UNITED STATES DEPARTMENT OF AGRICULTURE

BIBLIOGRAPHICAL BULLETIN No. 13

Washington, D. C. Issued January 1951

Mrs. Denton has no supply of this; BPI Pub. Off. has some (85-447)

HARVESTING, HANDLING, AND TRANSPORTATION OF CITRUS FRUITS

A digest of information on the subject published mostly from 1938 to 1948

By

DEAN H. ROSE
Formerly Senior Physiologist

HAROLD T. COOK
Senior Pathologist

and

W. H. REDIT
Mechanical Engineer

Division of Fruit and Vegetable Crops and Diseases
Bureau of Plant Industry, Soils, and Agricultural Engineering
Agricultural Research Administration

UNITED STATES DEPARTMENT OF AGRICULTURE
BIBLIOGRAPHICAL BULLETIN NO. 13

Washington, D. C. 833434 Issued January 1951

HARVESTING, HANDLING, AND TRANSPORTATION OF CITRUS FRUITS[1]

A digest of information on the subject published mostly from 1938 to 1948[2]

By DEAN H. ROSE, formerly *senior physiologist,* HAROLD T. COOK, *senior pathologist,* and W. H. REDIT, *mechanical engineer, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration*

CONTENTS

[1] This digest is a report of a study made under the Research and Marketing Act of 1946. It is the second in a series intended to cover the biology and physical handling of important horticultural crops during the marketing period. Sections are included on chemical composition, food value, and antiseptics.

[2] For the sake of continuity a few references of earlier and later dates are included.

CONTENTS (Continued)

INTRODUCTION

Lemons, limes, grapefruit, and both round and mandarin (tangerine) types of oranges all have their places in the food supply of the American people. The place of each one is so peculiarly its own that no one is a perfect substitute for any of the others. And yet they have certain characteristics that set them off from most other fruits on American markets. Among these are a distinctive flavor, a unique blending of sweetness and acidity—in properly matured grapefruit and oranges—and a desirably high content of vitamins, especially vitamin C. Some are more acid than others; hence they are valued for use in summer drinks and as sources of citric acid. All of them are also good sources of pectin. In addition, they contain various mineral salts that are necessary for bodily health.

The popularity of citrus fruits with consumers is well indicated by the steady increase in the production of them over a long period of years, since it is obvious that growers would not continually increase their plantings and production unless they felt assured of a continuing demand for the fruit. Statistics published in 1945 and 1948 by the United States Bureau of Agricultural Economics (*6, 7*)[3] showed that production of citrus fruits for the 1946–47 season reached a record total of nearly 7.9 million tons and that in each of the five seasons 1942–43 to 1946–47 successive record totals were produced. Production for the 1947–48 season was off slightly from that for 1946–47, but higher than that of any season preceding 1946–47.

According to Rutherford (*9*) in 1948, the annual production of lemons in California and Arizona ranged from 13 to 14 million boxes during the preceding 5 years. Of these, about 9 million boxes per year were shipped fresh. The remainder, about 5 million boxes per year, was used for making citric acid, sodium citrate, pectin, stock feed, essential oils, juice products, pectin albedo, and vitamin P.

Black (*2*) in 1944 concluded from a study of consumer buying in Syracuse, N. Y., that it is erroneous to assume that oranges and apples are competitive merely because they happen to be fruits. One of the most important facts to be remembered is that the seasonal time of their consumption differs so much that only a small proportion of the two meet on the market.

Fisher (*3, p. 59*) concluded in 1944 from a study of the demand for lemons in the United States that—

> the average person of a given income in the South will buy more lemons than one of the same income in the North, and when his income is increased he will also increase his purchases of lemons to a greater extent. However, because incomes in the South are in general lower than in the North, the amount

[3] Italic numbers in parentheses refer to Literature Cited for Introduction, p. 8.

of lemons in pounds sold per capita is about the same. If incomes were the same in both sections, more lemons would be sold per capita in the South. The reason for the higher individual demand in the South is probably due in part to longer and hotter summer weather, and in part to different food and drink habits of the population.

Mullen (*5*) pointed out in 1947 that per capita consumption of fresh citrus fruit in 1944 was 68 pounds, which is nearly half the per capita consumption of all fresh fruits (144.6 pounds). More citrus fruit is consumed in the United States than in any other country in the world. Although production in the United States has increased enormously during the past 25 years, demand has substantially kept pace with it, the chief outlets being the domestic fresh market, processing, and the export of both fresh and processed fruit.

Because of the importance of citrus fruit as a protective food and because the fields of work that have engaged most of the attention of investigators are those concerned with production or processing rather than with marketing problems, the Fruit Industry Advisory Committee appointed under the Research and Marketing Act of 1946 has made recommendations for research in the marketing of this crop and new projects have been started. As already mentioned, the field of work in the program is foreign to that which has engaged most attention of investigators heretofore. Many of the workers may not have ready access to extensive library facilities. The administrative advisors who supervise regional research projects conducted by the State agricultural experiment stations therefore recommended that the Bureau of Plant Industry, Soils, and Agricultural Engineering be given the responsibility for preparing digests of recent literature dealing with the physical handling of horticultural crops in the postharvest period. This resulted in the establishment of a project under the Research and Marketing Act of 1946 for that specific purpose.

This digest of literature pertaining to citrus fruits is the second in the series of bulletins contemplated under this project. Conforming to the requests of the committee of administrative advisors of the State agricultural experiment stations, the digest is purposely confined largely to the physical and biological rather than to the economic aspects that are usually presented in considering the marketing of agricultural commodities. It is further limited by excluding most of the material dealing with the fundamental physiology of citrus and of that dealing with industrial products derived from citrus. To include all of this vast literature would involve an encyclopedic treatment not germane to present requirements.

The aim has been to deal with the subject in a practical way, but to make sure that governing physiological principles are applied as rigorously, so far as the writers are able, as they would be by a competent investigator at work on a problem in pure research.

The most striking development during recent years in the marketing of citrus fruits has been the growth of the processing industry. That growth and the importance of processing as an outlet for citrus fruits are shown by the following tabulation based on figures compiled by the United States Bureau of Agricultural

Economics (*6, 7*) on the utilization of citrus fruits for processing:

Crop year:	Thousands of tons
1909–10	1
1919–20	25
1929–30	107
1939–40	1,081
1947–48	3,095

Processing in 1947–48 accounted for slightly more than 3 million tons of fruit, 39 percent of the production, as compared with 2.6 million tons in 1946–47, 33 percent of the production. Fresh fruit sales from the 1947–48 crop amounted to almost 4.7 million tons, about 11 percent less than in 1946–47 and 1945–46.

Mullen (*5*) in 1947 commented on the tremendous increase in the processing of citrus fruits in the United States, as shown by the fact that during the five crop years 1939–40 to 1943–44 about 25 percent of the fruit was processed and that in the 1945–46 season in Florida alone about half the entire production was used by processing plants. In California 8 to 10 percent of production was processed. The author, however, made the statement (*p. 72*) :

> There is widespread belief throughout the industry that improvement of the quality of fresh citrus fruit, plus modern marketing and aggressive merchandising practices, will insure the marketing of the bulk of the fruit in the fresh form.

This statement seems open to question, for Florida at least, since during the 1949–50 season about 60 percent of the Florida citrus production was processed.

An interesting conclusion as to the future of fresh citrus fruit was reached in 1948 by Matthew (*4, p. 12*) of the Union of South Africa after a trip to Florida. He wrote:

> I think it can be shown that, in all cases where acceptable products have been made from a fruit, the overall consumption of that fruit has been materially increased. The history of the tomato is a very good example, but there are many others. In spite of the great quantities of tomatoes used in the form of canned juice, soups and the like, the consumption of fresh tomatoes has increased rather than decreased.
>
> I believe the same will apply to citrus fruits. The present indication is that fresh citrus fruit as well as each of the different citrus products will, in time, find a particular outlet for which it is best suited.

Reitz (*8, p. 8*) in 1946, in an article entitled "Fresh vs. Canned Citrus," pointed out that—

> in the past 14 years the production of oranges in Florida has increased 241 percent. In that same time, our processing of oranges has grown from less than 1 per cent of the crop to almost 40 per cent for the season just ending [1945–46]. . . . production [of grapefruit] in the last 14 years has increased . . . 199 per cent. At the same time, the percent processed has increased from approximately 20 percent to almost 70 percent for the season just ending.

At that time (1946) the author said that there seemed to be a tendency during the past few years for shipments of fresh grapefruit to level off at about 10 million boxes a year and for shipments of fresh oranges to level off at about 30 million boxes a year. He did not see any reason for panic on the part of handlers of fresh fruit.

Reduction of packing-house costs to meet canner competition can be brought about, he said, by more efficient handling from the time the fruit is picked until it is dropped on the conveyor belt leading to the washing tank. One important factor in more efficient handling would be the elimination of field boxes (p. 11), not so much because of their cost as because of the extra labor involved in handling them.

Reasons for the rapid increase in the processing of citrus fruits are obvious. Processing avoids the necessity for much of the treatment in getting the fruit ready to be packed for marketing; it also avoids the cost of packages and of packing operations, as well as transportation and refrigeration charges on a bulky commodity between shipping point and market. Furthermore, a product that is convenient to handle, ready for consumption with a minimum of preparation, and available on the market throughout the year is obtained. A further advantage which, however, does not seem to have been mentioned in the literature on the subject is that processing does away with the danger of loss from decay that must always be considered in handling fresh fruit. Loss from decay is especially important in Florida and Texas, where stem-end rot is an insidious and as yet largely unconquered foe of oranges and grapefruit.

One fact to be kept in mind, however, is that, although processing furnishes an outlet for a large part of the citrus crop, it is not an outlet for second-grade fruit or culls. Processors in general insist on using first-grade fruit, so that there is still the problem of disposing of fruit that does not meet their requirements. Part of this is shipped fresh, and part is used in making various byproducts such as pectin, citric acid, essential oils, and stock feed.

For information on all phases of the citrus industry the reader is referred to the works of Webber and Batchelor, published under the general title "The Citrus Industry." Volume 1 (*10*), published in 1943, covers history, botany, and breeding. Volume 2 (*1*), published in 1948, covers the production of the crop. These editors (*10*) stated that a third volume, which will cover harvesting, marketing, and utilization of the crop, is to be published.

The kinds and varieties of citrus fruit that Webber listed as grown in different parts of the United States and in other countries are given in tables 1 and 2 (*10, ch. 3*). In commenting on the varieties in table 1, Paul Harding [4] said that Ruby orange is no longer important in Florida, but that Pope is important. J. R. Winston [5] stated that St. Michael and Maltese are more important than Ruby. Harding added Thompson and Ruby to the list of grapefruit grown in Florida.

---

[4] [5] Correspondence.

Table 1.—*Kinds and varieties of citrus fruits grown commercially in the United States*

State	Kind of citrus	Varieties
Arizona	Orange	Parson Brown, Valencia.
	Grapefruit	Marsh, Foster.
	Lemon	
	Lime	
California	Orange	Valencia, Washington Navel, Thomson Navel, Homosassa, Ruby.
	Grapefruit	Marsh.
	Lemon	Eureka, Lisbon, Villafranca.
Florida	Orange	Hamlin, Parson Brown, Homosassa, Pineapple, Jaffa, Lue Gim Gong, Valencia, Ruby, King, Temple.
	Grapefruit	Duncan, Marsh, Foster.
	Lime	Key (Mexican), Tahiti (Persian).
	Lemon	Villafranca.
	Mandarin	Dancy tangerine, Satsuma.
Louisiana	Orange	Washington Navel, Parson Brown, Valencia.
Texas	Orange	Parson Brown, Hamlin, Pineapple, Valencia, Homosassa.
	Grapefruit	Marsh, Duncan, Foster, Ruby, Thompson.

Table 2.—*Kinds and varieties of citrus fruits grown commercially in different countries or parts of the world*

Country or area	Kind of citrus	Varieties or types
Australia	Orange	Valencia, Washington Navel.
	Mandarin	Emperor, Beauty.
	Grapefruit	Marsh.
	Lemon	Lisbon, Eureka.
China	Mandarin	Ponkan, Cheokan.
	Lemon	White and red.
Egypt	Sweet orange	
	Mandarin	
	Lemon	
	Lime	
	Grapefruit	Marsh, Duncan.
India	Orange	Malta, Mosambi.
	Tangerine	Nagpur Santara.
Italy	Orange	Oval, or Calabrian; Blood type.
	Lemon	Primo flore, Limone invernale, Biancuzzo, Verdelli, probably also Eureka and Lisbon.
Japan	Orange	Washington Navel.
	Mandarin	Satsuma.
Palestine	Orange	Jaffa (Shamouti).
	Grapefruit	Marsh.
Union of South Africa	Orange	Valencia, Washington Navel.
	Grapefruit	Marsh, Triumph.
South America	Orange	Washington Navel, Pera, Valencia, Babiana (Brazil).
	Grapefruit	Marsh.
Spain	Orange	Washington Navel, Valencia, Parssons, Cadenera, Betmar, Red Oval, Seville (sour).
	Mandarin	Clementine tangerine.

LITERATURE CITED FOR INTRODUCTION

(1) Batchelor, L. D., and Webber, H. J., editors.
1948. The citrus industry. Volume II. Production of the crop. 933 pp., illus. Berkeley and Los Angeles.

(2) Black, W. E.
1944. To what extent do oranges compete with apples? N. Y. Agr. Col. (Cornell) Farm Econ. No. 141, pp. 3610–3611.

(3) Fisher, W. D.
1944. The consumer demand for lemons in the United States. 96 pp., illus. Chicago. [Processed.] (Thesis, Ph. D.).

(4) Matthew, A.
1948. The Florida citrus industry. VI.—General conclusions. Citrus Grower [So. Africa] No. 168, p. 12.

(5) Mullen, A. J.
1947. Consumption of citrus fruits is on the increase. Dom. Com. (U. S. Dept. Com.) 35 (3): 67–72, illus.

(6) Palmer, C. D., Schlotzhauer, E. O., and Kiesler, P. F.
1945. Citrus fruits. Production, farm disposition, value and utilization of sales. Crop seasons 1909–10 to 1943–44, inc. U. S. Bur. Agr. Econ. [Unnumb. Rpt.], 44 pp. [Processed.]

(7) ——— Schlotzhauer, E. O., and Kiesler, P. F.
1948. Citrus fruits. Acreage, production, farm disposition, value and utilization of sales. Crop seasons 1946–47 and 1947–48. U. S. Bur. Agr. Econ., Crop Rptg. Bd. [Unnumb. Rpt.], 10 pp. [Processed.]

(8) Reitz, J. W.
1946. Fresh vs. canned citrus. Citrus Leaves 26 (10): 8–9, 30.

(9) Rutherford, D. M.
1948. What happens to surplus lemons? Calif. Citrog. 33: 331, 348–351, illus.

(10) Webber, H. J., and Batchelor, L. D., editors.
1943. The citrus industry. Volume I. History, botany, and breeding. 1028 pp., illus. Berkeley and Los Angeles.

HARVESTING AND HANDLING

IN THE UNITED STATES

It might be thought that the picking of citrus fruit in the United States is so well standardized and knowledge concerning how it should be done is so well disseminated that no one would feel a need for saying much more about it. However, it seemed advisable to someone (*1*) [6] in 1942 to republish instructions on picking citrus fruit that were issued originally by the California Citrus Exchange in 1921. These can be summarized as follows: Avoid making clipper cuts and leaving long stems or stems ending in a sharp point on the fruits; set straight ladders as nearly perpendicular as possible; avoid injuries by thorns or dry twigs and place fruits carefully in the picking bag; wear gloves while picking; do not fill the picking bag too full; allow fruits to roll gently from picking bag to field box; and do not fill the field boxes so full that fruit is injured when the boxes are stacked on the truck for hauling from the field.

The 1921 recommendations undoubtedly were based on the epoch-making work of Powell (*14*), reported in 1908, and the experience of the citrus industry in applying his results to the solution of practical problems.

Recommendations for the picking and subsequent handling of citrus fruits in Florida, as given by Winston (*21*) in 1950, are much the same as those just given for California except that in Florida the problem of stem-end rot makes certain additional precautions necessary. Stem-end rot is also a problem in the other Gulf States.

In years of heavy production, according to Nixon (*13*) in 1940, close picking for quality, as well as the usual precautions to prevent mechanical injury to the fruit, is desirable; that is, picking should be done so as to obtain fruit of uniform quality so far as possible and of maximum vitality for storage. Nixon also recommended delaying picking for some time after oil sprays have been applied. He said (*p. 101*):

> Even then, with the most diligent precautions, some effect of the oil will remain for several months, and some irregular color and bronzing may result.

As a result the fruit may not color properly in the house, and the grades may be materially lowered.

PULLING VS. CLIPPING

In 1936 Winston (*20*) published results showing that pulled grapefruit, except when very ripe, is less rapidly affected by stem-end rot than clipped grapefruit. He recommended the pulling of grapefruit intended for storage or for export. The particular virtue in pulling is that it removes the stem button (or most of it), which is the part from which the stem-end rot fungi spread into the fruit.

---

[6] Italic numbers in parentheses refer to Literature Cited for Harvesting and Handling, p. 12.

For several years it was thought that oranges could not be pulled safely because of the danger of "plugging"—tearing of the peel next to the button—and subsequent infection by blue mold. Meckstroth (*11*) reported in 1944, however, as a result of 6 seasons' work, that pulling Florida oranges decreases stem-end rot and total decay but that it may increase blue mold rot, particularly in very ripe oranges, because of more tearing, or plugging, of the rind. The greater the proportion of stem parts adhering the more stem-end rot that can be expected. He stated (*p. 18*):

> Packing house managers who have had a large part of the late oranges pulled as well as some of the midseason varieties, feel that tearing of the rind or "plugging" is no more serious than injuries from clipper cuts and stem punctures or bruises.

TIME OF PICKING

Jennings (*10*) concluded in 1947, on the basis of the production records of an orange company with large holdings in southern California, that any net change in navel or Valencia orange production brought about by either early or late picking has been very small over a period of several years. The principal effect has been to upset the normal bearing routine of the trees sufficiently to throw them into a tendency to alternate bearing at least for 2 years after removal of the fruit.

F. E. Gardner [7] stated that ordinarily the next year's crop is favored by early picking and decreased by late picking and that the Florida grapefruit, in particular, is adversely affected by late picking.

USE OF PICKING BOXES

For some time there has been dissatisfaction in citrus-growing areas with the picking boxes in which the fruit is placed for removal from the grove. Wilson (*19*) in 1937 reported that 41 sizes of citrus picking boxes, whose capacity varied from 38 to 61 pounds, were in use in California as recently as 1937. He pointed out (*p. 351*):

> This is obviously too wide a variation in a container that is widely used as a measure for calculating the amount of money paid for picking and hauling fruit and the quantity of fruit as it comes from the orchard as compared to the same fruit after it is sorted and packed.

He mentioned minor changes that could be made to eliminate many of the sizes now in use and suggested (*p. 381*):

> The standard citrus picking box shall have an inside capacity of 3115 cubic inches with an allowable variation of one per cent. The thickness of top cleats shall be seven-eighths of an inch.

Information on the types of field boxes used in the Gulf States was given by Winston (*21*) in 1950. He mentioned the standard-size box (31½ by 12 by 13 inches), a smaller box, about two-thirds the standard size, and a jumbo, or oversize, box for grapefruit.

Recently growers and packing-house operators have interested themselves in the possibility of doing away with picking boxes

[7] Correspondence.

altogether and of handling the fruit in bulk from grove to packing house. Crosby (*6*) reported that bulk handling of citrus fruit (navel and Valencia oranges and grapefruit) in trucks or trailers is used by a large number of packing-house managers in Arizona and that all are well satisfied with the results. Bulk handling eliminates field boxes, box replacement, damage to a grove from trucks hauling boxes in and out, labor required to handle boxes, and need for box storage space. It also eliminates fire hazard, packing houses are cleaner because dirt from boxes is not brought in, and the number of tractor and truck drivers needed is reduced. Users find little or no damage from bruising and decay; there is even less than where field boxes are used. Whether such a practice can be followed in other States with oranges that are to be packed and shipped should be investigated. In 1948 Rutherford (*15, p. 181*) in California commented that—

> bulk handling of grapefruit has much in its favor and, according to those who are using it, nothing against it. In fact they seem to infer that the use of field boxes in handling fruit from grapefruit orchards is just a little archaic.

Hauling in bulk from the grove is common practice where fruit is destined for processing.

WASHING AND COLOR-ADDED PROCESS

The only extended description of the washing of citrus fruits that has been found is that given by Winston (*21*) in 1950 for Florida conditions. He also discussed the use of the color-added process by means of which oranges that are fully mature and edible but poorly colored are made to assume the color usually associated by the public with ripe fruit.

MECHANIZATION OF HARVESTING

Much interest has developed recently in the possibility of mechanizing the harvesting of citrus fruits. Allen (*2*) in 1948 reported remarks by Roy Smith of the University of California on the search for cheaper harvesting methods. Smith suggested that the picking ladder will disappear and possibly the field box will also. The ladder might be replaced by a picking machine like that used in some northern peach orchards, by means of which the pickers work on booms that lift them up and down and in and out of trees. The field box might be replaced by trailers for bulk movement of fruit to the packing house, and the orange crate by "prepackaging—something beyond the mesh bag."

In 1948 Crosby (*5*) commented on the use of the peach-picking machine mentioned by Allen (*2*). He also suggested the possibility (1) of using a platform-type machine from which men could harvest the fruit and place it in a chute so that it can roll into a trailer; (2) of handling oranges and lemons in bulk from the grove to the packing house; and (3) of using larger field boxes, possibly two to three times the size now used. The most important problems to be studied, in connection with these or other new methods are those of cost (or savings) and of possible increased damage to the fruit from rough handling.

IN OTHER COUNTRIES

Metters (*12*), of Australia, commented in 1936 in an article on the citrus industry of America that harvesting is, in his opinion, the most important operation in connection with successful marketing. He stated that in California the use of picking bags, field picking boxes, fruit clippers, and gloves was at that time universal, in fact compulsory.

In 1939 Bates (*4*), reporting from Rhodesia, pointed out the need for care in handling oranges during picking and between grove and packing house, for the use of blunt-nosed clippers, and for canvas picking bags and field boxes with rounded edges to minimize bruising and other mechanical injury. He also stated that the practice of storing fruit in large, airy rooms for 3 to 5 days to permit wilting and presumably to reduce injury, at one time followed in most citrus-growing countries, has been found not only unnecessary but actually harmful because it helps to increase decay. One or two days' wilting is considered ample.

In 1938 the Australian Citrus Advisory Council (*3*) recommended care in picking citrus fruit, keeping stems short, and placing fruit carefully in the picking boxes. They recommended that gloves be worn throughout the whole process of picking, packing, and wrapping.

In 1946 Williams (*17, 18*) made recommendations for the harvesting and packing of Australian lemons that are very similar to those recommended in California and Arizona. Similar statements were made by Dallas (*7*) in 1944 and by Everett (*8*) in 1946 for New Zealand lemons.

Hazen (*9*), reporting in 1938 on the citrus industry of Palestine, stated that picking of the fruit there is done in much the same way as in the United States. He wrote that field boxes were largely displacing the burlap-lined wicker baskets formerly used for carrying the fruit from field to packing house.

Singh (*16*) in 1945 recommended practices for picking oranges in India that are similar in some respects to those followed in the United States. However, his warning that the fruit stem should be cut with special clippers, not snapped off with the fingers, that the fruit should not be allowed to drop on the ground when removed from the tree, and that pickers should wear gloves in order to avoid fingernail scratches on the fruit would seem elementary to the highly developed citrus industry in this country. He stressed the importance of careful handling at all stages of the harvesting operation.

LITERATURE CITED FOR HARVESTING AND HANDLING

(1) Anonymous.
1942. how to pick fruit to avoid injuries. Calif. Citrog. 27: 68.

(2) Allen, B.
1948. seeking cheaper harvesting methods. Citrus Leaves 28 (7): 8.

(3) Australian Citrus Advisory Council.
1938. citrus industry. advice on the picking, handling and packing of oranges intended for export to new zealand. So. Austral. Dept. Agr. Jour. 41: 1016–1017.

(4) BATES, G. R.
1939. RECENT DEVELOPMENTS IN THE PROCESSING OF RHODESIAN ORANGES. Rhodesia Sci. Assoc. Proc. 37: 29–35.

(5) CROSBY, J.
1948. CAN CITRUS PICKING BE MECHANIZED? Calif. Farmer (South. ed.) 189: 46–47, illus.

