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LITERATURE SURVEY ON CAUSES OF SPOILAGE OF FRESH PRODUCE - 1959 TO 1977

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AUGUST 1982

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A literature survey was conducted to determine the causes of spoilage of fresh produce. This report summarizes experimental work and knowledge that appeared in technical books, reports and journals primarily from 1959 to 1977, although one article dates back to 1931. An abstract or summary of each reference is included. In addition, a series of tables was developed from the literature survey listing the market diseases and their causes for nine of the fruits and vegetables.

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PREFACE

Work has been performed intermittently over a number of years by the Food Engineering Laboratory of NLABS in mathodology for reducing spoilage and extending shelf-life of fresh produce shipped to Military organizations overseas. NLABS was requested by DPSC to prepare a Technical Report on the literature that had been surveyed in studying the causes of spoilage, by DPSC–CD(S) letter dated August B, 1980.

This work was compiled by NLABS under Project Number 1L161724AH99BB, Food Processing and Preservation Techniques. Mr. Harold Gorfien was the Official Investigator and Project Officer.

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LITERATURE SURVEY ON CAUSES OF SPOILAGE OF FRESH PRODUCE – 1959 to 1977

INTRODUCTION

Availability of fresh fruits and vegetables of good quality in sufficient quantity to supply the requirements of military personnel is of concern to the Armed Forces. For civilian markets, fresh produce items such as lettuce are usually sold within two weeks of picking. Lettuce destined for distribution does not arrive at overseas distribution points until three to four weeks after picking. It is then required to be in good condition for an additional one to four weeks. Fresh produce items such as lettuce exhibit a greater tendency towards spoilage prior to overseas use because of this extended shipping and storage period.

The problem of fresh produce spoilage overseas, particularly lettuce spoilage, has been known for many years. Technical improvements have been made in packaging, refrigeration, and shipping through research in industry, government, and university laboratories. Yet, reports continue concerning spoilage losses, and sporadic shortages develop in terms of fresh produce supply to Military organizations overseas.

With limited funding, the Food Engineering Laboratory of NLABS has performed work intermittently over a number of years in methodology for reducing spoilage and extending shelf-life of fresh produce shipped to Military organizations overseas.

This report summarizes experimental work and knowledge that appeared in the literature from 1959 to 1977, with one article dating back to 1931. Each entry referenced in this report includes either an abstract or a summary. When the book or journal included an abstract, a copy of the abstract as it appeared or with minor changes follows the entry. If no abstract was available, the author of this literature survey prepared a summary to be included with the entry.

The body of knowledge concerning spoilage of fresh fruit and vegetables is extremely large. Rather than prepare an additional reference listing, a publication by Kader, *et al*. (1974) is cited that lists 547 technical books or articles on post-harvest handling and physiology of horticultural crops.

In addition to the abstracts and summaries that have been included for each reference, a series of tables has been developed from the literature survey that provides in capsule form a listing of the market diseases and their causes for nine of the fruits and vegetables.

REFERENCE BOOKS AND HANDBOOKS

1. J.M. Harvey and W.T. Pentzer, 1960. **Market Diseases of Grapes and Other Small Fruits.** USDA Agric Hand No. 189, 47 pp.

Summary: Diseases of small fruits including occurrences, symptoms, casual factors and control measures are discussed. Diseases caused by fungi, freezing, high carbon dioxide, senescence, chilling, ammonia, bruising, hail, insects, and high temperature during ripening are covered. Fruits discussed are blackberries, dewberries, raspberries, blueberries, cranberries, currants, and gooseberries. A larger discussion covers two fruits that are more important economically, grapes and strawberries.

2. J.M. Harvey, Will Smith Jr., and J. Kaufman, 1972. **Market Diseases of Stone Fruits: Cherries, Peaches, Nectarines, Apricots, and Plums.** USDA Agric Hand No. 414, 74 pp.

Abstract: The market diseases of cherries (Prunus *avium* L.), peaches (P. *persica* (L.) Batsch), nectarines (P. *persica* (L.) Batsch var. nectarina (Ait.) Maxim.), apricots (P. *armeniaca* L.), plums (P. *salicina* Lindl.), and prunes (P. *domestica* L.) are discussed in this publication. The diseases are divided into two groups, the parasitic diseases and the nonparasitic diseases or disorders. Parasitic diseases are those caused by pathogenic organisms (fungi and bacteria) and viruses. Nonparasitic diseases are those caused by physical forces (bruising or freezing), physiological effects (internal breakdowns or shriveling), other nonpathogenic factors, and by insects. The parasitic diseases are further separated on the basis of host fruit diseases of cherries, diseases of peaches, nectarines, and apricots, and diseases of plums (and prunes). Diseases of each of these fruits, or groups of fruit, are arranged by causal factor. Frequently a particular organism will cause disease in more than one host. In such cases, the symptoms of the disease are given for each host, but details about the causal organism and control are given only for the host on which the disease is most common or of greatest economic importance. Cross-references are provided, which enable the reader to obtain additional information about the cause and control of the disease. In this handbook, nonparasitic diseases are separated into three groups: diseases that are orchard and weather-related, those that are storage-related, and those that are transit and handling related. The causes of nonparasitic disorders cannot always be clearly defined, so that these disorders are arranged primarily on the basis of symptom expression (cracking, russeting, shriveling). Each disease is considered in respect to its geographical distribution, where it occurs in marketing channels, its economic importance, varietal susceptibility or resistance, external and internal symptom expression, causal factors, temperature relations, and control measures. For parasitic diseases, consideration also is given to the mode of infection, where and when it takes place, predisposing factors to infection, dissemination of the disease, and how it may be related to other disorders (bruising). Control of market diseases or prevention of disorders is considered primarily in relation to postharvest handling, storing, and shipping practices. Orchard treatments vary with the locality, and instruction on such control measures should be obtained from farm advisors or county agents serving the pertinent production area. Available information is given on control or reduction of disease losses by proper refrigeration practices, controlled atmospheres, fungicide treatments, heat treatments, or packaging. Injurious insects sometimes cause disorders of stone fruits that resemble certain parasitic diseases or orchard-related nonparasitic disorders. Insect injuries that may be confused with these market diseases are described; injuries that obviously are the direct result of boring or chewing insects are not included in the handbook.

3. J.W. Lipton, 1977. **Compatibility of Fruits and Vegetables During Transport in Mixed Loads.** USDA MRR 1070, 5 pp.

Summary: This publication describes the grouping of commodities in transit to protect them from causing losses to one another. Thus odors or physiologically active gases such as ethylene emanating from specific fruits or vegetables can damage other crops. Biphyenyl used as a fungicide on citrus fruits or sulfur dioxide released from fumigated grapes may cause impart off odors to other crops. Chilling injury can occur in certain fruits as avocados held below 50°F (10°C). Recommended shipping temperature, relative humidity and mixture compatabilities are given for fruits and vegetables in terms of eight groups. In addition, a listing of commodities with special requirements is included.

4. W.J. Lipton and J.K. Stewart, 1972. **An Illustratad Guide to tha Idantification of Some Markat Disordars of Head Lettuce.** USDA MRR 950, 26 pp.

Summary: Head lettuce is subject to a variety of market disorders, some of which are confused easily because they resemble each other. This confusion causes difficulties at market inspections when accurate identification is needed to help avoid or settle disputes. This publication is designed as an aid in identifying various disorders of lettuce with precise descriptions and illustrations of each. With the exception of bacterial soft rot, diseases caused by fungi and most bacteria are not included. The early symptoms of bacterial soft rot resembling those of russet spotting have been included. Description and color photographs are included showing carbon dioxide injury (brown stain, heart leaf injury), low oxygen injury, internal rib necrosis (blackheart, gray rib, gray streak and rib hlight) pink rib, rib discoloration (rib blight, brown rib), rusty-brown discoloration, russet spotting, and bacterial soft rot.

5. J.M. Lutz and R.E. Hardenburg, 1968. **The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks.** USDA Agric Hand No. 66, 94 pp.

Summary: This handbook developed by various scientists covers a number of aspects involved in the spoilage of fresh fruits and vegetables. Sections of the brochure were written by various authors who are noted authorities in their areas of specialization. It presents brief summaries of the essential average storage requirements of fresh fruits and vegetables. Since the handbook is intended primarily as a general practical reference, many details have been omitted. Decay and other types of deterioration in storage are discussed generally with respect to various fruits and vegetables (e.g., bacterial soft rot is the most serious disease of lettuce; tipburn is also considered a major market disease). This handbook is divided into several sections. There are sections dealing with (a) Factors in cold storage concerning best conditions, product quality, temperature and precooling, relative humidity, air circulation and product spacing, respiration rates — heat evolution and refrigeration, weight loss in storage, sanitation and air purification, supplements to refrigeration, chilling injury, freezing injury, ammonia injury, effect of cold storage on subsequent behavior of fruits and vegetables, (b) Mixed commodities in terms of compatability, (c) Fresh fruits in relation to best storage conditions, shelf-life, and disorders which may occur in storage and (d) Fresh vegetables in relation to best temperature and relative humidity storage conditions, shelf-life, and spoilage. The discussion on fresh fruits covers apples, apricots, avocados, bananas, berries, cherries, coconuts, dates, figs, grapes, guavas, lemons, limes, lychees, mangos, olives, oranges, papayas, peaches and nectarines, pears, persimmons, pineapples, plums, pomegranates, quinces, and tangerines. Fresh vegetables that are discussed are artichokes, asparagus, beans, beets, broccoli, brussels sprouts, cabbage, cauliflower, celeriac, celery, corn, cucumbers, eggplant, endive, garlic, ginger, leafy greens, horseradish, kohlrabi, leeks, lettuce, melons, mushrooms, okra, onions, parsley, parsnips, green peas, peppers, potatoes, pumpkins, radishes, rhubarb, rutabagas, salsify, spinach, squashes, sweet potatoes, tomatoes, and turnips.

6. L.P. McColloch, H.T. Cook, and W.H. Wright, 1968. **Market Diseases of Tomatoes, Peppers and Eggplants.** USDA Agri Hand No. 28, 90 pp.

Summary: This handbook is concerned with diseases of tomatoes, peppers and eggplants on the market. These diseases cause spoilage of these products in market channels. They are associated with the vigor of plants and the extent of diseases present in the field, weather conditions during the time the fruits were maturing and at the time they were harvested, and conditions of handling. Various types of market diseases and injuries are described including 46 types for tomatoes, 16 types for peppers, and 10 types for eggplants. Color photographs are presented showing a number of these types of diseases and injuries.

7. E.B. Pantastico, 1975. **Post Harvest Physiology Handling and Utilization of Tropical and Subtropical Fruits and Vegetables.** Avi Publ. Co., Westport, CT, 560 pp.

Summary: This book covers an expanded scope of post-harvest physiology. Included are operational techniques which regulate both chemical and physical changes. Thus, the mechanism of respiration after harvest resulted in research developments covering chemical treatments, controlled atmosphere storage, refrigeration, handling, and packaging of produce. Sections of this book include structure of fruits and vegetables, post harvest physiology, regulation of ripening and senescence, harvest and handling, physiological disorders and diseases, and distribution and utilization. With respect to lettuce, this book includes CA storage, harvesting, maturity index, morphology, and various disorders as marginal browning, pink rib, tipburn, russet spotting, and rib discoloration.

8. C.F. Pierson, M.J. Ceponis, and L.P. McColloch, 1971. **Market Diseases of Apples, Pears and Quinces.** USDA Agric Hand No. 376, 129 pp.

Abstract: Pome fruits – apple (*Malus sylvestris* Mill), pear (*Pyrus communis* L.), and quince (*Cydonia oblonga* Mill.) – should be harvested at proper maturity, handled carefully, stored promptly, and cooled to the desired temperatures quickly if ripening processes are to be slowed and spoilage held to a minimum. Careful handling and refrigeration should be continued during transportation and marketing. The word "disease" as used in this publication means any departure from the normal condition of fruits that detracts from their appearance, interferes with their usefulness, or reduces their value. Under such a broad definition, the term "disease" includes abnormalities caused by fungi, viruses, functional or physiological disorders, and injuries such as mechanical, chemical, physical, and insect. The common names of diseases used herein are for the most part those that have become well established in publications on plant diseases and that are in general use among persons concerned with the growing and marketing of apples, pears, and quinces. A few, such as Jonathan spot and York

spot, include the name of the variety on which they were first described or on which they are most common. Some of the names, such as **bull's eve rot**, **flyspeck**, and **scald** briefly describe the diseases to which they are applied. Still others contain the name of the causal or inducing agent; among these are **elternerie rot** and **freezing injury**. A few of the names imply a quality of the affected tissues that is not really characteristic or typical, but the names are so well established by usage that it has seemed best to retain them. The diseased flesh of apples affected with bitter rot and bitter pit is not always bitter; black rot lesions are often only dark brown, and brown rot lesions eventually become black. Most of the insect injuries are named for the insects that cause them. The occurrence, importance, symptoms cause, and control of diseases of pome fruits are discussed under appropriate headings.

9. G.G. Ramsey, B.A. Friedman and M.A. Smith, 1959. **Market Diseases of Beets, Chicory, Endive, Escarole, Globe Artichokes, Lettuce, Rhubarb, Spinach and Sweet Potatoes.** USDA Agric Hand No. 155, 61 pp.

Summary: This handbook discusses market diseases of beets, chicory, endive, escarole, globe artichokes, lettuce, rhubarb, spinach, and sweet potatoes. Diseases found in the market on these products may have been present in the field, may be associated with weather conditions during growth, or may have been caused by improper handling after harvest. Various types of market diseases are described – five types for beets, two types for globe artichokes, ten for lettuce, four for rhubarb, five for spinach, and 21 for sweet potatoes. Casual factors and methods of control are also discussed. Photographs are included showing a number of these diseases.

10. G.B. Ramsey and M.A. Smith, 1961. **Market Diseases of Cabbage, Cauliflower, *Turnips, Cucumbers, Melons, and Related Crops.*** USDA Agric Hand No. 184, 73 pp.

Summary: Various diseases of a number of economically important food crops are discussed in this book. Symptoms, causal factors and control measures for these diseases are covered. These diseases may be caused by fungi, bacteria, nutrient deficiency while growing, insects, low temperature in storage, sunscald, freezing, or may be of unknown source. Crops discussed are cabbage, chinese cabbage, brussel sprouts, broccoli, cauliflower, collards, kale, horseradish, kohlrabi, mustard, radish, rutabagas, turnips, cucumber, muckmelon, pumpkins, squash and watermelon.

11. A.L. Ryall and J.M. Harvey, 1959. **The Cold Storage of Vinifers Table Grapes.** USDA Agric Hand No. 159, 46 pp.

Summary: The accumulation of many years of research and experience in grape storage have been brought together in this book. Operators of storage plants, packers, growers, and buyers will find it of value. Information is presented on temperature, humidity, air movement, storage design, fumigation, storage disorders and sources of such information. This information can be used to maintain quality, reduce spoilage and improve marketing of grapes. Included are sections on factors affecting quality of stored table grapes, types of refrigeration systems, factors affecting refrigerated capacity requirements and disorders of grapes in storage. Other sections deal with fumigation with sulfur dioxide, symptoms of sulfur dioxide injury, factors affecting sulfur dioxide injury, precautions to follow when using sulfur dioxide and selective marketing of storage lots.

12. A.L. Ryall and W.J. Lipton, 1972. **Handling, Transportation, and Storage of Fruits and Vegetables.** Avi Publ. Co., Westport, CT, 473 pp.

Summary: This book includes biological and physical aspects of marketing fresh vegetables. Various types of research have been collated and covered; such as harvesting, preparation, packaging, transportation and storage. Information is provided on control of post-harvest diseases and disorders, and physiological changes of harvested crops. Included are general discussions of market diseases of leafy vegetables and unripe and ripe fruits.

