 5 4 to 5	95	6 to 8 days 24 to 48 h
Spinach	H, I	0	95 to 100	10 to 14 days
Squash, Summer	R, F, H	5 to 10	95	2 weeks
Sweet potatoes	Cure at 29 ^o ±1, 90 to 97% RH for 4 to 7 days	13 to 15	90	1 year
Tomatoes Mature green Ripe	R, F to 20 ^o for ripening to 12 ^o for storage	19 to 21 13	90 to 95 90 to 95	7 to 28 days
Turnips		0	90 to 95	4 to 5 months

¹For products where no precooling method is indicated, precooling is not required.
Precooling methods: F= forced air; R = refrigerator; H = hydrocooling; V = vacuum; HV
= hydrovacuum; I = icing; PI = package icing

Table developed from data in *The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Crops*, Gross, K.C., Yang, C.Y., and Saltveit, M. Eds., Agricultural Research Service, Beltsville, MD. Draft version of USDA Handbook 66 on the internet at <http://www.ba.ars.usda.gov/hb66/index.html>

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