by destroying the toxic substances of plant foods, brought a major evolutionary advantage to man. As the supply of animal protein fails to keep pace with the protein requirement of a growing world population, particularly in the lesser developed countries, man's continued survival may depend more than ever on an even greater use of plant foods as a source of life-sustaining protein.

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MICRO-CONTAMINATION OF HORTICULTURAL PRODUCTS

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The role of horticulture in helping to meet world food requirements increases in importance as the population of the world increases. With the new development of improved cultivars of plants, new harvesting and handling systems, and food fortification practices, changes in the methods of preventing contamination of foods may also need to be re-evaluated.

Horticultural products are generally considered to be highly nutritious. These foods, unfortunately, are also frequently highly perishable. Restrictions by regulatory authorities on use of food additives complicates the problems confronting the food industry.

The degree of contamination of foods is usually directly related to the degree of deterioration. Further, the consumer advocates are requiring higher qualities of foods free from all contamination.

Industry and public health officials have been concerned for many years with contamination losses due to spoilage and of possible health hazards due to contamination. This, however, has not prevented serious problems from arising. Consideration of common types of contamination as well as new or unusual contaminants must be a continuous process.

Although many types of contaminants exist, the primary concern in this presentation is with direct or indirect contamination by microorganisms.

COMMON SOURCES OF MICROBIOLOGICAL CONTAMINATION

The contamination of horticultural products by microorganisms usually occurs by contact with soil or dirt, insects, animals, and normal flora of the product.

Soil or dirt.

Soil or dirt may be a major source of contamination of fruits and vegetables, particularly with mechanical harvesting and bulk systems of handling. This is also true if frequent applications of animal manure have been made. Soil under cultivation may receive increased exposure to contamination because of visitations by wild animals in search of food. These animals are frequently found to be healthy carriers of organisms causing food-borne illness. Another source of organisms in the soil is the use of contaminated irrigating water. Bacterial counts of coliform organisms (organisms commonly associated with contamination) have been found to be as high as 2.0 x 10^5 organisms/g in irrigating water (6). Estimates for total populations of microorganisms in the soil vary, but they are reported to be more than 2.5 x 10^9 organisms/g (4). Thus it can be assumed that soil contains nearly all of the spoilage and toxin producing organisms commonly found in plant products.

A further cause of contamination by soil is the use of mechanical harvesters. Soil type and wetness of harvesting conditions are factors contributing to the degree of contamination of products by soil.

Insects

Of the possible sources of natural contaminants, insects contribute less microbial contamination than any other source. Coliforms are not present as normal flora in the fecal material of insects. However, these bacteria are transients that attach to the hairy exterior of the insects when they come in contact with fecally contaminated debris.

Animals

The direct contamination of horticultural products by the fecal material of domestic and wild animals is probably the most significant means of transmission of contaminating microorganisms. More than 13% of all farm animals contain disease producing bacteria, viral pathogens, and enteric parasites. Approx 7.5% of wild animals contain microorganisms which are considered contaminants (17).

Microorganisms

Common types of microorganisms in food are bacteria, fungi, viruses, and perhaps some types of protozoans. Viruses have been increasingly incriminated in food-borne illness, as have protozoa, but not in food spoilage. Bacteria are the most significant in contamination, and fungi are next in importance.

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MICROORGANISMS AS CONTAMINANTS

Microorganisms have been considered the universal inhabitants of food (15). For many years organisms in food were divided into 2 groups: those which are helpful or harmless (non-pathogens) and those which are harmful (pathogens). This simple classification has served as a useful guideline to the food producer and processor.

About 20 genera of bacteria (Table 1) and fungi are important in horticulture. Usually many genera exist in the same food product making it extremely difficult to separate the useful or desired organisms, such as those required for fermentation, from those which are harmful.

Table 1. Genera of bacteria important in horticultural products. From (11).

Pseudomonas	*Erwinia*	*Leuconostoc*
Acetobacter	*Serratia*	*Lactobacillus*
Halobacterium	*Salmonella*	*Propionibacterium*
Alcaligenes	*Shigella*	*Bacillus*
Achromobacter	*Micrococcus*	*Clostridium*
Flavobacterium	*Staphylococcus*	
Escherichia	*Streptococcus*	

Excessive numbers

Contamination of food products is possible by excessive numbers of organisms even though the incidence of harmful ones may be low. An excessive microbial load indicates a critical source of microorganisms somewhere between the producer and the consumer. The cause is frequently careless handling.