(6) ———
1949. ARIZONA LEADS CALIFORNIA IN CITRUS BULK HANDLING. Calif. Farmer (South. ed.) 190: 619, illus.

(7) DALLAS, W. K.
1944. LEMON CULTURE IN NEW ZEALAND. [CONCLUSION.] New Zeal. Jour. Agr. 69: 49, 51–53, illus.

(8) EVERETT, P.
1946. PICKING AND HANDLING THE LEMON CROP. New Zeal. Jour. Agr. 72: 279–280, illus.

(9) HAZEN, N. W.
1938. THE CITRUS INDUSTRY OF PALESTINE. U. S. Bur. Agr. Econ. F. S. Rpt. 78, 96 pp., illus. [Processed.]

(10) JENNINGS, R. F.
1947. EFFECT OF TIME OF PICKING ON NAVEL AND VALENCIA FRUIT PRODUCTION. Calif. Citrog. 33: 72–75, illus.

(11) MECKSTROTH, G. A.
1944. PULLING VERSUS CLIPPING OF FLORIDA ORANGES. Citrus Indus. 25 (11): 9, 12, 18.

(12) METTERS, F. H.
1936. THE CITRUS INDUSTRY OF AMERICA. So. Austral. Dept. Agr. Jour. 40: 222–236, illus.

(13) NIXON, H. W.
1940. LEMONS. PICKING—WASHING—GRADING—PACKING. Calif. Citrog. 25: 101, 114–116, illus.

(14) POWELL, G. H.
1908. THE DECAY OF ORANGES WHILE IN TRANSIT FROM CALIFORNIA. U. S. Bur. Plant Indus. Bul. 123, 79 pp., illus.

(15) RUTHERFORD, D. M.
1948. BULKING IS BETTER, THEY SAY. Calif. Citrog. 33: 180–181, illus.

(16) SINGH, K. K.
1945. PICKING ORANGES. Punjab Fruit Jour. 9: 163–165.

(17) WILLIAMS, C. G.
1946. HARVESTING AND PACKING LEMONS. Queensland Agr. Jour. 63: 270–279, illus.

(18) ———
1946. HARVESTING AND PACKING LEMONS. Queensland Dept. Agr. and Stock, Div. Plant Indus., Advisory Leaflet 109, 10 pp., illus. (Reprinted with additions from Queensland Agr. Jour., Nov. 1946.)

(19) WILSON, R.
1937. CAN THE CITRUS PICKING BOX BE STANDARDIZED? Calif. Citrog. 22: 351, 381.

(20) WINSTON, J. R.
1936. A METHOD OF HARVESTING GRAPEFRUIT TO RETARD STEM-END ROT. U. S. Dept. Agr. Cir. 396, 8 pp., illus.

(21) ———
1950. HARVESTING AND HANDLING CITRUS FRUITS IN THE GULF STATES. U. S. Dept. Agr. Farmers' Bul. 1763, 67 pp., illus. (Revised.)

SMALL SIZES

In the last decade one of the major problems of the California citrus industry has been that of small sizes. The problem arises at times in Florida also in connection with fruit from old trees, but it seems to be much less important there. Hodgson (*5*)[8] in 1947 stated that the problem of small sizes in citrus when it occurs in Florida results from a combination of (1) a heavy crop; (2) a variety that is inherently small-fruited, such as Hamlin orange; and (3) a rootstock that tends to reduce fruit size.

The chief factors that appear to have contributed to the production of small sizes in California are (1) a pronounced deficiency in total heat, (2) a succession of heavy crops, and (3) a widespread lack of tree vigor caused by a nutritional disturbance. In two other papers (*4, 7*) in 1947 and 1948 Hodgson suggested further that some of the causes of small-size oranges may be (1) accumulation of salines that interfere with root absorption of water and mineral nutrients, (2) nematode infestation of the soil, (3) deficiency of total heat available to trees and fruit, (4) earliness or lateness of bloom, (5) general lack of tree vigor, and (6) long continued use of oil sprays.

No evidence has been obtained that extra fertilization with nitrogen increases fruit size.

In 1946 Harlan (*3*) listed the factors that have been suggested as possible causes of small sizes of oranges in California. These were (1) changes in climatic conditions that had reduced the number of hours of sunshine and kept temperatures low; (2) nutritional deficiencies in the soil; (3) increasing age of trees; (4) nematodes; (5) increasing use of oil sprays; (6) increased volume of industrial smoke and gases in the air; and (7) failure of root systems of trees to function properly, through activity or lack of activity of certain soil flora. He expressed the opinion (*p. 10*) that "all of these factors in combination are seriously affecting the prosperity and health of the trees."

In 1947 Hodgson (*6, p. 4*) repeated the opinion he had previously expressed—namely: "A permanent solution to the small fruit size problem in California undoubtedly can be provided only by an adequate plant breeding program with larger-fruited varieties as its objective."

In 1948 L. D. Batchelor reported encouraging results from the use of 2,4-D in increasing the size of Valencia oranges (*1*). He stated (*1, p. 152*): "In most cases there has been a notable increase in the size of the fruit if a sufficiently strong spray was applied prior to, during or just after bloom." Definite recommendations as to the strength of the spray that should be used were not made in the report; 20 p.p.m. reduced foliage loss and preharvest

---

[8] Italic numbers in parentheses refer to Literature Cited for Small Sizes, p. 16.

fruit drop. It also reduced fruit-stem dieback and caused a reduction in the number of fruits per tree.

Stewart and Heild (*10*) in 1950 reported that spraying lemons with 5 p.p.m. of 2,4-D or 2,4,5-T reduced drop of mature fruit and increased the size. The yield was increased 24.4 percent by the 2,4-D spray and 31.9 percent by the 2,4,5-T spray.

Jones (*9*) in 1949 described the experience of a citrus grower in California who recommends that for best results the spraying with 2,4-D be done during the first half of June, depending on the time of bloom.

Chapman, Brown, and Rayner (*2*) reported in 1948 that their work gives no evidence of a lack of potash in most California soils and suggested that some other reason or reasons for small sizes must be sought.

Johnston (*8*) in 1950 concluded from a survey of 429 groves in California over a 5-year period that the two outstanding causes of small fruit are poor physical condition of the soil and inadequate irrigation.

LITERATURE CITED FOR SMALL SIZES

(1) Anonymous.
1948. NO. 1 STUDY AT CITRUS STATION IS SMALL ORANGE SIZES. Calif. Farmer (South. ed.) 189: 152–153. (Report of L. D. Batchelor.)

(2) Chapman, H. D., Brown, S. M., and Rayner, D. S.
1948. SOME EFFECTS OF POTASH DEFICIENCY AND EXCESS ON ORANGE TREE GROWTH, COMPOSITION AND FRUIT QUALITY. Calif. Citrog. 33: 278–279, 290, illus.

(3) Harlan, P. W.
1946. THE SMALL SIZE QUESTION. Citrus Leaves 26 (2): 10.

(4) Hodgson, R. W.
1947. CAUSES OF SMALL SIZE ORANGES. Calif. Cult. 94: 838–839.

(5) ———
1947. THE FRUIT SIZE PROBLEMS OF CALIFORNIA AND FLORIDA. Calif. Citrog. 32: 332, 344–346.

(6) ———
1947. SMALL SIZE CITRUS FRUITS MAY BE A GENETICS PROBLEM. Calif. Agr. 1 (12): 1, 4.

(7) ———
1948. CALIFORNIA STUDIES SMALL SIZES. Citrus Mag. 10 (7): 10–11.

(8) Johnston, J. C.
1950. ORANGE FRUIT SIZE SURVEY. Calif. Citrog. 35: 274, 294–296.

(9) Jones, W. E.
1949. EXPERIMENT SHOWS EFFECT OF 2,4-D ON FRUIT SIZES. Citrus Leaves 29 (1): 10–11.

(10) Stewart, W. S., and Heild, H. Z. ("H. Z. Hield")
1950. EFFECTS OF WATER SPRAYS OF 2,4-D AND 2,4,5-T ON FRUIT DROP AND PRODUCTION OF LEMON TREES. Calif. Citrog. 35: 93, 112.

HORMONES

The remarkable success achieved in preventing fruit drop in apple orchards by the use of hormones, or growth substances, has encouraged citrus investigators to test the effect of a similar treatment on oranges and grapefruit. The premature dropping of these fruits has been a serious problem for many years; hence it was felt that any treatment that gave promise of holding fruits on the trees until they were ready for picking should be given a trial.

FOR FRUIT DROP

According to Pomeroy and Aldrich (*3*)[9] in 1943, applications of alpha-naphthalene acetic acid, indoleacetic acid, indolebutyric acid, furacrylic acid, and calcium furoate did not increase fruit set of Washington Navel orange and Marsh grapefruit.

Stewart and Klotz (*5*) reported in 1947 that when 2,4-D was applied to Valencia orange trees in full bloom blossom drop was delayed 8 to 10 weeks or even more but fruit set was not increased. When applied to Valencia orange trees bearing mature fruit (*p. 161*) "the sprays decreased preharvest fruit-drop as much as 78%, even when applied 2 weeks after severe drop had begun." Abnormalities in shape and morphology were observed in both Navel and Valencia oranges from trees sprayed with 2,4-D at a concentration of 225 p.p.m. These sprays were not recommended for commercial use by Stewart and Klotz pending accumulation of additional data.

Stewart, Klotz, and Heild (*6*) in 1947 commented on results from earlier work that showed that drop of Valencia oranges was reduced by the use of water sprays containing 2,4-D and reported that such sprays gave good results when used on Navel oranges. The reduction in fruit drop in this later work (with Navels) ranged from 27 to 96 percent when 2,4-D was applied in a water spray at concentrations of 5 to 25 p.p.m. of the free acid equivalent. It was found that the spray may be applied over a considerable period of time. It appeared necessary to have only an interval of about 6 hours free from rain after application. Application of an 8-p.p.m. water spray at the beginning of a flush of leaf growth or before a growth flush had fully expanded sometimes caused some curling of the leaves. The effect did not extend to succeeding growth flushes. Leaf curling did not seem to decrease production or the quality of the fruit. Similar results were reported by Stewart and Parker (*7*) in 1948.

Cameron (*1*) in 1948 reported good results from winter spraying of grapefruit in Australia with 2,4-D to prevent fruit drop. The optimum concentration had not been determined when the report was written.

---

[9] Italic numbers in parentheses refer to Literature Cited for Hormones, p. 18.

890503—51—2

FOR FRUIT IN STORAGE

Stewart (*4*) reported in 1948 that the prevalence of black buttons and alternaria decay of lemons in storage was greatly reduced either by spraying the lemon trees with 2,4-D or 2,4,5-T or by dipping the fruit, just before storage, in lanolin emulsions containing 500 or 1,000 p.p.m. of 2,4-D. Similar beneficial results were obtained in storage tests with grapefruit and Navel oranges from trees drenched with water sprays containing either 8 or 25 p.p.m. of 2,4-D. The amount of decay and aging and the number of black buttons were reduced. There was some evidence (*4, p. 81*) "that a reduction of 'black buttons' may be obtained on fruit harvested any time within five or six months after spraying with 2,4-D."

Kessler and Allison (*2*) stated in a progress report in 1948 that black buttons and alternaria decay of lemons are largely eliminated by dipping in an aqueous solution containing 100 to 1,000 p.p.m. of 2,4-D. Membranous stain was not controlled, but the dropping of buttons was prevented and color was improved.

LITERATURE CITED FOR HORMONES

(1) CAMERON, A. E.
1948. WINTER GRAPEFRUIT DROP. Citrus News 24: 125.

(2) KESSLER, K. L., and ALLISON, J. R.
1948. USE OF GROWTH REGULATORS ON LEMONS IN STORAGE. Calif. Citrog. 34: 24–25, 28, illus.

(3) POMEROY, C. S., and ALDRICH, W. W.
1943. SET OF CITRUS FRUITS IN RELATION TO APPLICATIONS OF CERTAIN GROWTH SUBSTANCES. Amer. Soc. Hort. Sci. Proc. 42: 146–148.

(4) STEWART, W. S.
1948. EFFECT OF PLANT GROWTH REGULATORS ON STORED CITRUS FRUIT. Calif. Citrog. 34: 58, 80–84, illus.

(5) ——— and KLOTZ, L. J.
1947. SOME EFFECTS OF 2,4-DICHLOROPHENOXYACETIC ACID ON FRUIT-DROP AND MORPHOLOGY OF ORANGES. Bot. Gaz. 109: 150–162, illus.

(6) ——— KLOTZ, L. J., and HEILD, H. Z.
1947. 2,4-D SPRAYS FOR CONTROL OF NAVEL ORANGE DROP. Calif. Citrog. 33: 49, 77–79, illus.

(7) ——— and PARKER, E. R.
1948. SPRAYS TO REDUCE FRUIT DROP FROM GRAPEFRUIT TREES. Calif. Citrog. 33: 332, 351–353, illus.

DEGREENING

In many citrus-growing countries difficulty is experienced with varieties of citrus fruit that mature internally before they develop their color, or at least their full color, externally. In Florida some of the early and midseason oranges behave in this way. Winston and Tilden (*19*, *p.* [*1*])[10] stated in 1935:

> In Florida, some of the early oranges such as the Parson (Parson Brown) mature before they develop their color or at least their full color. Citrus fruit of any variety growing on densely foliated trees and shaded by the foliage, such as an inside crop of grapefruit, retains much of its greenness even after maturity. In both Florida and California, Valencia oranges develop almost full color in winter and become mature in the spring but have a habit of regreening, particularly at the stem end when spring growth sets in, if allowed to remain on the tree until fully ripe. Late varieties of grapefruit sometimes remain green in the spring and need to be put through the coloring treatment. It is highly desirable to make the appearance of the fruit match its eating quality throughout its marketing season.

So far as can be determined from research papers published in various parts of the world the same or a similar situation must be dealt with wherever citrus is grown. For this reason various treatments, but especially the ethylene treatment, are widely used in an attempt to make fruit color and appearance correspond to the eating quality (*18*). In 1947 Miller (*9*) published an account of the development of the use of ethylene for coloring fruits and vegetables.

In the United States two different methods are used—the "shot" method and the "trickle" method. In the first of these, ethylene is introduced into the coloring room in intermittent charges at intervals of several hours; when the second is used, the gas enters the room in a continuous flow. For best results from the intermittent method, the interval between charges should not be more than 3 or 4 hours. A greater interval usually results in a slow rate of coloring. The trickle method of introducing and regulating ethylene under continuous flow is preferable and may be accomplished by using suitable reducing valves attached to the high-pressure cylinder in which the gas is purchased. The gas is thoroughly mixed with air before it enters the coloring room, is supplied in uniform concentration at all times, and continuous ventilation is practicable. (See Winston and Tilden (*19*), 1935; Winston (*18*), 1950.)

The treatment of citrus fruits with ethylene is variously referred to as ripening, coloring, sweating, or degreening. The last term seems preferable, because citrus fruits do not change markedly or ripen and become more desirable for consumption after they are picked. They are as good when harvested as they ever will be. The effect of ethylene on them, the end result at least, is mainly to destroy the chlorophyll in the rind and allow the

---

[10] Italic numbers in parentheses refer to Literature Cited for Degreening, p. 22.

yellow or orange color to become evident. (See Miller (*9*), 1947.) This is rather generally understood in the citrus industry. Color in citrus rinds is caused by the presence of chlorophylls and carotenoids, as stated by Miller and Winston (*10*) in 1939. Degreening on the tree results in a loss of chlorophylls and an increase of carotenoids in the rind. Degreening of oranges with ethylene removes chlorophylls without affecting carotenoids. Carotenoids, as well as chlorophylls, of limes, lemons, and grapefruit tend to decrease whether they are degreened on the tree or with ethylene according to Miller (*8*) in 1938.

It is important to emphasize here that degreening may occur on the tree, in cool or cold storage, or during treatment with ethylene. In the last case, the changes that occur are not "artificial ripening," as was pointed out in 1940 by Thornton (*15*). Ethylene merely accelerates changes that would occur naturally later whether or not ethylene is used.

Zakharov (*20*) reported in 1936 that propylene gave as good results as ethylene in the "artificial ripening" of citrus fruits so far as appearance and flavor are concerned, but it is expensive. He recommended the use of bivinyl (1.3 butadiene), because "it does not affect the vitamin C content of the fruit and its disagreeable odor disappears after the treatment."

In the work of Bagster and Connah (*3*), reported in 1939, it was found that the ethylene treatment when applied to oranges had no apparent effect on their catalase or ascorbic acid content. They used ethylene at a concentration of 2 to 1,000 at a temperature of 64.4° to 68° F. and a relative humidity of 75 to 80 percent. Both catalase and ascorbic acid are present in the pulp, whereas the oxidase system (which is affected by ethylene) is present in the peel but not in the pulp. In oranges treated with 0.2 percent ethylene for about 4 days catalase increased as the fruit ripened; the ascorbic acid content varied but little throughout the season, but it tended to increase slightly as the oranges ripened. Some oranges had a slight musty flavor after treatment with ethylene.

According to an anonymous reviewer (*1*), Gregory and Prest in Australia used acetylene gas (1 oz. carbide to each charge) and ethylene gas (1 to 1,000 cu. ft. of air twice daily) for the degreening of citrus fruits of various stages of maturity. They reported that there was not much difference in efficiency between acetylene and ethylene in coloring, although ethylene appeared to have a slight advantage. The least decay occurred when ethylene was used. In southern Africa Bates (*4*) reported in 1939 on the use of ethylene at the rate of 1 to 5,000 at temperatures between 70° and 80° F. and a relative humidity of 80 to 90 percent. Frequent ventilation was found necessary to remove the carbon dioxide that accumulates rapidly in coloring rooms, because of the accelerated respiration of the fruit.

In 1940 an unsigned report (*2*) was published on the "artificial" coloring of oranges in Cyprus. Ethylene (1 to 2,000) at 79° to 88° F. and a relative humidity of 82 to 90 percent was used for decolorizing green Famagusta oranges. The ethylene treatment was believed to be advantageous only for very green fruit shipped in

October or the first week in November. It was concluded that if the fruit has begun to change color, as happens when the sugar-acid ratio is about 5.5, it would probably entirely lose its green color without ethylene treatment by the time it reached the United Kingdom or Scandinavia.

Hall (*7*) in 1940, reporting on the coloring of citrus fruits with ethylene, recommended a uniform fruit temperature of 75° to 80° F. for Navel and Mediterranean Sweet oranges and 70° to 75° for Valencia; he advised the use of a relative humidity of 80 to 85 percent while the fruit is being heated and 90 to 95 percent when the proper temperature has been reached or the fruit is being cooled. The concentration of ethylene that gave the best results was 1 to 5,000 calculated on the volume of the empty room. The room should be ventilated whenever the concentration of carbon dioxide reaches 1 percent—usually every 6 to 8 hours. Hall recommended that the concentration of ethylene be 1 to 20,000 for lemons and that a uniform temperature of 75° be used for grapefruit.

Rakitin (*11*) in 1941 recommended a concentration of 1 to 5,000 of ethylene for the "ripening" of oranges.

In the work reported by Salcedo (*14*) in 1942 it was found that the optimum conditions for "ripening" oranges with ethylene are a temperature range of 64.4° to 68° F., a relative humidity of 75 to 80 percent, ethylene concentration 2 parts to 1,000 of air, and continuation of treatment for 4 days with the air-gas mixture in the room changed every 8 hours. Early varieties (Clementine, Sucrena, Washington Navel, Thomson, and Cadena) responded best to the treatment. A temperature of 64.4° to 68° is considerably lower than that generally used in the United States. The fruit used in this work was of the varieties more commonly cultivated in Spain.

As shown by the various citations, ethylene has been found useful for degreening citrus fruits in this and other countries. Rohrbaugh and MacRill (*13*) reported in 1943, however, that ethylene is undesirable in lemon storage rooms, because it speeds up the life processes of the fruit and so shortens its life. It gets into the rooms from two sources: (1) fruit decaying with green mold and (2) exhaust fumes from motor vehicles such as trucks unloading at the packing house. The gas can be detected in storage rooms in concentrations as low as 0.05 p.p.m. by means of pea seedlings, which become twisted and distorted—show epinasty—when ethylene is present. (See Rohrbaugh (*12*), 1943, and pp. 43 and 46.) Ethylene can be eliminated or its concentration can be kept low by keeping the storage room free of decaying fruit, by avoiding contamination of the air by motor vehicles, by providing sufficient ventilation and air circulation, and by treating the water of the air washer with hypochlorites or chloranines to oxidize the ethylene.

In the work of Biale (*5, p. 212*) reported in 1940 it was found:

> Vapors of a single lemon infected with green mold bring about a more rapid rate of respiration of 50 to 60 green lemons. They also hasten color development and cause shedding of "buttons." Blue mold, sour and cottony rot produce very slight or no effects.

At the time his report appeared it was not known that the active substance given off by molds is ethylene. In 1941, however, Biale and Shepherd (*6*) reported that they had obtained a positive epinasty test with pea seedlings exposed to emanations from *Penicillium digitatum*, which is the reaction given by pea seedlings when ethylene is present.

In reports by Winston (*16*, *17*) in 1942 and 1943 it was stated that oil sprays impede the development of color in the rind of oranges not only while the fruit is on the tree but also while it is undergoing treatment in the coloring room. Development of rind color is retarded less by sprays of the cheaper lubricating oils than by the expensive highly refined white-oil sprays; less by spring applications than by fall applications; and less by low concentrations than by higher concentrations of the spray.

LITERATURE CITED FOR DEGREENING

(1) Anonymous.
1938. colouring citrus fruit. Queensland Agr. Jour. 49: 276–279. (Reviews work of J. H. Gregory and R. Prest.)

(2) ———
1940. artificial colouration of oranges. Cyprus Agr. Jour. 35: 17–18.

(3) Bagster, L. S., and Connah, M. V.
1939. artificial ripening of oranges. Roy. Soc. Queensland, Proc. (1938) 50: 153–157.

(4) Bates, G. R.
1939. recent developments in the processing of rhodesian oranges. Rhodesia Sci. Assoc. Proc. 37: 29–35.

(5) Biale, J. B.
1940. effect of vapors from moldy fruits on coloring and respiration of lemons. Calif. Citrog. 25: 186, 212, illus.

(6) ——— and Shepherd, A. D.
1941. respiration of citrus fruits in relation to metabolism of fungi. i. effects of emanations of penicillium digitatum, sacc., on lemons. Amer. Jour. Bot. 28: 263–270, illus.

(7) Hall, E. G.
1940. ethylene gas to colour fruits and hasten the ripening of tomatoes. Agr. Gaz. N. S. Wales 51: 98–101, 143–145.

(8) Miller, E. V.
1938. a physiological study of the rind color of certain citrus fruits. Science 87: 394–395.

(9) ———
1947. the story of ethylene. Sci. Monthly 65: 335–342.

(10) ——— and Winston, J. R.
1939. investigation on the development of color in citrus fruits. Fla. State Hort. Soc. Proc. 52: 87–90.

(11) Rakitin, Yu.
1941. hastening the ripening of fruit. Pishchevaya Promysh. 1 (2): 18–21.

(12) Rohrbaugh, P. W.
1943. measurement of small concentrations of ethylene and automobile exhaust gases and their relation to lemon storage. Plant Physiol. 18: 79–89, illus.

(13) ——— and MacRill, J. R.
1943. ethylene in lemon storage rooms. Calif. Citrog. 28: 118, illus.

(14) Salcedo, R. G.
1942. coloring and ripening oranges by the ethylene gas method as applied to the varieties more commonly cultivated in spain. Ciencia [Mexico] 3: 165–170, 213–218. [Not seen; abstract in Chem. Abs. v. 37, column 2478. 1943.]

(15) Thornton, N. C.
1940. the facts about "artificially" ripened fruit. parts 1 and 2. Food Indus. 12 (7): 48–50, 80, illus.; 12 (8): 51–52, illus.

(16) WINSTON, J. R.
1943. DEGREENING OF ORANGES AS AFFECTED BY OIL SPRAYS. Fla. State Hort. Soc. Proc. (1942) 55: 42–45, illus.

(17) ———
1943. DEGREENING OF ORANGES AS AFFECTED BY OIL SPRAYS. Citrus Indus. 24 (2): 5, 8, 16, illus.

(18) ———
1950. HARVESTING AND HANDLING CITRUS FRUITS IN THE GULF STATES. U. S. Dept. Agr. Farmers' Bul. 1763, 67 pp., illus. (Revised.)

(19) ——— and TILDEN, R. W.
1935. THE COLORING OR DEGREENING OF MATURE CITRUS FRUITS WITH ETHYLENE. U. S. Bur. Plant Indus., [Unnumb. Pub.], [14] pp., illus. [Processed.]