13. A.L. Ryall and W.T. Pentzer, 1974. **Handling, Transportation, and Storage of Fruits and Vegetables.** Avi Publ. Co., Westport, CT., 545 pp.

Summary: These authors have attempted to describe practices used by the fruit industry in supplying markets with fresh fruits throughout the year. The fruit industry of the United States produces over 22 million tons of fruit annually. It is a major task to clean, grade, pack, store and ship this quantity of fruit to markets which in some cases, are thousands of miles away. In the fruit industry's early days, heavy losses were experienced from spoilage. Improvements have been made in crop handling, refrigeration, and in controlling market diseases. Post-harvest handling of fruit improvements have been a worldwide development. The biological and engineering aspects of post-harvest care of fruits are covered. The book is of value in terms of marketing and horticulture; it is also concerned with fruit movement from the orchard to the consumer.

14. M.A. Smith, L.P. McColloch and B.A. Friedman, 1966. **Market Diseases of Asparagus, Onions, Beans, Peas, Carrots, Celery and Related Vegetables.** USDA Agric Hand No. 303, 82 pp.

Abstract: The vegetable crops included in this handbook have widely different problems of culture, field disease control, harvesting-methods, and handling practices. Each commodity, therefore, must be considered separately in controlling post-harvest diseases. Each commodity has a natural population of bacteria and fungal spores on its surface at harvest; these bacteria and spores are a potential hazard to its keeping quality. Subsequent infection and disease development will depend on such factors as commodity vigor, natural resistance, extent of mechanical injury, relative humidity, and temperature. In addition to the fungal and bacterial diseases, these vegetable crops are subject to virus and physiological diseases. Some of the physiological diseases and all of the virus diseases, as well as a few of the blemish-type diseases caused by bacteria or fungi, not only originate in the field but are obvious at harvest. If blemished vegetables are included in the pack, it is either because they are acceptable or because they are overlooked during packing. Certain rots that are normally field diseases may also appear after harvest. These may have been small lesions that were overlooked during sorting and packing or may have developed from invisible infections or from spores present at harvest. In addition, there are certain diseases that occur or are important only after harvest. The basic control for diseases that occur in the field must be applied during the preparation for and production of the crop. Recommendations for such control measures are available from the State agricultural experiment station or extension service. This handbook is concerned primarily with those control measures that can be successfully applied after harvest. In general, careful handling practices and prompt and proper temperature and humidity controls are standard recommendations for disease control after harvest. In certain situations chemical treatment may also be recommended.

15. J.J. Smoot, L.G. Houch and H.B. Johnson, 1971. **Market Diseases of Citrus and Other Subtropical Fruits.** USDA Agric Hand No. 398, 115 pp.

Abstract: Market diseases of fruits and vegetables are those that develop during the process of marketing. Marketing includes the harvesting, grading, and packing of the crop, its transportation to market, its storage at shipping point or at the market, and the various handling operations required to move it from the wholesale dealer to the retail store and the ultimate consumer. During any of these operations the product may be subjected to conditions that impair its appearance and food value and render it liable to attack by decay-producing organisms or physiological breakdown. The fruits discussed in this publication, like all other fruits and vegetables, are susceptible to invasion by bacteria and fungi at bruises and skin breaks. Hence, it is of prime importance that they be handled as carefully as possible at all times. Clipper cuts, fingernail scratches, injuries caused by packinghouse machinery, packing bruises, and damage caused by rough handling in transit and on the market are all sources of danger. This is especially true if the places where the fruit is packed, stored, or offered for sale are not kept free of rotting fruit and other infectious material. These injuries, as well as those caused by insects, must all be considered when judging the storage or shipping quality of the fruit or the likelihood of maintaining its quality until it is consumed. Temperature and humidity directly affect the development of decay in fruit. They should have the critical attention of those who ship or store fruit and of those who attempt to determine why a given lot, at any stage in marketing, shows decay or other deterioration. Too low a temperature may freeze the fruit, or it may cause only chilling injury; subtropical fruits are particularly susceptible to such injury. Too high a temperature favors decay and may cause undesirable color changes. High humidity favors the growth of fungi. Low humidity causes loss in weight and possible shriveling, especially if temperatures are high. For all of these reasons, the management of storage rooms for citrus and other subtropical fruits and the choice of conditions under which to ship them to market, whether under refrigeration or under ventilation, are not likely to give the best results unless based on an intelligent use of all available information concerning the market diseases of those fruits. This handbook discusses 87 different market diseases of citrus, avocados, bananas, figs, lychees, mangos, papayas, pineapples, and pomegranates.

16. F.B. Abeles, 1972. **Biosynthesis and Mechanism of Action of Ethylene.** Ann Rev Plant Physiol. **23**, 259–292.

Summary: The author reports on the biosynthesis and mechanism of action of ethylene. Ethylene production by fungi, such as penicilium has been intensively studied. Various substrates used by penicillium to produce ethylene have been studied. Some of these are glucose, alamine, glycine, aspartic acid, glutamic acid, methionine, seraine, betaine-methyl, glyoxalate, acrylate, propionate, ethanol, acetate, citrate, fumarate, malate, pyruvate and succinate. Methionine has been established as the precursor of ethylene in plants. The effect of ethylene on some enzymes was reported. Ethylene was found to increase the amount of protease and invertase in pineapple fruits. Ethylene was also found to increase RNA synthesis in preclimacteric fruit.

17. W.R. Barger, J.M. Harvey and S.M. Ringel, 1959. **Transit Temperatures of California Mature-Green Tomatoes Shipped by Rail.** USDA MRR 349, 11 pp.

Abstract: Transit temperatures of mature-green tomatoes were compared in a conventional ice-bunker car equipped with electric fans, a Cargotemp car, and a mechanically refrigerated car. The Cargotemp car is a modified ice-bunker car equipped with a small diesel engine to power thermostatically controlled fans. Loads in all the cars were heavy enough to qualify for reduced freight rates. Temperatures fluctuated more in the conventional car than in the other two cars and approached the chilling point (50°F) in the coldest positions in the load. Temperatures in the Cargotemp and mechanically refrigerated cars remained close to the thermostat settings of 55°F. Ripening in transit in the Cargotemp and mechanical cars was uniform and sufficient to permit marketing within a few days of arrival at the terminal market. The colder temperatures in the conventional car retarded ripening and reduced the percentage of salable fruit.

18. G.S. Birth and K.H. Norris, 1965. **The Difference Meter for Measuring Interior Quality of Foods and Pigments in Biological Tissues.** USDA Tech Bull 1341, 20 pp.

Abstract: It is generally believed that objects such as whole apples, tomatoes, or potatoes are opaque. Actually these objects, and biological tissue in general, will transmit some of the light falling on them. Although the amount of light that can be transmitted through a 2-inch-diameter apple is small, it is sufficient to permit evaluation of the internal color under controlled conditions without damage to the fruit. Specifically, measurements can be made to determine if the flesh of a red apple is green or white, whether or not there is blood in an egg, and if the interior of potatoes is the normal white flesh or if browning is present. The most satisfactory method of making these evaluations in a practical manner has been to measure the optional density of the product at two wavelengths and compute the optical-density difference. A number of instruments have been developed in the Instrumentation Research Laboratory of the US Department of Agriculture to make such a measurement quickly. This report describes a design that has evolved over a period of years in the use of such instruments. The instrument described here is compact, portable, easy to use, and has given very reliable

service. The instrument employs interference filters to isolate the desired wavelengths and a photometer capable of measuring the extremely low light levels transmitted by intact product. The instrument is of considerable value in the biological research laboratory because an estimation of the concentration of pigments in fresh tissue can be determined without making an extract. The convenience of use and the nondestructive f: :ure make the instrument useful for the quality control laboratory and for establishing grades.

19. M.C. Bourne, 1977. **Post Harvest Food Losses – The Neglected Dimension in Increasing the World Food Supply.** Cornell International Agriculture Mimeograph 53, 49 pp.

Abstract: Most international donor organizations have identified the food supply and nutritional status of populations in developing countries as major problem areas and consequently have expended considerable effort in the fields of agriculture and nutrition. The bulk of these efforts has been concentrated on increasing agricultural production and decreasing field losses in order to produce more food. However, increasing agricultural production is not sufficient to improve the nutritional status of poor populations. The increased production must pass safely along the chain that links the farmer to the ultimate consumer, and this chain is fraught with perils for the food. Large quantities of food that leave the farm never reach the consumer. Concomitant with the increased efforts in food production there should be increased effort expended in caring for that food so that it reaches the ultimate consumer. This requires a knowledge of food science and technology. storage engineering, entomology, and biology. This paper outlines the nature of the problem of post harvest food losses, discusses the causes of loss, what is known of the extent of losses and where losses occur. It describes briefly the available techniques for pre-serving food and identifies those techniques that offer the greatest promise for increasing the available food supply in developing countries.

20. S.D. Burg, 1962. **The Physiology of Ethylene Formation.** Ann Rev Plant Physiol. 13, 265–297.

Abstract: This review has tried to bring into perspective the evidence that ethylene is a common if not ubiquitous product of plant tissue and that concentrations with physiological potency do occur within fruits and may occur elsewhere. Because the amounts of ethylene which are produced by most plant tissues are so small that only the most sensitive devices suffice to detect them, a tendency has arisen to assume a **priori** that the concentration of the gas within various plant structures could not be significant. This practice should be discontinued and replaced by serious efforts to determine the actual amounts of ethylene contained within tissues. The need for this approach becomes apparent when it is considered that a rate of production of only 0.01 μl/kg/hr may suffice to cause the accumulation of the small concentration of ethylene needed to hasten the ripening of some fruits, and in the past it has not been uncommon to regard rates of ethylene production below a few μl/kg/hr as difficult to measure and insignificant. Ethylene may or may not contribute to the physiology of the wound response, leaf dehiscence, flower senescence, seed germination, rooting, and dormancy; we simply do not know. It does participate as a hormone, stimulating ripening in some and perhaps all fruits, and this should provide incentive to examine these new possibilities with fresh enthusiasm.

21. M.J. Ceponis, 1973. **The Natura and Extent of Retail and Consumer Losses in Apples, Oranges, Lettuca, Peaches, Strewberries, and Potatoes Marketed in Greatar New York.** USDA MRR No. 996, 23 pp.

Abstract: Six major fresh produce crops were periodically sampled at wholesale, studied in retail stores, and purchased for consumptability during their respective seasons in the Greater New York area from 1966 to 1969. The condition of each crop in wholesale samples was compared with that found in retail stores two or three days later. Losses in retail stores were categorized and measured. Purchased retail store samples were held for varying times at room temperatures (or 70°F) or at 38° to 40°F to simulate consumer holding before they were examined for defects resulting in loss of edible tissue. Retail and consumer losses in each commodity for the completed study follow. Wastage in Pacific Northwest Red Delicious apples marketed from October through April was 1.0 percent in retail and 2.6 percent in consumer samples for 1966 to 1969. Mechanical injury (0.6 percent) was the leading cause of loss in retail. Nonparasitic disorders (1.2 percent) and mechanical injuries (1.2 percent) caused most of the loss in consumer samples. Little retail loss occurred in Appalachian Red Delicious apples that were usually marketed from September to December. In consumer samples, 1.5 percent loss occurred. Mechanical injuries caused 1.0 percent and parasitic and nonparasitic disorders the remaining 0.5 percent. Retail and consumer losses in California navel oranges marketed from November to April were 1.9 and 2.3 percent, respectively, for the three-year study. Parasitic diseases, mainly penicillium rots, caused almost 75 percent of the loss at both levels. Parasitic diseases caused about 75 percent of the loss in Florida Valencia oranges marketed in the February to June periods of the study. Losses from all causes totaled 1.2 percent in retail and 2.0 percent in consumer samples. Mechanical injury was the leading cause of loss in California crisp head lettuce marketed from April to October of 1967 to 1969. It comprised 2.7 percent of the total 4.6 percent loss in retail and 3.1 percent of the total 7.1 percent loss in consumer samples. Parasitic disorders caused 1.5 and 1.2 percent loss in retail and consumer samples, respectively. Losses from nonparasitic disorders were 0.4 percent in retail and 2.8 percent in consumer samples. Mechanical injury and decay caused practically all the loss in retail and consumer samples of peaches marketed from May to September of 1967 to 1969. Retail losses totaled 4.5 percent: 2.8 percent from mechanical injury and 1.7 percent from decay that was chiefly brown rot. Decay caused 4.5 percent loss and bruising 3.6 percent loss in consumer samples of peaches that were held at room temperatures until they were ripe. Strawberry losses in retail and consumer samples totaled 4.9 and 18.0 percent, respectively, during the March to October periods of the three-year study. Parasitic disorders, mainly gray mold rot, spoiled 3.6 and 11.6 percent of the berries in retail and consumer samples, respectively. Mechanical injuries wasted the rest. A 3.6 percent loss occurred in consumer samples of Main Katahdin potatoes marketed in Greater New York in the December to May periods of 1966 to 1969. Mechanical injuries caused 1.5 percent; parasitic diseases, 1.1 percent; and nonparasitic disorders, 1.0 percent. Consumer losses in California White rose potatoes marketed in the May to July periods of 1967 to 1969 totaled 3.2 percent. Parasitic diseases spoiled 2.1 percent. Losses from mechanical injuries and nonparasitic disorders were 0.7 and 0.4 percent, respectively. Assuming that our retail and consumer losses are representative, the following losses have been estimated for the marketing of these six crops in Greater New York during 1966 to 1969. Red Delicious apples from the Pacific Northwest and Appalachia, 4.6 million pounds; Florida Valencia and California navel oranges, 16.6 million pounds; California lettuce, 49.7 million pounds; peaches, 35.0 million pounds; strawberries, 9.8 million pounds; and Maine Katahdin and California White Rose potatoes, 30.0 million pounds.

22. M.J. Ceponis and 8.A. Friedman, 1959. **Pectolytic Enzymes of Pseudomonas Marginalis and Their Effects on Lettuce.** Phytophathol 49, 141–44.

Abstract: Soft rot, vascular browning, and russet spotting were produced on lettuce leaves with sterile filtrates of *Pseudomonas marginalis* cultures. Strong protopectinase and pectin depolymerase activity were found in filtrates with pH optima about 7.5 to 8.5. The activity of these enzymes was reduced sharply by heating 20 minutes above 50°C. Pectinmethylesterase activity was weak in the culture, filtrates. A polygalacturonase forming monogalacturonic acid could not be detected.

23. M.J. Ceponis and J. Kaufman, 1968. **Effect of Relative Humidity on Moisture Loss and Decay of Eastern Lettuce Prepackaged in Different Films.** USDA ARS 51–18, 9 pp.

Abstract: Film characteristics and ambient relative humidity greatly affected the amount of moisture lost from and the decay that developed in film-wrapped lettuce held for five days at 60°F. Less moisture was lost from but more decay developed in artificially inoculated lettuce when heads were wrapped in nonperforated polystyrene and minutely perforated polyvinyl chloride than when wrapped in 195–LSAD cellophane with three 1/4-inch holes per overwrap or in polyethylene, polyvinyl chloride, and polypropylene, multiperforated to 0.4, 0.4, and 1.3 percent of their surface area, respectively. Decay increased in all prepackaged lots when the ambient relative humidity was increased. (More decay developed in shrink-film-wrapped lettuce when the overwrap was heat-shrunk than when it was not.) While less decay developed in the more extensively perforated film-wrapped lots, excessive moisture loss caused wilting in many heads held at 50 percent and in some heads held at 70 percent ambient relative humidity. No wilting occurred in any prepackaged lot at 90 percent relative humidity or in lots wrapped in polystyrene or in minutely perforated polyvinyl chloride held at 50 and 70 percent relative humidity. Despite more decay development, the non-heated polystyrene-wrapped and minutely perforated polyvinyl-chloride-wrapped lots were more marketable than the more perforated film-wrapped lots at 50 percent relative humidity. At 70 and 90 percent relative humidity there were more marketable heads in the nonheated and more perforated film-wrapped lots than in the heated and least perforated film-wrapped lots.