Several problems become evident when the microbial content in a food is high. The first problem is that adequate processing becomes difficult, resulting in processed food containing excessively high counts. Processing is usually adequate for reducing microbial numbers to a desirable level without total destruction. Examples of the presence of viable organisms are not infrequent in processed food. Reports indicate that 22% of canned foods tested contain viable organisms. In some fermented canned products more than 80% of the samples tested contained viable organisms (16). Frozen and dried foods are generally on the suspect list.

A second factor is the increase in the possibility of the presence of pathogens. Fecal coliform counts of from 1 to 1,000 organisms/g showed that 53% of the samples also contained pathogens, whereas counts above 1,000 organisms/g showed 96% of the samples contained pathogens (6).

Spoilage organisms

The USDA has estimated a yearly loss of 25 million dollars in agricultural products due to field and postharvest diseases. Estimates indicate that about one-fourth of the world's food supply is lost through the action of microorganisms (8). Many types of products which develop postharvest infections are initially infected with field diseases (Table 2). These diseases cause lesions and otherwise weaken the product making it easier for microorganisms to invade after the crop is harvested. Bacteria are common spoilage organisms in vegetable crops with a relatively high pH. Molds more commonly cause disease and spoilage in fruits and other products with a low pH (Table 3).

Bacteria which commonly cause spoilage in processed foods are often contaminants on the raw product originating in soil. Examples are *Aerobacter, Achromobacter, Bacillus, Clostridium, Escherichia, Streptococcus, Lactobacillus, Leuconstoc* and many others (11).

Spoilage organisms may be inadvertantly added to horticultural products during processing. Ordinary table salt has been found to contain heat resistant, salt tolerant organisms in high quantities. Commercially processed compressed yeast used for fermentation processes in bakeries has been found to contain counts of bacterial contaminants as high as 1,000,000 organisms/g (13).

Disease producing microorganisms

Public health officials, processors, and producers alike are concerned about the incidence of pathogenic microorganisms in food products. Although many pathogens are easily destroyed by processing, others such as *Clostridium* spores are extremely heat resistant. Studies of the survival of common pathogens indicate relatively long survival times on some horticultural products (Table 4).

Table 4. Pathogen and total coliform survival on contaminated horticultural products. From (9).

Organism	Produce	Maximum survival time (days)
Salmonella	Root crops	53
	Leaf vegetables	40
	Berries	5
	Orchard crops	2
Shigella	Leaf vegetables	7
	Orchard crops	6
Enterovirus	Root crops	60
	Leaf vegetables	60
Ascaris eggs	Leaf vegetables	35
Endamoeba histolytica	Leaf vegetables	3
Total coliforms	Leaf vegetables	35

A second serious problem is the incidence of food-borne illness caused by microorganisms. More than 25,000 cases are reported annually, and this is probably less than half the number of actual cases in the U. S. Bacteria are reported to cause more than 90% of the cases (Table 5).

The total number of outbreaks of food-borne illness caused by horticultural and related products constituted about 34% of the total (Table 6).

More than 15 common species of mycotoxic fungi have been directly incriminated in the cause of disease by toxin production in man and animals. Among these are *Claviceps* species producing ergot (10), as well as the patulin, aflatoxin and other toxin producing species (Table 7). Common food products incriminated are sweet potatoes, carrots, celery, rice, grains, and dead and decaying vegetable matter (9).

Table 2. Spoilage bacteria which cause field disease affecting market quality. From (8).

Bacterium	Diseases	Product affected
Pseudomonas apii)Jagger)	Bacterial blight	Celery
Pseudomonas cichorii (Swingle) Stapp.	Bacterial zonate spot	Cabbage, lettuce
Pseudomonas pisi (Sackett)	Bacterial blight	Peas
Xanthomonas phaseoli (E. F. Sm.) Dows	Common blight	Beans
Xanthomonas vesicatoria (Doidge) - Dowson	Bacterial spot	Tomato, peppers
Corynebacterium flaccumfaciens (Hedges) Dows	Bacterial wilt	Beans
Corynebacterium sepedonicum (Speick and Kotth) Skapt. and Burkh.	Ring rot	Potatoes
Erwinia carotovora (L. R. Jones)	Soft rot	Tomatoes, potatoes, peppers, cucumbers

Table 3. Fruit spoilage molds.

Fruit	Mold	Defect
Cherries, peaches	*Penicillium expansum* (Thom)	Green to blue mold rot
Apples, pears	*Penicillium expansum* (Thom)	Brown spots & blue mold
Tomatoes, strawberries	*Rhyzopus nigricans* (Ehn)	Soft rot
Tomatoes	*Alternaria solani* (Ell. & G. Martin) Sor.	Blight rot

Table 5. Foodborne disease, 1969. From (1).