(20) ZAKHAROV, N. A.
1936. NEW TESTS ON THE ARTIFICIAL RIPENING OF CITRUS FRUITS. Sovet. Subtrop. 1936 (10): 69–70. [Not seen; abstract in Chem. Abs. v. 32, column 2238. 1938.]

GRADING

The grading of citrus fruit is, of course, important to the whole citrus industry. However, not much has been seen in the literature dealing specifically with the subject. Nedvidek (*1*)[11] in 1948, in discussing the handling of fruit at processing plants, emphasized the need of (1) more care in the loading and unloading of trucks—it is especially desirable to avoid shoveling the fruit whenever possible and to keep workers from walking on top of the load when covering or uncovering it with a heavy canvas tarpaulin—and (2) careful grading to remove defective fruits before processing begins. The same care is equally or more important in handling fruit for fresh consumption. The author wrote (*p. 91*):

> With a fairly firm fruit the average visible waste from crushing alone is 10 percent. In addition 10 to 15 percent is internally crushed resulting altogether in a 25 percent loss in juice yield, and is one of the chief factors contributing to the loss in flavor and keeping quality of the final products.

Lots containing too many internally crushed fruits are suitable only for the peel plant.

In a discussion of the picking, washing, grading, and packing of lemons, Nixon (*2*) in 1940 commented on the need for separating lemons into grades according to color, elimination of all fruit showing unhealed injuries, avoidance of irregular sizing, and avoiding the shipment of lemons that are lacking in juice.

Rutherford (*3*) in 1947 described the construction and operation of a mechanical device for automatically taking samples of lemons at regular intervals as they pass over a 100-roller elevator after leaving the washer. The samples are carried by a conveyer to a small 4-bin roller sizer that sorts the lemons into large, medium, small, and lemonette sizes. After segregation for color the fruit is stored for a period and then graded for quality. The weight of each grade is then taken and divided by the total weight of all grades to get the percentage of each grade in the entire lot. By these means it is possible to determine accurately and quickly the grade of the grower's fruit on which payment is made. What is apparently the same device or a very similar one was also described by Thym and Smith (*4*) in 1948. Something of the sort is also in use in some packing houses and processing plants in Florida.

LITERATURE CITED FOR GRADING

(1) Nedvidek, R. D.
1948. BETTER ORANGE PRODUCTS THROUGH IMPROVED FRUIT HANDLING. Calif. Citrog. 33: 90–91, illus.

(2) Nixon, H. W.
1940. LEMONS. PICKING—WASHING—GRADING—PACKING. Calif. Citrog. 25: 101, 114–116, illus.

(3) Rutherford, D. M.
1947. GADGET REMOVES GRADING GRIPES. Calif. Citrog. 32: 164–166, illus.

(4) Thym, A. M., and Smith, R. J.
1948. A MECHANICAL SAMPLER FOR LEMONS. Calif. Citrog. 33: 423, 434, illus.

[11] Italic numbers in parentheses refer to Literature Cited for Grading.

PACKAGING AND PACKING

For many years the standard package for citrus fruits was the nailed wooden crate with a partition. The capacity of the crates was slightly different in different States, but the construction and weight of material used were much the same. In 1934 wire-bound crates without the partition (Bruce boxes) began to be used in Florida. Winston (*14*)[12] stated in 1950 that they have gained great popularity in Florida. They have also been introduced into Texas. Bruce boxes were used to some extent in California during World War II, but their use has been discontinued.

Other changes have occurred. Ryall (*10*), commenting in 1947 on citrus packaging in Texas, noted a shift from standard crates to consumer packages, wire-bound crates, and gift packages. In consumer packages the preference seemed to be for 4- to 5-pound packages rather than for the 8- to 10-pound size. Of the 41,589,859 boxes of Florida citrus fruit shipped as fresh fruit in the 1946–47 season, approximately 10 percent were shipped in consumer-size containers; most of the oranges were packed in 8-pound mesh bags (*2*). During the 1948–49 shipping season, large numbers of 5-pound bags were seen on the markets.

In 1942 Stahl and Vaughan (*12*) reported the results of tests conducted with Pliofilm as a means of preserving Florida fruits and vegetables. They stated that this material reduced loss of weight from citrus fruits without restricting the escape of gas produced by their respiration. Texture and flavor of wrapped fruit (round oranges, mandarin oranges, grapefruit, limes, and kumquats) were well maintained during the period of observation. The original color of the stem button (green) and of the rind was maintained in accordance with the preservation of other characteristics of quality. Pitting occurred on all unwrapped fruit held under refrigeration, but was almost totally absent on Pliofilm-wrapped fruit. This finding is particularly important for grapefruit and limes because control of pitting considerably lengthens their storage life. No significant difference in decay was found between wrapped and unwrapped fruit until the latter became more subject to attack by molds. At all temperatures the flavor of wrapped fruit was superior to that of unwrapped fruit.

Winston (*14*) stated in 1950 that in the Gulf States moisture-proof wrappers such as Pliofilm, cellophane, and aluminum foil are used to a limited extent, mainly to reduce loss in weight through evaporation. If too much moisture is retained inside the wrapper, however, surface mold and decay may be more than when ordinary sulfite-tissue wrappers are used.

Van der Plank and Rattray (*8*) stated in 1940 that use of oiled-paper wrappers caused only a small reduction in shrinkage of

[12] Italic numbers in parentheses refer to Literature Cited for Packaging and Packing, p. 29.

oranges. The same authors (*7*) reported, however, that in the case of grapefruit crystalline-paper wrappers appreciably increased the total quantity of juice extractable after storage and that freshness and turgidity were preserved by the use of waxed crystalline-paper box liners. Van der Plank, Rattray, and Crous (*9*) reported that, although box liners preserved turgidity of lemons, they caused an increase in waste from green mold and shriveling and from molding and dropping off of the buttons.

In 1948 Nedvidek, Baker, and Waldafel (*6*) stated that the chief problem in the prepackaging (or repackaging) of lemons is how to prevent accumulation of moisture inside the container. This moisture leads to decay, which, together with anaerobic break-down in heat-sealed packages, makes it difficult to keep the packages attractive and desirable to consumers. They concluded that the only solution at present seems to be the use of bags of porous material or perforated bags.

Comments have been made by a few authors on problems that arise during the packing of citrus fruits.

Clark and Stearns (*4*) reported in 1941 that "puffy" tangerines should be handled as little as possible. Simply washing with soap and water and drying on a roller conveyor appears to be the best method of handling such fruit. The machinery used should be such that it will cause only a minimum of mechanical injury. Waxing seemed to have no effect.

McClelland (*5*) in 1938 discussed the part played by light, color, and eyes in packing-house grading, with special reference to the grading of citrus fruits. He pointed out that in a packing house consideration must be given to avoiding color contrasts that produce eye strain, to preventing glare from outside windows, and to examining and studying prospective sorters in order to obtain operators adapted to sorting operations.

In 1941 in an unsigned article (*1, p. 48*) it was reported that J. M. Tinley, in investigating operations in California lemon packing houses, found that—

> factors influencing returns between different organizations [lie] in the efficiency of management, quality of fruit handled, amount of fruit shipped for fresh fruit consumption, amount of fruit decayed, and the area or district in which a house operates.

Tinley concluded that there is no relation between the size of a packing house and its unit cost of handling lemons.

Wager (*13*) in 1948 stated that in Australia, because of scarcity of labor, many growers do a large part of the work in their groves themselves, but that very few pick their own fruit. Most of the fruit is delivered to or collected by the packing house. Field boxes are of rough-hewn lumber with splinters and projecting nails that are very likely to injure the fruit. Bushel boxes of rough-hewn lumber holding 50 pounds of fruit are used for shipment. The fruit is not wrapped except for export. The fruit passes through a bath, which contains no sterilizing agent. Loss from mold and decay is said to be heavy, probably because of the use of rough field boxes and failure to use chemically treated wrappers and an antiseptic in the wash water.

Mention should be made of two papers that appeared in 1938 on the possibility of injury to the skin of pickers and packers of citrus fruit. Schwartz (*11*) reported that, in all processes used in orchards and factories in Florida and California, citrus oils and juices were the chief causes of dermatitis and that d-limonene was the most irritating chemical. No eczemas were found that were attributable to dyes, waxes, or insecticides.

Beerman, Fondé, and Callaway (*3*) stated that dermatitis caused by citrus fruits is of four kinds: true allergies; reactions (specific or allergic) caused by yeast or other parasitic contaminants; the allergic reactions caused by dyes or preservative contaminants; and pseudoallergic reactions, probably due to some other causes than citrus fruits. They also stated that it has been found that oil from lemon peel may be a primary cutaneous irritant.

It does not appear, however, that dermatitis from handling citrus fruits is considered of much importance, because the only papers dealing with it that have been seen are the two cited above.

LITERATURE CITED FOR PACKAGING AND PACKING

(1) Anonymous.
1941. WHEN IS A PACKING HOUSE EFFICIENT? STUDY OF LEMON ASSOCIATIONS SHOWS SIZE OF OPERATION IS NOT DETERMINING FACTOR. Calif. Citrog. 27: 48–49. (Résumé of preliminary report [oral] by J. M. Tinley before citrus institute.)

(2) ———
1948. CONSUMER PACKAGING OF CITRUS. Citrus Mag. 10 (7): 5. (Reprinted from Pre-Pack-Age.)

(3) Beerman, H., Fondé, G. H., and Callaway, J. L.
1938. CITRUS FRUIT DERMATOSES. Arch. Dermat. and Syph. 38: [225]–234.

(4) Clark, C. K., and Stearns, C. R., Jr.
1942. "PUFFY" TANGERINES IN THE PACKING HOUSE PROCESS. Fla. State Hort. Soc. Proc. (1941) 54: 45–52.

(5) McClelland, G. L.
1938. PARTS PLAYED BY LIGHT, COLOR AND EYES IN PACKING HOUSE GRADING. Calif. Citrog. 23: 195, illus.

(6) Nedvidek, R. D., Baker, J. L., and Waldafel, C. J.
1948. PREPACKAGED LEMONS. Calif. Citrog. 33: 310–312.

(7) Plank, J. E. van der, and Rattray, J. M.
1940. THE EFFECT OF TEMPERATURES OF STORAGE FROM 40° TO 70° F. ON MARSH GRAPEFRUIT. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Ann. Rpt. 1938–39: 103–110.

(8) ——— and Rattray, J. M.
1940. THE EFFECT OF LIGHTLY OILED CITRUS WRAPS ON THE BEHAVIOUR OF ORANGES IN STORE. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Ann. Rpt. 1938–39: 122–124.

(9) ——— Rattray, J. M., and Crous, P. A.
1940. THE STORAGE OF LEMONS. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Ann. Rpt. 1938–39: 110–122.

(10) Ryall, A. L.
1947. PACKAGING, TRANSPORTING AND STORING TEXAS CITRUS. Tex. Farming and Citric. 23 (7): 10, 12–13.

(11) Schwartz, L.
1938. CUTANEOUS HAZARDS IN THE CITRUS FRUIT INDUSTRY. Arch. Dermat. and Syph. 37: [631]–649, illus.

(12) Stahl, A. L., and Vaughan, P. J.
1942. PLIOFILM IN THE PRESERVATION OF FLORIDA FRUITS AND VEGETABLES. Fla. Agr. Expt. Sta. Bul. 369, 92 pp., illus.

(13) Wager, V. A.
1948. THE CITRUS INDUSTRY IN AUSTRALIA. Citrus Grower [So. Africa] No. 173, pp. 3, 5–7.

(14) Winston, J. R.
1950. HARVESTING AND HANDLING CITRUS FRUITS IN THE GULF STATES. U. S. Dept. Agr. Farmers' Bul. 1763, 67 pp., illus. (Revised.)

STORAGE

Growers and shippers of citrus fruits in all producing regions have long been interested in the possibility of storing these fruits to avoid market gluts and to prolong the marketing season. Published reports differ somewhat as to the temperatures desirable for the storage of different kinds of citrus and the possible length of the storage periods. The differences noted may be due partly to the maturity of the fruit stored and partly to inherent differences in the storage behavior of fruits grown in different countries or in different parts of the same country. The storage behavior of various citrus fruits is discussed separately so far as possible. However, before this is done it is desirable to review papers that discuss factors other than temperature that are important in citrus storage.

RESPIRATION AND OTHER PHYSIOLOGICAL PROCESSES

In 1937 Addington (*4*),[13] writing on the air-conditioning problems of the citrus industry, stated that in rooms used for the conditioning or storage of citrus fruit, the fruit is kept continuously in a specially prepared atmosphere from the time of delivery to the packing house until it is unloaded at the terminal. Oranges are treated with ethylene in coloring rooms maintained at 70° to 80° F. and 85 to 90 percent relative humidity. Carbon dioxide must not exceed 2 percent by volume and preferably should be kept to 1 percent. The coloring process requires 36 to 72 hours.

Brooks (*11*) in 1940 in a review of work on modified atmospheres for fruits and vegetables reported that storage of citrus fruit in such atmospheres had not given much promise. Failures in the gas storage of citrus fruits have been reported from Great Britain, Australia, Palestine, and Trinidad. Brooks and McColloch (*13*) reported in 1936 that exposing grapefruit for 20 to 48 hours to atmospheres containing 20 to 45 percent of carbon dioxide before storing at low temperature caused a decrease in the later development of pitting and did not have an unfavorable effect on flavor. Pitting and membranous stain were reduced in similar tests with lemons. Brooks, Bratley, and McColloch (*12*) in 1936 reported that prestorage carbon dioxide treatments are of significant value in the control of orange and grapefruit decay in storage. Samisch (*63*) in 1936 concluded from his investigation that gas storage of oranges would be of only minor practical importance in preserving the fruit. Hall (*19*) in Australia reported in 1938 that gas storage was not useful for oranges.

Leonard and Wardlaw (*31*) stated in 1937 that accumulation of carbon dioxide in the storage atmosphere was accompanied by an increase in the concentration of carbon dioxide in the fruit.

---

[13] Italic numbers in parentheses refer to Literature Cited for Storage, p. 47.

Huelin (*26*) in Australia stated in 1942 that, if ventilation is restricted and carbon dioxide accumulates until there is a concentration of 5 percent or more, stored oranges are likely to acquire an off-flavor. Stahl and Cain (*67*) in 1937 reported that treatment of Hamlin oranges with carbon dioxide showed that a 75 to 80 percent concentration of the gas for 1 week before storage reduced decay 75 percent during the first month of storage. They also stated that small amounts of carbon dioxide in the storage room reduced pitting. No reduction in percentage of decay was found during the second and third months. Twenty to 30 percent of carbon dioxide for 18 days reduced decay by 50 percent for 3 months. Treatments of Valencia oranges with paradichlorobenzene vapor before storage reduced decay in storage but caused soggy break-down to appear too early in the storage period. For best results in storage the storage atmosphere should not contain more than 6 percent of carbon dioxide or 12 percent of oxygen. High humidity was found best for citrus fruits in storage. Washing the fruits before storage decreased their storage quality.

In 1948 Hendrickson and MacRill (*24*) recommended that the concentration of carbon dioxide in citrus storage rooms be kept low (not higher than 0.2 percent and preferably about 0.1 percent). This was accomplished by means of adequate ventilation and air circulation. Two types of air-distributing systems were described. A technical discussion of the equipment needed and sample calculations of the refrigeration load involved under each system were included.

Harvey (*23*) in 1946 stated that, according to his results, not enough carbon dioxide accumulates in common storage to injure lemons, but other emanations of molds and of the lemons themselves may become injurious to lemons during long storage.

In 1945 Baier (*5*) discussed the principles of ventilation for lemon storage rooms and an instrument used in California for determining the carbon dioxide content in such rooms. He wrote that the purpose of ventilation as understood at present is to supply oxygen for use in respiration by the fruit, to remove products of fruit respiration, including ethylene, that accelerate color changes, and to remove carbon dioxide. He stated that carbon dioxide is not harmful, at least in low concentration, but the quantity found at a given time is a convenient measure of how well the ventilating is being done. This is the reason for using a convenient, quick-acting apparatus for measuring it.

The respiration of citrus fruit in storage, or that of any other fruit or vegetable, is important for two reasons. It produces carbon dioxide which may become harmful to the stored product if allowed to accumulate. It also releases heat, which becomes a part of the refrigeration load and which must be removed if the fruit or vegetable is to be kept cooled to the desired temperature. All citrus respiration data available to the writers of this digest were obtained from tests made with citrus fruits after they were picked. The results can therefore be considered as applicable to fruits in storage.

The importance of the respiration of one variety of citrus fruit in storage can be seen from figures published in 1949 by Rose, Wright, and Whiteman (*61*). Those figures show that the heat of respiration of a ton of Florida seedling oranges cooling from 80° to 35° F. during a period of 10 days amounts to 30,000 B. t. u., which would be enough to melt approximately 208 pounds of ice. If the refrigeration load has to be figured for say 10 carloads containing 20 tons each of such fruit, it is easy to see that to remove the heat evolved by this quantity of fruit under the conditions specified would require the meltage of about 21 tons of ice. These amounts of ice are in addition to about 56 tons required to remove the sensible, or initial, heat of the 10 cars of fruit. If the storage period is shorter, less ice will be needed; if longer, more ice will be needed.

The most complete set of figures known to the writers, for the respiration of citrus fruits, is that published by Haller and others (*20*) in 1945. They reported that the respiratory rate of oranges, grapefruit, and lemons increased greatly with increased temperature. At 32°, 40°, and 50° F. the respiratory rates remained fairly constant with time, whereas at temperatures of 70° to 110° the rates generally decreased with time. The results indicate that the respiratory activity of oranges and lemons decreases with increased maturity. Oranges from trees on sour orange rootstocks had a higher respiratory rate than those from trees on rough lemon. Ethylene added at the rate of 1 to 10,000 parts of air greatly increased the respiratory rate of all the fruits. The maximum respiratory activity was generally attained 2 to 3 days after the addition of ethylene. The rate then decreased and returned to normal after aeration of the respiration chamber. Lemons infected with green mold respired up to 12 times as fast as sound lemons. Grapefruit from trees sprayed with lead arsenate respired less rapidly than that from trees not so sprayed. Other publications on the respiration of citrus fruits were reviewed by Haller and others (*20*).

Trout, Tindale, and Huelin (*74*) in 1938 reported from Australia that respiration of oranges was greatest between 36° and 59° F. and most constant at 42°. It was greatest in the earliest picked oranges. Respiration in the rind and flesh was at the rate of 90 and 30 mg. of carbon dioxide per 10 kg. per hour, respectively.

The importance in storage rooms of vapors given off by decaying fruit was shown by Biale (*7, 8*) in 1940 and 1948. His findings are given in the subsection on lemons (p. 43).

Hopkins and Loucks (*25*) reported in 1948 that holding oranges for about 72 hours in a coloring room at 86° F. and 90 percent relative humidity (with or without ethylene) produces a marked curing effect that makes the fruit much less susceptible to decay by *Penicillium*. The results of several tests in which oranges were held at a low relative humidity indicated that the curing effect is not caused solely by a drying out of the fruit. The reason for the effect was not determined. This seems to be a "lead" that should be followed up. Curing, as practiced with lemons, might prove to be useful also for oranges and grapefruit.

In tests by Harding (*21*) in Florida in 1949, curing 1 week at 50° or 70° F. did not reduce the amount of decay resulting during

890503—51—3

1 week at 70° after storage at 32° or 38° for 8, 12, or 16 weeks. In fact, somewhat more decay developed in the cured lots. Curing at 70° did result in a slight but general decrease in storage pits and a decrease in aging.

Solarino (*66*) in 1937 reported tests for distinguishing aged and fresh citrus essential oils and juices that might prove useful during investigations on stored citrus fruit. For testing essential oils he used a solution containing 1 gm. of benzidine in 50 cc. of ethyl alcohol and 25 cc. of water. The aqueous layer of the fresh product is colored yellow to yellowish green, and that of the aged product is colored dark orange to orange red. For citrus juices he used a solution of 1 gm. of benzidine in 100 cc. of ethyl alcohol and 4 cc. glacial acetic acid. Equal volumes of juice and reagent were used. Fresh juice remained colorless, but aged juices colored the aqueous layer red to red violet. The color gradually faded in about 4 hours. Juices up to 6 months old reacted like fresh juices, but the time after which the juice began to give a coloration was not stated.

A review of literature on the physiology of citrus fruits in storage (75 titles) was published by Miller (*38*) in 1946. A digest of this review appeared in another journal also in 1946 (*37*).

COLD INJURY

Some of the investigators who have referred to "cold injury" of citrus fruit have not made clear what they mean. As is well known, cold injury may express itself in various ways. Among these are pitting, aging, brown stain, watery break-down, and actual freezing injury.

Plank (*58*) in 1938 discussed cold injury to fruit. He stated that citrus cannot be stored below 41° F. This statement is not in agreement with results reported in many of the papers reviewed later in this section. Plank reported further that tropical fruits are subject to marked cold injury at relatively high temperatures. This is well known. (See Rose, Wright, and Whiteman (*61*), 1949, and the literature cited therein.) Internal break-down is often a sign of cold injury, but its absence is not necessarily a sign of satisfactory storage. The stored fruit should also ripen normally and develop its full flavor and market value.

Van der Plank and Davies (*48*) in 1937 determined the temperature-cold-injury curves of plums, peaches, Marsh grapefruit, and navel oranges. They found that pitting of Marsh grapefruit was worse after relatively short storage at intermediate temperatures than at either 30° to 32° F. or 50° to 55°. They advanced the theory that greater injury occurs at intermediate temperatures because the development of visible manifestations of cold injury is the result of the interaction of two opposing factors:

1. An equilibrium factor. The disposition of the fruit toward injury increases as the temperature is lowered.
2. A kinetic factor. The processes within the fruit by which the visible injury develops are governed by the thermochemical rule and are retarded as the temperature is lowered.

Van der Plank (*46*) in 1938 described and discussed the different forms of cold injury of Marsh grapefruit and navel oranges and the modifying effect of varying temperatures in storage. He stated that button browning of navel oranges is a common form of cold injury of fruit stored at 39° to 45° F. and that stylar-end blotching also results from cold injury.

Gonzales (*18*), reporting in 1948, found that freezing accelerates the respiration of citrus fruits. In his experiments navel oranges and Eureka lemons frozen at 19.4° F. respired more rapidly at 32° and 77° than fruits that had not been frozen. A similar acceleration at 77° was observed for Valencia oranges. Gonzales suggested that this fact might be useful in determining whether citrus fruits have or have not been frozen. Van der Plank (*45*, *47*) reported in 1938 and 1939 that grapefruit is most susceptible to cold injury (pitting) if it is picked from the outside of the tree. In fruit stored without delay, injury developed most during the first few weeks at 40° or 45°. When fruit was stored at 40° for short periods (3 to 4 weeks) delaying storage was generally beneficial and the length of the delay was not of very great importance. With intermediate periods of storage, 1 or 2 days' delay at 80° was most beneficial and long delays were dangerous. In tests by Van der Plank and others (*53*), reported in 1938, it was found that wastage in navel oranges was not increased by exposure to 80° for 26 to 30 hours, as may happen to rail shipments, and subsequent storage at 39° for 24 to 31 days. If the storage period was long, delayed storage of any length caused very little reduction of injury.

In 1937 Bates (*6*) reported that heavy applications of potassium sulfate and magnesium sulfate had no effect on the storage quality of oranges. He obtained some evidence that fruit from groves that received liberal applications of phosphate showed most injury from cold while in storage. The least injury was shown by fruit from trees receiving a complete fertilizer.

STORAGE BEHAVIOR OF DIFFERENT FRUITS

ORANGES

Stahl and Camp (*69*) and Stahl and Fifield (*70*) in 1936 and Stahl and Cain (*67*, *68*) in 1937 and 1939 reported the results of studies on the cold storage of Florida citrus fruits. Their conclusions relative to oranges are summarized in part as follows:

Both Pineapple and Valencia oranges kept well at 32° to 37.5° F., and best at 37.5°.

Moistureproof wrappers (aluminum foils) and those made of moistureproof grades of Cellophane, Sylphrap, and Kodapak (transparent cellulose acetate products) were better than other wrappers in reducing weight loss and preserving appearance.

Loss of weight, firmness, and pitting of Florida citrus fruit in storage were markedly affected by the humidity. High humidity was the most desirable. Both taste and texture of grapefruit were adversely affected by high concentrations of oxygen and carbon dioxide in the atmosphere. Pitting was increased by oxygen and slightly decreased by nitrogen as compared with that in ordinary air. Forced-air circulation in the storage room is harmful to texture of fruit and length of its storage life. Fruit stored at 37° F. in still air containing about 6 percent of carbon dioxide and 12 percent of oxygen and high in relative humidity can be kept in good condition for 4 months. Controlled ventilation in storage houses is very desirable, to prevent accumulation of respiratory gases.