24. H. Daun, S.G. Gilbert, Y. Ashkenazi and Y. Henig, 1973. **Storage Quality of Bananas in Selected Permeability Films.** J. Food Sci. 38, 1247–1249.

Summary: 8ananas are among the three most widely consumed fruits in the United States. The total annual import of this fruit is estimated at over 3.5 billion pounds. Losses during transport, wholesale and retail storage are much greater than with other fruits. A retail package was developed which allowed ethylene-treated bananas to retain excellent color, odor, taste and texture for as long as 30 days at 15°C. The beneficial conditions were obtained by using film with proper gas permeability for the particular weight of the fruit and package dimensions. The desired oxygen, carbon dioxide and water vapor concentrations were generated by the system itself as a result of balance between the respiration of the bananas and the diffusion from surrounding atmosphere through the film.

25. R.R. Dedolph, S.H. Wittwer and H.E. Larzelene, 1963. **Consumer Verification of Quality Maintenance Induced by N^6-Benzyladenine in the Storage of Celery** (*Apium graveolens*) **and Broccoli** (*Brassica Oleracea var. Italica*). Food Technol 17 (10), 111–112.

Abstract: Post-storage flavor and appearance of broccoli and celery were significantly improved by treatment with N^6-Benzylodeine. Treated celery was preferred over untreated by over eight-tenths of the panel members. Sensory evaluation in a triangle taste test showed that only four out of ten panel members could tell the difference between petioles from treated an untreated celery stalks. Two out of three of those who could distinguish the difference preferred the samples from the treated stalks. Visual evaluation of fresh broccoli showed almost universal preference for the N^6-benzyladenine treated samples. Eighty percent of the panel could distinguish between the cooked samples, and of this 80 percent, two out of three preferred the treated sample.

26. C.A. Eaves and C.L. Lockhart, 1960. **Storage of Tomatoes in Artificial Atmospheres Using the Calcium Hydroxide Absorption Method.** J. Hort Sci 36 (2), 85–92.

Abstract: A simplified method for the maintenance of artificial atmospheres in storage cabinets under laboratory conditions and its use in tomato storage studies is described. Eight different atmospheres containing various concentrations of CO_2 and O_2 were used. The results showed that CO_2 was the dominant gas in the retardation of ripening and tended to mask the effect of reduced O_2 levels. Fungal wastage was reduced in the presence of all levels of CO_2, with the exception of that observed in the fruit stored at the 7 percent level and examined immediately after removal from the gas mixture. The delaying influence of reduced concentrations of O_2 was noted after removal to air. Best results from the standpoint of ripening were obtained with a gas mixture containing 5 percent CO_2 during a storage period of 12 weeks at 12.7°C. A gas mixture of 2.5 percent CO_2 and 2.5 percent O_2 was associated with the minimum development of fungal decay, which was found to be the major limitation to the prolonged storage of tomatoes. The dominant fungal organisms were *Phoma destructiva, Alternaria tenuis, Botrytis cinera* and *Fusarium spp*.

27. H. Gorfien, K.R. Johnson and E.E. Anderson, 1968. **Effects of Badran Process on Storage Life of Lettuce.** NLABS Tech Rpt 69–46–FL (FL–86), 22 pp.

Abstract: Tests were conducted to determine the feasibility of using BADRAN processing as a means of improving the quality and extending the storage life of lettuce shipped to military organizations overseas. BADRAN is a process for controlling atmosphere of fresh produce by the use of packaging materials of selective gas permeability. Field tests were conducted on lettuce shipped from California to Germany. Statistical analyses were conducted on data from an edible yield inspection test and from the standard Veterinary Corps inspection. Analysis showed that BADRAN processing, in its current state of the art, gave poorer quality and storage life for both untrimmed (naked-packed) and field trimmed and wrapped lettuce at certain inspection periods. At no time did the BADRAN processed lettuce show higher quality than specification lettuce. An internal reddish-brown defect developed only in the BADRAN processed lettuce. There was an indication that field trimmed and wrapped lettuce results in less spoilage overseas than untrimmed (naked-packed) lettuce, confirming results of an earlier study by the US Department of Agriculture.

28. H. Gorfien, A.R. Rahman, K.R. Johnson and E.E., 1969. **Effects of a Controlled Atmosphere System on the Storage Life of Lettuce, Part I -- Laboratory Tests.** NLABS Tech Rpt 70-23-FL (FL-99), 11 pp.

Summary: Laboratory tests were conducted to determine the effects on lettuce of TECTROL, a proprietary system for shipping fresh vegetables and fruits in specially proportioned atmospheres in refrigerated containers and railcars. Storage periods approximating the extended overseas shipping and distribution time frames of four to eight weeks required by the military were used. The tests showed that, where controlled atmospheres were maintained, significant improvements in quality and storage life were obtained. Reductions in slime, pink rib, and russet spotting were found. Increased storage life in air remained after removal from controlled atmosphere when compared with the quality of lettuce which had been stored in air by the conventional method.

29. H. Gorfien, A.R. Rahman, G. Taylor and D.E. Westcott, 1970. **Controlled Atmosphere System Laboratory Studies** on **Tomatoes.** NLABS Tech Rpt 70-58-FL (FL-108), 16 pp.

Abstract: Laboratory tests were conducted to determine the effect of low-oxygen controlled atmosphere (which is carbon dioxide free) on tomatoes. Storage periods approximating the extended overseas distribution time of three to eigth weeks as required for military shipments were used. The tests showed that the use of low oxygen controlled atmosphere would lead to significant reductions in spoilage, inhibition of black spot type rot similar to Alternaria rot, improvements in tomato quality, and as much as two weeks additional storage life when compared with tomatoes initially stored in air at the same optimum 50°F to 55°F temperatures. These factors became apparent from one to four weeks after transfer of tomatoes from low oxygen controlled atmospheres to 40°F air. The break-even point to defray the additional cost of a commercially available controlled atmosphere method of shipping is estimated to be in the range of 1.8 percent to 3.3 percemt improvement in tomato yield. Data developed in this investigation indicate that improved tomato yields on overseas shipments of tomatoes may be anticipated to be more than enough to defray the additional cost of such a system for shipping fresh produce in refrigerated containers at low levels of oxygen and carbon dioxide. It is concluded that sufficient information has been developed to warrant a field test on tomatoes shipped in controlled atmosphere containers to military organizations overseas.

30. H. Gorfien, A.R. Rahman, T.J. DiNicola, M. Driver and D.E. Westcott, 1970. **Controlled Atmosphere System Studies on Celery.** NLABS Tech Rpt 71-22-FL (FL-120), 17 pp.

Abstract: Laboratory tests were conducted to determine the effect of controlled atmosphere on celery. Storage periods were three to eight weeks. The data indicate that the use of controlled atmosphere results in celery which is greener in color, more turgid and of more intense celery flavor. Significant reductions in spoilage of the soft type were found in celery which had been initially stored in controlled atmosphere. However, spoilage data were limited to three crops of celery only and must be viewed with caution. The fourth

crop as represented by celery hearts, exhibited the least amount of spoilage. The data in this report also show that wrapped celery lost less moisture than unwrapped celery. The break-even point to defray the additional cost of a commercially available controlled atmosphere method of shipping is estimated to be in the range of 2.5 percent to 4.7 percent improvement in celery yield. It is concluded that sufficient laboratory data and information in the technical literature are available to warrant a series of field tests on celery and other fresh fruits and vegetables shipped in commercial controlled atmosphere containers to military organizations overseas.

31. H. Gorfien, A.R. Rahman and D.E. Westcott, 1969. **Effects of a Controlled Atmosphere System on the Storage Life of Lettuce, Part II – Field Test.** NLABS Tech Rpt 70–26–FL (FL–100), 17 pp.

Abstract: Tests were conducted to determine whether TECTROL-controlled atmosphere would lead to an improvement in the quality and storage life of lettuce shipped to military organizations overseas. TECTROL is a proprietory system for shipping fresh fruits and vegetables through the introduction of specially proportioned gases into existing refrigerated containers and rail cars. The tests showed that, where controlled atmospheres can be reasonably maintained, improvements in quality and increases in storage life will result. Reduction in the extent of pink rib and decay was found. In these tests lettuce was shipped from the West Coast to Japan, requiring five weeks; reductions in lettuce losses were found to range from 5.0 to 16.4 percent when compared to lettuce shipped conventionally in air. The breakeven point to defray the additional cost of TECTROL is estimated to be in the range of 2.7 to 5.4 percent reduction in lettuce loss. This indicates that the cost of TECTROL would be defrayed by reductions in lettuce loss during overseas shipment. Some data are presented to indicate that temperatures in loaded refrigerated containers are frequently somewhat higher than their thermostat settings indicate. There are engineering problems and shipping precautions associated with the maintenance of controlled atmosphere which remain to be resolved. A failure in maintaining refrigeration for an extended period of time can lead to levels of oxygen less than one percent; thus resulting in the loss of an entire shipment due to anaerobic spoilage. It is concluded that shipments of lettuce in controlled atmosphere containers to military organizations overseas be initiated on a larger scale. Controlled atmosphere field test shipments would assist the controlled atmosphere industry and military users in defining and eliminating any engineering flaws which might exist in current commercial scale equipment.

32. E.G. Hall, 1968. **Atmosphere Control in Storage and Transport of Fresh Fruit and Vegetables.** Fd Preserv Q 28 (1–2), 2–8.

Abstract: Controlled atmosphere (CA) storage is the term applied to the storage of fruits and vegetables in an atmosphere containing more carbon dioxide and less oxygen than air. This article explains the biological principles on which the practice is based, and describes the methods used to produce atmospheres of the desired composition.

33. C.B. Hall and R.E. Stall, 1971. **Association of "*Pseudomonas Marginalis*" with Pink Rib of Lettuce.** Proc. Florida State Hort Soc 81, 163–165.

Abstract: The bacterium *Pseudomonas Marginalis* was isolated from pink rib lesions on lettuce during the 1970 to 1971 season. Pink rib was produced by injecting isolated bacteria into the ribs of disease-free lettuce followed by storage at 35°F and 47°F. A brown discoloration was produced when the inoculated lettuce was held at 60°F and 72°F. The discoloration progressed from the main rib into the veins and leaf margin where a nonodorous soft rot developed with time. Symptoms in naturally infected lettuce seemed associated with injury. Cultivar differences in the incidence of pink rib during storage might have been due to differences in injury. The number of affected leaves increased during storage.

34. R.E. Hardenburg and J.M. Lutz, 1962. **Commodity Storage Requirements.** ASHRAE Guide and Data Book 1962, 483–494.

Summary: Information is presented on the essential average storage requirements of most of the important perishable foods that enter the market on a commercial scale. Also included is a short discussion on the use of refrigeration in the mushroom industry as well as information on the storage of furs and fabrics. The statements made are derived from scientific experimentation and from the best commercial practice at the present time. The data given in Table 1 are based on the storage of high quality commodities shortly after harvest. When products are transported from a distance, or are deteriorated, appropriate allowances should be made. The temperatures recommended are the optimum temperatures for long storage and are actual commodity temperatures rather than air temperatures. For short storage, higher temperatures are often satisfactory. Conversely, products subject to chilling injury can sometimes be held at a lower temperature for a short time without injury. Exceptions are bananas, cranberries, cucumbers, eggplant, melons, okra, pumpkins and squash, white and sweet potatoes, and tomatoes. Recommended temperatures for those products should be strictly adhered to. The values given for water content and freezing points are the results of actual laboratory determinations, but it should be realized that, at best, they can be only approximate because of the great variability in plant and animal tissues and the products thereof. The optimum storage temperature for many foods has been found to be just above their freezing points. It is important to remember that fresh fruits and vegetables in storage are alive and carrying on, within themselves, processes characteristic of living things. In particular, the heat of respiration must always be considered a part of the refrigeration load in storage handling.

Sealed polyethylene box liners are used extensively in commerce for pears and sweet cherries. The slight accumulation of carbon dioxide and depletion of oxygen extend the storage life of pears at 31°F by one or two months and of sweet cherries by several days. Non-sealed film liners are used extensively to maintain freshness and prevent excessive moisture loss of Golden Delicious apples, rose bushes, and strawberry plants. There are indications that similar liners would be beneficial to other crops (such as parsnips) susceptible to excessive weight loss during storage or marketing. Reduction of frost accumulation on refrigeration coils is another advantage of polyethylene liners.

35. C.M. Harris and J.M. Harvey, 1976. **Quality Maintenance of California Strawberries Exported to Far Eastern Markets.** USDA MRR 1053, 6 pp.

Abstract: Transit times for air shipments of strawberries sent from shipping points in California to wholesale markets in Tokyo and Hong Kong averaged 28 and 36 hours, respectively. These times may vary, however, because of differences in schedules among various airlines serving these areas. Pallet loads of fruit remained cooler during transit when shipped in enclosed airline containers than when shipped on open, netted master pallets. Warming of berries in the top layers was slowed by the use of dry ice and plastic film pallet covers. The covers also provided a gas barrier around the fruit that retained carbon dioxide atmospheres, which retard development of decay.

36. J.M. Harvey, 1971. **Air Transportation of Perishables to Foreign and Domestic Markets.** Blue Anchor, 49, 1–4.

Summary: Air transport of perishable commodities has grown steadily since the airlines began using the jet air freighter. Temperature has a significant effect on the respiration rate of cherries and strawberries and activity of decay organisms. The decay may not show up when the fruit arrives at its destination, but differences in spoilage, due to temperature differences in transit, do show up at retail level. Sometimes when ideal temperatures cannot be maintained in transit, controlled atmosphere can partially compensate for lack of refrigeration.

37. J.M. Harvey and C.M. Harris. **Air Transport of California Strawberries – Pallet Covers to Maintain Modified Atmospheres and Reduce Market Losses.** USDA MRR 920, 10 pp.

Abstract: Various types of pallet covers were tested as a means of maintaining high carbon dioxide (CO_2) atmospheres during air transport of California strawberries. The use of dry ice with covers that provided an effective gas barrier resulted in atmospheres with 20 percent or higher concentrations of CO_2. Both curtain-coated fiberboard and heat-shrunk polyethylene covers were effective. Berry temperatures in the top layers of pallets averaged about 38°F at shipping point and 50°F at destination; respective temperatures in the middle layers averaged 39° and 42°F. Ambient temperatures averaging 64°F at the origin airport and 58°F on the plane contributed to the rise in fruit temperature. Relative humidity on the plane was generally about 11 to 12 percent. Time from shipping point to wholesale delivery averaged about 13 hours for nonstop flights in which actual flying time was about five hours. Shelf-life of berries was increased by high CO_2 atmospheres, which reduce decay during marketing. Overall cutting and bruising injury of berries averaged about 4 percent.

38. R. T. Hinsch and R.E. Rij, 1976. **Packing and Shipping Mechanically Harvested Lettuce.** USDA MRR 1049, 5 pp.

Summary: The largest volume of a single perishable shipped out of California is western iceberg lettuce. It accounts for approximately 20 percent of all carlots of fresh fruits and vegetables shipped out of the state. Lettuce shipments increased approximately 17 percent

between 196B and 1972. A mechanical lettuce harvester has been developed which may be a key element of a handling and marketing system that will enable producers and marketers of lettuce to keep pace with increasing costs. Field tests have shown that the two-row experimental mechanical lettuce harvester can harvest about 450 cartons per hour (24 heads per carton). The purpose of this study was to determine if lettuce could be handled in large containers and the effect of this handling on lettuce quality. Mechanically harvested lettuce in both the pallet-size bin and in the jumble-filled box was found to have less trim loss than hand-harvested, hand-packed lettuce in conventional cartons. Firmness and appearance of the lettuce on arrival was found to be the same for both methods of packaging and harvesting. Hand-harvested lettuce packed in conventional cartons had slightly less crushing and bruising than mechanically harvested lettuce.