Type of disease	No. outbreaks	Persons involved No.	Persons involved % of total
Bacterial	243	25,911	90.70
B. cereus	3	14	0.05
C. bolulinum	10	17	0.10
C. perfringens	65	18,527	64.90
E. coli	5	398	1.40
Salmonella	49	1,892	6.60
Shigella	10	1,444	5.10
Staphylococcus	94	3,481	12.20
Streptococcus	4	37	0.10
Vibrio parahemolyticus	2	71	0.20
Multiple etiologies	1	30	0.10
Parasitic	12	54	0.20
Viral (Hepatitis)	9	116	0.40
Chemical	27	172	0.50
Unknown	80	2,310	8.10
Total	371	28,563	100.00

THERMAL RESISTANCE AND pH RANGE

The pH range at which microorganisms grow varies between 2 - 10. Molds and yeasts are acid tolerant and grow at pH values below 2. The range for bacteria is 4 to 10. The optimum pH range for most bacteria, however, is 6.5 - 7.5. Organisms causing food-borne infections will not tolerate pH much above or below 7.0. Toxin usually will not be produced below a pH of 5.0 (3).

Foods may be divided into groups based on their pH. These range from low to high acid content (Table 8).

Thermal resistance of many microorganisms is partly dependent on the pH of the environment. A broad classification of heat resistant organisms shows tolerances as high as 120°C for 45 minutes (Table 9).

MICROBIOLOGICAL CONTROL AND SAFETY OF HORTICULTURAL PRODUCTS

Changes in the types of horticultural cultivars and changes in harvesting procedures and handling have changed the normal or historical ecology of the products. The standard conditions for growth, thermal death times, and pH tolerances are generally acceptable, but more exceptions have occurred due to the previously mentioned changes. These exceptions are frequently responsible for diseases or mass spoilage. Organisms which were once considered harmless commensals have been found to cause disease and death. Genera such as *Flavobacterium, Escherichia, Pseudomonas,* and *Serratia* have been incriminated. These facts require the horticulturist to take a new look at procedures which have previously been adequate. New methods will need to be found to deal with organisms which are not inhibited by antibiotics and which actually thrive in certain antiseptics. Reliance on heat treatment unit processing may need to be modified and procedures such as an atmosphere of controlled gaseous composition for storage, direct current electrical food preservation, ozone or ethylene dioxide bacterial treatment may need to be adopted.

These problems however, do not excuse the food producer from differentiating between food safety and food keeping quality. A check of reasons for seizures by the Food and Drug Administration (FDA) of food products reveals food held under insanitary conditions to be the most often stated reason.

Many of the basic features of cleanliness and control of contamination which have been practiced will still apply. For example, washing procedures which are adequate will remove microorganisms no matter how difficult they may be to destroy in processing. An 86% reduction of soil on the surface of tomatoes by proper washing techniques reduces the microbial load making processing procedures much less difficult (Fig. 1). Other practical aspects of contamination control have been outlined by Davis (5).

Table 7. Examples of mycotoxic fungi associated with agricultural products. From (9).

Organism	Toxin	Food
Aspergillus species	aflatoxins	peanuts, sweetpotatoes
	patulin	rice, wheat
Fusarium species	toxic glycosides	barley, corn
Penicillium species	rubratoxin	rice, wheat

Table 8. Common horticultural products and their average pH values. From (11).

Group	Food	pH
Low acid	peas	6.2
pH over 5.3	potatoes	6.1
	asparagus	5.6
	spinach	5.5
	sweetpotatoes, bread	5.4
	beets	5.3
Medium acid	cabbage, turnips	5.2
pH 5.2 - 4.5	cucumbers	5.1
	carrots, pumpkins	5.0
	pimentoes, figs	4.6
Acid	tomatoes	4.3
pH 4.5 – 3.7	pears	3.9
	sweet cherries	3.8
High acid	sauerkraut	3.6
pH below 3.7	peaches	3.5
	strawberries	3.4
	apricots	3.3
	dill pickles	3.2
	apples, grapefruit	3.1
	plums	2.9
	lemons	2.2
	limes	2.0

Table 6. Horticultural and related products causing foodborne illness. From (2).