In 1947 Ryall and Buford (*62*) (see also (*3*)) reported that 38° to 40° F. was better than 32° to 34° for Texas-grown Valencia oranges. More pitting developed at 32° to 34° and the fruit deteriorated more rapidly when removed to room temperatures. The maximum storage period for oranges was about 20 weeks. The greatest single cause of damage to oranges in cold storage was aging at the stem end (around the button). Valencia oranges that were carefully selected and handled could be held in cold storage at 38° for as long as 4 months with moderate loss from decay, but more information is needed about reducing aging at the stem and about pitting.

Neither a borax dip nor treatment with nitrogen trichloride gas gave consistently reduced storage decay of oranges. Diphenyl and Alpha wraps (patented types of chemically treated wraps) reduced the average percentage of decay found at the final inspection. Valencia oranges harvested in mid-May held up as well as those harvested in mid-April. From this it was concluded that Valencia fruit for storage might be harvested even later than early May, the last date of the Texas tests.

In 1939 Bratley and Winston (*10*) stated that storage of Valencia oranges on the tree might be one way to avoid some of the problems that arise in connection with cold storage of citrus fruit. They found that the total acid content of Valencia oranges picked March 19 fell from 1.15 to 0.9 percent during the 2 months that the fruit was in transit and in storage and that the total solids remained about the same. During the same period the acid content of fruit remaining on the tree also decreased from 1.15 to 0.9 percent, but the total solids increased from 11.4 to 12.7 percent.

Rose, Wright, and Whiteman (*61*) in 1949 recommended a temperature of 34° to 38° F. for oranges held in storage for 8 to 10 weeks (usually the maximum). Within this range some decay, chiefly blue mold or green mold rot, may occur during storage of 2 months or more and some fruit may begin to show pitting or brown stain of the rind. If oranges are stored for a longer time, decay increases and the spotted fruit may turn brown over most or all of the surface. Watery break-down may develop, as in grapefruit. The recommendations of MacRill, Nedvidek, and Nixon (*34*, *35*) in 1946 for the storage of California oranges are given in table 3.

The storage and transportation of tropical fruits and vegetables were discussed by Wardlaw (*76*) in 1937. In that paper he recommended storage temperatures above 45° F. for both oranges and grapefruit, especially when long storage is required. He further stated that early cold storage, rapid cooling to the required temperature, avoidance of chilling, and thereafter the maintenance of uniform temperature and high relative humidity (88 to 92 percent) are advisable. Chilling injury, he said, is a superficial blemishing variously referred to in the literature as pitting, scald, storage spots, or pox, but now known to be due to injury by low temperatures. He quoted Fawcett (*17*), to the effect that some decay from fungus development at too high temperatures is, in most cases, probably less injurious than general spotting and breakdown from physiological derangement at too low temperatures. Wardlaw included a comprehensive review of storage temperatures recommended for citrus in 1937 in various countries. None of these were lower than 32° to 34° for oranges or above 52° to 58° for grapefruit. Most recommendations were in the range 36° to 45° for oranges and 32° for grapefruit in Florida to 50° in California.

In 1938 the work of W. J. Williams in Australia was reported (*2*). Fruit stored at 36° and 38° F. kept better than that stored at higher or lower temperatures. He recommended a relative humidity of 78 to 80 percent. Oranges dipped in a 5-percent sodium bicarbonate solution or in a 5-percent borax solution were just as susceptible to mold in storage as untreated fruit.

Van der Plank and others (*50*) in 1938 reported that skin blemishes were very prevalent in navel oranges stored 4 weeks at 35° F. and that in one instance there was a distinct off-flavor. They suggested temperatures of 39° to 40° for fruit that was fully ripe or which had a tendency to spoil and 50° to 55° for greenish or undercolored fruit or for fruit that had a tendency to blemish in storage. The same authors (*51*) reported that navel oranges kept well in storage at 50° for 2 months but became stale. Fruit stored at 39° for the same length of time was unimpaired in flavor unless it had been picked at an advanced stage of ripeness. They (*52*) also found that rapid cooling to 35° followed by storage at 45° did not increase wastage and did decrease blemishes slightly.

In 1939 Van der Plank and others (*55*) published the results of investigations on the storage of navel oranges. Button browning, pitting, and various other forms of cold injury were worst at 40° and 50° F. Hard, dark-brown areas near the bottom which resembled what is now called aging or rind break-down in the United States developed at 50°, but not at 40°. Considerable difference was found in resistance to cold injury in fruit from different parts of the Union of South Africa. In general fruit from the Transvaal was very resistant to injury even at 35°.

Trout, Tindale, and Huelin (*74*) reported in 1938 that the best storage temperature was 40° to 42° F. for navel oranges and 40° to 43° for Valencia. Sweating (degreening) treatments for 3 to 5 days at 78° to 90° and 50 to 85 percent relative humidity did not control mold development in navel oranges wounded and inoculated before storage, but it did decrease mold in the fruit inoculated after the treatments. They found that the length of the storage period during which there was no loss of palatability and the wastage from mold amounted to not more than 10 percent decreased with the advance in maturity at time of picking. Sweating increased mold wastage during storage. The loss in weight at 50 percent humidity was twice that at 85 percent. During storage at 40° and 80 percent humidity it was approximately 0.1 percent per day. Delay in picking reduced the storage life by approximately the length of the additional time the fruit was left on the tree.

In 1938 Tommasi, Beer, and Marracino (*73*) in Italy reported that an average temperature of 6° C. (42.8° F.) and a relative humidity of about 80 percent (78 to 83 percent) are most effective for the storage of mandarin oranges. Sound fruit, disinfected, wrapped in semiwaxed [14] paper, and kept for 2 months showed losses of at least 15 to 20 percent. Composition of the fruit at time of storage and after 1 month in storage is shown in the following tabulation:

Item:	*At time of storage*	*After 1 month in storage*
Specific gravity	1.0440	1.0424
Acid as citric anhydride	.94	.61
Reducing sugars before inversion	2.14	1.35
Reducing sugars after inversion	8.68	8.00
Cane sugar	6.24	6.31
Sugar-acid ratio	9.34	13.11

Hall (*19*) concluded in 1938 that the best storage temperature is 40° F. for Emperor mandarin oranges (Australia), 45° for Valencia, and 45° for early navel fruit and 40° for fruit of that type picked later. Vorotyntseva, Pokromovich, and Treisster (*75*) in 1941 in U. S. S. R. reported that in general mandarin oranges keep at 3° C. (37.4° F.) until March, oranges at 5° (41°) until the beginning of May, but at 1.5° (34.7°) the peel of oranges softens more quickly and the fruit begins to rot. Lemon peel develops spots at 3° (37.4°) but lemons can be stored until July if they are kept for 2 months at approximately 9° (48.2°) and 66 to 77 percent humidity, and then at 5° (41°) and 85 percent humidity.

Cheema, Karmarkar, and Joshi (*15*) in India reported in 1937 on storage investigations with the Nagpur orange, a loose-skinned variety of the mandarin type. They found that fully ripe yellow oranges could be kept in good condition for 3 months at 40° F. without appreciable wastage. Green and turning fruits lost some juice during storage at 45° and 52°. Discoloration at the stem end was particularly noticeable in green and turning fruits soon after they were placed in storage. Internal break-down developed in fruits of all three degrees of maturity after different periods of storage. Prestorage treatments with antiseptic solutions did not lenghen the storage life of the fruit. In regard to a later investigation of the storage of Nagpur oranges, Karmarkar and Joshi (*28*) in 1942 said that green (unripe) fruit acquired a good orange color at 50° to 52° but was not suitable for cold storage because it lost some juice during storage at all the temperatures used (35°, 40°, 45°, and 52°). Mature and yellow oranges remained in good condition for 3 months at 40° without appreciable wastage. At 40° and 52° the vitamin C content remained practically unchanged during 3 months' storage. Percentage of total sugars showed little variation in storage at 35°, 40°, and 45°. The percentage of reducing sugars increased steadily at all temperatures. Respiration of the fruit at 52° was approximately the same as that at 40°.

Singh and Hamid (*65*) in 1942 gave 36° to 39° F. as the best temperature range for the storage of citrus fruits (Malta and Sangtra, mandarin-type oranges of the Punjab, India). The storage

[14] Not explained in the report.

TABLE 3.—*Summary of recommendations for storage of oranges*

Reference	State or country	Variety or type	Treatment	Maturity	Optimum storage temperature	Relative humidity	Length of storage period	
					°F.	*Percent*	*Weeks*	*Months*
Stahl and Camp (*69*)	Florida	[1]			37.5	[2]	[3] 5–20	
Ryall and Buford (*62*)	Texas	Valencia			38–40	[1]		4
Rose, Wright, and Whiteman (*61*).	United States	[1]			34–38	85–90	8–10	
MacRill, Nedvidek, and Nixon (*34*, *35*).	California	Navel	Ethylene	Early to full	35–37	86–88	6	
		do	None	do	35–37	86–88	8	
		do	Ethylene	Full to overripe	35–37	86–88	4	
		do	None	do	35–37	86–88	5	
		Valencia	Ethylene	Early to full	35–37	86–88	6	
		do	None	do	35–37	86–88	8	
		do	Ethylene	Full	35–37	86–88	4	
		do	do	Full to overripe	35–37	86–88	4	
		do	None	do	35–37	86–88	6	
Wardlaw (*76*)	Trinidad	[1]			Above 45	88–92	6–10	
Williams (see *2*)	Australia	[1]			38	78–80	[1]	
Van der Plank and others (*55*)	Union of South Africa.	Navel			40	[1]	[3] 4	
Trout, Tindale, and Huelin (*74*).	Australia	do			40–42	[1]	12	
		Valencia			40–43	[1]	14	
Tommasi, Beer, and Marracino (*73*).	Italy	Mandarin			39.2–44.6	78–83		2
Hall (*19*)	Australia	Emperor mandarin			40	[1]	[1]	
		Valencia			45	[1]	[1]	
		Navel			40–45	[1]	[1]	
Vorotyntseva, Pokromovich, and Treisster (*75*).	U. S. S. R	Mandarin			37.4	[1]		[4]
		[1]			41	[1]		[5]
Cheema, Karmarkar, and Joshi (*15*).	India	Nagpur			40	[1]		3
Karmarkar and Joshi (*28*)	do	Nagpur mandarin			40	[1]		3
Singh and Hamid (*65*)	do	Malta mandarin			36–39	[1]		2¾–4½
		Sangtra			36–39	[1]	4–5	

[1] Not specified. [2] High. [3] About. [4] Until March. [5] Until May.

life of Malta oranges varied with variety from 4½ months for Valencia Late to 2¾ months for Musambi. Loose-skinned Sangtra from two localities remained in good condition for 4 and 5 weeks. Large fruits kept longer and in better condition than small ones. Wrapped fruits had better color and fresher appearance than unwrapped ones and also contained more juice and suffered less from decay.

In 1934 Chen (*16*) in China reported that thick-skinned mandarin and round oranges had high contents of acids and solids and good keeping qualities. Loose-skinned oranges were low in acid and the flavor became insipid after 4 months in storage. In all varieties the acid content decreased in storage, but the amount of solids varied only slightly. Soaking the fruit in 5-percent borax solution for 5 minutes immediately after picking reduced penicillium rot but caused injury at the stem and calyx ends.

A summary of the recommendations of various investigators for the storage of oranges is given in table 3.

GRAPEFRUIT

Stahl and Camp (*69*), in Florida in 1936, stated that the best temperatures for the storage of unwrapped, untreated Silver Cluster and Marsh seedless grapefruit were from 37.5° to 42° F., preferably 37.5°.

In 1936 Stahl and Fifield (*70*) reported from Florida that moistureproof wrappers (aluminum foils and moistureproof grades of Cellophane, Sylphrap, and Kodapak) were better than other wrappers in reducing loss of weight and preserving appearance of both grapefruit and oranges. For statements by Stahl and Cain (*67*, *68*) on the effect of storage atmospheres on grapefruit and oranges, see page 35 of this digest.

In 1940 Martin, Hilgeman, and Smith (*36*) reported that waxed and carefully handled Arizona-grown grapefruit can be stored for at least 3 months at 60° F. and 88 percent relative humidity if it is harvested before the spring flush of growth and bloom in April. If it is picked after that time, its storage life becomes increasingly short. This seems to be associated with decreases in total solids and citric acid.

In Texas in 1947 Ryall and Buford (*62*) (see also (*3*)) reported that 46° to 50° F. was better than 32° to 34° or 38° to 40° for storage of grapefruit. Storage pitting was worse on grapefruit at 38° to 40°. The maximum storage period for grapefruit was 1 to 2 months. So far as pitting was concerned, the first picking of grapefruit held up better in storage than the second picking. The first and second pickings generally showed about the same amount of decay in storage, but the fruit from the second picking stored at 32° showed more decay than the fruit from the first picking stored at the same temperature. The difference was thought to be due to break-down and increased susceptibility of fruit of the second picking at the low temperature. The authors concluded that there does not appear to be much promise for storing grapefruit into the summer. After 8 to 9 weeks' storage fruits of the first picking showed the lowest percentage of pitting at 46° to 50°, the highest percentage at 38° to 40°, and an intermediate amount at 32° to 34°. Most of the pitting found at 46° to 50° was of the mild type (less than 15 percent of the fruit surface affected), whereas at the lower temperatures a large proportion of the fruits were affected with moderate to severe pitting. Decay was least at 46° to 50°. Aging around the stem was found at all temperatures, but it seemed to be more prevalent in fruit stored at 50°. Treatment with hot borax solution, nitrogen trichloride gas, or a combination of the two decreased decay during the 8 to 9 weeks' storage.

In 1948 Hendrickson and MacRill (*24*) reported on methods used in California and Arizona for the storage of grapefruit. They stated that the most desirable storage temperature for grapefruit produced in the States named is in the range from 58° to 60° F. Grapefruit from districts where stem-end rot is common should be stored at 32° to 34° and even then for only short periods. The authors recommended a relative humidity of 86 to 88 percent. The same subject was covered in 1946 in much the same way by MacRill, Nedvidek, and Nixon (*34, 35*).

In 1937 Wardlaw (*76*) reported from Trinidad that loss from decay during storage was increased by treating grapefruit with borax. In the same year Leonard and Wardlaw (*31*) reported that prolonged cold storage of grapefruit caused a marked loss of flavor but only a slight change in the sugar content and titratable acidity of the expressed juice. Decay in storage was favored by relatively low concentrations of carbon dioxide in the atmosphere. Wardlaw and Leonard (*77*) reported in 1939 that in the British West Indies the chilling temperature for wet-season fruit is very close to 45° F., the temperature then used for storage. It was found inadvisable to use air at 40° for rapid cooling for more than the first 12 to 15 hours.

Van der Plank and others (*54*) in 1938 reported that temperatures of 50° to 55° F. are necessary for complete insurance against cold injury. During the early part of the season these temperatures were beneficial with respect to flavor and texture. Van der Plank and Rattray (*49*) in a 1940 report showed that grapefruit of good keeping quality had very little decay even when stored at 60° F. in boxes lined with waxed crystalline [15] paper. Slight but inconsistent changes in the percentage of soluble solids in the juice were found during storage at 40°. At higher temperatures the ratio of soluble solids to acid decreased slightly during storage. The percentage of juice extractable with a hand reamer increased in storage; it was small at 40° and greatest at 60°.

In Australia, Hall (*19*) reported in 1938 that grapefruit is particularly susceptible to storage spot and keeps best at higher temperatures than are desirable for oranges. Fungus wastage and decay were least in the early-picked fruit, but such fruit was more susceptible to storage spot than the fruit of later pickings.

Tindale (*71, 72*) in 1944 and 1945 reported that all skin disorders of Australian grapefruit were prevented by storing at 55° F. The use of certain skin coating treatments overcame shriveling. After

[15] Not explained in the report.

TABLE 4.—*Summary of recommendations for storage of grapefruit*

Reference	State or country	Variety or type	Optimum storage temperature	Relative humidity	Length of storage period	
					Weeks	*Months*
			°*F.*	*Percent*		
Stahl and Camp (*69*)	Florida	Silver Cluster and Marsh seedless.	37.5	([1])		1–2
Martin, Hilgeman, and Smith (*36*)	Arizona	([1])	60	88		3
Ryall and Buford (*62*)	Texas	([1])	46–50	([1])		1–2
Hendrickson and MacRill (*24*)	California and Arizona.	([1])	58–60	86–88		1–3
Rose, Wright, and Whiteman (*61*)	United States	([1])	[2] 32–34	85–90	[3] 6	
			[4] 45–55	85–90	[3] 6	
Van der Plank and Rattray (*49*)	Union of South Africa	Marsh	50–55	([1])		[5] 1
Tindale (*71, 72*)	Australia		55	([1])		[6] 3

[1] Not specified.
[2] Fruit from areas where stem-end rot occurs.
[3] Maximum.
[4] Fruit from areas where stem-end rot does not occur.
[5] Approximately.
[6] Or slightly longer.

3 months' storage the fruit was very juicy and the flavor excellent. Decay was extremely high in untreated fruit. The author suggested that the addition of a fungicide to the skin coating might greatly reduce loss from decay during storage.

A summary of the recommendations of various investigators for the storage of grapefruit is given in table 4.

LEMONS

The storage of lemons in California and Arizona presents special problems that are not encountered in that of other citrus fruits grown in those States. For one thing, the lemon crop, or a large part of it, has to be stored, sometimes for 3 or 4 months or even longer. The reason is that the heaviest pickings are made in winter and early spring whereas the best market demand comes when hot weather prevails in the Eastern and Southern States. (See Nixon (*44*).) As Fawcett (*17, p. 588*) pointed out in 1936:

> This [delay] gives time for the appearance of a number of additional kinds of breakdown and decay that require longer periods for their development or that depend upon age and weakness of the fruit.

Consequently, it came about that the lemon-growing industry was forced to study the whole general problem in order to determine what treatments and storage conditions are necessary if lemons are to be stored satisfactorily for 3 or 4 months or longer. During this study, which has extended over many years, the lemon industry has had to consider the question of what temperature and humidity are best. It has also determined very definitely about the need for curing and the ways in which curing should be done.

In California the curing of lemons in storage is an indispensable part of the process of preparing them for market. The earliest discussion of curing that has been seen is in a bulletin of the Bureau of Plant Industry, United States Department of Agriculture, by Sievers and True (*64*), published in 1912. In that bulletin the authors stated (*p. 38*):

> The forced curing or sweating of lemons as at present practiced consists in subjecting the green fruit to heat and humidity in closely confined inclosures until the desired yellow color is produced, the time required ranging from 5 to 14 days.

In the process most commonly in use in 1912, the fruit was placed in tents in the packing house, without excessive heat or humidity; 30 to 60 days was required to bring the fruit to a marketable condition. Sievers and True found that heat and humidity were of minor importance in the coloring of lemons and that it was the fumes given off by oil stoves that produced the desired effect. It was unknown then, of course, that ethylene was the effective coloring agent in the gaseous combustion products of oil stoves and in the exhaust products of gasoline-burning motors, which some California operators were using at the time the bulletin was published. The authors (*p. 12*) found that "the rind of . . . green lemons is markedly thicker than that of cured, sweated, or tree-ripe fruits," because of rapid evaporation of water from the rind during the forced-curing process. They also found that forced-cured (sweated) lemons are equal to tree-ripe fruits and fruits cured by the ordinary kind of storage then in use, both in the volume and in percentage of juice obtainable.

In 1940 Nixon (*44*) made the statement that curing (forced curing as understood by Sievers and True) is distinctly a California practice, but Williams (*78, 79*) in 1946 reported that in Australia, after grading, culling, washing, and drying, the lemons are wrapped in sulfite paper and placed in shallow trays in a cool place to remove moisture from the rind (that is, to cure them). Nixon stated that in Italy and Spain (both heavy-producing countries) lemons are shipped fresh or shortly after being picked. As far back as 1939 Hyatt and Keys (*27*) discussed the curing of lemons in New Zealand. They stated (*p. 319B*):

> The term "curing" as applied to New Zealand lemons appears to involve both (*a*) physical and (*b*) physiological processes: (*a*) Thinning and toughening of the skin occurs, so that it loses its turgescence and becomes pliable, meanwhile losing its greenness and acquiring the characteristic lemon color; (*b*) the interior of the fruit becomes clear, juicy, and of mature flavour.

So far as the writers are aware, that statement describes what happens in the curing of lemons as it is practiced in California. Cured lemons are more resistant to mechanical injury and attack by organisms than uncured lemons and they have better internal color and quality of juice.

The changes described by Hyatt and Keys are affected by temperature, humidity, and various other factors. These authors recommended as standard conditions for lemon curing a temperature of 70° F. and a relative humidity of 90 percent with ethylene gas at 1 part in 30,000 for the first 7 days. Under these conditions, depending on the fruit being treated, curing should be adequate in 4 to 6 weeks. Curing at higher temperatures is more rapid but more likely to cause increased wastage. Humidities of 70 percent and lower cause the fruit to soften and to deteriorate in appearance. Sievers and True (*64*) found that forced curing could be accomplished in 5 to 14 days. A résumé of developments in the use of ethylene in this and other countries for coloring fruits and vegetables was published by Miller (*39*) in 1947.

MacRill (*32, p. 121*) in 1940 stated:

> There is nothing gained by holding fruit in California in atmospheres nearly saturated with moisture, allowing little or no curing of the rind, and then shipping the fruit to auction or private sale markets in a ventilated car.

Shrinkage of such fruit shipped under these conditions is rapid and results in such a loose pack that the fruit rattles in the boxes on arrival on the market. MacRill (*p. 121*) continued: "It is advisable to take the normal shrinkage in California, improve the ap-appearance of the package, and make the increased juice content available. Above all, cure the rind." He reported that the best temperature for storing lemons is 58° F. Low and fluctuating temperatures produce high color and bronzing, and temperatures below 50° cause membranous stain. Temperatures above 58° are favorable to decay organisms. A relative humidity of 86 to 88 percent usually seems desirable for curing, but in some sections 80 percent would be more nearly ideal. Ventilation is necessary to remove dust, mold spores, and the products of respiration. The latter were believed in 1940 to be largely the cause of the aging of the fruit and the blackening of the buttons and to create the conditions favorable to the development of alternaria rot. Air circulation is needed to maintain uniform conditions in the storage room. In reference to the need for curing, the author pointed out that the rate of shrinkage of uncured fruit while on the way to market is likely to be high.

In 1948 MacRill (*33, p. 16*) reported from the results of storage tests with several varieties and strains of lemons grown in southern California: "The greater production, returns, appearance and keeping quality of the Prior strain Lisbon was outstanding and is a factor to consider." In these tests he used a temperature of 58° to 60° F. and a relative humidity of 88 percent; the fruit was held for a period that might be considered its maximum life. The storage lots were rated on the percentage they showed of (1) blue and green mold rots and miscellaneous decay; (2) visible alternaria rot; (3) alternaria rot on cutting; and (4) green buttons. Hendrickson and MacRill (*24*) in 1948 recommended, especially for California and Arizona, that lemons be stored at a temperature of 58° to 60° and a relative humidity of 84 to 88 percent. MacRill, Nedvidek, and Nixon (*34, 35*) made similar recommendations.

Brooks and McColloch (*14*) in 1937 (see also (*1*)) stated that the darkening of the membrane between the segments of the flesh (membranous stain) is a common fault of lemons stored at about 40° F. Increasing the carbon dioxide in the storage atmosphere, waxing the fruit, or the use of oiled wrappers tended to prevent membranous stain. Fawcett (*17*) in 1936 stated that this discoloration may occur in storage at temperatures below 55°. Miller and Schomer (*40, 41*) in 1939 reported that they found no relationship between sugar, acid, glucosides, acetaldehyde, and reductase activity and the incidence of physiological disorders except in the case of reductase. Low reductase activity (rate of reduction of a standard potassium permanganate solution) was shown by the peel of fruits stored at temperatures of 40°, 36°, and 32°, which are most conducive to pitting.

In the work of Harvey (*23*), published in 1946, it was shown that air circulation cannot be substituted for ventilation as ordinarily provided in common storage. Not enough carbon dioxide accumulates in common storage to injure lemons, but other emanations of molds and of the lemons themselves can easily become injurious to lemons during long storage. The percentage of buttons that are green and their rate of change from one color class to another afford a practical means of predicting the maximum safe period for holding a given lot of lemons. The first external sign of alternaria decay seldom indicated that more than 1 percent of the lemons were affected. When at least 2 percent of the lemons showed externally visible symptoms of alternaria decay, the lot was considered to have reached the "decay break," or a stage of increased susceptibility to *Alternaria* that made further holding very hazardous. Lemons picked in midwinter had the best storage quality.