39. R.T. Hinsch, R.E. Rij and J.E. Stewart, 1976. **Quality of Iceberg Lettuce in Film Overwraps During Simulated Export.** USDA AR W–33, 6 pp.

Abstract: Three types of film overwraps for lettuce (polypropylene, polyethylene, and polystyrene) were held under simulated conditions of transit to overseas markets. Quality differences were slight; however, more heads were salable when wrapped in polyethylene film than when wrapped in either polypropylene or polystyrene film and stored for 1B days at 38°F plus four days at 50°F. The percentage of salable lettuce by weight was highest for polyethylene wraps. Statistically, however, only the differences between the polyethylene and polypropylene films were significant. Polystyrene film was not significantly different from either polyethylene or polypropylene film.

40. S. Jadhau, B. Singh and D.K. Salunkhe, 1972. **Metabolism of Unsaturated Fatty Acids in Tomato Fruit: Linoleic and Linolenic Acid as Precursors of Hexanol.** Plant and Cell Physiol. **13**, 449–459.

Summary: The typical aroma of tomato fruit is caused by volatile compounds of which aldehydes and ketones represent 32 percent, short-chain alcohols 10 percent, and hydrocarbons, long-chain alcohols and esters 5B percent. These studies were undertaken to determine whether fatty acids could serve as precursors of hexanal, one of the predominant aldehydes of tomato volatiles. Incubation of linoleic or linolenic acid with tissue slices as well as cell-free extracts of tomato fruits produced hexanal. Biogenesis of hexanal from these fatty acids was further substantiated by the use of uniformally labelled ^{14}C substrates. Based on the fact that hydrogen peroxide inhibited oxygen uptake and also production of carbonyls, it is apparent that lipoxidase is involved in these reactions. The activity of the crude soluble extract was increased by dialysis and ammonium sulphate fractionation. In general, ripe fruits contained greater enzymatic activities but smaller amounts of linoleic and linolenic acid than green fruits. The enzymatic activity was enhanced by metal ions and compounds containing free -SH groups.

41. H. Johnson, Jr., 1970. **Internal Rib Necrosis of Head Lettuca in Imperial Valley.** Calif Agric, **24** (9), 8–10.

Summary: A serious physiological disorder developed in Imperial Valley lettuce fields during the winter lettuce season. The symptoms of the disorder were described as diffuse, dark gray-green discoloration of the lower midrib and has been named internal rib necrosis;

it develops in climax lettuce. Another type of tissue breakdown associated with Climax lettuce develops after harvest in cold storage and is named, "rusty rib discoloration". A combination of low temperature and rainfall was thought to be the major factor involved in internal rib necrosis. Planting resistant varieties appears to be the only solution to the Imperial Valley lettuce problems of internal rib necrosis and rusty rib. The popular Climax lettuce variety is highly susceptible to both.

42. A.A. Kader, L.L. Morris and J.A. Klaustermeyer, 1974. **Post-Harvest Handling and Physiology of Horticultural Crops.** A List of Selected References. Vegetable Crops Series 169, Dept of Veg. Crops, Univ. of Calif., Davis, 44 pp.

Abstract: This list is prepared as a possible aid to research and extension workers, teachers, and students interested in the general area of postharvest horticulture. It is also expected to be useful to those in industry and to reference librarians. It should serve as a starting point for the development of background information on harvesting, handling and storage of horticultural commodities and on their physiology, composition and quality. The references are classified into 12 sections. Each citation was arbitrarily placed under a given section but is cross-referenced under additional sections. The titles included represent a somewhat arbitrary selection with emphasis on relatively current publications in English.

43. A.K. Khudairi, 1972. **The Ripening of Tomatoes.** Amer Sci, 60 (6), 696–707.

Summary: In many fruits, ripening is associated with color changes accompanied by a delicate aroma which makes the fruit attractive to eat. Molecular changes that occur within the cells are biochemical processes such as the biosynthesis of carbohydrates, organic acids, pigments, and flavor compounds. Some factors involved are genetic control of enzyme induction and of various physiologic changes as color, enzymes involved in biosynthesis or catabolic activities, and hormonal control of the ripening process. Covered in this review are the effects of light, temperature, and gas exchange. Internal changes during ripening are discussed. The known enzymes involved in carotenoid synthesis are enzymes that convert mevalonic acid to isopentenyl pyrophosphate; enzymes involved in addition of isopentenyl pyrophosphate and the formation of geranyl-geranyl pyrophosphate; enzymes that convert geranyl-geranyl pyrophosphate to carotene phyotene; enzymes that convert phyotene to red lycopene; enzymes causing ring closure resulting in carotenes; oxygenases that form xanthophylls. Color change in tomatoes is triggered by light. Red light which is absorbed by phytochrome is specific in the ripening of tomatoes. The reactions that occur are ethylene production, chlorophyll degradation, oxygen uptake, abscisic acid synthesis, and the enzymatic transformation of colorless carotenes to yellow, then orange, and finally red.

44. W.J. Lipton, 1967. **Market Quality and Rata of Respiration of Head Lettuce Held in Low-Oxygen Atmosphers.** USDA MRR 777, 9 pp.

Summary: The market quality of head lettuce was evaluated after seven days at 36°, 41°, or 50°F in atmospheres containing 0, 1/4, 1/2, 1, 2, 5, or 8 percent O_2 or in air and after an additional three or four days in air at 50°F. Concentrations of O and 1/4 percent O_2 injured the lettuce. Gray dead patches on the wrapper and cap leaves and dead young

heart leaves were the principal symptoms of injury. The injuries became more severe as the temperature was increased. Russet spotting was reduced substantially in all low-oxygen (O_2) atmospheres tested, regardless of temperature. The incidence of pink rib was not affected by low-O_2 atmospheres. The severity, however, was reduced in 1/2 percent O_2 when all test temperatures are considered, but decreased in 2 percent O_2 at 50°F. Decay was reduced, but not significantly in 1 percent O_2. Low temperature was more effective in reducing decay than low O_2.

Butt discoloration was generally less intense in 1/2 and 1 percent O_2 than in air, but not after three or four additional days in air. The general appearance of nontrimmed lettuce was not affected significantly by holding it in 1/2 to 8 percent O_2 at 36° or 41°F; although lettuce held at 50° in 1, 2, 5, or 8 percent O_2 for seven days plus three or four days in air appeared significantly greener and fresher than that held in air throughout. However, the quality of lettuce held in air at 36° or 41° was equal to and often superior to that held under low O_2 at 50°. After the lettuce was trimmed, the only benefit from low O_2 was a significant reduction in russet spotting. The rate of respiration (carbon dioxide [CO_2] production) was reduced by about a third to a half in 1/2, 1 or 5 percent O_2 compared with that in air, depending upon O_2 concentration and temperature. At 41°, a 50 percent decrease in the rate of CO_2 production would reduce vital heat production from 40,000 to 20,000 Btu per day per 20-ton load of lettuce. This reduction of 20,000 Btu is equivalent to the refrigeration capacity of about 140 pounds of ice or 115 pounds of liquid nitrogen (N_2). When N_2 is used as the refrigerant or as a supplement to mechanical refrigeration, the O_2 concentration should be at least 1 percent, never less than 1/2 percent. For maximum quality retention, low temperatures must accompany low-O_2 atmospheres.

45. W.J. Lipton, 1971. **Controlled Atmosphere Effects on Lettuce Quality in Simulated Export Shipments.** USDA ARS 51–45, 14 pp.

Abstract: The market quality of head lettuce was evaluated after storage for one month at 36.5° or 41°F in atmospheres containing 21 or 3 percent oxygen (O_2) combined with 0, 2, or 4 percent carbon dioxide (CO_2). Market quality was again evaluated after an additional three days in air at 50°F. Some of the lettuce was stored with wrapper leaves and some without. These variables simulated conditions encountered during transportation overseas. Carbon dioxide injured the lettuce in three of the four tests. The principal symptoms of injury were dead heart leaves and brown stain. Low O_2 increased the sensititivy of lettuce to high CO_2 injury. Controlled atmospheres (CA) reduced decay, particularly when low O_2 and high CO_2 were combined. However, removal of all wrapper leaves before storage reduced decay nearly as much as CA. Pink rib was inhibited by high CO_2 at both O_2 concentrations, but low O_2 tended to increase pink rib regardless of CO_2 concentration. Yield of edible lettuce was higher after storage in CA than in air, but only lettuce stored at 36.5°F was considered salable after one month, regardless of storage atmosphere. When the danger of injury from high CO_2 is balanced with the benefits of significant reductions in decay and pink rib, CA can be advantageous for storage periods of about one month, or possibly longer. A combination of 3 percent O_2 with 2 percent CO_2 seems optimal. However, even with CA, temperatures must be 36°F or lower if a reasonable amount of salable, or even edible, lettuce is to be recovered at destination.

46. J.R. Lugg, 1971. **Controlled Atmosphere; A Sophisticated Way of Shipping Perishables.** Def. Trans J., Jul-Aug 1971, 50–52.

Abstract: Many shippers have found that atmosphere can be of significant benefit while others question the value in performance of the various systems. The fact remains that over 15,000 vehicles will be equipped to handle atmosphere shipments by the end of 1971. About 10 percent will be operated over the water by eight companies. The remainder of the equipment is composed of rail cars, piggyback vans, and truck trailers. The reservoir of equipment is certainly a great source of encouragement to shippers who have lived through the frustrating years of trying to convince transporation companies that, first, they should get the atmosphere containers to the proper origins for reloading. What's in the future? If history is a reliable indicator of trends in the future, modified atmosphere will be increasingly utilized to maintain freshness of perishables. As the process becomes more widely accepted, additional vehicles are sure to be equipped for atmosphere. Most important of all, wherever in the world perishables are destined, atmosphere can truly benefit the consumer by reducing losses and maintaining freshness.

47. L.P. McColloch and J.T. Worthington, 1952. **Low Temperature as a Factor in the Susceptibility of Mature-Green Tomatoes to Alternaria Rot.** Phytopathol 42 (8), 425–427.

Abstract: *Alternaria tenuis* is recognized as a weak pathogen that is ordinarily unable to produce decay in healthy mature-green tomatoes. The occurrence of severe altenaria rot in certain commercial shipments of tomatoes indicated that low temperature was possibly a factor in susceptibility. Tests with mature-green fruit held at 32°F for various periods before inoculation and those with fruit held at 32° and 70° after inoculation indicated clearly that sound, mature-green tomatoes are weakened by holding at low temperatures and that the low-temperature injury causes them to become susceptible to alternaria rot.

48. L.P. McColloch and J.N. Yeatman, 1966. **Color Changes and Chilling Injury of Pink Tomatoes Held at Various Temperatures.** USDA MRR 735, 6 pp.

Abstract: Pink tomatoes of different stages of ripeness were held at several temperatures to simulate normal transit conditions and also to test temperatures considerably lower than those recommended for tomatoes. The purpose was to determine temperatures needed to control ripening and to find out whether short periods at 40°F would adversely affect subsequent ripening. In addition, tomatoes were held at 32°F to insure the development of chilling injury. The color of each fruit was determined by visual inspection, and in some tests the color was also measured by a color and color-difference meter (CDM) of the Hunter type. Simulated transit temperatures of 55° and 50°F for four days provided better control of ripening than 60° for tomatoes whose surfaces were 30 to 50 percent colored at the start of the test. However, 60°F was superior to 55° and 50°F for tomatoes of 10 to 25 percent color that needed to ripen during transit. The rate of change in color during the four-day simulated transit period was directly related to holding temperature and stage of ripeness. The greatest change in color occurred in fruits with the greatest need to ripen. Pink fruit increased in color very little at 40°F, but if held only a few days, they later ripened satisfactorily at a favorable temperature such as 70°. Chilling injury was not evident in pink tomatoes held at 40° for six days. If

necessary, pink tomatoes can be shipped at temperatures as low as 40° for two to four days. However, that temperature is lower than is needed or is recommended. Fruits held at 32°F lacked intensity of red when ripened at 70°F and were less firm than fruits held at the higher temperatures. Fruits held at 32° for 10 to 14 days developed serious chilling injury, as indicated by the extent of alternaria rot (*Alternaria tenius* auct.) that developed on apparently wound-free areas when the fruits were shifted to 70°. Mature-green tomatoes were injured more by low temperature than pink fruits, as indicated by increased alternaria rot on mature-green tomatoes after a 14-day holding period at 32°F.

49. C.C. Mpelkas and E.M. Kenyon, 1972. **The Effect of Light Quality on the Ripening of Detached Tomato Fruit.** NLABS Tech Rpt 72–29–FL, (FL–134), 20 pp.

Abstract: A better knowledge of the factors affecting the rate and nature of ripening and its subsequent phase over ripening and spoilage of fresh fruits and vegetables could lead to control of this process. Such control could lead to substantial savings in the storage and distribution of such products in the Defense subsistence feeding system. Preliminary studies were conducted on the effect of light of various wavelengths and under a dark situation on detached tomato fruit, with humidity, temperature and CO_2 content of the atmosphere controlled. Color development, taste, firmness and chemical change (acid-base ratio) were used to study rates of ripening over an eight-day period. Light which emits strongly in the red and blue regions of the spectrum appears to result in acceleration of ripening as measured by taste panel, chemical analysis, and color development. Thus, these wavelengths appear to play a role in ripening rates and subsequent spoilage of tomatoes under controlled conditions of temperature, humidity, and carbon dioxide atmosphere.

50. C.J. Nicholas, 1976. **A Comparison of Transport Costs, Physical Performance, and Spoilege Factors for Intermodal Shipments of Iceberg Lettuce to European Markets.** USDA ARS–NE–77, 37 pp.

Abstract: Agricultural Research Service researchers at the request of and in cooperation with the Defense Supply Agency of the US Department of Defense conducted studies in 1970 and 1972 on the handling and transport problems for shipping iceberg lettuce to US Army commissaries in Europe. Representative transport costs were updated in 1976. The study identifies some of the problems and opportunities of air cargo and surface (van container) shipments. Cost comparisons are made between these two transport modes. Also, the cost effectiveness of air cargo transport is weighed. Physical performance factors showed that, because good iceberg lettuce can be shipped by surface (van container) transport to European markets in good condition and at a reasonable cost, air cargo transport is warranted only when an emergency resupply situation exists. Also, the use of the bonded-block pattern was adequate if it was combined with such improved practices as precooling of lettuce to desirable temperatures before loading, harvesting, and packaging in the field, and accurate scheduling to prevent delays and layovers at terminals and in transit. Current transport technology is adequate for surface transport of lettuce to European destinations in good condition and at a reasonable cost. Also, successful shipping of lettuce to European markets depends not only on the transport equipment but also on how the transport equipment is handled and to what use this equipment is put. The out turn of the experimental test shipments was excellent

when the following conditions were met: (1) The quality of the product was good at time of shipment, (2) the refrigeration unit operated properly, (3) the thermostat was accurately calibrated, (4) the shipment was loaded in a van container in a bonded-block pattern, and (5) the product was not roughly handled in loading and unloading. The cost differential of 10 cents a pound between air and surface transport and average spoilage losses of 5 to 6 percent by surface transport during a 6-month test period confirmed the cost effectiveness of containerized surface transport for the movement of lettuce to European markets. This proved that air transport was warranted only in emergencies. The intermodal transport of lettuce by van container is the best method for shipping U.S. produced lettuce to European markets in good condition and at a reasonable cost. Loading lettuce in van containers at the shipping point, moving them to the port of embarkation by the fastest transport mode at the lowest cost, and expediting the movement of these van containers from the overseas port to the receiver eliminate some major transport problems.

51. C.S. Parsons, 1959. **Extending the Storage Life of Cabbage, Celery, Lettuce, and Tomatoes Aboard a Navy Supply Ship.** USDA MRR 336, 15 pp.