Etiology	Veg. & fruits	Mush-rooms	Bakery products	Chinese food	Other	Unknown	Total
Bacterial							
B. cereus			1			1	2
C. bolulinum	6	1				3	10
C. perfringens	7					2	9
Salmonella	4		5		1	11	21
Shigella	2					4	6
Staphylococcus	8		9	1	3	6	26
Viral							
Hepatitis						2	2
Chemical							
Monosodium glutamate				2			2
Mushroom		4					4
Other chemical	8			1	4	1	14
Unknown	6		6	2	3	24	41
Total	41	5	21	6	11	53	137

Table 9. Broad classes of thermal resistance in microorganisms. From (14).

Type of organism	Maximum lethal time/temperature	Examples of genera surviving this time/temp
Molds, yeasts, and non-spore forming bacteria	30 min/65°C or 1 min/80°	*Penicillium, Aspergillus, Strep. facecallis, Corynebacterium*
Spores of low heat resistance	10 min/90°	*Cl. bolulinum* type E. *B. macerans, B. megaterium*
Spores of medium heat resistance	30 min/100°	*Cl. botulinum* types A & B
Spores of high heat resistance	10 min/115° or 4 min/120°	*B. stearothermophilus, Cl. nigrificans, Cl. sporogenes*
Spores of exceptionally high heat resistance	45 min/120°	*Cl. thermosaccharolyticum*

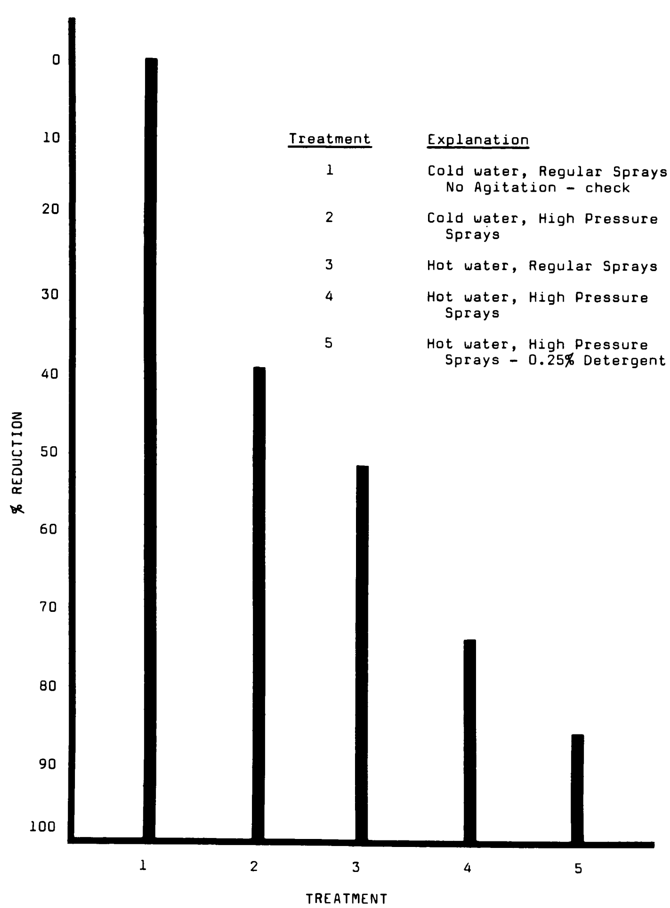

Fig. 1. Effect of combination of specific chemical and physical factors on *Drosophila* egg and larvae removal in washing tomatoes (7).

Raw materials

All raw materials used in food production and processing should be checked, where appropriate, for visual, chemical and microbiological quality. Standards of quality should be specified and adhered to. Success in improving the quality of a raw product from a substandard level is most difficult. This is especially true of the microbiological quality. In some cases as much as a 9-fold increase has been found in the coliform count between field and the marketing of certain vegetable products.

Prevention vs. preservation

The prevention of microbiological growth by removal or by processing is generally considered better than relying on preservatives, particularly in these times. Practices needing more emphasis are:

1. Proper temperatures in initial raw product storage for each commodity.
2. Adherence to rigid process times and temperatures.
3. Storage of the processed food at adequate temperatures for each method of preservation.
4. Design of equipment for cleaning in-place to insure a sanitized plant.
5. Heat sterilization of equipment for sanitizing at temperature of 121°C for steam, and dry heat at 160° for 3 min.
6. Changing the sterilizing chemicals periodically to prevent buildup of microbial film.
7. Constant checking for bacteriological purity of water as well as an adequate water supply.

Finally, the adoption of microbiological quality assurance methods and procedures by the various segments of the food industry. The horticulturist has a major stake in the future of the processing industry and his up-dating of control of microorganisms is one of the key factors in assuring acceptable products for the ultimate consumer.

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