Biale and Young (*9*) reported in 1947 that the longest storage life and the least loss from fungus or physiological disorders were attained at 5 percent oxygen in the atmosphere. The critical oxygen concentration for lemons, that is, the concentration below which the respiration rate dropped and above which it rose, was within the range from 0.5 to 5.0 percent. Biale (*7*) in 1940 reported that the vapors of 1 lemon affected with green mold increase the rate of respiration of 50 to 60 green lemons by 50 to 100 percent over that of lemons not exposed to the mold emanations. These effects are produced very slightly or not at all by blue mold, sour rot, or cottony rot. The harmful vapors can be readily absorbed from the air by passing it through a bromine solution. Activated charcoal treated with bromine is also highly effective.

Rohrbaugh and MacRill (*60*) in 1943 reported the effects of ethylene on lemons. These effects were of the same kind as those noted by Biale. Rohrbaugh (*59*) in 1943 described a method of using pea seedlings to detect small concentrations of ethylene in the exhaust fumes of automobiles and in fruit storage rooms. He found the concentration of ethylene necessary to cause noticeable epinasty (distortion) of pea seedlings or lemons to change color to be between 1 part in 40 million and 1 part in 20 million parts of air. The phenomenon of epinasty caused by ethylene was known, however, prior to the appearance of Rohrbaugh's report in 1943.

Miller, Winston, and Fisher (*42*) in 1940 stated that the production of epinasty in test plants such as potato and tomato is generally conceded to indicate the presence of ethylene in the emanations from plant tissue. They found that epinasty was produced in tomato or potato plants when these were held in the presence of oranges, tangerines, limes, lemons, and grapefruit. Still earlier than this, and fundamental to the whole practical problem, was the discovery by Neljubow (*43*), reported in 1901, that ethylene produces horizontal bending in the young stems of garden-pea seedlings in concentrations as low as 1 part per million of air. Somewhat later, in 1910 and 1913, respectively, papers were published by Knight, Rose, and Crocker (*30*) on the use of sweet-pea seedlings to detect the presence of ethylene in greenhouses and by Knight and Crocker (*29*) on the detection of ethylene in smoke. Harvey (*22*) in 1913 said that castor-bean seedlings could be used to show the presence of ethylene in laboratory air.

The practical significance of the facts brought out concerning epinasty, ethylene, and respiration in the storage of lemons is that while ethylene is useful for hastening the coloration of lemons it can be used to excess or for too long a time. Too much ethylene or too long exposure accelerates respiration and shortens the storage life of the fruit. Epinasty of pea seedlings can be used to detect ethylene when and where it is not desired.

The work of Hyatt and Keys (*27*) in New Zealand on the curing of lemons has already been mentioned (p. 44). These authors also found that, starting from the green or silver stage, curing lemons for 4 to 6 weeks results in an average 25-percent decrease in peel thickness, a 25- to 35-percent increase in juice percentage, and a 10- to 15-percent increase in total yield of juice (juice per lemon) as well as increases in citric acid, vitamin C (increased from 48 to 55 mg. per 100 cc.), total solids, and specific gravity. These changes were accelerated and satisfactory color was produced by the gassing treatment. For the first week of this treatment a temperature of 70° F. and a relative humidity of 90 percent were recommended.

Van der Plank and others (*57*) in 1939 reported that lemons picked moderately green developed more extractable juice, soluble solids, and acid if stored at about 50° F. Van der Plank, Rattray, and Crous (*56*) reported in 1940 that on a percentage basis there was an increase in the juice of lemons during storage, the increase being greater as the storage temperature was increased from 40° to 70°. Generally, though not always, there was an increase in soluble solids and acid. Gains in total soluble solids and acid accompanied gains in extractable juice. Temperatures as low as 40° retarded lemon decay slightly in storage. Fruit that had been stored at 40° decayed slightly faster when removed to warmer temperatures than that stored continuously at higher temperatures. Maturity at time of picking greatly affected decay in storage, the riper fruit being most susceptible. Coloring in storage was slow at 40° but increased rapidly with rising temperature to a maximum at about 60°. Curing and the increase of juice, etc. were rapid at higher temperatures and, like coloring, reached a maximum at about 60°.

LITERATURE CITED FOR STORAGE

(1) Anonymous.
1938. LEMONS IN [COLD] STORAGE. EFFECT OF CO_2 UPON DISEASE AND WASTAGE. Ice and Cold Storage 41: 152. (Review of Brooks and McColloch (*14*).)

(2) ———
1938. COLD STORAGE OF ORANGES. FACTORS AFFECTING ROT AND DECAY. Ice and Cold Storage 41: 203. (Reports work of W. J. Williams, Sydney, Australia.)

(3) ———
1947. EFFECT OF COLD STORAGE ON TEXAS GRAPEFRUIT AND VALENCIA ORANGES. Tex. Farming and Citric. 24 (4): 7. (Reviews work of A. L. Ryall.)

(4) Addington, H. B.
1937. AIR CONDITIONING PROBLEMS IN THE CITRUS FRUIT INDUSTRY. Heating and Ventilating 34 (12): 53-56, illus.

(5) Baier, W. E.
1945. HOW THE CITRUS INDUSTRY MEASURES IT. IV. LEMON STORAGE VENTILATION. Calif. Citrog. 30: 306, 318, illus.

(6) Bates, G. R.
1937. REPORT OF THE PLANT PATHOLOGIST FOR THE YEAR ENDING DECEMBER 31, 1936. Brit. So. Africa Co., Mazoe Citrus Expt. Sta., Ann. Rpt. 1936: 157–167. [Not seen; abstract in Chem. Abs. v. 34, column 6004. 1940.]

(7) Biale, J. B.
1940. EFFECT OF EMANATIONS FROM SEVERAL SPECIES OF FUNGI ON RESPIRATION AND COLOR DEVELOPMENT OF CITRUS FRUITS. Science 91: 458–459.

(8) ———
1948. RESPIRATION OF CITRUS FRUITS IN RELATION TO METABOLISM OF FUNGI. II EFFECTS OF EMANATIONS OF PENICILLIUM DIGITATUM, SACC. ON LEMONS AT DIFFERENT STAGES OF RIPENESS. Amer. Soc. Hort. Sci. Proc. 52: 187–191, illus.

(9) ——— and Young, R. E.
1947. CRITICAL OXYGEN CONCENTRATIONS FOR THE RESPIRATION OF LEMONS. Amer. Jour. Bot. 34: 301–309, illus.

(10) Bratley, C. O., and Winston, J. R.
1939. COLD STORAGE VERSUS TREE STORAGE OF VALENCIA ORANGES. Citrus Indus. 20 (2): 8–9, 15, 22, illus.

(11) Brooks, C.
1940. modified atmospheres for fruits and vegetables in storage and in transit. Refrig. Engin. 40: 233–237.
(12) ——— Bratley, C. O., and McColloch, L. P.
1936. transit and storage diseases of fruits and vegetables as affected by initial carbon dioxide treatments. U. S. Dept. Agr. Tech. Bul. 519, 24 pp., illus.
(13) ——— and McColloch, L. P.
1936. some storage diseases of grapefruit. Jour. Agr. Res. 52: 319–351, illus.
(14) ——— and McColloch, L. P.
1937. some effects of storage conditions on certain diseases of lemons. Jour. Agr. Res. 55: 795–809, illus.
(15) Cheema, G. S., Karmarkar, D. V., and Joshi, B. M.
1937. the cold storage of nagpur oranges (citrus aurantium). Indian Jour. Agr. Sci. 7: 168–175.
(16) Chen, S. H.
1934. storage of citrus fruits. Nanking Univ. Col. Agr. and Forestry, Bul. 28, 27 pp. [Not seen; abstract in Chem. Abs. v. 34, column 4478. 1940.]
(17) Fawcett, H. S.
1936. citrus diseases and their control. Ed. 2, 656 pp., illus. New York and London.
(18) Gonzales, L. G.
1948. effects of freezing on the respiration rate of oranges and lemons. Amer. Soc. Hort. Sci. Proc. 51: 132–136, illus.
(19) Hall, E. G.
1938. the storage of oranges. Agr. Gaz. N. S. Wales 49: 558, 618–620, 667–668.
(20) Haller, M. H., Rose, D. H., Lutz, J. M., and Harding, P. L.
1945. respiration of citrus fruits after harvest. Jour. Agr. Res. 71: 327–359, illus.
(21) Harding, P. L. [16]
1949. storage of florida oranges. orlando, florida—1949. U. S. Bur. Plant Indus., Soils, and Agr. Engin., H. T. & S. Off. Rpt. 219, [48] pp., illus. [Processed.]
(22) Harvey, E. M.
1913. the castor bean plant and laboratory air. Bot. Gaz. 56: 439–442.
(23) ———
1946. changes in lemons during storage as affected by air circulation and ventilation. U. S. Dept. Agr. Tech. Bul. 908, 32 pp., illus.
(24) Hendrickson, H. M., and MacRill, J. R.
1948. refrigeration of lemons and grapefruit. Refrig. Engin. and Appl. Data 18–R, 10 pp., illus. (Section 2 of Refrig. Engin. v. 56, No. 1; follows p. 48.)
(25) Hopkins, E. F., and Loucks, K. W.
1948. a curing procedure for the reduction of mold decay in citrus fruits. Fla. Agr. Expt. Sta. Bul. 450, 26 pp., illus. (In cooperation with Fla. Citrus Comn.)
(26) Huelin, F. E.
1942. the handling and storage of australian oranges, mandarins, and grapefruit. Austral. Council Sci. and Indus. Res., Bul. 154, 60 pp., illus.
(27) Hyatt, J. B., and Keys, O. H.
1939. the curing and colouring of new zealand lemons. New Zeal. Jour. Sci. and Technol., Sect. B, 20: 318B–340B, illus.
(28) Karmarkar, D. V., and Joshi, B. M.
1942. investigations on the cold storage of nagpur oranges. [India] Imp. Council Agr. Res. Misc. Bul. 49, 17 pp., illus.
(29) Knight, L. I., and Crocker, W.
1913. toxicity of smoke. Bot. Gaz. 55: 337–371, illus.
(30) ——— Rose, R. C., and Crocker, W.
1910. effect of various gases and vapors upon etiolated seedling of the sweet pea. Science 31: 635–636.

[16] Available generally only in the larger libraries of the country.

(31) Leonard, E. R., and Wardlaw, C. W.
1937. STORAGE INVESTIGATIONS WITH TRINIDAD CITRUS FRUITS 1935–36. Imp. Col. Trop. Agr. [Trinidad], Low Temp. Res. Sta. Mem. 6, 28 pp., illus.

(32) MacRill, J. R.
1940. LEMONS. CURING—STORING—AIR CONDITIONING. Calif. Citrog. 25: 101, 121–123, illus.

(33) ———
1948. LEMON VARIETIES IN STORAGE. Calif. Citrog. 34: 16–17.

(34) ——— Nedvidek, R. D., and Nixon, H. W.
1946. [COLD STORAGE OF] CITRUS FRUITS. *In* Amer. Soc. Refrig. Engin., The Refrigerating Data Book (Refrigeration Applications volume), pp. 145–160, illus.

(35) ——— Nedvidek, R. D., and Nixon, H. W.
1946. STORAGE OF CITRUS FRUITS. Refrig. Engin. 51: 325–330, illus.

(36) Martin, W. E., Hilgeman, R. H., and Smith, J. G.
1940. GRAPEFRUIT STORAGE STUDIES IN ARIZONA. Amer. Soc. Hort. Sci. Proc. (1939) 37: 529–534, illus.

(37) Miller, E. V.
1946. THE PHYSIOLOGY OF CITRUS FRUITS IN STORAGE. Citrus Indus. 27 (4): 6–8, 20, 22. (Digest of (*38*).)

(38) ———
1946. PHYSIOLOGY OF CITRUS FRUITS IN STORAGE. Bot. Rev. 12: 393–423.

(39) ———
1947. THE STORY OF ETHYLENE. Sci. Monthly 65: 335–342.

(40) ——— and Schomer, H. A.
1939. PHYSIOLOGICAL STUDIES OF LEMONS IN STORAGE. Amer. Soc. Hort. Sci. Proc. (1938) 36: 432–434.

(41) ——— and Schomer, H. A.
1939. PHYSIOLOGICAL STUDIES OF LEMONS IN STORAGE. Jour. Agr. Res. 59: 601–607.

(42) ——— Winston, J. R., and Fisher, D. F.
1940. PRODUCTION OF EPINASTY BY EMANATIONS FROM NORMAL AND DECAYING CITRUS FRUITS AND FROM PENICILLIUM DIGITATUM. Jour. Agr. Res. 60: 269–277, illus.

(43) Neljubow, D.
1901. UEBER DIE HORIZONTALE NUTATION DER STENGEL VON PISUM SATIVUM UND EINIGER ANDEREN PFLANZEN. Bot. Centbl. Beihefte (Abt. II) 10: [128]–138, illus.

(44) Nixon, H. W.
1940. LEMONS. PICKING—WASHING—GRADING—PACKING. Calif. Citrog. 25: 101, 114–116, illus.

(45) Plank, J. E. van der.
1938. DELAYED STORAGE OF MARSH GRAPEFRUIT. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Rpt. 1936–37: 154–158, illus.

(46) ———
1938. I. THE DIFFERENT FORMS OF COLD INJURY OF MARSH GRAPEFRUIT AND NAVEL ORANGES: AND THE MODIFYING EFFECT ON THEM OF VARYING TEMPERATURES OF STORAGE. II. SOME STORAGE BLEMISHES OF ORANGES WHICH ARE NOT DUE TO COLD INJURY. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Rpt. 1936–37: 159–172, illus.

(47) ———
1939. COLD INJURY OF GRAPEFRUIT. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Rpt. 1937–38: 145–155, illus.

(48) ——— and Davies, R.
1937. TEMPERATURE—COLD INJURY CURVES OF FRUIT. Jour. Pomol. and Hort. Sci. 15: 226–247, illus.

(49) ——— and Rattray, J. M.
1940. THE EFFECT OF TEMPERATURES OF STORAGE FROM 40° TO 70° F. ON MARSH GRAPEFRUIT. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Ann. Rpt. 1938–39: 103–110.

(50) PLANK, J. E. VAN DER, RATTRAY, J. M., BOYES, W. W., and VILLIERS, D. J. R. DE.
1938. THE EFFECT OF TEMPERATURE OF STORAGE ON NAVEL ORANGES. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Rpt. 1936–37: 122–138, illus.

(51)——— RATTRAY, J. M., BOYES, W. W., and VILLIERS, D. J. R. DE.
1938. THE STORAGE OF NAVEL ORANGES FOR A PERIOD OF ABOUT 60 DAYS. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Rpt. 1936–37: 139–143, illus.

(52) ——— RATTRAY, J. M., BOYES, W. W., and VILLIERS, D. J. R. DE.
1938. THE EFFECT OF FAST COOLING AND UNDER-COOLING OF NAVEL ORANGES. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Rpt. 1936–37: 143–145.

(53) ——— RATTRAY, J. M., BOYES, W. W., and VILLIERS, D. J. R. DE.
1938. THE EFFECT OF PRE-STORAGE HEATING OF NAVEL ORANGES. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Rpt. 1936–37: 145–147.

(54) ——— RATTRAY, J. M., BOYES, W. W., and VILLIERS, D. J. R. DE.
1938. THE EFFECT OF TEMPERATURE OF STORAGE ON MARSH GRAPEFRUIT. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Rpt. 1936–37: 147–150.

(55) ——— RATTRAY, J. M., BOYES, W. W., and VILLIERS, D. J. R. DE.
1939. THE EFFECT OF TEMPERATURES OF STORAGE BETWEEN 35° F. AND 55° F. ON NAVEL ORANGES. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Rpt. 1937–38: 126–142, illus.

(56) ——— RATTRAY, J. M., and CROUS, P. A.
1940. THE STORAGE OF LEMONS. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Ann. Rpt. 1938–39: 110–122.

(57) ——— RATTRAY, J. M., CROUS, P. A., and KRIEL, J.
1939. THE STORAGE OF LEMONS. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Rpt. 1937–38: 156–169, illus.

(58) PLANK, R.
1938. CONTRIBUTION TO THE THEORY OF COLD INJURY TO FRUIT. Food Res. 3: 175–187, illus.

(59) ROHRBAUGH, P. W.
1943. MEASUREMENT OF SMALL CONCENTRATIONS OF ETHYLENE AND AUTOMOBILE EXHAUST GASES AND THEIR RELATION TO LEMON STORAGE. Plant Physiol. 18: 79–89, illus.

(60) ——— and MACRILL, J. R.
1943. ETHYLENE IN LEMON STORAGE ROOMS. Calif. Citrog. 28: 118, illus.

(61) ROSE, D. H., WRIGHT, R. C., and WHITEMAN, T. M.
1949. THE COMMERCIAL STORAGE OF FRUITS, VEGETABLES, AND FLORISTS' STOCKS. U. S. Dept. Agr. Cir. 278, 60 pp. (Revised).

(62) RYALL, A. L., and BUFORD, W. R.
1947. COLD STORAGE STUDIES WITH TEXAS CITRUS FRUIT. Lower Rio Grande Val. Citrus and Veg. Inst. Proc. 2: 102–108, illus.

(63) SAMISCH, R. M.
1937. OBSERVATIONS ON THE EFFECTS OF GAS STORAGE UPON VALENCIA ORANGES. Amer. Soc. Hort. Sci. Proc. (1936) 34: 103–106.

(64) SIEVERS, A. F., and TRUE, R. H.
1912. A PRELIMINARY STUDY OF THE FORCED CURING OF LEMONS AS PRACTICED IN CALIFORNIA. U. S. Bur. Plant Indus. Bul. 232, 38 pp., illus.

(65) SINGH, L., and HAMID, A.
1942. THE COLD STORAGE OF FRUITS IN THE PUNJAB. I. CITRUS FRUITS: MALTA (CITRUS SINENSIS) AND SANGTRA (C. NOBILIS). Indian Jour. Agr. Sci. 12: 757–778, illus.

(66) SOLARINO, E.
1937. COLOR REACTIONS OF AGED JUICES FROM CITRUS FRUIT. I. Ann. di Chim. Appl. [Rome] 27: 525–527. [Not seen; abstract in Chem. Abs. v. 32, column 5948. 1938.]

(67) STAHL, A. L., and CAIN, J. C.
1937. COLD STORAGE STUDIES OF FLORIDA CITRUS FRUITS. III. THE RELATION OF STORAGE ATMOSPHERE TO THE KEEPING QUALITY OF CITRUS FRUIT IN COLD STORAGE. Fla. Agr. Expt. Sta. Bul. 316, 41 pp., illus.

(68) STAHL, A. L., and CAIN, J. C.
1939. COLD STORAGE STUDIES OF CITRUS FRUITS. Fla. Agr. Expt. Sta. Ann. Rpt. 1938–39: 110.

(69) ——— and CAMP, A. F.
1936. COLD STORAGE STUDIES OF FLORIDA CITRUS FRUITS. I. EFFECT OF TEMPERATURE AND MATURITY ON THE CHANGES IN COMPOSITION AND KEEPING QUALITY OF ORANGES AND GRAPEFRUIT IN COLD STORAGE. Fla. Agr. Expt. Sta. Bul. 303, 67 pp., illus.

(70) ——— and FIFIELD, W. M.
1936. COLD STORAGE STUDIES OF FLORIDA CITRUS FRUITS. II. EFFECT OF VARIOUS WRAPPERS AND TEMPERATURES ON THE PRESERVATION OF CITRUS FRUITS IN STORAGE. Fla. Agr. Expt. Sta. Bul. 304, 78 pp., illus.

(71) TINDALE, G. B.
1944. GRAPEFRUIT STORAGE EXPERIMENTS—1934–44. Citrus News 20: 106–107.

(72) ———
1945. GRAPEFRUIT STORAGE TRIALS. Victoria Dept. Agr. Jour. 43: 352–353.

(73) TOMMASI, G., BEER, S., and MARRACINO, Q.
1938. COLD STORAGE OF MANDARIN ORANGES. Ann. della Sper. Agr. [Rome] 29: 113–128. [Not seen; abstract in Chem. Abs. v. 33, column 4336. 1939.]

(74) TROUT, S. A., TINDALE, G. B., and HUELIN, F. E.
1938. THE STORAGE OF ORANGES WITH SPECIAL REFERENCE TO LOCALITY, MATURITY, RESPIRATION, AND CHEMICAL COMPOSITION. Austral. Council Sci. and Indus. Res., Pam. 80, 59 pp., illus.

(75) VOROTYNTSEVA, E. N., POKROMOVICH, S. P., and TREISSTER, YU. S.
1941. OPTIMUM STORAGE CONDITIONS AND PERIODS FOR CITRUS FRUITS. Kholodil'naya Prom. 19 (1): 22. [Not seen; abstract in Chem. Abs. v. 37, column 3520. 1943.]

(76) WARDLAW, C. W.
1937. STORAGE AND TRANSPORT OF TROPICAL FRUITS AND VEGETABLES. CITRUS. Trop. Agr. [Trinidad] 14: 131–139, 163–170.

(77) ——— and LEONARD, E. R.
1939. STORAGE INVESTIGATIONS WITH TRINIDAD GRAPEFRUIT, 1938–39. Trop. Agr. [Trinidad] 16: 208–215, illus.

(78) WILLIAMS, C. G.
1946. HARVESTING AND PACKING LEMONS. Queensland Agr. Jour. 63: 270–279, illus.

(79) ———
1946. HARVESTING AND PACKING LEMONS. Queensland Dept. Agr. and Stock, Div. Plant Indus., Advisory Leaflet 109, 10 pp., illus. (Reprinted with additions from Queensland Agr. Jour., Nov. 1946.)

MATURITY AND QUALITY

The two sections of this digest entitled "Maturity and Quality" and "Composition" are not mutually exclusive. Maturity in citrus fruits cannot be discussed without some consideration being given to their composition, particularly their content of soluble solids and acid. On the other hand, a discussion of the composition of citrus fruits, although it must deal with a variety of substances that occur in those fruits, must still give special attention to their content of soluble solids and acid. Consequently, the writers have had some difficulty in deciding which papers, out of about 150 found, should be reviewed under Maturity and Quality and which under Composition. It is possible that the separation made will not be approved by all readers.

It is important to remember that oranges and grapefruit do not improve appreciably in quality after being severed from the tree. It is therefore apparent that these fruits must be of desirable eating quality at time of harvest if they are ever to have such quality (*26*).[17] So long as these fruits hang on the tree their composition is continually changing. The problem of determining proper maturity for harvesting, therefore, is one of determining when they reach satisfactory edible quality and how long they will remain in that condition. The internal quality of grapefruit, oranges, and other citrus fruits must be correlated with their physical characters and chemical constituents to determine when harvesting should be done.

Formerly maturity in citrus fruits was thought to be largely a question of seasonal changes in their contents of soluble solids and acid and of the relation of those constituents to each other. In discussing maturity one must take account also of seasonal changes in texture, color of both rind and juice, flavor, and aroma. Recent research on the subject has considered and attempted to evaluate the significance of all these factors in a continually changing complex. It has done even more than that. It has shown that the decisive test of maturity of a citrus fruit is whether it has good edible quality and is therefore acceptable to the consumer. Citrus fruits are grown to be consumed in one form or another. If they are not "good to eat," the mere fact that they pass some chemical test will not make consumers consider them ripe.

In 1947 Hodgson (*31*) discussed fruit-quality problems of California and Florida. Quality in citrus fruit, he said, apparently results from the interaction of several factors, among which are variety, rootstock, nutrition, and climate. He considered climate first in importance for both quality and size, rootstock next for quality, and nutrition next for fruit size. Quality is, of course, the property of citrus fruit that is of prime importance. He said

---

[17] Italic numbers in parentheses refer to Literature Cited for Maturity and Quality, p. 64.

(*p. 48*) that in Florida the problem of fruit quality "is most acute with early varieties during the early part of the shipping season and particularly with varieties, such as the Hamlin orange, which at full maturity are characterized by relatively low total solids." In California the most troublesome problem (*p. 48*) "is concerned with the late ripening Valencia variety in late districts, where the fruit is commonly held on the trees long after maturity because of marketing problems and requirements." The practical problem, therefore, in all citrus-growing areas is to make use of every possible means by which quality can be improved and to avoid conditions that reduce quality. In established groves the variety is fixed unless top-working is practiced, and not much can be done to modify climate. Attention must therefore be given in all the major citrus-growing areas to developing rootstocks better for fruit quality than those now in use and to obtain a better understanding of mineral nutrition particularly with reference to the minor elements. It is also clear, he said, that effective substitutes for oil sprays must be found. Such sprays are believed to have a dwarfing effect on the fruit and may damage quality if applied at the wrong season or in improper amounts.