Abstract: Tests were conducted aboard a US Navy supply ship to evaluate the effects of polyethylene liners, temperature, and trimming on the storage life of cabbage, celery, and lettuce. Also, the storage life of ripe and mature-green tomatoes held continuously at low temperatures was compared with that of tomatoes ripened at 58°F before being stored at low temperatures. Adoption of polyethylene liners for holding cabbage, lettuce, and celery would result in much higher quality and longer-storing commodities. Tomatoes, which are not carried as a replenishment item at the present time, would be available for replenishment purposes for periods up to six or seven weeks after sailing. After six weeks' storage at 36°F, 79 percent of the celery was edible in polyethylene-lined crates; only 71 percent remained edible in unlined crates. Of the trimmed lettuce stored in lined crates at 35°F, 81 percent remained edible after six weeks, while only 61 percent of that stored untrimmed and in unlined crates was edible. At the end of four weeks storage at 36°F, 79 percent of the cabbage in lined crates was still edible, compared with 70 percent in the unlined crates. The original color and crispness of cabbage were ratained longer in lined than in unlined crates at both 36°F and 38°F. When mature-green tomatoes were ripened for three weeks at 58°F, and stored for two weeks at 35°F, nearly 90 percent remained edible. 8ut, when firm-ripe tomatoes were stored continuously at 35°F for about the same time (34 days), only 10 percent were edible. Mature-green tomatoes stored at 35°F did not ripen at all. Celery stored in unlined crates at 36° and at a relative humidity of about 85 percent wilted badly during the six-week test period. Celery stored in lined crates, on the other hand, remained crisp and firm throughout the test. Lettuce stored in the regular ship's cargo crates at 35° was slightly to moderately wilted at all inspections. Weight losses in lettuce stored in lined crates never exceeded 1 percent and the heads remained crisp during the entire test. Trimmed lettuce stored in unlined crates wilted more severely than lettuce stored by any other method. Tomatoes that were ripened before being stowed aboard ship at 35°F kept well for approximately three weeks but deteriorated rapidly thereafter. The flavor and color of tomatoes ripened at 8eltsville or on board ship were very good and far superior to those in tomatoes carried in the ship's store stock.

52. C.S. Parsons and R.E. Anderson, 1970. **Controlled Atmosphere Storage of Tomatoes, Peaches and Nectarines.** 1970 Yearbook United Fresh Fruit and Vegetable Assoc., 175–182.

Abstract: The tests indicated that mature-green tomatoes can be held longer at 55°F in controlled atmospheres than in air. An atmosphere containing 3 percent O_2 and 97 percent nitrogen was judged best of several tested. Tomatoes held in this atmosphere remained firm and predominantly green for up to six weeks at 55°F. After removal to air at 65°F, these tomatoes ripened normally with acceptable flavor. Peaches and nectarines have a longer storage life at 32°F when stored in an atmosphere of 1 percent O_2 with 5 percent CO_2 than they would have in air. The maximum storage period in controlled atmospheres was six weeks for peaches and nine weeks for nectarines.

53. C.S. Parsons, R.E. Anderson and R.W. Penney, 1970. **Storage of Mature-Green Tomatoes in Controlled Atmospheres.** J. Am Soc Hort Sci, 95 (6), 791–794.

Abstract: Tomato fruits, initially mature-green and held at 55°F for six weeks kept significantly better in 3 percent O_2 and zero CO_2, than in air. Three or 5 percent CO_2 combined with the low O_2 atmosphere did not materially affect the amount of decay, and sometimes resulted in CO_2 injury. Mature-green tomatoes ripened to a full red when held in air for six weeks at 55°F. When stored in an atmosphere containing 3 percent O_2, tomatoes ripened to pink. Red color development was further retarded in a low-O_2 atmosphere supplemented with 3 or 5 percent CO_2. Exposing mature-green tomatoes to air for 16 hours midway in a 6-week holding period in low-O_2 did not affect the decay or color of the fruits while in storage as compared to a continuous holding in low-O_2. After ripening, however, the tomatoes from the interrupted treatment did not keep as well as those from the continuous treatment. Mature-green tomatoes stored at CO_2 levels of 3 or 5 percent tended to be more acid after ripening than tomatoes held in CO_2 free atmospheres.

54. C.S. Parsons, J.E. Gates and D.H. Spalding, 1964. **Quality of Some Fruits and Vegetables After Holding in Nitrogen Atmospheres.** Am Soc Hort Sci 84, 551–556.

Abstract: Small lots of fruits and vegetables were stored in atmospheres of 100 percent N_2 plus 1 percent O_2, and in air. Samples from each lot were removed after various periods and evaluated for flavor, appearance, and keeping quality. Flavor and keeping quality of lettuce were not affected when heads were held ten days in 100 or 99 percent N_2 atmospheres at 33°F. Russet spotting and butt discoloration were reduced in the N_2 atmospheres. Ripening of green bananas and tomatoes was retarded in N_2 atmospheres at 60°F. After removal to air, fruit previously held in 99 percent N_2 was often damaged and did not ripen fully. Flavor of bananas and tomatoes was not affected by holding four days in 100 percent N_2 or up to ten days in 99 percent N_2. Strawberries held ten days at 33°F kept as well in atmospheres of 99 and 100 percent N_2 as air, and mold growth was reduced. Off-flavor developed in peaches held in 100 percent N_2 at 60°F for four days or longer, but not in peaches held in 99 percent N_2. Decay of peaches stored in N_2 atmospheres was retarded.

55. C.S. Parsons, L.P. McColloch and R.C. Wright, 1960. **Cabbage, Celery, Lettuce, and Tomatoes – Laboratory Tests of Storage Methods.** USDA MRR 402, 30 pp.

Abstract: Cabbage, celery, and lettuce, packaged in various ways, were stored at 32°, 38°, and 45°F to determine the optimum method of handling each vegetable to assure its maximum storage life. Tomatoes, ripened and unripened, were stored at various temperatures to determine the best method of maintaining quality and lengthening their storage life. Results were about the same when the vegetables were stored in sealed, unperforated plastic crate liners or individual bags, and when they were stored in unsealed, perforated liners and bags. Because of this and because produce is sometimes damaged by major changes of the atmosphere that may occur in sealed, unperforated containers, it is suggested that only perforated or unsealed liners and bags be used for storing cabbage, celery, lettuce, or similar produce. Cabbage kept about equally well at 32° or 38°F for periods up to six weeks but kept slightly better at 32°F for longer periods. It deteriorated most rapidly at 45°F where its condition was only fair after four weeks' storage. Weight loss of cabbage stored in unlined crates increased with the length of the storage period, and ranged from 5.0 percent of the original weight after three or four weeks at 32°F to 3.7 percent after seven or eight weeks at 45°. This loss, principally by evaporation of moisture, was manifested by a moderate to severe wilting of the cabbage. The use of perforated or unperforated polyethylene crate liners reduced weight loss of stored cabbage during the same periods to less than 1 percent. Cabbage losses due to discoloration, decay, and breakage were usually less than 1 percent, and usually less in polyethelene-lined than in unlined crates. Green color in fresh cabbage was retained for longer periods in polyethylene-lined than in unlined crates. Celery kept considerably longer at 32°F than at 38° or 45°. When stored in unlined crates, celery wilted badly at all temperatures. When stored in polyethylene-lined crates or in individual polyethylene bags, no wilting was observed. Also, losses due to discoloration, decay, and broken leafstalks were usually less in celery packaged and stored in individual polyethylene bags than in celery stored in unlined crates. Lettuce retained good quality for considerably longer periods at 32°F than at 38° or 45°. It kept as well for four weeks at 32° as it did for only two weeks at 38° or 45°. Similarly, it was still as good after six weeks at 32° as after only two weeks at 45°F. Weight losses up to 11 percent of the original weight occurred in lettuce stored in unlined crates. Losses in polyethylene-lined crates, in contrast, never exceeded 1 percent. Individual parchment wraps reduced weight loss in stored lettuce, but not as effectively as a packaging in polyethylene bags. More lettuce remained edible in polyethylene-lined than in unlined crates during storage, due principally to the reduction of weight loss. Removing wrapper leaves from lettuce before storage proved to be the most practical method for holding the greatest amount of edible lettuce per unit weight and space. Mature-green tomatoes stored directly at 38°F failed to ripen properly, became injured by low temperature, and developed extensive alternaria rot. Mature-green tomatoes ripened slowly at 48°F and developed less decay than tomatoes showing some color when stored for the same period of time. All of the sound fruits were edible, but none ripened sufficiently at 48° to be good quality. Tomatoes ripened at 55° or 65°F kept better at 32°F than at 38°F, but the slow ripening at 55°F followed by storage at 32° and 38°F favored extensive decay. Tomatoes ripened at 65°F and stored at 32° and 38°F kept satisfactorily for about three weeks. The most successful method for extending the storage life of tomatoes was to ripen mature-green fruits at a moderate rate at 58°F, and then store them at 32°F to 35°F.

56. C.S. Parsons and J.K. Stewart, 1960. **Effects of Trimming and Packaging Methods on Keeping Quality of Lettuce.** USDA AMS–376, 12 pp.

Abstract: Western lettuce, trimmed and packaged by various methods immediately after harvest, was shipped east by rail in regular Navy shipments, then stored at 33° and 38°F, to determine the effectiveness of different methods of trimming and packaging in prolonging storage life. Unwrapped and parchment-wrapped lettuce cooled somewhat faster by the vacuum process than lettuce in polyethylene-lined crates or in individual polyethylene bags. The average transit temperatures also were slightly lower in the unwrapped and parchment-wrapped heads. Arrival temperatures, however, were approximately the same in all packages after a nine- or ten-day transit period. Lettuce in polyethylene-lined crates and in individual polyethylene bags lost far less weight and remained much more crips during transit and storage than unwrapped or parchment-wrapped lettuce, which was badly wilted after only three weeks in storage. Weight losses in all packages were generally greater at 33° than 38°F, particularly after five and seven-week storage periods. The smallest trimming losses at every inspection and at both storage temperatures occurred in polyethylene-bagged lettuce. The greatest losses occurred in unlined crates containing commercially trimmed heads. The amount of trimming before packaging directly influenced the amount of trimming subsequently required. The data obtained at 38°F, for example, show that commercially trimmed heads, with seven or more wrapper leaves, required about 5 percent more trimming after storage than regularly trimmed heads which had only five or six wrapper leaves. Specially trimmed heads, with only three or four wrapper leaves, required the least trimming after storage. Lettuce decayed much more rapidly at 38°F than at 33°F and more rapidly in polyethylene-lined and unlined crates than in individual polyethylene bags. At almost every inspection, more lettuce remained edible in polyethylene bags than in any other package. The least amount of edible lettuce was found in unlined crates of commercially trimmed heads. About equal amounts remained edible in unlined crates of parchment-wrapped heads and in polyethylene-lined crates of unwrapped heads. The average amount of edible lettuce in all packages was greater after seven weeks at 33°F than after five weeks at 38°F. An average of three pounds more lettuce per crate remained edible after three to seven weeks' storage at 33°F when the heads were specially trimmed and packed in individual polyethylene bags than when they were packed by the conventional Navy method (heads regularly trimmed and parchment-wrapped). Russet spotting, a serious physiological disease of lettuce, was much more severe in lettuce stored at 38°F than in lettuce stored at 33°F. It was also much more severe in test 4, initiated in December, January, and March. Trimming the lettuce before packaging markedly reducted the weight and shipping space required. Crates of commercially trimmed heads averaged 48 pounds when shipped; crates of regularly trimmed heads with five or six wrapper leaves averaged 45.5 pounds; and crates of specially trimmed heads with three or four wrapper leaves averaged only 40 pounds.

57. A.R. Rahman, G. Schafer, T.J. DiNicola and D.E. Westcott, 1972. **Shelf Life of Tomatoes as Affected by a Post Harvest Treatment and Storage Conditions.** NLABS Tech Rpt, 72–74–FL (FL–165), 19 pp.

Abstract: Laboratory tests were conducted to determine the effect of treating tomatoes with an aqueous solution of chlorine dioxide as well as storage under a low oxygen (4 to 5 percent) controlled atmosphere system on their overall quality and shelf life. Tomatoes treated with chlorine dioxide and then stored under low oxygen at 50° to 55°F exhibited

the highest edible yield at the end of six weeks storage. Color and flavor of tomatoes stored under low oxygen regardless of the chlorine dioxide treatment at 50° to 55°F as evaluated by a technological panel were significantly preferred to those stored under normal atmosphere at similar temperatures. Time of storage was the only factor affecting the texture of tomatoes.

58. A.R. Rahman, G. Schafer, G.R. Taylor and D.E. Westcott, 1970. **Storage Life of Lettuce as Affected by Controlled Atmosphere System.** NLABS Tech Rpt 70–48–FL (FL–106), 20 pp.

Abstract: The effect of Oxytrol controlled atmosphere system on the shelf life of lettuce was evaluated. Lettuce stored under Oxytrol at oxygen levels ranging from 3 to 5.8 percent and temperatures from 34° to 36°F for two to seven weeks gave significantly higher mean scores for overall quality than lettuce stored under normal atmosphere at similar temperatures.

59. A.R. Rahman and D.E. Westcott, 1970. **Quality of Lettuce as Affected by Refrigeration and Controlled Atmosphere Systems During Transportation.** NLABS Tech Rpt 71–10–FL (FL–114), 19 pp.

Abstract: A shipping test from Oakland, California to Japan was conducted to determine the effect of a low oxygen controlled atmosphere system (Oxytrol) as well as a new refrigeration system (Cooltainer) on the shelf life of lettuce shipped to military organizations overseas. The Oxytrol system is a complete, self-contained atmosphere control system designed to be used as an adjunct to normal refrigeration equipment in conventional transport vehicles.

Results indicated that lettuce shipped under the low oxygen controlled atmosphere system (oxygen level ranged from 2.2 to 4 percent) gave significantly higher edible yields than lettuce shipped in conventional or Cooltainer vans regardless of the packaging (wrapping vs no wrapping and packing (wire-bound wooden boxes vs cardboard wax impregnated boxes).

All wrapped lettuce exhibited significantly higher edible yields than unwrapped lettuce regardless of packing and shipping vans. However, no significant difference was shown between lettuce packed in wirebound wooden boxes and that packed in cardboard wax impregnated boxes regardless of the shipping vans. The ambient temperature in the vans as indicated by the Ryan recorders as well as the heart (compact portion) temperature of the lettuce as indicated by thermocouples fluctuated widely. Although the controls in all vans except Cooltainer were set at 34°F, temperatures as high as 45°F were recorded. Chill damage to the lettuce occurred in the Cooltainer van in which temperatures as low as 29°F to 31°F were recorded for several thermocouples upon arrival to Japan. It was concluded that shipping lettuce in controlled atmosphere vans under the conditions presented in this field test was advantageous. However, further shipping tests to various overseas destinations are recommended in order to obtain sufficient factual data on the effect of various atmosphere systems and refrigeration systems on the quality of lettuce and other fresh produce.

60. R.E. Rij, R.R. Hinds and T. Hinsch, 1976. **Current Practices and Trends in Marketing Western Iceberg Lettuce in Relation to Other Produce.** USDA MRR 1052, 9 pp.

Summary: Western iceberg lettuce shipments account for approximately 20 percent of all carlots of fresh fruits and vegetables shipped from California. The purpose of this study

was to provide information on current practices, trends, and problems encountered during the handling and marketing of lettuce and to determine changes other commodity groups were making. Receivers expressed a desire for some type of control over the minimum and maximum weights of carton lettuce when marketed. The biggest problems with lettuce as identified by receivers are variation of maturity within a lot, crushing of cartons shipped by rail and truck, and rusty-brown discoloration. Receivers and wholesalers had the following percentage responses to various problems with lettuce; quality, 49 percent; packaging, 20 percent; crushing and bruising, 20 percent; maturity, 10 percent. The recommendation was made that any new system developed for the marketing of lettuce should increase efficiency, maintain high quality and help stabilize the costs of marketing Western iceberg lettuce.