Baier (*2*) in California in 1945 discussed the problem of color in citrus fruits and described methods used in California for measuring it. Chief among these are secondary standards consisting of rings, disks, or plastic models colored to match specified Maerz and Paul colors. These can be used conveniently in the field. Another method consists in the use of spheres the size of grapefruit whose segments, or lunes, are painted various shades from green (matching undeveloped fruit) to yellow white (matching mature fruit). Spinning a series of these spheres on a shaft makes it possible to provide a set of standards by which the concept of percentage of color can be demonstrated. Colorimeters have also been used in connection with a reaction of citrus juice with boric acid, which produces an intensified and measurable color.

Neumark (*42, p. 117*), reporting in 1938 on "The Citrus Industry of South Africa" and the quality of oranges imported into the United Kingdom during the South African season, stated:

> The Californian oranges . . . have a rich golden colour, are juicy, sweet and of uniform quality. South African oranges have generally a good colour, but lack in juice, sweetness and uniformity. The Brazilian oranges, on the other hand, have a pale colour, often develop more waste than the South African fruit, but taste much sweeter, contain much more juice, and are of uniform quality.

South African oranges, especially Valencia, grapefruit, and seedlings are excessively sour; this, he said, is one of the factors that have prevented South African oranges from being as popular in European markets as those from certain other regions. It probably explains also why more work, judging by the number of papers published, has been done in South Africa than in other countries on the use of sprays to reduce acidity. However, high acidity is not mentioned by Hodgson (*31*) in California or by South African investigators other than Neumark as a characteristic of South African citrus fruit. Neumark reported the results of various surveys in the United Kingdom which showed that juice content and good eating qualities are the two factors that influence consumer demand most. Because of these characteristics Brazilian oranges were found to be very popular on the British market. Such consumer judgments should always be checked by analytical studies if the investigator is to have a true idea of the relative merits of citrus fruits from various parts of the world.

In a South Africa Department of Agriculture and Forestry publication in 1939 (*49*) it was stated that for the maturity test a random sample is satisfactory if the selection is done on fruits of lowest juice content. For the juice-content test the chances are considerable that random sampling will give a higher figure than selective sampling.

EFFECT OF ROOTSTOCK ON ORANGES AND GRAPEFRUIT

The question of the effect of rootstock on fruit quality has been much investigated. Webber, discussing it in 1948, stated (*3, p. 88*) :

> Apparently, slow-growing stocks with a dwarfing tendency tend to hasten fruit ripening. In the stock experiments at the California Citrus Experiment Station, in some seasons, Washington Navel oranges on trifoliate orange stock have colored in the fall nearly two weeks earlier than the fruits of the same variety on sour and sweet stocks. This effect, however, was partly seasonal and in ordinary seasons is not exhibited to the same degree.

According to Hall (*14, p. 173*) in Australia in 1943—

> the best quality fruit of Navels, Valencias and grapefruit came from trees on *trifoliata* stock, which was often highest in specific gravity and juice contents, was usually highest in acidity and was in nearly all cases highest in soluble solids in the juice and in flavour.

Kebby and Skepper (*32*) pointed out in 1948, however, that Washington Navel oranges on this stock produce a certain number of dwarf trees which are not satisfactory commercial units. This condition also occurred with Marsh grapefruit but was more than offset by the improved fruit quality.

Rutherford (*45*) in 1946, in discussing the citrus industry of Union of South Africa, reported that navel and Valencia are the principal oranges. Rough lemon is a good commercial rootstock. Sweet orange gives better quality, but trifoliate orange is better than either of the other two.

Webber referred to the work of Fudge (*11*) and of Fudge and Fehmerling (*12*) showing that the Pineapple orange in Florida contained more citric acid, total solids, and total sugars when grown on sour orange stocks than when grown on rough lemon stocks (*3, ch. 2*). He also mentioned results reported by Harding (*15*), and Harding, Winston, and Fisher (*26*) in 1940 showing that amount of sugar, degree of acidity, proportion of acidity to sugars, and aroma are influenced by the kind of rootstock on which the fruit is grown. Batchelor and M. B. Rounds concluded (*3, p. 187*) from the results reported by Sinclair and Bartholomew (*47*) in 1944 in California that—

> there is not enough difference in the yields of trees on sweet and sour orange rootstocks, either at Riverside or at Tustin, to predicate exclusively on a basis of yield the use of these rootstocks for Valencias.

They stated further (*pp. 193–194*) that (in California)—

> The sour orange, sweet orange, and Rough lemon have all produced satisfactory trees when used as rootstocks for the Washington Navel orange variety. . . . The fruit from the Rough lemon rootstock trees is not so high in quality, however, as that from either sweet or sour orange trees.

The superiority of sour orange rootstock in producing fruit of high quality in Florida is attested in reports by Fudge (*11*), Fudge and Fehmerling (*12*), Harding (*15*), and Harding, Winston, and Fisher (*26*), all referred to in volume 2 of "The Citrus Industry" (*3, ch. 2*). Similar testimony is furnished by Harding, Winston, and Fisher (*25*) in 1939, Harding and Fisher (*20*) in 1945, Camp (*6*) in 1942, Miller, Winston, and Fisher (*39*) in 1941, and Winston (*51*) in 1944.

According to Camp (*6, 7*), however, rough lemon is the most widely used rootstock in Florida. It produces trees very quickly on light sandy soils. These come into bearing at an early age, but the fruit tends to have a coarse skin and to be lacking in flavor. Much of this trouble, however, has been found to be due to lack of the so-called minor elements. When these are added it is easier to maintain the trees in good condition than when they are lacking, and the quality of the fruit shows very great improvement.

Harding (*15*) in 1940 and Harding, Winston, and Fisher (*25, 26*) in 1939 and 1940 reported that during the commercial season for early oranges the highest total solids were found in Parson Brown grown on sour orange and the lowest in Sixteen-to-One. Among midseason oranges, Conner, seedling oranges, and Jaffa contained more total solids than Pineapple or Homosassa. Total solids increased at about the same rate in Valencia oranges, whether they were grown on sour orange, Cleopatra tangerine, sweet orange, or grapefruit rootstock. Parson Brown and Valencia had lower total solids on rough lemon than on sour orange rootstock. In immature grapefruit Harding and Fisher (*20*) in 1945 reported that there was no significant difference in flavor (taste) among the several varieties regardless of the rootstock. Rootstock did, however, affect the quality of the ripened fruit; fruit on sour orange rootstock was superior in flavor to that on rough lemon. Furthermore, although the varieties Marsh and Duncan were about equal in quality when grown on sour orange, the Duncan was rated superior to the Marsh when both were grown on rough lemon. Comparisons between varieties on the same kind of rootstock showed that the Duncan contained higher total solids than the Marsh.

SOLIDS-ACID RATIOS

In a 1935 report on the solids-acid ratio, Croucher (*9, p. 7*), recommended consideration of the following tests for maturity of Jamaica citrus fruits:

> (1) Total Solids (Brix) : Acid Ratio (Florida).
> For Oranges, 8.5 (Minimum)
> For grapefruit, Minimum ratio dependent on amount of total Solids in the fruit.
> Mature fruit show greater values than those given.

(2) Titratable Acidity. (0.1 N NaOH to 10 ml. juice).
For Oranges : 20
For Grapefruit : 20
Mature fruit show less than values given.

(3) Titratable Acidity: pH (mv.) Ratio
For Oranges : 12 Minimum
For Grapefruit : 12 Minimum

(4) Sugar: Acidity Factor
For Oranges (°Brix—5.25)—5.25 Acid=0
For Grapefruit (°Brix—3.25)—5.25 Acid=0
Negative values show non-maturity.
Positive values show maturity.

In 1936 Baier (*1*) pointed out that two different lots of oranges may have the same solids-acid ratio and still be very different in palatability and may even differ in sweetness. Some of the factors responsible for this situation are ash constituents and other buffers (substances that affect the active but not the titratable acidity), flavoring constituents, essential oils, and bitter substances. Baier suggested that it would be desirable to establish a minimum Brix requirement; say, 9.5° Brix or 9.5 percent total solids. The standard suggested for oranges was the minimum 8 to 1 ratio, total solids of 9.5 percent or higher if the ratio is between 8 to 1 and 12 to 1, and total solids of 10 percent or higher if the ratio is greater than 12 to 1. This embodies the same idea as that used by Harding and his associates in their reports on the maturity and palatability of citrus fruits.

In 1938 Trout, Tindale, and Huelin (*50*) in Australia considered titratable acidity a better index of maturity than the Brix-acid ratio. If the acidity was not greater than 26 cc. of 0.1 N alkali per 10 cc. of juice this was reduced to 22 cc. by treatment for 2 or 3 days with ethylene (1 to 5,000). Coman (*8*) suggested in 1940 that, from the standpoint of health, tentative minimum standards for oranges should be as follows:

Standard:	*Most desirable*	*Satisfactory*
Volume of juice (percent by weight)	60	50
Citric acid (percent)	.9	.8
Total sugar (percent)	12.0	10.0
Vitamin C (mg. per 100 cc.)	75.0	50.0
Calcium (percent)	.009	.008
Phosphorus (percent)	.018	.015

It will be noted that this tabulation does not include the solids-acid ratio.

Wood and Reed (*53*, *54*) stated in 1936 and 1938 that the best measure of the maturity of grapefruit known to them was the solids-acid ratio.

According to Hilgeman (*27*) in 1941, the Brix-acid ratio increased with maturity but, contrary to the findings of Wood and Reed, its numerical value was not by itself a satisfactory measure of maturity of grapefruit. The most satisfactory standard indicated by these investigations requires 35 percent minimum color and a Brix-acid ratio that varies inversely with the percentage of juice by volume.

It is thus evident that even 10 or 12 years ago the solids-acid ratio was not accepted by all investigators as the sole criterion for judging the maturity of citrus fruit.

A later statement concerning the significance and shortcomings of the solids-acid ratio, based on work in Florida, was made by Harding (*18*, *19*) in 1947. He reported that a statistical study of the taste ratings of a panel of judges showed definite association between palatability of citrus fruits and contents of total solids and total acid. As a rule, the tasters rated a fruit satisfactory only if it had a higher solids-acid ratio than that needed to pass State maturity laws. The approximate dates of acceptable eating quality of fruits of various kinds and varieties of citrus follow: Parson Brown orange on rough lemon rootstock about November 11 and on sour orange about November 15; Hamlin orange on rough lemon rootstock December 3; midseason varieties of orange between December 20 and January 25; Valencia orange on grapefruit rootstock February 20 and on sweet orange, sour orange, rough lemon, or Cleopatra tangerine about March 1; Marsh and Duncan grapefruit between December 15 and January 15; Temple orange and tangerines about December 1.

Harding (*17*) summarized his results on maturity of citrus fruits under the title "Citrus at Its Best" in 1947. The same subject was discussed in relation to Florida conditions by Fudge (*11*), who stated that factors that affect fruit composition, and thus quality, are variety, rootstock, soil type and fertility, and fertilizer treatment.

MATURITY AND QUALITY OF DIFFERENT FRUITS

ORANGES

Harding, Winston, and Fisher (*25*, *26*) and Harding (*15*) in 1939 and 1940 reported on seasonal changes in the principal varieties of Florida oranges. The chief facts brought out by the investigations can be summarized in part as follows:

1. Sucrose and reducing sugars increased as the fruit ripened, the former somewhat more rapidly than the latter.

2. During the commercial shipping season for early oranges the highest total sugars were found in Parson Brown oranges grown on sour orange rootstock and the lowest in Sixteen-to-One oranges grown on rough lemon rootstock. Among the midseason varieties, Conner and Jaffa had higher total sugars than Pineapple and Homosassa. In Valencia, however, only slight differences were found in fruit grown on sour orange, sweet orange, Cleopatra tangerine, and grapefruit rootstock; the lowest amount was found in fruit grown on rough lemon rootstock. The authors stated that in this investigation it was found that to have all the oranges pass the 8 to 1 ratio it would have been necessary to delay picking 16 to 58 days, by which time the ratio of the average juice ranged from 8.35 to 1 to 18.95 to 1. They (*26, p. 52*) gave as their opinion that—

> a more desirable maturity standard for oranges could be obtained by the adoption of an adequate standard based on a minimum total-solids content and a maximum as well as a minimum total-acid content.

Salcedo (*46*) in Mexico reported in 1942 that during the ripening period (on the tree) total sugars in oranges increase. Throughout this period the ratio of sucrose to reducing sugar was approximately 1 except in the mandarin orange in which it was 3. When the fruits are fully ripe the total-sugars-acid ratio is about 19 for mandarin varieties and between 6.2 and 9.7 for the others.

Miller, Winston, and Fisher (*39*) in 1941 and Miller and Winston (*38*) in 1942 reported further that degree of pigmentation of the juice was not an index of maturity and sometimes it was not an index of quality. Early and midseason fruits were marketable before the juice attained full color and Valencia fruits were often marketed after decline in pigmentation had begun.

On the basis of work by Harding and associates the United States Department of Agriculture and the Florida Citrus Commission adopted in 1941 the internal quality grade A for Florida oranges. This grade, as had been suggested in 1940 by Harding, Winston, and Fisher (*26, p. 52*) was based on "a minimum total-solids content and a maximum as well as a minimum total-acid content." It also provided a graduated solids-acid ratio for the juice. The higher the solids the lower the required ratio. (See also Winston (*52*), 1950.)

Harding and Lewis (*21*) reported in 1941 that as ripening proceeds the total solids and volume of juice increase and the acidity decreases for all the usual-size fruit. Throughout the ripening process the smaller sized fruits contain the highest percentages of solids, acid, and juice. Differences in solids, acidity, and volume of juice for different-sized fruits of the same variety were most pronounced late in the season. Winston (*51*) reported in 1944 as Harding and Lewis (*21*) had done in 1941 that the juice from small oranges has higher quality and is richer and more flavorful than that from larger fruit. In 1939 Kimbrough and Page (*33*) as the result of a study of Louisiana oranges reported that closely related size groups, 176 to 200, do not differ greatly in quality but that there is a pronounced difference in acidity, percentage of juice, and thickness of rind as size increases. They stated (*p. 15*) : "The smaller the size, the thinner the rind and the higher the per cent of juice and acidity." They concluded that, by test, Louisiana oranges surpass those from all other States in the flavor of the juice. Usually they have the thinnest rind and as high percentages of juice, total solids, and total sugars as oranges from any other State.

In 1945 and 1947 Harding and Wadley (*23, 24*) published the results of investigations on quality in Temple oranges grown in Florida. These were really studies on seasonal changes in the fruits of that variety. Harding and Wadley found that the palatability of Temple oranges rose rapidly through the late fall and early winter, reached a maximum in late winter, and dropped off a little in early spring. Not much difference was found between fruits grown on different rootstocks although there was some indication of inferiority of those grown on rough lemon. Acidity decreased and total solids increased as the season advanced. Palatability increased with solids up to about 12.5 percent and then fell off with further increase of solids.

Moore (*40, 41*) in 1945 expressed the belief, based on temperature records and time of first shipment, that in Tulare County, Calif., high temperatures in the fall, as well as low temperatures in the spring, may retard the maturing of navel oranges. Other factors that may influence navel maturity are location with reference to elevation and direction of slope, soil type, rootstock variety, bud strain, and certain cultural practices.

In 1947 Sinclair and Bartholomew (*48*) in California stated that factors affecting the edible quality of oranges are ratio of total sugars to total soluble solids, ratio of total soluble solids to total acids, essential oils, esters, and amino acids. They found that, during the growth of the fruit from the very immature to the mature stage, the titratable acidity decreased more than 50 percent with less than one unit change in pH. Both changes greatly affected the sour taste during ripening. This change in acidity was also reported by Grebinskii (*13*) in 1940 in U. S. S. R., by Salcedo (*46*) in 1942 in Mexico, and by Harding and his associates.

Parker, Rounds, and Cree (*43*) in California reported in 1943 that the number of irrigations showed no consistent relation to percentage of puffy fruit and that the number of fruits with hollow centers decreased with increasing numbers of irrigations. They stated (*p. 269*):

> Commercial grade of fruit was not related to (1) fertilizer practices; (2) cover cropping; (3) amount of irrigation water; or (4) to number of annual irrigations applied.

They found that puffiness of fruit was more severe in oil-sprayed orchards, but that there was no consistent relation between puffiness and type of soil.

An investigation designed to furnish further data relative to the maturity of Florida oranges was made by Lewis (*34*) in Florida during the seasons of 1938, 1939, and 1940. He reported extensive data on size, yield of juice, and chemical composition of early oranges and midseason common sweet oranges for the purpose of establishing standards for the internal quality of oranges. Ninety-eight percent of the oranges contained at least 4.5 gallons of juice per standard packed box of 1⅗ bushels from October 8 to December 2. Practically all the fruits contained at least 0.5 percent citric acid and 83 percent or more of the fruit contained not less than 0.7 percent acid. After November 1 nearly all of the fruits of the early and midseason varieties being shipped contained more than 9 percent solids in the juice.

Miller (*37*) reported in 1943 that the juice quality of Florida citrus fruit is not seriously affected by the two most common rind blemishes, melanose and rust mite russeting.

Randhawa and Dinsa (*44*) in 1947 concluded from their results that in India the Valencia variety produces high-quality fruit all over the tree under hot climatic conditions. Loizides (*35*) reported in 1940 that in Cyprus oranges growing on sandy soils mature earlier than those growing on loamy sand and sandy loam. Maturity was judged by the sugar-acid ratio.

Fudge (*11*) reported in 1940 that the quality of fruit from trees on Norfolk soil fertilized for 18 years with nitrogen, phosphorus, and potassium was brought up to that of fruit in the stock hammock groves by the use of a copper, zinc, and manganese physiological spray, and by application of magnesium to the soil. His findings relative to rootstocks are reviewed under the subsection on rootstocks (p. 55).

Kebby and Skepper (*32*) in Australia reported in 1948 that fruit quality depends on rootstock and also on the proper use of fertilizers, not only the major elements, nitrogen, phosphorus, and potassium, but also the minor elements such as zinc, copper, manganese, magnesium, and others.

GRAPEFRUIT

Most of the work on grapefruit maturity in the United States has been done in Florida, Texas, and Arizona.

Harding (*16*) reported in 1944 that the concentration of ascorbic acid in Florida grapefruit varies with maturity, the greatest concentration being found in the juice of immature fruit. As the fruit ripens, the decrease in concentration is balanced by an increased quantity of juice so that the total content per fruit is highest in ripe fruit. Variety, location, cultural practices, seasonal conditions, and rootstock had little effect except that slightly lower concentrations of vitamin C were found in fruit from Marsh grapefruit trees on rough lemon rootstock. Concentrations reported ranged from 32 to 62 mg. per milliliter.

Harding and Fisher (*20*) in 1945 reported extensive data on seasonal changes in Florida grapefruit. Their results, in part, were summarized as follows:

The volume of juice, computed as milliliters of juice per 100 gm. of fruit, increased as the fruit ripened and then remained rather constant. Varieties differed in juice content. Probably because of its practically seedless character, the Marsh consistently had a slightly greater amount of juice than the Duncan.

During the commercial shipping season the acidity of the juice decreased gradually with ripening. In very ripe fruit picked in April and May the acidity was found to have decreased abruptly.

Reducing sugars increased with the ripening of the fruit. Sucrose usually increased during the fall months, remained rather constant during midseason, and decreased sharply between February and April. Total sugars increased during the fall and midseason and usually remained constant in ripe fruit.

Total solids, or total soluble solids (principally sugars), were generally highest when the grapefruit was in prime eating condition. Slightly lower total solids were usually found earlier in the season in immature fruit and also late in the season in very ripe fruit.

A downward trend in total acid characterized both Marsh and Duncan as they ripened, but the Duncan was consistently higher in total acid than the Marsh. Although total acid was influenced more by variety than by rootstock, fruit on sour orange rootstock was rather consistently higher in total acid than that on rough lemon.

The solids-acid ratio generally increased with the ripening of the fruit. This increase was primarily due to a diminution in the total acid of the fruit, since the total solids remained rather constant in ripe fruit.

Included in the bulletin (*20*) are two charts, or nomographs, one for Marsh grapefruit and the other for Duncan, showing the content of total solids and total acid when the fruit was rated as meeting consumer approval according to the taste test.

Wood and Reed (*53*) in 1936 in Texas reported that lime-sulfur, zinc-lime, and oil sprays had no effect on the maturing of Texas grapefruit but that heavy fertilization and iron sulfate hastened it. Sugar content increased and citric acid decreased progressively as the season advanced. The same authors (*54*) in 1938 stated that the best measures of maturity of grapefruit known to them at that time were (1) content of total solids in degrees Brix, (2) ratio of solids to acids, and (3) volume of juice.

Cultural practices had more effect on the physical than on the chemical character of the fruit. Seasonal trends of invert sugar and of total sugar were upward on all plots. Sucrose remained constant. Bitterness disappeared from the fruit during November each season.

Wood and Reed stated further that grapefruit of good quality has a relatively thin rind, regular segments, a large volume of juice, and tender flesh, is not bitter, and has a ratio of solids to acid that gives it a tart to sweet taste. In their investigations it was found that the total soluble solids was approximately constant for all test plots. As the season advanced, citric acid decreased and the ratio of solids to acid increased. Fruit from 15-year-old trees matured earlier than that from 10-year-old trees, but it averaged less rind, more rag, less juice, and lower specific gravity.

Hilgeman and Smith (*29*) in Arizona reported in 1938 that satisfactory grapefruit has a wide range of percentage of juice and Brix-acid ratio. Usually higher Brix-acid ratios are obtained from large fruit than from small. Wide seasonal differences in ratio appear to be due to variations in the percentage of acid, because the Brix readings do not change markedly from year to year. The same authors (*30*) reported in 1940 that total sugars in Arizona grapefruit increased until midwinter and then decreased. Sucrose increased rapidly in the early fall and decreased in late winter and spring. Invert sugar, calculated as percentage of total sugar, decreased for a short time in the fall and then increased at an accelerated rate as the season advanced. Maximum amounts of sucrose were associated with ripening.

Hilgeman (*27*) stated in 1941 that the average percentage of juice by volume was 7 percent greater in small fruit than in large. This is owing to differences in the percentage of peel. The percentage of juice in the edible portion is the same in all sizes. Juice color was not closely correlated with maturity. Total soluble solids increased gradually from early October to midwinter and decreased in the spring.

Fruit from old trees colored more rapidly, contained more citric acid, and had a lower Brix-acid ratio than fruit from young trees. High-nitrogen fertilization in February produced fruit with lower acid, a higher Brix-acid ratio, and a greater volume of juice than were found in fruit from unfertilized trees.

Martin (*36*) wrote in 1941 that some of the factors affecting the quality of grapefruit grown in the Salt River Valley, Ariz., are production, summer cover crops, and water supply. Quality improves as yields increase up to about four boxes per tree. Further increase in production does not seem to cause any further improvement in quality. Water supply should amount to at least 3 acre-feet per year.

Finch (*10*) recommended in 1944 that, in order to produce high-quality grapefruit, Arizona growers should (1) maintain seasonal control of nitrogen to furnish ample supplies in the winter but reduced supplies in the summer and fall and (2) irrigate groves to prevent wilting of the fruit while it is developing.

Grebinskii (*13*) reported in U. S. S. R. in 1940 that in contrast with mandarin and other oranges, the content of sucrose in lemons and grapefruit reaches a maximum and then begins to decrease long before the fruit is full ripe.

Hodgson (*31*) in 1947 commented on the results of work with grapefruit groves in Arizona showing that a high nitrogen level during the growing season is associated with poor quality. He also expressed the opinion (*pp. 62–63*) that—

> the low average quality of oranges produced on the muck soils [in Florida], irrespective of rootstock or nutritional program is almost certainly associated with the high nitrogen level which obtains in these soils. And conversely, it seems probable that the superior quality and texture which characterize the fruit produced in the "hammock" groves—where little or no tillage is employed and a more or less permanent sod condition exists—are in part, at least, caused by the low nitrogen level resulting from competition.

Benton (*4*) in Australia wrote in 1941 that, aside from the practice of delayed harvesting, improvement of the palatability of Marsh grapefruit is largely impossible because the chief factors determining palatability are fixed by the stock used and by local growing conditions, particularly temperature and humidity; that is, climate. Some improvement in juice content and palatability can be brought about by practices that limit vegetative growth, especially during the summer and autumn months. The same author (*5, p. 169*) in 1944 reported that in Australia "regions with fairly high temperatures during most of the year and with mild winters should be selected for the production of good to best quality Marsh grapefruit." If the soil and the climatic conditions are suitable, cultural factors should be studied and care should be taken to avoid excessive applications of nitrogenous fertilizer and heavier irrigation than is necessary for good tree growth.

Hilgeman (*28*) in 1943 reported the results of an attempt to measure maturity in Arizona grapefruit by tenderness tests. He found a direct correlation between tenderness of the flesh and juiciness, but concluded that to adapt such a test to legal maturity standards for grapefruit would require the development of a special type of pressure tester.

TANGERINES

Continuing the series of reports on seasonal changes in Florida citrus fruits, Harding and Sunday (*22*) published in 1949 a bulletin on the course of such changes in tangerines. Their results can be summarized, in part, as follows:

1. Eating quality increased very rapidly during October and November and reached the minimum standard of consumer acceptance about November 15 and prime eating condition in January and February.

2. Total solids increased gradually as the fruit ripened, but total acid decreased.

3. The concentration of ascorbic acid became gradually lower as the fruit developed and ripened.

4. Volume of juice and average weight per fruit increased rapidly with maturity.

5. Degreening of the rind was associated with the ripening of the fruit.

6. Color of flesh was associated with texture. Usually, immature, ricey fruit was orange yellow; coarse-textured fruit yellow orange; and good-textured fruit orange.

7. Kind of rootstock had little effect on the physical characters except juiciness. Its principal effect was on total solids and total acid, which largely determine eating quality. According to taste tests, tangerines on Cleopatra tangerine rootstock rated first, those on sour orange second, and those on rough lemon third.

LITERATURE CITED FOR MATURITY AND QUALITY

(1) Baier, W. E.
1936. solids-acid ratio and palatability of citrus fruits. Calif. Citrog. 22: 11.

(2) ———
1945. how the citrus industry measures it. vii. color. Calif. Citrog. 31: 6, 11, illus.

(3) Batchelor, L. D., and Webber, H. J., editors.
1948. the citrus industry. volume ii. production of the crop. 933 pp., illus. Berkeley and Los Angeles.

(4) Benton, R. J.
1941. improving quality of marsh grapefruit. Agr. Gaz. N. S. Wales 52: 30–31, illus.

(5) ———
1944. quality of marsh grapefruit. climatic conditions most important influence. Citrus News 20: 169, 175.

(6) Camp, A. F.
1942. the present status of rough lemon rootstock. Fla. State Hort. Soc. Proc. (1941) 54: 75–81.

(7) ———
[1945]. citrus growing in florida. *In* Citrus Industry of Florida, pp. [5]–140, illus. (Fla. Dept. Agr. in cooperation with Univ. of Fla.)

(8) Coman, D.
1940. quality [of citrus fruits] from the health standpoint. Fla. State Hort. Soc. Proc. 53: 97–98.

(9) Croucher, H. H.
1935. maturity tests for citrus. a report on laboratory data. Jamaica Dept. Sci. & Agr. Bul. (n. s.) 5, 8 pp.

(10) Finch, A. H.
1944. improving desert grapefruit quality. Citrus Leaves 24 (4): 12–13, illus.

(11) Fudge, B. R.
1940. factors that influence quality fruit. Citrus Grower [Orlando, Fla.] 2 (41): 3–5, 8.

(12) Fudge, B. R., and Fehmerling, G. B.
1940. some effects of soils and fertilizers on fruit composition. Fla. State Hort. Soc. Proc. 53: 38–46. (Also Citrus Indus. 21 (9): 6–7, 11, 14–15.)

(13) Grebinskii, S. O.
1940. the accumulation and transformation of substances during ripening and storing of citrus fruits. Biokhim. Kul'tur. Rasteniĭ 7: 276–300. [Not seen; abstract in Chem. Abs. v. 35, column 2927. 1941.]

(14) Hall, E. G.
1943. effect of stocks on citrus fruit quality. trials with navels, valencias and marsh grapefruit. Agr. Gaz. N. S. Wales 54: 173–176, illus.

(15) Harding, P. L.
1940. seasonal changes in the principal varieties of florida oranges. Fla. State Hort. Soc. Proc. 53: 78–86.

(16) ———
1944. seasonal changes in the ascorbic acid concentration of florida grapefruit. Amer. Soc. Hort. Sci. Proc. 45: 72–76.

(17) ———
1947. citrus at its best. U. S. Dept. Agr. Yearbook 1943–47 (Science in Farming), pp. 858–862.

(18) ———
1947. quality in citrus fruits. seasonal changes in relation to consumer acceptance of oranges, grapefruit, temple oranges, and tangerines. Citrus Indus. 28 (2): 5–9, 20, illus.

(19) ———
1947. quality in citrus fruits: seasonal changes in relation to consumer acceptance of oranges, grapefruit, temple oranges, and tangerines. Amer. Soc. Hort. Sci. Proc. 49: 107–115, illus.

(20) ——— and Fisher, D. F.
1945. seasonal changes in florida grapefruit. U. S. Dept. Agr. Tech. Bul. 886, 100 pp., illus.

(21) ——— and Lewis, W. E.
1941. relation of size of fruit to solids, acid and juice volume in the principal varieties of florida oranges. Citrus Grower [Orlando, Fla.] 3 (32): 3, 8, illus.

(22) ——— and Sunday, M. B.
1949. seasonal changes in florida tangerines. U. S. Dept. Agr. Tech. Bul. 988, 59 pp., illus.

(23) ——— and Wadley, F. M.
1945. study of quality in temple oranges. Food Res. 10: 510–517, illus.

(24) ——— and Wadley, F. M.
1947. study of quality in temple oranges. Fla. State Hort. Soc. Proc. (1946) 59: 16–20.

(25) ——— Winston, J. R., and Fisher, D. F.
1939. seasonal changes in the ascorbic acid content of juice of florida oranges. Amer. Soc. Hort. Sci. Proc. (1938) 36: 358–370.

(26) ——— Winston, J. R., and Fisher, D. F.
1940. seasonal changes in florida oranges. U. S. Dept. Agr. Tech. Bul. 753, 89 pp., illus.

(27) Hilgeman, R. H.
1941. studies of the ripening of marsh grapefruit in arizona with especial reference to the improvement of maturity measurements. Ariz. Agr. Expt. Sta. Tech. Bul. 89, pp. [93]–168, illus.

(28) ———
1943. a note on the measurement of flesh tenderness in arizona marsh grapefruit. Amer. Soc. Hort. Sci. Proc. 42: 253–254.

(29) ——— and Smith, J. G.
1938. grapefruit maturity studies in arizona. Calif. Citrog. 24: 54, 64.

(30) ——— and Smith, J. G.
1940. changes in invert sugar and sucrose during ripening of arizona grapefruit. Amer. Soc. Hort. Sci. Proc. (1939) 37: 535–538, illus.

(31) Hodgson, R. W.
1947. citrus fruit quality problems of california and florida. Calif. Citrog. 33: 48, 62–66.

890503—51—5

(32) KEBBY, R. G., and SKEPPER, A. H.
1948. CITRUS FRUIT QUALITY. WHAT ARE THE MAIN CONSIDERATIONS? Agr. Gaz. N. S. Wales 59: 357–362, illus.

(33) KIMBROUGH, W. D., and PAGE, G. N.
1939. A COMPARATIVE STUDY OF QUALITY IN ORANGES FROM LOUISIANA AND OTHER STATES. La. Agr. Expt. Sta. La. Bul. 311, 16 pp.

(34) LEWIS, W. E.
[1942.] ANALYSIS OF DATA RELATIVE TO THE MATURITY OF FLORIDA EARLY AND MIDSEASON COMMON SWEET ORANGES, SEASONS 1938, 1939, AND 1940. U. S. Agr. Market. Serv. [Unnumb. Pub.], 20 pp., illus. [Processed.]

(35) LOIZIDES, P. A.
1940. PRELIMINARY OBSERVATIONS ON THE MATURITY OF ORANGES IN THE FAMAGUSTA DISTRICT. Cyprus Agr. Jour. 35: 4–6, illus.

(36) MARTIN, W. E.
1941. AN EVALUATION OF SOME OF THE FACTORS AFFECTING QUALITY OF GRAPEFRUIT IN COMMERCIAL GROVES OF THE SALT RIVER VALLEY. Amer. Soc. Hort. Sci. Proc. 39: 59–66, illus.

(37) MILLER, E. V.
1943. RELATIONSHIP BETWEEN RIND BLEMISHES AND JUICE QUALITY OF FLORIDA ORANGES. Fla. State Hort. Soc. Proc. (1942) 55: 25–28.

(38) ——— and WINSTON, J. R.
1942. JUICE COLOR AND QUALITY IN CERTAIN VARIETIES OF FLORIDA CITRUS FRUITS. Fla. State Hort. Soc. Proc. (1941) 54: 64–67.

(39) ——— WINSTON, J. R., and FISHER, D. F.
1941. A PHYSIOLOGICAL STUDY OF CAROTENOID PIGMENTS AND OTHER CONSTITUENTS IN THE JUICE OF FLORIDA ORANGES. U. S. Dept. Agr. Tech. Bul. 780, [32] pp., illus.

(40) MOORE, E. C.
1945. INFLUENCE OF TEMPERATURE ON TIME OF RIPENING OF NAVEL ORANGES IN TULARE COUNTY. Calif. Citrog. 30: 121.

(41) ———
1945. TEMPERATURE INFLUENCES ON MATURITY OF TULARE COUNTY NAVEL ORANGES. Citrus Leaves 25 (1): 9.

(42) NEUMARK, S. D.
1938. THE CITRUS INDUSTRY OF SOUTH AFRICA. ITS NATIONAL AND INTERNATIONAL ASPECTS. 192 pp., illus. Johannesburg. (Thesis, M. Com., Univ. Witwatersrand).

(43) PARKER, E. R., ROUNDS, M. B., and CREE, C. B.
1943. ORCHARD PRACTICES IN RELATION TO YIELD AND QUALITY OF VALENCIA ORANGES. PARTS 1 AND 2. Calif. Citrog. 28: 226–227, 238–239, 242, 260, 268–269, illus.

(44) RANDHAWA, G. S., and DINSA, H. S.
1947. QUALITY OF VALENCIA ORANGES AS AFFECTED BY ASPECT, EXPOSURE, AND HEIGHT ON THE TREE. Amer. Soc. Hort. Sci. Proc. 50: 161–164.

(45) RUTHERFORD, D. M.
1946. REPORT FROM SOUTH AFRICA. Calif. Citrog. 31: 373, 386.

(46) SALCEDO, R. G.
1942. COLORING AND RIPENING ORANGES BY THE ETHYLENE GAS METHOD AS APPLIED TO THE VARIETIES MORE COMMONLY CULTIVATED IN SPAIN. Ciencia [Mexico] 3: 165–170, 213–218. [Not seen; abstract in Chem. Abs. v. 37, column 2478. 1943.]

(47) SINCLAIR, W. B., and BARTHOLOMEW, E. T.
1944. EFFECTS OF ROOTSTOCK AND ENVIRONMENT ON THE COMPOSITION OF ORANGES AND GRAPEFRUIT. Hilgardia 16: 125–176, illus.

(48) ——— and BARTHOLOMEW, E. T.
1947. COMPOSITIONAL FACTORS AFFECTING THE EDIBLE QUALITY OF ORANGES. Amer. Soc. Hort. Sci. Proc. 50: 177–186, illus.

(49) SOUTH AFRICA. DEPARTMENT OF AGRICULTURE AND FORESTRY.
1939. FRUIT PRODUCTION IN THE UNION REPORT NO. 24: THE 1938 CITRUS EXPORT SEASON. Union So. Africa Dept. Agr. and Forestry, Bul. 200, 72 pp.

(50) TROUT, S. A., TINDALE, G. B., and HUELIN, F. E.
1938. THE STORAGE OF ORANGES WITH SPECIAL REFERENCE TO LOCALITY, MATURITY, RESPIRATION, AND CHEMICAL COMPOSITION. Austral. Council Sci. and Indus. Res., Pam. 80, 59 pp., illus.

(51) Winston, J. R.
1944. Juice quality relation to orange size. Citrus Mag. 7 (6): 12.

(52) ———
1950. Harvesting and handling citrus fruits in the gulf states. U. S. Dept. Agr. Farmers' Bul. 1763, 67 pp., illus. (Revised.)

(53) Wood, J. F., and Reed, H. M.
[1936.] Factors affecting the maturity of grapefruit. Tex. Agr. Expt. Sta. Ann. Rpt. (1935) 48: 246.

(54) ——— and Reed, H. M.
1938. Maturity studies of marsh seedless grapefruit in the lower rio grande valley. Tex. Agr. Expt. Sta. Bul. 562, 39 pp., illus.

COMPOSITION

In this section are reviewed publications that deal with the composition of citrus fruits as affected by growing conditions and various treatments and practices, but that do not refer explicitly to seasonal changes in the fruit or to the relation of such changes to eating quality, or palatability. Seasonal changes are treated in the section on Maturity and Quality. Articles on the pectin and oil contents of citrus fruits are not reviewed, because those substances are of interest chiefly in connection with processing, which does not lie within the scope of this digest.

Bartholomew, Sinclair, and Janes (*8*)[18] in 1938 and Bartholomew and Sinclair (*6, 7*) in 1939 and 1941 found that in California 22 percent of 268 segments of Valencia oranges picked between January 5 and February 16 had a lower soluble-solids content in the stylar-end than in the stem-end half. Two months later when the fruits were more mature only 1 segment of 248 fruits tested had a higher soluble-solids content in the stylar end. Oranges from the outside of trees had slightly higher soluble solids in the three north segments than in the three south segments of the same fruit. This was true of fruit from the north, east, south, or west sides of the tree. Navel oranges and grapefruit showed the same north-south polarity as the Valencia fruits. In immature fruits the amounts may be equal in both halves or the higher concentration may be in the stem half. Of 130 fruits tested, 87 percent had a higher concentration of total soluble solids in their 3 north than in their 3 south segments. The color of the juice in the fruits tested was not the same in all the segments of a given fruit or in the stem and stylar halves of the segments.

MacDowell (*59*) in 1945 in Florida stated that in a limited number of samples the total solids in size 176 of midseason and Valencia oranges increased, respectively, from 11.50 to 12.29 percent and from 11.32 to 12.37 percent during the interval from 1936 to 1941. The ascorbic acid content increased, respectively, during the same time from 56.3 to 64.5 mg. and from 48.9 to 53.1 mg. per 100 gm. It would be interesting to know whether changes such as these would have been found if the quantity of fruit tested each time had been comparable with those on which statements made by Lewis (*55*) were based. (See p. 60 of this digest.) MacDowell concluded from a tabulation of data for the 5-year period that there was strong indication of a trend toward higher solids and vitamin C content in both midseason and Valencia oranges during that period and suggested that it might be due in part to the use of minor elements on the lighter soils. As factors affecting the quality of citrus fruit he mentioned variety, fertilizer treatment, root-

[18] Italic numbers in parentheses refer to Literature Cited for Composition, p. 80.

stock, age of the tree, climatic conditions, size and grade of the fruit, position of fruit on the tree, time of sampling, and maturity. Martin (*62, p. 47*) in 1942 reported: "Old trees tend to produce better quality fruit than younger ones."

Martin (*62*) also stated, as did Harding and Dyer (*45*) (also in 1942), that trees with a heavy crop usually bear better fruit than trees with a light crop, other conditions being equal. Size of crop would depend to some extent on the age of the tree, although various complicating factors might prevent the change from being regular and progressively increasing.

The values published by Ross (*73, 74*) in 1941 and 1942 for total solids and total acid in Florida orange and grapefruit juices used for canning purposes follow:

Kind of juice:	*Total solids (percent)*	*Total acid (percent)*
Orange	10.4–12.4	0.67–1.05
Grapefruit	9.5–11.3	1.23–1.54

Harding and Dyer (*45*) in 1942 reported that the juice of oranges from unthinned trees on rough lemon rootstock had a lower pH than that of fruit from thinned trees, but that no difference was found between fruit from thinned and unthinned trees on sour orange rootstock. Matumoto (*63*) in Japan reported in 1939 that Satsuma oranges contained 1 percent free acid, 2.7 percent reducing sugars, and 3.8 percent sucrose and maintained that ratio between invert sugar and sucrose for a long time in storage. Rodriguez (*72*) reported in 1938 that in contrast with the 7 to 1 ratio of total solids to acid found in California, the ratio for Peruvian (La Molina) oranges is not less than 11 or 12 to 1.

Grebinskii (*38a*) in 1940 in the U. S. S. R. reported that there were qualitative chemical differences between different kinds of citrus fruits such as the presence of naringin in grapefruit, consistent predominance of sucrose over monosaccharides in ripe oranges, various essential oils, exceptionally high citric acid content in lemons, and vitamin C content.

Braverman and Carmi (*12*) in 1937 in Palestine reported that the percentage of juice in Shamouti (Jaffa) oranges decreased after the first rains. Total solids in the juice, the density of the juice, and the amount of oil in the peel increased during ripening, whereas the total acidity decreased regularly. The pH values of large fruits were usually lower than those of small ones, but neither varied greatly during the growing season. The total quantity of reducing sugars remained practically constant during the growing season, the increase in total sugars being mainly due to sucrose.

In 1940 Puche Alvarez (*69*) reported that during the winter the acid content of both Valencia and Washington Navel oranges decreased fairly regularly and the sugar content increased. Similar, though not quantitatively equal changes, were found in nine other varieties. Sosa and Sannié (*89*) in France reported in 1944 that green and ripe fruits of *Citrus trifoliata* contain sugars, araban, pectin, and several enzymes. Pulp of green fruits contains an average of 67 mg. of ascorbic acid per 100 gm. and pulp of ripe fruits 84 mg. Joachim and Pandittesekere (*50*) concluded in 1939 from analyses of 62 samples of local and imported grapefruit and oranges that Ceylon fruits are similar in composition to citrus from other countries. Ceylon fruits were inferior in color, thickness of rind, facility of peeling, character of rag, and seedlessness.

EFFECT OF ROOTSTOCK

Hodgson and Eggers (*47*) in 1938 in California and Richards (*71*) in 1940 in Ceylon reported that trifoliate orange, the most dwarfing rootstock used, produced the highest soluble-solids content in the juice of Valencia and Washington Navel oranges, Eureka and Lisbon lemons, Bearrs lime, and Marsh grapefruit. Rough lemon, the most vigorous rootstock, gave the lowest soluble-solids content in all these fruits. Rough lemon as a rootstock produced the lowest acid content in the fruit, whereas trifoliate orange tended to produce high acid content. The solids-acid ratios were about the same on both rootstocks.

Richards (*71*) reported that all the varieties studied had the lowest contents of both citric acid and soluble solids when they were on rough lemon, the most invigorating stock. This stock seemed to hasten granulation or drying out of the vesicles. The kinds of citrus studied were navel and Valencia oranges, Satsuma and Dancy tangerines, Marsh grapefruit, and rough lemon.

Halma (*40, 42*) in 1943 and 1944 in California reported that Eureka lemon rootstock as compared with sweet orange rootstock has a marked dwarfing effect on the Valencia orange and also produced fruit with a lower percentage of total solids and acid, a higher solids-acid ratio, and a thicker rind, but an equal quantity of juice in the edible portion. The author commented that his results do not substantiate the common belief that dwarfing rootstocks heighten fruit quality.

Sinclair and Bartholomew (*78*) in 1944 in California reported on the results of 7 years' investigations of the effect of rootstocks and environment on the composition of oranges (Valencia and Washington Navel) and grapefruit. They found (*p. 172*):

> With all three scion varieties, the highest amount of chemical substances [reducing sugars, total sugars, and total acid] in peel, pulp, and juice of the fruit was found, usually, in samples from Morton- and Savage-citrange and Trifoliate-orange rootstocks; the lowest values, except for limited data reported for Palestine sweet lime, were obtained in samples from rough-lemon stock.

They stated that total sugars and acids, as percentages of the total soluble solids in the juice of samples of fruit from different rootstocks, bore no relation to the mineral constituents. Total acids decreased during the growth and ripening, while total solids increased, but wide fluctuations in total acid occurred without change in the total soluble solids. The chemical composition varied according to the rootstock and the growing location.

Haas (*39, p. 330*) in 1948 reported from California that—

> Wide ranges in percentages were found in the inorganic composition of the various portions of citrus trees and fruits when the trees were grown on various rootstocks under approximately the same environmental conditions.

Details of the findings cannot be adequately discussed or summarized in the space available here.

Halma (*41*, *43*) in 1944 and 1946 reported from California that Valencia oranges from own-rooted trees were generally higher in total and citric acids and lower in total-solids-acid ratio than fruits from budded trees. In Washington Navel oranges the trend was in the opposite direction. From a commercial standpoint the differences found were not considered significant.

The importance of rootstocks in relation to the composition of citrus fruits is widely recognized both here and abroad. What seems to be needed is a continuation of the systematic studies now under way on the effect of rootstocks of several kinds on the composition of a large number of commercial varieties of citrus. Such investigations might well include tests to determine the value of rootstocks not now in common use and, if possible, to discover new ones that might be worth while.

EFFECT OF MINERAL NUTRITION

H. D. Chapman and W. P. Kelley in 1943, after reviewing the literature on the effect of mineral nutrition on fruit quality, stated (*95, p. 766*):

> It is clear from the work cited that no adequate understanding of the effects of potash, phosphate, or nitrate on all the characters included in the term quality can be gained from the data available. Clearly a great deal more experimental work must be carried out before final conclusions can be reached.

In 1948 Batchelor, commenting on the work of Parker and Batchelor (*68*) published in 1942 on the effect of fertilizers on orange yields, pointed out (*9, p. 370*) that—

> with only relatively small fluctuations in weight of fruit produced per tree, there have been notable seasonal variations in the commercial quality of the oranges, as well as in their size. Such changes may mask results of fertilizer trials conducted for the purpose of determining the effect on fruit size and quality.

A few papers that were included in these two reviews and several others are reviewed herein. The selection was made with a view to giving the reader a basis on which to judge where gaps in our knowledge exist. On the whole, information on the relation of the mineral nutrition of citrus to fruit quality is not much more clear-cut or satisfactory now than it was when the previous comments were made.

Fudge (*33*) reported in 1938 that whole fruits of seedy varieties of grapefruit contained slightly higher percentages of dry matter, total nitrogen, total ash, phosphorus, potassium, calcium, magnesium, iron, and manganese and less aluminum than did comparable fruits of the Marsh seedless variety. The same relation was found for the whole fruit without the seeds, but the differences were not as large. Insofar as mineral composition may be a factor, the food value of the seedy varieties appears to be superior to that of the Marsh seedless. The respiratory ratios for the whole fruits and the seeds of the seedy and seedless varieties did not differ significantly.

Fudge and Fehmerling (*36*) in 1940 concluded that in Florida in hammock groves, soils and rootstocks are of major importance in determining fruit composition, but in groves on Norfolk sand the heavy use of commercial fertilizers exerts a major influence, which must be properly balanced with respect to both major and minor elements. They also reported, as did Camp (*14, 15, 16, 17*) in 1943 to 1945, that copper, manganese, zinc, and magnesium tend to improve fruit composition and quality. In 1941 and 1942 Fudge (*34, 35*) reported that the large amounts of fertilizers that must be applied to the soil to produce the relatively small changes in the mineral composition of the juice that he obtained probably are not warranted in practical grove culture. Addition of calcium salts improved the physical condition of the soil, but there was no evidence that the calcium content of trees or fruit was increased thereby. Magnesium was the only element that improved the physical condition of the trees.

NITROGEN

Young (*97*) in 1917 reported that in California experiments nitrogen was the only fertilizer that affected the composition of oranges. In his work the interaction between nitrogen and phosphorus was apparently not considered. (See Chapman, Brown, and Liebig (*19, 20*), 1943.)

Finch and McGeorge (*30*) in 1940 reported that in Arizona in both the 1937–38 and the 1938–39 season they found an increase in yield of grapefruit in groves that had received some form of commercial nitrogen together with 3 tons of barnyard manure per acre. Potassium and phosphorus either alone or in combination with each other or with nitrogen seemed to have little effect upon yields. Trees receiving nitrogen yielded consistently larger crops than those not receiving nitrogen, but the quality in the different plots was not widely different, possibly because none of the trees bore really heavy crops.