61. P. Rood, 1956. **Relation of Ethylene and Post-Harvest Temperature on Brown Spot of Lettuce.** Proc Am Soc Hort Sci **68**, 296–302.

Summary: Brown spot on the leaf blades and on both sides of the midribs of lettuce were reported as being caused by ethylene. Little injury occurred at 32°F. However, if the storage temperature following harvest was about 44°F this injury was found to be most severe.

62. D.K. Salunkhe, B. Singh, C.C. Yang and D.J. Wang, 1971. **Controlled Atmosphere Storage of Lettuce.** NLABS Tech Rpt 72–18–FL (FL–143), 43 pp.

Abstract: Studies were conducted on the effect of controlled atmosphere storage as well as chemical pretreatments on the quality of lettuce as well as biochemical composition of lettuce leaves, *Lactuca sativa* L., cultivar "Great Lakes." In a CA of 2.5 percent CO_2 and 2.5 percent O_2, the lettuce heads could be stored up to 75 days. Pre-storage treatments with microbe- and senescence-inhibiting chemicals (Captan, Phaltan, Mycostatin and N^6-benzyladenine) had detrimental effects on the control atmosphere storage of lettuce at 35°F. CA significantly inhibited the degradation of chlorophyll throughout the storage period. There was no significant effect of CA or other treatments on total sugars, reducing sugars, starch, total N, pH, organic acids, amino acids or total carotenes. The soluble proteins and the reducing sugars were lower in the CA lettuce than in the control lettuce. The lettuce treated with Plantan or Phaltan in combination with polyethylene packaging had higher amounts of soluble proteins and lower amounts of chlorophylls.

63. B. Singh, D.J. Wang, D.K. Salunkhe and A.R. Rahman, 1972. **Controlled Atmosphere Storage of Lettuce. 2. Effects on Biochemical Composition of the Leaves.** J Food Sci **37**, 52–55.

Summary: The biochemical changes occurring in the leaves of lettuce during storage under controlled Atmosphere (CA) (2.5 percent carbon dioxide and 2.5 percent oxygen) alone and in combination with Phaltan(R) treatment and polyethylene packaging were studied. Chlorophy retention was significantly higher in lettuce under CA and CA combined with packaging, but was lower in lettuce treated with Phaltan. Titratable acidity, starch and total sugars were found to be higher in lettuce under CA. Changes in total protein were not significant under CA, but soluble proteins increased.

64. B. Singh, C.C. Yang, D.K. Salunkhe and A.R. Rahman, 1972. **Controlled Atmosphere Storage of Lettuce. 1. Effects on Quality and the Respiration Rate of Lettuce Heads.** J Food Sci 37, 48–51.

Summary: Effects on the quality and respiration rate of lettuce with different combinations of carbon diozide and oxygen, temperature, microbe inhibiting and senescence inhibiting chemicals in combination with controlled atmosphere (CA) and colyethylene packaging are reported. Temperature is of primary importance in maintaining quality of lettuce. Generally, CA storage of lettuce resulted in sweeter and more salable lettuce at the end of 45, 60, and 75 days than normal refrigerated storage at 35°F. Lettuce treated with Phaltan alone or in combination with polyethylene packing before storage in CA had a higher rate of respiration and poorer quality than the CA or normally refrigerated lettuce.

65. D.H. Spalding, 1968. **Effects of Ozone Atmospheres on Spoilage of Fruits and Vegetables After Harvest.** USDA MRR 801, 9 pp.

Abstract: Effectiveness of ozone for reducing post-harvest decay of fruits and vegetables was tested at 0.5 p.p.m. ozone and 90 percent relative humidity. Ozone did not reduce rhizopus and brown rot of peaches or rhizopus and botrytis rot of strawberries stored for one week at 35°F. Ozone treatment during storage had no influence after storage on the shelf life of peaches held in air for four days at 70°F. Size of fungal nests was somewhat reduced in peaches and strawberries held in ozone at 60°F, but nesting can be more effectively controlled by low temperature storage. Present results confirmed previously reported data showing that 0.5 p.p.m. ozone did not injure peaches but it damaged the caps of strawberries and caused the caps to dry and shrivel. Ozone did not reduce rot in blueberries held in ozone at 35°F for two days followed by four days in air at 70°F. Blueberries held in ozone for six days at 60°F had essentially the same amount of rot as fruit held in air under otherwise identical conditions. Cantaloupes developed the same amount of rot regardless of the present or absence of ozone when held for seven days at 45°F followed by five days at 60°F. Ozone inhibited surface mold growth without reducing gray-mold rot on Thompson seedless and Tokay grapes held for six or seven days at 60°F. The amount of alternaria rot developing in green beans held in ozone for seven days at 45°F and in air for five days at 60°F did not differ significantly from that in untreated beans. Ozone injured exposed layers of beans during storage at 45°F.

66. J.K. Stewart, 1976. **Spaced Load Patterns for Improved Temperature Control in Export Shipments of Lettuce.** USDA MRR 1051, 9 pp.

Abstract: Test shipments of lettuce to overseas markets were made to compare the modified bonded block (MBB) and the pigeonhole (PH) load patterns. Solid loads were not tested in the overseas shipments because they proved unsatisfactory for even the short transit period from harvest area to the port, as indicated by excessive temperatures within parts of the loads. Both spaced load patterns provided equally good air circulation in refrigerated van containers as indicated by uniform temperatures throughout the loads. Load shifting or crushing of the bottom layer cartoons did not differ in the two types of load. Quality of the lettuce at destination also was the same from both load patterns. Thus, the choice of which loading patterns to use can be based on the dimensions of the van and the package because one of the loading patterns might fit into a specific van better than the other. Further, some loading

crews object to the MBB pattern, and, in some instances, charge a premium for using it. Thus, labor or economics, or both, may be an important consideration in the choice of load pattern. A spaced load pattern, rather than a solid load pattern, should be used in truck trailer loads of lettuce during the inland trip to the port because high temperatures often develop in the solid loads. A solid load pattern for the inland trip may be acceptable if it is only for about one day, but additional research is needed in this area.

67. J.K. Stewart, 1976. **Transit Temperatures and Quality of Fresh Vegetables Shipped in an Experimental and a Commercial Van Container to the Far East.** USDA MRR 1054, 7 pp.

Abstract: Transit temperatures and arrival condition of mixed vegetables (cabbage, carrots, celery, and lettuce) were determined in produce shipped in a US Dept of Agriculture (USDA) experimental van container and a commercial refrigerated van container from San Francisco, CA, to Pusan, South Korea. The test was made in cooperation with the US Dept of Defense. The USDA experimental van, tightly stacked with packages of produce in a solid load pattern, provided commodity temperatures comparable to those in a commercial refrigerated van that had a spaced load with air channels for air circulation around the packages. Solid load patterns are faster and easier to load than spaced load patterns and allow more packages to be placed in a van container. Solid loads, however, can only be used in vans with refrigeration and air distribution systems designed to force refrigerated air through the package. Otherwise, excessive temperatures would occur within the load, accompanied by deterioration of product. Quality of the cabbage, carrots, and celery shipped in the two vans was good at destination, but lettuce suffered losses from decay in both vans.

68. J.K. Steward and M.J. Ceponis, 1968. **Effects of Transit Temperatures and Modified Atmospheres on Market Quality of Lettuce Shipped in Nitrogen-Refrigerated and Mechanically Refrigerated Trailers.** USDA MRR 832, 9 pp.

Abstract: Transit temperatures and market quality of Western lettuce were studied in test shipments made from California to east coast markets in piggyback trailers in which liquid nitrogen was used both to refrigerate the load and to modify the atmosphere and in trailers with conventional mechanical refrigeration systems and normal atmospheres. Average transit temperatures were 36°F in the nitrogen(N) trailers and 39°F in the conventional (MR) trailers. Average temperature variation within the loads was about 2° to 3°F in both types of trailers. The N trailers had some freezing of lettuce in certain parts of the load, and the MR trailers had some refrigeration equipment failures. The N trailers provided reduced, but not controlled oxygen (O_2) atmospheres during transit. The O_2 concentration in N trailers in which O_2 recorders were installed averaged 3.3 and 3.8 percent. Market quality of lettuce from both types of trailers was generally satisfactory at destination, but discoloration was slightly less severe at time of arrival in lettuce shipped in the N trailers than in the MR trailers. This slight difference disappeared after a four-day holding period at 50°F. Decay also was less prevalent in lettuce from the N than from the MR trailers. These differences in market quality were probably due to the lower transit temperatures in the N trailers rather than the modified atmosphere. The low O_2 atmosphere in the N trailers significantly reduced russet spotting in the one test in which this disorder occurred to an appreciable extent.

69. J.K. Stewart and M.J. Ceponis, 1970. **Modified Atmosphere Effects on the Market Quality of Lettuce Shipped by Rail.** USDA MRR 863, 9 pp.

Abstract: Test shipments of head lettuce were sent in 12 paired railcars or paired trailers on flatcars from California and Arizona to East Coast markets during 1967 and 1968. The purpose of the tests was to compare the market quality of lettuce held in modified atmospheres (MA) and in normal atmospheres (NA) during transit. The cars and trailers in which the atmospheres had been modified had low oxygen and above normal carbon monoxide concentrations during transit. This modified atmosphere was established after loading by purging the car or trailer with nitrogen to lower the oxygen level and by adding carbon monoxide afterwards. Bags of lime were placed in the load compartments to absorb carbon dioxide produced by respiration of the lettuce. No attempt was made to modify the atmosphere in the normal-atmosphere cars and trailers. All cars and trailers had conventional mechanical refrigeration equipment and all lettuce was vacuum-precooled before loading. Transit temperatures averaged 37°F in both the MA and NA vehicles. Temperature differences between the warmest and coolest locations in the vehicles averaged 3°F. At shipping point, the oxygen concentrations in the MA and NA vehicles averaged 6.9 and 18.3 percent, respectively. The only quality factor significantly affected by the two different atmospheres in this study was pink rib. The incidence of pink rib was significantly lower (5 percent probability level) in lettuce shipped in the MA vehicles than in lettuce shipped in the NA vehicles. However, pink rib data were limited to two tests only. Russet spotting was not prevalent enough in these tests to justify statistical analyses. However, previous laboratory and shipping tests with low-oxygen atmospheres have shown that modified atmospheres similar to those studied were effective in reducing russet spotting of lettuce predisposed to this disorder. External appearance, butt discoloration, decay, and tipburn were not significantly influenced by the atmosphere in transit. A disorder of lettuce not reported previously in commercial shipments was observed in lettuce from both the MA and the NA vehicles. We have named the disorder "brown stain". Pictures and a description of this disorder are included. It was associated with carbon dioxide concentrations above about 2 percent.

70. J.K. Steward, M.J. Ceponis and B.A. Billeter, 1973. **Ventilation of Mechanical Refrigerator Cars to Prevent Carbon Dioxide Accumulation and Brown Stain in Lettuce Loads.** USDA MRR 978, 12 pp.

Abstract: Lettuce was shipped from California to the east coast in mechanically refrigerated railcars with various venting systems to prevent the accumulation of injurious concentrations of respiratory carbon dioxide (CO_2). Lettuce shipped in cars with modified atmospheres also was studied. Propping open one of the two water drains at each end of the car prevented the accumulation of dangerous levels of CO_2; many cars with drains in the normal closed position accumulated excessive CO_2 (3.0 to 4.5 percent at destination). CO_2 levels in the modified atmosphere cars ranged from 0.6 to 2.2 percent at destination. Transit temperatures of the lettuce were in a satisfactory range in all test cars. Incidence of brown stain was insignificant in the cars with drains open, but the disorder affected about 40 percent of the lettuce in the control cars with drains closed and about 32 percent of the heads in the mofidied atmosphere cars. Decay, butt discoloration, tipburn, and rib discoloration were not affected by the car atmosphere, nor was the overall, external appearance of the lettuce, with or without wrapper leaves.

71. J.K. Stewart, M.J. Ceponis and W.R. Wright, 1972. **Carbon Dioxide Levels in Railcars and Their Effect on Lettuce.** USDA MRR 937, 11 pp.

Abstract: Carbon dioxide (CO_2) and oxygen (O_2) concentrations were determined during transit in ten test cars of lettuce shipped from Salinas, CA, to eastern markets. Market quality of test packages of lettuce from these cars was evaluated at destination. Eight of the cars were conventional, mechanically refrigerated cars in which no effort was made to modify the atmospheres. Any modification that did occur was due to the respiration of the lettuce and the tightness of the cars. Atmospheres in two of the cars were modified at shipping point by the Transfresh Corporation to provide low O_2 levels and high carbon monoxide (CO) levels. Average CO_2 levels during transit ranged from a low of 0.4 percent in one conventional car to 3.9 percent in another. Three of the eight conventional cars had average CO_2 levels of 2.7, 3.6, and 3.9 percent, respectively. There was a highly significant positive correlation between the average percentage of CO_2 in conventional cars during transit and the occurrence of brown stain in lettuce from those cars. Carbon dioxide averaged 1.5 percent in each Transfresh-treated car. Incidence of brown stain was significantly higher, at a given level of CO_2, in the Transfresh cars than in the conventional cars. Calmar, the principal lettuce cultivar grown in the Salinas Valley, developed more brown stain than R–200. However, since the two cultivars were not from the same field, and differed in maturity, the difference in brown stain could have been due to environmental rather than genetic factors. In the conventional cars, the CO_2 level during transit did not affect russet spotting, decay, pink rib, tipburn, butt discoloration, or general external appearance of the heads. In the Transfresh cars, russet spotting was reduced and brown stain was increased, but the effects of the controlled atmosphere on the other quality factors were not consistent in the two cars.

72. J.K. Stewart and J.M. Harvey, 1971. **Carbon Dioxide Levels in Rail Cars – There Effect on Lettuce.** Western Grower and Shipper 42, 5–6.

Summary: Lettuce was shipped from California to New York in rail cars. Gas samples from the cars were periodically examined. Carbon dioxide concentrations in conventional cars ranged from 0.4 to 6.6 percent. 8rown stain on lettuce was found at levels of carbon dioxide as low as 1 percent, and its incidence increased with increasing amounts of carbon dioxide. The test and related laboratory studies showed that different lots of lettuce varied in susceptibility to carbon dioxide injury. Lettuce from the central coastal area of California was particularly susceptible to carbon dioxide injury.

73. J.K. Stewart and M. Uota, 1971. **Carbon Dioxide Injury and Markat Quality of Lettuce Hald in Controlled Atmospheres.** J Am Soc Hort Sci 96 (1), 27–31.

Abstract: Storage atmospheres with 2–1/2, 5 or 10 percent CO_2 caused a physiological injury to lettuce almost identical to the brown stain observed in lettuce from rail cars and trailers in which CO_2 concentrations exceeded 2 percent at destination. Carbon dioxide injury, or brown stain, was not always evident when lettuce was removed from the controlled atmosphere after seven days at 38°F, but became more evident during a subsequent four days at 50°F in air. About 16 percent of the heads held at 2–1/2 percent CO_2 developed brown stain while 38 and 86 percent of the heads developed the disorder in lots held at 5 and 10 percent CO_2 respectively. Significantly, more heads developed brown stain when the CO_2 was

combined with 3 percent oxygen than when combined with 21 percent O_2. Decay, pink rib, and tipburn were not significantly influenced by the O_2 or CO_2 level. Increased levels of CO_2 reduced the severity of butt discoloration in lettuce examined immediately after storage in the controlled atmosphere, but after an additional four days at 50°F in air, the differences were not evident. The danger of physiological injury from 2–1/2 to 10 percent CO_2 during storage or shipping outweighs the small improvement in butt color and general appearance.

74. J.K. Stewart and M. Uota, 1976. **Post-Harvest Effect of Modified Levels of Carbon Monoxide, Carbon Dioxide and Oxygen on Disorders and Appearance of Head Lettuce.** J Am Soc Hort Sci **101** (4), 382–384, 3 pp.

Abstract: Lettuce (*Lactuca sativa* L.) held in an atmosphere of 3 percent O_2 plus 1.5 percent CO for seven days at 3.3°C had a better appearance before and after the wrapper leaves were removed than lettuce held in atmospheres with various other combinations of CO, CO_2, and O_2. Butt discoloration and pink rib also were inhibited by this atmosphere. These effects were no longer apparent after an additional four-day holding period in air at 10 percent. Rusty brown discoloration was not affected by any of the atmospheres tested during the initial seven days, but after four additional days in air, the incidence of objectionable rusty brown discoloration was higher in lettuce previously held in atmospheres with CO_2 than in those without CO_2.

75. J.K. Stewart and M. Uota, 1972. **Carbon Dioxide Injury to Lettuce as Influenced by Carbon Monoxide and Oxygen Levels.** J Am Soc Hort Sci **7** (2), 189–190.

Abstract: Added carbon monoxide or low-oxygen (3 percent) increased the susceptibility of head lettuce (*Latuca sativa* L., "Great Lakes" type) to carbon dioxide injury (brown stain). The combination of low oxygen, added carbon monoxide and high carbon dioxide,(2–1/2 to 10 percent) was particularly damaging.

76. A.W. Wells, 1962. **Effects of Storage Temperature and Humidity on Loss of Weight by Fruit.** USDA MRR 539, 15 pp.

Abstract: The rates of weight loss of several kinds of fruit, stored at various temperatures and humidities, were measured in laboratory tests. At a constant temperature and for limited periods, the rate of weight loss increased about 50 percent for each 100 percent increase in vapor pressure deficit. The rate of weight loss increased or decreased with an increase or decrease in temperature, even though the vapor pressure deficit remained constant. A straight line relationship exists between weight loss and vapor pressure deficit, at a given temperature, when plotted in actual units on simple chart paper. The loss of weight varied inversely with the size of the fruit. Softening of oranges, as measured by compression, varied with the quantity of weight lost.

77. J.M. Wells, 1968. **Growth of *Rhizopus Stolonifer* in Low-Oxygen Atmosphere and Production of Pectic and Cellulolytic Enzymes.** Phytopathol 58, 1958–1602.

Abstract: Decay development on strawberries inoculated with *Rhizopus stolonifer* and then held in atmospheres of 21, 1, 0.5 and 0 percent oxygen at 15°C decreased linearly with

decreasing O_2 concentration. Decayed areas on strawberries in 1 percent O_2 averaged one-half the size of those on strawberries in air, and least decay development occurred in 0 percent O_2. Polygalacturonase (PG), pectin methylesterase (PME), and cellulase (Cx) activities in crude extracts were directly related to decay development in each atmosphere. In vitro effects of low O_2 on linear-phase growth of *R. stolonifer* at 18°C depended on the substrate. On potato-glucose medium, growth in 2 percent O_2 averaged 14 percent of that in air and decreased linearly with decreasing O_2 concentration. On potato- pectin medium, growth in 2 percent O_2 averaged 22 percent of that in air, and no growth occurred in 0.25 or 0 percent O_2. PG, PME, and Cx activities in potato-pectin culture filtrates were directly related to growth, with highest activities in normally aerated cultures. In potato-glucose cultures, PG activity was higher in cultures held for 24 hours in low-oxygen atmospheres following 48 hours of growth in normal atmosphere than in cultures continually exposed to normal atmosphere. This was due to the rapid disappearance, or repression, of PG activity in late linear phase growth. Low O_2 atmospheres, in inhibiting further growth, also interfered with PG repression.

78. J.M. Wells and M. Vota, 1970. **Germination and Growth of Five Fungi in Low-Oxygen and High Carbon-Dioxide Atmospheres.** Phytopathol 60 (1), 50–53.

Abstract: Mycelial growth of *Alternaria tenuis, Fusarium roseum, Botrytis cinerea, Cladosporium herbarum,* and *Rhizopus stolonifer* on a liquid glucose-salt medium at 19°F in atmospheres of 21, 4, 2, 1, 1/2, 1/4, and 0 percent oxygen decreased linearly with decreasing O_2 concentrations below 4 percent. Mean percents growth of the respective organisms at 4 percent oxygen, as compared to growth in air, were 31, 38, 45, 50, and 85 percent; at O_2 percent oxygen, only *R. stolonifer* grew significantly. Growth of *A. tenuis, B. cinerea, R. stolonifer*, and *C. herbarum* in atmospheres of 10, 20, 30, and 45 percent CO_2 plus 21 percent O_2 decreased linearly with increasing CO_2 concentrations, and was inhibited about 50 percent in an atmosphere of 20 percent CO_2. Growth of *F. roseum*, however, was stimulated at 10 percent CO_2 and inhibited 50 percent at 45 percent CO_2. When the O_2 concentratation was 2 percent and thereby limiting to growth, CO_2 at the lower levels tested stimulated growth of all the fungi except *R. stolonifer*. Low oxygen atmospheres inhibited germination of all fungi tested. Responses to high CO_2 atmospheres, however, varied. At 16 percent CO_2, the germination of *R. stolonifer, B. cinerea*, and *C. herbarum* was inhibited 90 percent. *A. tenuis* was inhibited only at CO_2 levels higher than 32 percent, and *F. roseum* was stimulated by concentrations of CO_2 as high as 16 percent. When the oxygen concentration was 1 percent and thereby limiting, CO_2 at the lower levels tested stimulated the the germination of all fungi except *A. tenuis*.

79. W.R. Wright, 1975. **Marketing Losses of Selected Fruits and Vegetables at Wholesale, Retail and Consumer Levels in the Chicago Area.** USDA MRR 1017, 21 pp.

Abstract: The market loss incurred on six major produce items in the metropolitan Chicago area was compiled from July 1966 through November 1969. These data are still valid to show the wholesale (W), retail (R), and consumer (C) losses involved. Wholesale losses were determined by a simulated retail cull of weekly unit samples obtained from a chainstore distributing center and from an independent street broker. Retail losses were gathered from the in-store cull operations of four stores, two of which were affiliated with the chain distributor

and two serviced by the independent wholesale source. Consumer wastes were obtained by simulated consumer tests on produce obtained from the retail displays of the cooperating stores. Wholesale and retail losses were based upon visible defects and unit discard of the affected item. Consumer examination entailed salvage of edible portions, with waste constituting anything over and beyond normal paring for table preparation. Summary results express the percentage of loss on a waste-weight basis per product by market level for the survey and the relative percentage of contribution of the dominant loss category to its respective market level. The categories consisted of the parasitic loss from fungi, bacteria, and yeasts; nonparasitic losses were physiological and insect loss damage, as well as miscellaneous defects such as freezing, and chemical-induced damage; the physical injury category included mechanical injury and bruising. Summary data are presented in the order of wholesale, retail, and consumer marketing levels, unless noted. Northwest Red Delicious apples had a percentage loss of 2.9(W), 2.9(R), and 2.4(C). Physical injury, largely bruising, led all marketing levels, contributing 78, 88, and 49 percent, respectively. California head lettuce percentage losses were 5.7(W), 1.7(R), and 13.9(C). Physical injury was dominant in a flavorable temperature. Chilling storage did not slow up or prevent ripening in fully mature green tomatoes so noticeably as in less mature ones. When stored at 50°F, tomatoes in the turning stage or beginning to show color when picked usually ripened almost normally. At 40°F storage usually no ripening developed in tomatoes of any stage of immaturity. The lowest temperature at which fall ripening with good color and flavor developed was 55°F. At this temperature the rate of ripening was comparatively slow, but the development of normal decay was also slow. No indications of abnormal decay or breakdown were apparent. This temperature is recommended for either storage or delayed-ripening purposes. At 60° to 70°F the rate of ripening was considerably increased. These temperatures are recommended for ripening, but not for storage. For rapid ripening a temperature much higher than 70°F is not desirable because of the rapid rate of decay. Firm, fully ripe tomatoes held up most satisfactorily at 55°F storage. Ripe tomatoes may be expected to keep in good condition at temperatures as low as 32°F for eight to ten days, but when removed to a higher temperature, as would be necessary in getting commercial lots to the consumer, they soon break down. Tests on a commercial lot of mature green tomatoes shipped from Florida and stored and ripened under conditions similar to those for the tomatoes grown at the Arlington Experiment Farm showed similar results. Mature green tomatoes picked the evening before the first field frost ripened in storage more rapidly and developed less decay than those picked the morning following the frost.

80. R.C. Wright, W.T. Pentzer and D.H. Ross, 1931. **Effect of Various Temperatures on the Storage and Ripening of Tomatoes.** USDA Tech Bull 268, 35 pp.

Abstract: Exposure of mature green tomatoes at temperatures of 40°F or below did not necessarily prevent subsequent ripening. Tomatoes ripened normally when exposed for 18 to 21 hours to temperatures as low as 25°F, which is almost 5.5°F below their average freezing point, if subsequently stored at a favorable temperature. When stored at 32°F and 36°F for periods up to five to eight days, tomatoes later ripened to practically normal color and flavor, but the rate of ripening was slower than fruits not so exposed. The ripening of tomatoes stored at 40°F for 11 to 15 days was delayed, but took place normally. If stored at 50°F for less than 14 to 18 days, the tomatoes ripened normally when placed in a favorable temperature. Chilling storage did not slow up or prevent ripening in fully mature green tomatoes

as noticeably as in less mature ones. When stored at 50°F, tomatoes in the turning stage or beginning to show color when picked usually ripened almost normally. At 40°F storage usually no ripening developed in tomatoes at any stage of maturity. The lowest temperature at which full ripening with good color and flavor developed was 55°F. At this temperature the rate of ripening was comparatively slow, but the development of normal decay was also slow. No indications of abnormal decay or breakdown were apparent. This temperature is recommended for either storage or delayed ripening purposes. At 60° to 70°F the rate of ripening was considerably increased. These temperatures are recommended for ripening but not for storage. For rapid ripening a temperature much higher than 70°F is not desirable because of the rapid rate of decay. Firm, fully ripe tomatoes held up most satisfactorily at 55°F storage. Ripe tomatoes may be expected to keep in good condition at temperatures as low as 32°F for eight to ten days, but when removed to a higher temperature, as would be necessary in getting commercial lots to the consumer, they soon break down. Tests on a commercial lot of mature green tomatoes shipped from Florida and stored and ripened under conditions similar to those for the tomatoes grown at Arlington Experiment Farm showed similar results. Mature green tomatoes picked the evening before the first field frost ripened in storage more rapidly and developed less decay than those picked the morning following the frost.

CAUSES OF SPOILAGE

This literature review has indicated that various factors are responsible for different types of produce market diseases found in fresh fruits and vegetables. Many of these diseases may be found in advanced conditions in fresh produce shipped to military organizations overseas due to the extended shipping and storage times required prior to actual use. Some of these diseases are microbial in nature, others are virus in origin and still others are physiological in effect.

The major cause of spoilage in lettuce is Bacterial Soft Rot caused by *Pseudomonas marginalis*. Russet spotting, pink rib, and rib discoloration are physiological types of lettuce spoilage.[1] In tomatoes, Bacterial Soft Rot is caused by a different organism, *Erwinia caratovora*. Cladosporum Rot caused by *Cladosporum herbarum* and Gray Mold Rot caused by *Botrytis cinerea* are diseases that also result in losses in market tomatoes.[2] Wounded and dead tissue in celery is prone to become infected by *Erwinia caratovora* which causes Bacterial Soft Rot.[3] Cucumbers can become infected in the field with Anthracnose caused by *Colletotrichum lagenarium* that directly or indirectly, by overgrowth with other organisms, results in losses during refrigerated storage. Cucumbers held for one week or longer at 32° to 40°F develop low temperature injury. Low temperature injury results in sunken spots that become overgrown with various fungi.[4] A major cause of spoilage in stored apples is Blue Mold Rot caused by *Penicillium expansum*.[5] Blue Mold Rot and Green Mold Rot caused by *Penicillium italicum* and *P. digitatum*, respectively, cause 90 percent of the decay in citrus on storage and on the market. Alternaria Rot caused by *Alternaria citri* can also be a major cause of spoilage in citrus.[6] Brown Rot caused by *Monilia fructicola* and *M. laxa* is the most important disease of peaches;[7] *M. fructicola* and *M. laxa* can grow at temperatures as low as 32°F as low as

[1]G.G. Ramsey, B.A. Friedman and M.A. Smith, 1959. Market diseases of beets, chicory, endive, escarole, globe artichokes, lettuce, rhubarb, spinach, and sweet potatoes. USDA Agri Hand No. 155.

[2]L.P. McColloch, H.T. Cook and W.H. Wright, 1968. Market diseases of tomatoes, peppers, and eggplants. USDA Agri Hand No. 28, 90 pp.

[3]M.A. Smith, L.P. McColloch and B.A. Friedman, 1966. Market diseases of asparagus, onions, beans, peas, carrots, celery and related vegetables. USDA Agri Hand No. 303, 82 pp.

[4]G.B. Ramsey, M.A. Smith, 1961. Market diseases of cabbage, cauliflower, turnips, cucumbers, melons and related crops. USDA Agric Hand No. 184, 73 pp.

[5]C.F. Pierson, M.J. Ceponis and L.P. McColloch, 1971. Market diseases of apples, pears, and quince. USDA Agric Hand No. 376, 129 pp.

[6]J.J. Smoot, L.G. Houck and H.B. Johnson, 1971. Market diseases of citrus and other subtropical fruits. USDA Agric Hand No. 308, 115 pp.

[7]J.M. Harvey, Will Smith, Jr. and J. Kaufman, 1972. Market diseases of stone fruits: cherries, peaches, nectarines, apricots, and plums. USDA Agric Hand No. 414, 74 pp.

32 F. In long term storage Alternaria Rot caused by *Alternaria sp.* and Black Mold Rot caused by *Aspergillus niger* can also be responsible for strawberry spoilage.[8] Spoilage in grapes may result from Gray Mold Rot caused by *Botrytis cinerea* and *Cladosporum Rot* caused by *Cladosporum herbarum*.[8]

A series of tables has been developed from this literature survey. Tables 1, 2, and 4 thru 9 provide in capsule form a listing of the many market diseases and their causes for the nine fruits and vegetables discussed in this summation. In addition a table has been included describing methods for controlling lettuce losses, Table 3.

[8] J.M. Harvey and W.T. Pentzer, 1960. Market diseases of grapes and other small fruits. USDA Agric Hand No. 189, 47 pp.

Table 1. Classes and Types of Lettuce Losses

A. Microbiological (Bacteria and Fungii)

1. Bacterial Soft Rot – *Pseudomonas marginalis* and *P. cichorii*, less commonly *P. viridilivida*, *Xanthomonas vitians* and *Erwinia carotovora*
2. Gray Mold Rot – *Botrytis cinerea*
3. Downy Mildew – *Bremia lactura*
4. Watery Soft Rot *(Sclerotiniose)* – *Sclerotinia sclerotiorum*, *S. minor*

B. Virus Diseases

5. Aster Yellows
6. Big Vein
7. Mosaic
8. Spotted Wilt

C. Physiological

9. Marginal Browning
10. Pink Rib
11. Rib Discoloration
12. Tipburn
13. Russet Spotting (also due to viruses and bacterial soft rot)
14. Carbon Dioxide Injury
15. Low-Oxygen Injury
16. Internal Rib Necrosis
17. Rusty-Brown Discoloration

Table 2. Major Causes of Lettuce Losses

Lettuce

1. **Bacterial Soft Rot** is the greatest cause of lettuce waste because of decay-inducing organisms. The decay starts on crushed or bruised leaves; or follows tipburn, marginal browning russet spotting, downy mildew, gray mold rot, or freezing injury.

2. **Gray Mold Rot** is sporadic and may cause extensive damage.

3. **Downy Mildew** is regularly seen on California-grown lettuce.

4. **Russet Spotting** is a major nonparasitic disorder of lettuce and may cause serious losses in lettuce.

5. **Pink Rib** is a physiological disorder of unknown cause. Occurs in hard to to overmature lettuce and in lettuce stored for long periods.

6. **Marginal Browning** is a physiological disorder associated with adverse growing conditions and senescence.

7. **Tipburn** is a physiological disease but exact cause of breakdown is unknown.

8. **Rib Discoloration** is a physiological condition that originates in the field. Factors causing the condition are unknown. Bacterial soft rot follows advanced stages.

9. **Watery Soft Rot** may cause serious losses in lettuce.

Table 3. Control of Causes of Lettuce Losses

1. **Bacterial Soft Rot.** Reduced by shipping lettuce free from tipburn, trimming to remove leaves affected by diseases or defects, rapid precooling and the use of low refrigeration temperature.

2. **Gray Mold Rot.** Trimming of older wrapper leaves, rapid precooling, careful handling to prevent injuries, and low refrigeration temperatures during transit and marketing.

3. **Downy Mildew.** Trimming of older wrapper leaves, rapid precooling and transporting as close to 32°F as possible.

4. **Russet Spotting.** Do not store with apples or other products that generate ethylene. Hard lettuce more susceptible than less firm lettuce. Storage in low oxygen atmosphere is very effective in controlling russet spotting. Do not ship overmature heads; rapid precooling, transit temperature close to 32°F.

5. **Pink Rib.** Little is known about its control. Some evidence that removal of older wrapper leaves, rapid precooling, avoidance of overmature heads and low refrigeration temperatures will improve quality but may not control Pink Rib.

6. **Marginal Browning.** Avoid overmature heads, remove older wrapper leaves, rapid precooling and low refrigeration will improve quality but may not control marginal browning.

7. **Tipburn.** Rigid grading and inspection at shipping points, rapid precooling, transporting at temperatures close to 32°F.

8. **Rib Discoloration.** Measures for control are not known.

9. **Watery Soft Rot.** Trimming of diseased outer leaves, rigid grading and inspection, rapid precooling, shipment close to 32°F.

Table 4. List of Lettuce Market Diseases

1. **Bacterial Soft Rot.** *Pseudomonas marginalis* and *P. cichorii,* less commonly *P. viridilivida, Xanthomonas vitians* and *Erwinia carotovora.*

2. Gray Mold Rot. *Botrytis cinerea.*

3. Downy Mildew. *Bremia lactura.*

4. **Russet Spotting.** A term which includes a number of leaf discolorations which cannot be separated from each other with certainty at terminal markets. Some are of physiological or uncertain origin appears on lettuce grown on saline soils; on storage in the presence of ethylene emanations; caused by virus diseases as spotted wilt, aster yellows or lettuce mosaic.

5. Pink Rib. Physiological but its cause is unknown.

6. **Marginal Browning.** Physiological and is associated with adverse growing conditions or improper refrigeration.

7. Rib Discoloration. Physiological condition which originates in field; factors causing conditions are unknown.

Table 5. List of Tomato Market Diseases

Market Disease	Cause and Other Notes
Alternarie Rot	Alternaria tenuis
Anthracnose	Colletotrichum coccodes
Bacterial Canker	Corynebacterium michiganense
Bacterial Necrosis	Various species of bacteria (Aerobacter Xanthomonas)
*Bacterial Soft Rot	Erwinia carotovora and other bacteria
Bacterial Speck	Pseudomonas tomato
Bacterial Spot	Xanthomonas vesicatoria
Blossom-End Rot	Physiological (followed by alternaria rot, bacterial soft rot and other rots)
Buckeye Rot	Phytophthora spp. (P. capici, P. drechsleri, P. parasitica)
Chemical Injuries (Sulfur Dioxide, Nitrogen Trichloride)	Followed by Alternaria and Rhizopus
Chilling Injury	Followed by Alternaria rot
Cladosporium Rot	Cladosporium herbarum (heavy losses in transit and storage)
Cloudy Spot	By feeding punctures of Pentatomids known as stinkbuds
Early Blight Rot	Alternaria solani
Freezing Injury	
Fruit Tumor	Physiological
Fusarium Rot	Fusarium spp.
Ghost Spot	Botrytis cinerea
Gray Mold Rot	Botrytis cinerea
Gray Wall	See Internal Browning
Growth Cracks	Physiological (followed by alternaria rot)
Helminthosporium Rot	Helminthosporium carposaprum
Internal Browning Complex	Physiological (most important heavy losses)
Late Blight Rot	Phytophthera infestans
Mechanical Injuries	
Nailhead Spot	Alternaria tomato
Phoma Rot	Phoma destructiva
Phomopsis Rot	Diaporthe phaseolorum
Phytophthora Rot	Phytophthora sp.
Pleospora Rot	Pleospora lycopersici (serious losses)
Puffiness	Physiological
Pythium Rot	Pythium sp.
Rhizopus Rot	Rhizopus stolonifer
Ring Rot	Myrothecium sp.
Sclerotium Rot	Sclerotium rolfsii
Skin Checks	Physiological (or unknown)
Soil Rot	Rhizoctonia solani
Sour Rot	Geotrichum candidum (affects tomatoes in transit and on market)
Sunscald	
Virus Mottling (Tomato Mosaic)	Marmor tabaci
(Double-Virus Streak)	Marmor tabaci combined with Marmor dubium
(Spotted Wilt)	Lethum australiense
Watery Soft Rot	See sour rot

Table 6. List of Cucumber Market Diseases

Market Disease	Cause and Other Notes
Anthracnose	Colletotrichum lagenarium
Bacterial Soft Rot	Erwinia spp.
Bacterial Spot	Pseudomonas lachrymans
Black Rot	Mycospharerella citrallina
Cottony Leak	Pythium aphanidermatum
Low Temperature Breakdown	
Mosaic	Caused by a number of viruses
Scab	Cladosporium cucumerinum
Soil Rot	Rhizoclonia (Pellicularia filamentosa)
Other Implicated Diseases on Fruit	
Sclerotinia Fruit	Sclerotinia sclerotiorum
Sclerotium Rot	Pellicularia rolfsii
Blue Mold Rot	Penicillium spp.
Diplodia Rot	Diplodia sp.
Fusarium Rot	Fusarium spp.
Gray Mold Rot	Botrytis sp.
Pink Mold Rot	Cephalothecium roseum
Rhizopus Soft Rot	Rhizopus spp.

Table 7. List of Celery Market Diseases

Market Disease		Cause and Other Notes
Bacterial Blight		Pseudomonas apii
Bacterial Soft Rot		Erwinia carotovora (serious market disease)
Black Heart		Physiological (followed by bacterial soft rot)
Brown Spot		Cephalosporium apii
Cracked Stem		Physiological
Crater Spot		Rhizoctonia solani (Pellicularia filamentosa)
Early Blight		Cercospora apii
Freezing Injury		
Gray Mold Rot		Botrytis cinerea (probably principal cause of spoilage when celery held four weeks)
Late Blight		Septoria apiicola
Virus Diseases	(Cucumber Mosaic) (Western Celery Mosaic) (Spotted Witt) (California Aster Yellows)	
Pencil Stripe		Physiological
Phoma Root Rot		Phoma apiicola
Pithiness		Nonparasitic (Genetic pithiness, Physiological pithiness)
Watery Soft Rot		Sclerotinia spp. (instorage and transit)

Table 8. List of Apple Market Diseases

Market Disease		Cause and Other Notes
Alternaria Rot		Alternaria tenuis
Apple Moggot Injury		Rhagoletis pomonella
Apple Rust Diseases	(Apple-Cedar Rust)	Gymnosporangium juneperi-virginianae
	(Quince Rust)	Gymnosporangium clavipes
Bitter Pit		Physiological
Bitter Rot		Glomerella cingulata
Black Rot		Physolospora obtusa
Blossom-End Rot		Botrytis cinerea
Blotch		Phyllosticta solitaria
*Blue Mold Rot		Penicillium expansum (most common and most destructive of all rots found in transit, storage market)
Botryosphaeria Rot		Botryosphareria ribis
Brown Core		Nonparasitic
Brown Rot		Monilinia fructicola and M. laxa
Bull's-Eye-Rot		Pezicula malicorticis (serious losses after long storage)
Bruises		
Chemical Injuries		Ammonia injury
		Diphenylamine injury
		Formaldehyde injury
		Ozone Orthophenylphenate injury
Codling Moth Injury		
Controlled-Atmosphere Storage Injury		(Carbon Dioxide)
		(Low-Oxygen Injury)
		(Low-Oxygen and High Carbon Dioxide Combined Injury)
Core Rot and Moldy Core		(Penicillium, Physalospora, Alternaria)
		(Rhizopus, Coniothyrium, Aspergillus and Botrytis)
Cork (Boron-Deficiency Cork)		Physiological
Cork Spot (Fork Spot)		Complex nutritional problem
European Apple Sawfly Injury		Hoplocampa testudinea
Fisheye Rot		Corticium centrifugum
Flyspeck		Microthyriella rubi
Frost and Freezing Injury		
Fruit Spot		Mycosphaerella pomi
*Gray Mold Rot		Botrytis spp. (a storage disease 2nd to blue mold rot in losses)
Hail Injury		
Heat Injury While on Tree		
Honeydew and Sooty Mold		
Internal Breakdown		Overmature apples, unflavorable growing conditions
Internal Browning		Growing conditions and low temperature storage
Jonathan Spot		Physiological

Table B. List of Apple Market Diseases (cont'd)

Market Disease	Cause and Other Notes
Leafhopper Specking	
Leaf Roller and Green Fruitworm Injury	
Miscellaneous Rots –	Mucor piri formis
	Pleospora fructicola
	Mycosphaerella tulasnei
	Gliocladium viride
	Phoma spp.
	Microdiplodia sp.
	Pestalotia hartigii
	Coryneum foliicola
	Cephalosporium carpogenum
	Penicillium spp.
	Cladosporium herbarum
	Stemphalium congestum
	Aspergillus spp.
	Trichoderma sp.
	Fusarium spp.
	Epicoccum granulatum
	Ramularia magnusiana
	Sporonema oxycocci
	Pyrenochaeta mali
	Geotrichum sp.
	Helminthosporium papulosum
	Nigrospora sphaerica
	Chaetomium spp.
	Melanconium fuligineum
Pansy Spot	Frankliniella tritici
Pear Leaf Blister Mite Injury	Eriophes pyri
Phytophthora Rot	Phytophthora cactorum
Pink Mold Rot	Cephalothecium roseum
Plum Curculio Injury	Conotrachelus menuphar
Powdery Mildew	Podosphaera leucotricha
Red Spots	
Rhizopus Rot	Rhizopus sp.
Scab	Venturia inaequalis
Scald (Ordinary Scald)	Physiological
(Senescent Scald)	
Scale Insect Injurias	Aspidiotus spp.
Side Rot	Phialophora malorum
Skin and Flesh Cracking	
Soft Scald	
Soggy Breakdown	Physiological
Sooty Blotch	Gloeodes pomigena
Spongy Dry Rot	Colletotrichum dematium
Sunburn, Sunscalad and Delayed Sunsclad	
Virus Diseases (Russet Ring)	
(Star Crack)	
Water Core	

Table 9. List of Citrus Fruit Market Diseases

Market Disease	Cause and Other Notes
Aging (stem-end rind breakdown)	Physiological
Alga Spot	Cephaleuros virescens
Alternaria Rot of Lemons and Black Rot of Oranges	Alternaria citri
Anthracnose	Colletotrichum gloeosporioides
Armored Scale Injury	
Aspergillus Rot	Aspergillus niger, Aspergillus spp.
Black Pit	Pseudomonas syringe
Blue-Mold Rot	Penicillium italicum – Most common of all post-
Green-Mold Rot	Penicillium digitatum harvest (diseases of citrus fruit)
Botrytis or Gray Mold Rot	Botrytis cinerea (In storage and transit)
Brown Rot	Phytophthora citrophthora and others
Chewing-Insect Injury	
Chilling Injury	
Albedo Browning	Affects only lemons
Brown Stain	
Membranous Stain	Affects lemons
Oil-Gland Darkening	In grapefruit and tangelos
Watery Breakdown	
Citrus Rust Mite Russeting	Phyllocoptruta oleivora
Cottony Rot	Sclerotinia sclerotiorum
Creasing	
Endoxerosis	Physiological
Exanthema (Ammoniation)	Nutritional disease
Freeze Damage (Postharvest Freeze) (Freezing on the Tree)	
Fusarium Brown Rot	Fusarium spp.
Granulation	Physiological
Melanose	Phomopsis citri
Modified Atmosphere Injury	
Oil Spotting (Oleocellosis)	
Pitting (Pitting of Freshly Harvested Fruit) (Storage Pitting)	
Puffiness	
Scab	Elsinoe fawcettii
Sclerotium Rot	Sclerotium rolfsii
Septoria Spot	Septoria sp.
Sour Rot	Geotrichum candidum
Stem-End Rot	Phompsis citri and Diplodia natalensis
Stylar-End Breakdown	Affects limes
Sunburn	
Thrip Injury	Scirtothrips citri, Frankliniella bispinosa and Chaetanophothrips orehidii
Trichoderma Rot	Trichoderma viride (in some areas rates second after Green Mold)
Water Spot	
Wind Scarring	
Miscellaneous Spotting and Discoloration	

Tabla 10. List of Strawberry Market Diseases

Market Diseases	Cause and Other Notes
Anthracnose	Gloeosporium sp.
Gray Mold Rot	Botrytis cinerea (serious disease very common)
Leather Rot	Phytophthora cactorum
Rhizoctonia Rot	Rhizoctonia solani
Rhizopus Rot	Rhizopus nigricans
Sclerotinia Rot	Sclerotinia sp.
Stem-End Rot	Dendrophoma obscurans
Tan Brown Rot	Discohainesia oenotherae

Table 11. List of Peach Market Diseases

Market Disease	Cause and Other Notes
Alternaria Rot	Alternaria sp.
Anthracnose (Bitter Rot)	Glomerella cingulata
Bacterial Spot	Eanthomonas pruni
Black Mold Rot	Aspergillus niger
Blue Mold Rot	Penicillium sp.
Brown Rot	Monilinia fructicola and M. laxa (most important disease of peaches)
Cladosporium Rot	Cladosporium herbarum
Coryneum Blight	Coryneum carpophilum
Diplodia Rot	Diplodia natalensis
Gray Mold Hot	Botrytis cinerea
Leaf Curl	Taphrina deformans
Powdery Mildew	Sphaerotheca pannosa
Rhizopus Rot	Rhizopus stolonifer (2nd to Brown Rot as market disease)
Rust	Tranzschelia discolor
Scab	Cladosporium carpophilum
Sour Rot	Geotrichum candidum

Table 12. List of Grape Market Diseases

Market Disease	Cause and Other Notes
Almeria Spot	Alternaria sp., Stemphylium sp.
Alternaria Rot	
Amonia Injury	
Anthracnose	Elsinoe ampelina
Bitter Rot	Melanconium fuligineum
Black Meastes	
Black Rot	Guignardia bidwellii
Blue Mold Rot	Penicillium sp.
Bruising	
Cladosporium Rot	Cladosporium herbarum (Important cause of spoilage in storage)
Cracking	
Dead-Arm Rot	Cryptosporella viticola
Downy Mildew	Plasmopora viticola
Freezing Injury	
Gray Mold Rot	Botrytis cinerea (a principla cause of spoilage in storage)
Hail Injury	
Internal Browning	Physiological
Powdery Mildew	Unicunula necator
Raisining	
Rhizopus Rot	Rhizopus nigricans
Ring Mildew	
Ripe Rot	Botryosphaeria ribis
Scarring	
Shot Berry	
Sulfur Injury	
Sulfur Dioxide Injury	
Sun Injury	
Water Berry	

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SUBJECT INDEX