Martin (*61*) in 1940 reported that in Arizona fertilization with nitrogen during the winter, together with clean cultivation, induced a high nitrogen content of the grapefruit trees prior to bloom and gave satisfactory yields; the same practices followed in the summer resulted in vegetative trees and fruit of low commercial grades. In 1942 the same author (*62*) reported that, in general, nitrogenous fertilizers increased yield. Winter cover crops did not seem to be significantly beneficial, and there was some evidence that they may interfere with the uptake of nitrogen.

Innes (*48*) in 1946 reported that in Jamaica nitrogen fertilizers decrease the vitamin C content. Nitrogenous fertilizers applied to soils deficient in nitrogen improve juice quality in other respects. Innes said nothing about the time nitrogen should be applied for best results.

Jones, Bitters, and Finch (*52*) in 1944 reported evidence from work in Arizona that after a stage of maturity that corresponds roughly with "legal maturity" (in grapefruit) has been reached no more nitrogen will enter the fruit regardless of the amount applied. In their opinion it is the nitrogen that entered the tree the previous summer that accounts for the rapid deterioration in market grade that is associated with high nitrogen nutrition. If this be true, the advantages of winter fertilization with nitrogen are obvious.

Jones (*51*) reported in 1944 that the quality of grapefruit was best when fertilization was such that the nitrogen content of the spring flush of growth was about 2.2 percent and decreased progressively in the leaves during the summer to 1.2 percent. A suggested means for establishing this condition is fertilization with nitrogen in December and growing a grass cover crop during the summer.

Chapman, Brown, and Liebig (*19*, *20*) reported in 1943 from fertilizer experiments in California that none of the fruit in the high-nitrogen tests was coarser or of poorer quality than that in the low-nitrogen tests. There was no difference in sugar-acid ratio, acid, total solids, juice percentage, texture of rind, or size or taste of fruit, although fruit in high-nitrogen tests colored up a little less rapidly than that in the low-nitrogen tests. When nitrogen was in excess, the chief effect of deficiency in potassium was a reduction in fruit size. Parker and Batchelor (*68*) in 1942 reported large yield responses to nitrogen applications in California.

Jones and Parker (*53*) in 1947 in California reported an overall inverse correlation between nitrogen and ascorbic acid in navel orange juice. The amount of nitrogen in the juice varied with the amount applied in the fertilizers. (See also Jones and Parker (*54*), 1949.) Addition of organic matter to those fertilizer treatments providing equal amounts of nitrogen per tree annually resulted in a highly significant decrease in nitrogen in the juice but had no effect on the ascorbic acid content.

PHOSPHORUS

Neller and Forsee (*66*) working with oranges on an organic soil in the Florida Everglades, published evidence in 1942 that above the deficiency level increased fertilization with phosphorus reduces solids in the juice. Fruit from trees that had received no phosphorus since 1934 (experiments begun in 1938) was more acid than that from trees grown where phosphate was included in the fertilizer. Forsee and Neller (*32*) reported in 1944 that the quality of Lue Gim Gong oranges grown on a phosphorus-deficient soil in the eastern Everglades was poor. Parker and Batchelor (*68*) in 1942 stated that applications of phosphorus are not necessary for adequate yields of oranges in California. Chapman, Brown, and Liebig (*19*, *20*) in 1943 reported that in California the fruit from both low-phosphate and phosphate-deficient trees tended to be large and rather coarse-textured and to have thick rinds and less juice. (See also Anderssen (*1*), 1937, South Africa.) Excessive nitrogen and adequate phosphate gave fruit of excellent quality. In contrast with Neller and Forsee (*66*), they found that phosphorus decreased the acidity of the juice, as was also reported by Anderssen (*1*) in South Africa and by Jones and Parker (*54*) in 1949 in California.

Jones and Parker (*53*) also reported that as the percentage of phosphorus increased in orange juice the concentration of ascorbic acid decreased.

Innes (*48*) in 1946 in Jamaica reported that potash and phosphates not only give increased yields but also increase the average weight per fruit. Core thickness and skin thickness are increased by potash fertilizers but are reduced by the addition of superphosphates in soils deficient in phosphorus. Smith, Reuther, and Gardner (*88*) in 1949 stated that according to the results of their investigations increased phosphate fertilization is not beneficial to fruit quality. The lowering of total soluble solids, citric acid, and ascorbic acid resulting from such fertilization is deleterious to the internal fruit quality of Valencia oranges.

POTASSIUM

Anderssen (*1*) in 1937 in the Union of South Africa and Jones and Parker (*54*) in 1949 in California stated that a high percentage of potassium in the juice of oranges was accompanied by a high acid content. Roy (*75*) in 1945 in Florida reported that when potassium was deficient in the fertilizer there was an improvement in juice quality; namely, more reducing sugars and total sugars and an increase in the ratio of total solids to acid. Ascorbic acid was lower when potassium was deficient. No evidence was found that the kind of potassium used—muriate or sulfate of potash or sulfate of potash-magnesia—made any difference in the composition of the juice of Valencia oranges.

In 1941 McCollam (*57*) reported that in California heavier than usual applications of potash increased the weight of fruit per box of both Valencia and navel oranges. Over a 3-year period Valencia fruits from three out of six test plots contained more juice and in all but one they had thinner rinds. Navel oranges gave greater volume of juice and thinner rinds in the only two locations under observation from 1933 to 1936. In 1943 McCollam (*58*) reported that in two-thirds of his tests applications of K_2O fertilizers to citrus groves caused a definite trend toward greater volume of juice, heavier fruits, and a thinner rind. A similar result was reported by Innes (*48*) in 1946 from work done in Jamaica. Chapman, Brown, and Rayner (*22*) reported in 1948 that their work gave no evidence of a lack of potassium in most California soils. In controlled nutrient culture these authors (*21*) found that when potassium was in excess to the point of causing tree injury, the fruits were large, coarse, thick-skinned, and of poor eating quality.

MINOR ELEMENTS [19]

Cowart (*25*) in 1942, Cowart and Stearns (*26*) in 1942, Fudge and Fehmerling (*36*) in 1940, Roy and Bahrt (*76*) in 1940, Skinner, Bahrt, and Hughes (*87*) in 1934, Sites (*85*, *86*) in 1944 and 1948, Stearns and Sites (*91*) in 1943, Camp (*14, 15, 16, 17*) in 1943 to 1945, all working in Florida, reported data which they interpreted as showing that improvement in fruit quality results from the correction of deficiences of manganese, magnesium, zinc, and copper in soils on which citrus trees were grow-

---

[19] Zinc, magnesium, copper, and manganese.

ing. In 1943 and 1945 Camp (*14*, *17*) and in 1940 Roy and Bahrt (*76*) reported that zinc was found useful for the prevention of frenching (mottle-leaf) on certain soils and that magnesium was useful for correcting bronzing (a wholesale yellowing of the leaves followed by defoliation whenever a heavy crop is produced). (See also Bahrt (*3*), 1934.) Camp stated that the two most important elements of fruit quality are soluble solids and vitamin C content and that these are both higher in fruit produced on a complete-fertilizer program than in fruit from trees deficient in magnesium, zinc, copper, and manganese.

In this connection it is worth noting the statement made by Hamner (*44*) in 1945 that variations in the ascorbic acid content of plants under field conditions are influenced so greatly by differences between varieties and by climatic conditions that the possible influence of soil conditions and fertilizer practices will probably be found to have little practical importance. Reference may also be made to statements by MacDowell (*59*) in 1945, Martin (*61*) in 1940, and Hodgson and Eggers (*47*) in 1938 as to factors other than fertilizers that may affect fruit quality.

The determination of effect of minor and major nutrient elements on fruit composition under the widely variable conditions of rootstock, soil type, climate, and other environmental factors is difficult, and much critical research will be needed before final conclusions can be drawn.

PIGMENTS

Miller and Winston (*64*) in 1942, from studies of eight varieties of Florida oranges including Satsuma and tangerine, stated that there was a marked increase in the content of carotenoid pigments and a decrease in ascorbic acid as the fruit matured. In general, varieties that were high in ascorbic acid were low in carotenoid pigments and vice versa. The juice of Pineapple oranges was highest in ascorbic acid (0.677 mg. per milliliter) and that of the King variety was lowest (0.242 mg. per milliliter). The juice of Jaffa oranges was lowest in carotenoid pigments (3.11 p.p.m.) and that of the King variety highest (24.52 p.p.m.).

Miller, Winston, and Fisher (*65*) reported in 1941 that the degree of pigmentation of Florida oranges did not seem to be affected by rootstock. The quantity of carotenoid pigments in the juice generally varied with the locality in which the fruit was grown. Some evidence was obtained that low pigment content was associated with low soil fertility. Degree of pigmentation of the juice was not an index of stage of maturity or always of quality.

Stahl and Cain (*90*) reported in 1939 that in Florida carotene increased in both peel and pulp during the marketing season and continued to increase as the fruit became overripe; there was also a slight increase in xanthophyll. Flavones disappeared entirely from the pulp during ripening but increased in the peel. During the same period chlorophyll decreased in the peel.

In 1941 Carrante (*18*) reported that in Italy carotenoids, which are important for their vitamin value, occur in all oranges, whereas anthocyanin pigments occur only in some varieties. Carotenoids were measured as 2,500 to 2,700 international units of vitamin A, a quantity two-thirds that of North American oranges. Anthocyanins are important for the beauty of the fruits. They increase with increased ripening. Carotenoids and xanthophyll also increase with ripening. Storage of oranges at 39.2° F. increases the content of carotenoids, but after 20 days the concentration decreases.

ACIDS

Sinclair and Ramsey (*84*) reported in 1944 from California that analyses of Valencia oranges made monthly during the 8 months while the fruit was developing and ripening showed the following changes in organic acid: the maximum amount of free acid, 1.1 to 1.5 gm. of citric acid per fruit, developed early and then changed little. As the concentration of free acid decreased there was a corresponding increase in pH. The values on October 2 and May 2 are shown in the following tabulation:

Date:	*pH*	*Total free acid (mg. per liter)*	*Malic acid (percent)*
October 2	2.72	39.3	1.4
May 2	3.11	16.1	1.75

Sinclair and Eny (*81*, *82*) reported from California in 1945 and 1946 that the acids in lemon juice and grapefruit are chiefly citric and malic. The concentration of free acids (mg. per liter) in both increased and the pH of the juice decreased with increase in size of fruit. In grapefruit juice more than 50 percent of the total cations (calcium, magnesium, potassium, and sodium) are utilized in the formation of the organic acid salts, as compared with more than 70 percent in the juice of Valencia and navel oranges.

The same authors (*83*) in 1947 reported that ether-soluble organic acids in peels of oranges, grapefruit, and lemons are much lower than in samples of juice from corresponding pulps. These acids, citric and malic, are present in the salt form, not in the free state, as is shown by the high pH values of the peel saps. The authors considered the ether-liquid extraction satisfactory for isolating organic acids from the saps of orange peels.

ACETALDEHYDE AND ETHANOL

Biale and Weiss (*11*) in 1939 in California found that the acetaldehyde content of the peel of oranges, lemons, and grapefruit, as determined by steam distillation, is of the order 0.05 to 0.1 milliequivalent per 100 gm. of fresh rind. They believed that the aldehyde is produced in the rind by respiration and is not the result of the break-down of substances during the distillation. Biale and Shepherd (*10*) in 1940 in California reported that they had found acetaldehyde in lemons, oranges, and grapefruit subjected to restricted ventilation for 12 to 25 days. Fruit stored in air gave no acetaldehyde; that stored in nitrogen gave little or none. Rakitin (*70*) in 1945 reported from the U. S. S. R. that the largest quantities of ethanol and acetaldehyde in various fruits including lemons and oranges were always found during ripening.

REDUCTION OF ACIDITY WITH SPRAYS

In the United States considerable use has been made of arsenical and oil sprays to reduce the acidity of citrus fruits, but not much has been published on the subject. An early report in the United States is that by Gray and Ryan (*37*) in California in 1921. Those investigators (*p. 32*) in a discussion of facts established stated:

> The data secured have shown beyond any reasonable doubt that the acidity of both navel and valencia oranges is greatly reduced when a spray of [lead arsenate] is applied to the trees, even for one season only.

They quoted Webber and Swingle as saying that they had observed in Florida between 1893 and 1896 a reduction in acidity of oranges sprayed with a proprietary insecticide containing an arsenic compound and sulfur. Gray and Ryan believed that the arsenical ingredient of their sprays was the substance that caused the reduction in acidity.

Grebinskii (*38*) in the U. S. S. R. reported in 1940 that spraying citrus with arsenical compounds of lead lowers acidity and sucrose content and increases the content of invert sugar.

Harding and Fisher (*46, p. 4*) in 1945 in Florida found:

> Spraying the trees and fruit in July with one application of lead arsenate (at the rate of 1 pound of lead arsenate to 100 gallons of water), the practice commonly followed commercially, brought about a significant reduction in total acid [in grapefruit]. The total acid of immature sprayed fruit was about 4 to 9 percent below that of the unsprayed, and that of very ripe sprayed fruit was as much as 21 to 26 percent less. The lowering of the acidity by spraying with lead arsenate resulted in higher ratios of total solids to total acid; this, in turn, resulted in earlier maturity, as judged by present legal standards, and more palatable fruit, as shown by the higher average numerical taste ratings. On the other hand, spraying resulted in a slight decrease in the weight of the fruit and consequently in its size. It did not, however, significantly lower the volume of juice computed on a percentage basis or as milliliters of juice per 100 gm. of fruit, or affect the concentration of ascorbic acid or the total solids.

For a brief discussion of the use of arsenical sprays in Florida to reduce the acidity of citrus fruit and the law passed by the Florida legislature regulating the use of such sprays, the reader is referred to Harding and Fisher (*46*). The law at first applied to all citrus fruit. According to Harding and Fisher (*p. 35*) investigation eventually showed, however, that—

> the flavor of grapefruit apparently was not lowered by [the] spray, whereas its injudicious use on oranges and tangerines caused a very marked decrease in total acid and produced flat, insipid, poor-quality fruit. Therefore, in 1933 grapefruit was exempted from the Arsenical Spray Law . . . so that now this law is applied only to oranges and tangerines.

(See also (*31*), 1949.)

In California a State regulation (*13*) prohibits the use of all arsenicals on citrus of all varieties. Arizona and Texas, according to the latest information available, have no such prohibition.

Sinclair, Bartholomew, and Ebeling (*79, 80*) in California in 1941 reported that spraying citrus trees with light to medium petroleum oils at concentrations of 0.25 to 1.75 percent reduced the total soluble solids, the reducing sugars, and the total sugars of the fruit juice. This effect held in spite of wide differences in environmental conditions, soil types, and times the sprays were applied. Fumigation with hydrocyanic acid gas in either fall or winter did not affect the chemical composition of mature fruits. Thompson and Sites (*93*) in 1945 reported from Florida that when oil sprays were applied after August 1 they either delayed or prevented the formation of maximum solids, especially during the early part of the picking season.

In the Union of South Africa several investigators—Copeman (*23*, *24*) in 1931 and 1936, Marloth and Stofberg (*60*) in 1939, and Crous (*27*, *28*) in 1940, 1941, and 1947—reported that spraying with lead arsenate reduced the acidity of citrus fruits. Marloth and Stofberg, as well as Crous and workers in this country, found that such spraying had no effect on the total soluble solids of the juice and that consequently the solids-acid ratio was higher in sprayed than in unsprayed fruit. In fact, as is well known, this is precisely the object of spraying with lead arsenate, since it makes the fruit marketable at an earlier date than it would be if not sprayed.

Marloth and Stofberg found that the quantity of arsenic on fruit after the application of lead arsenate cover sprays was negligible. No increase in the lead or copper content of the juice resulted from cover sprays of lead arsenate or copper carbonate. Copper carbonate (five cover sprays) had no effect on acidity. Crous found in regard to arsenates that (1) spraying in December was more effective than spraying in March or July, (2) the carry-over effect lasted for 2 years, and (3) spraying the same trees oftener than once in 3 years made the fruit insipid. The spraying seemed to have no effect on yield, volume of juice, arsenic or vitamin C content of the fruit or its carrying quality. Crous also found that spraying Valencia oranges with lead arsenate had very little effect on the arsenic content of the fruit. He recommended that for best results (in South Africa) spraying should be done in January or even in December. Esselen and Oberholzer (*29*) in 1939, also in South Africa, reported that spraying citrus trees with 1.5 pounds of superphosphate in 3 gallons of water reduced acidity of the fruit and increased the solids-acid ratio. In contrast with the authors just cited, Wood and Reed (*96*) in 1936 reported that oil sprays had no effect on the maturing of Texas grapefruit. The same was true of lime-sulfur and zinc-lime sprays.

It is interesting to note that, judging from the amount of published material, more work has been done in the Union of South Africa than elsewhere on the use of sprays to reduce acidity. According to Neumark (*67*) citrus is higher in acidity there than in other countries.

In 1936–37 investigations were made by U. S. Bureau of Entomology and Plant Quarantine on the effect of tartar emetic spray on the composition of the juice of oranges and grapefruit. Strong, Chief of the Bureau (*94*), reported in 1937 that spraying citrus trees with tartar emetic at 10- to 20-day intervals with mist sprays containing 4 pounds of tartar emetic and 5 gallons of molasses in 100 gallons of spray produced no injurious effects on trunks, branches, leaves, or fruit. Analyses of juice samples showed no differences in quality that could be attributed to the use of the spray.

METHODS OF ANALYSIS

In 1939 Stevens and Baier (*92*) and in 1945 Baier (*4*, *5*) reported that the Brix spindle and the refractometer give too high and too low values, respectively, for soluble solids in citrus juices owing to the presence of citric acid, invert sugar, ash, insoluble solids, and essential oils. Citric acid seems to have the greatest influence upon the readings. The greatest difference between Brix and refractometric values was observed in highly acid juices. A table was prepared giving the correction to be added to a refractometer sucrose value to obtain the correct degree Brix and the true soluble solids for each percentage of acid. Tests made on known mixtures of citric acid and sucrose verified the corrections given in the table.

Jessep (*49*) in 1939 in Australia reported that a refractometer is a useful instrument for determining the soluble solids in various horticultural products including citrus fruits. By the use of a hand press a few drops of liquid, which suffice for the determination, can be obtained easily. In 1941 Lorenz and Arnold (*56*) described a method of preparing and estimating crude citrin solutions from lemons. Citrin, also known as vitamin P, has been found to counteract capillary permeability. The method is colorimetric and is based on the use of 0.05 N iodine as a standard. Appleman and Richards (*2*) in 1940 reported from California that, because of variability in the composition of Valencia oranges, a sample of 10 oranges is quite insufficient; 20 to 30 fruits give a much better representation. Baier (*5*) stated in 1945 that in California, to determine percentage of juice, the volume of fruit is measured by water displacement and then the juice is extracted, strained, and measured. The maturity ratio is the quotient obtained by dividing the weight of total solids by the accompanying weight of citric acid. Baier described a modified method for obtaining a definite volume of liquid for titration.

In 1946 there was presented a nomograph by Schneider (*77*) for determining the ratio of total solids to total acid in citrus juices once the corrected Brix and burette readings are known. It can be used only when a 25-cc. sample is being titrated and only when a standard sodium hydroxide solution of 0.1562 normality is being used.

LITERATURE CITED FOR COMPOSITION

(1) Anderssen, F. G.
1937. FERTILIZATION OF WASHINGTON NAVEL ORANGES. II.—INFLUENCE ON QUALITY AND COMPOSITION OF FRUIT. Farming in So. Africa 12: 373–376, 382, illus.

(2) Appleman, D., and Richards, A. V.
1940. VARIABILITY OF SUGAR-ACID RATIO AND TOTAL NITROGEN IN VALENCIA ORANGES. Amer. Soc. Hort. Sci. Proc. (1939) 37: 539–542.

(3) Bahrt, G. M.
1934. PROGRESS REPORT OF SOIL FERTILITY AND FERTILIZER EXPERIMENTS ON BRONZING OF CITRUS. Fla. State Hort. Soc. Proc. 47: 18–20.

(4) Baier, W. E.
1945. HOW THE CITRUS INDUSTRY MEASURES IT. II. CITRUS JUICE COMPOSITION. Calif. Citrog. 30: 234–239, illus.

(5) Baier, W. E.
1945. HOW THE CITRUS INDUSTRY MEASURES IT. V. JUICE VOLUME. Calif. Citrog. 30: 342, 356, illus.

(6) Bartholomew, E. T., and Sinclair, W. B.
1939. DISTRIBUTION OF SOLUBLE SOLIDS IN CITRUS JUICES. Calif. Citrog. 24: 352, 362–363, 382–384, illus.

(7) ——— and Sinclair, W. B.
1941. UNEQUAL DISTRIBUTION OF SOLUBLE SOLIDS IN THE PULP OF CITRUS FRUITS. Plant Physiol. 16: 293–312, illus.

(8) ——— Sinclair, W. B., and Janes, B. E.
1938. SOLUBLE SOLIDS IN CITRUS FRUITS. Science 87: 584.

(9) Batchelor, L. D., and Webber, H. J., editors.
1948. THE CITRUS INDUSTRY. VOLUME II. PRODUCTION OF THE CROP. 933 pp., illus. Berkeley and Los Angeles.

(10) Biale, J. B., and Shepherd, A. D.
1940. IDENTIFICATION OF ACETALDEHYDE AMONG THE VOLATILE PRODUCTS OF CITRUS FRUITS. Amer. Soc. Hort. Sci. Proc. (1939) 37: 543–547, illus.

(11) ——— and Weiss, F. T.
1939. IDENTIFICATION OF ACETALDEHYDE IN THE STEAM DISTILLATE OF THE PEEL OF CITRUS FRUITS. Amer. Chem. Soc. Jour. 61: 635–636.

(12) Braverman, J. S., and Carmi, A.
1937. THE COMPOSITION OF PALESTINE ORANGES. Hadar 10: 147–148, 150–152, illus.

(13) California Administrative Code.
1949. ADMINISTRATIVE CODE, TITLE 3. Sec. 2378, p. 184.

(14) Camp, A. F.
1943. A RESUME OF FEEDING AND SPRAYING CITRUS TREES—FROM A NUTRITIONAL VIEWPOINT. Citrus Indus. 24 (9): 3, 6–7, 9, 12–15, 18; 24 (10): 6–7, 14–15.

(15) ———
1944. A RESUME OF FEEDING AND SPRAYING CITRUS TREES FROM A NUTRITIONAL VIEWPOINT. Fla. State Hort. Soc. Proc. (1943) 56: 60–79.

(16) ———
[1945.] CITRUS GROWING IN FLORIDA. *In* Citrus Industry of Florida, pp. [5]–140, illus. (Fla. Dept. Agr. in cooperation with Univ. of Fla.)

(17) ———
1945. THE MINOR ELEMENTS IN CITRUS FERTILIZATION. Com. Fert. 70 (1): 22–24, 26, 28, 30, 32, 42, illus.

(18) Carrante, V.
1941. PIGMENTS OF ITALIAN ORANGES. Acireale R. Staz. Sper. di Fruttic. e Agrumic. Ann. 16: 193–236. [Not seen; abstract in Chem. Abs. v. 42, column 695. 1948.]

(19) Chapman, H. D., Brown, S. M., and Liebig, G. F., Jr.
1943. BIG 3 AND FRUIT QUALITY. Citrus Leaves 23 (8): 11–13, illus.

(20) ——— Brown, S. M., and Liebig, G. F., Jr.
1943. SOME EFFECTS ON CITRUS FRUIT QUALITY OF NITROGEN, PHOSPHORUS AND POTASSIUM. Calif. Citrog. 28: 198, 211, 230, 246, illus.

(21) ——— Brown, S. M., and Rayner, D. S.
1947. EFFECTS OF POTASH DEFICIENCY AND EXCESS ON ORANGE TREES. Hilgardia 17: 619–641, illus.

(22) ——— Brown, S. M., and Rayner, D. S.
1948. SOME EFFECTS OF POTASH DEFICIENCY AND EXCESS ON ORANGE TREE GROWTH, COMPOSITION AND FRUIT QUALITY. Calif. Citrog. 33: 278–279, 290, illus.

(23) Copeman, P. R. v. d. R.
1931. CHANGES IN THE COMPOSITION OF ORANGES DURING RIPENING. Roy. Soc. So. Africa, Cape Town, Trans. 19: 107–167, illus.

(24) ———
1936. THE COMPOSITION OF ORANGE SKINS. Jour. Pomol. and Hort. Sci. 14: 205–215.

(25) Cowart, F. F.
1942. THE EFFECT OF MAGNESIUM DEFICIENCY IN GRAPEFRUIT TREES UPON THE COMPOSITION OF FRUIT. Amer. Soc. Hort. Sci. Proc. 40: 161–164.

(26) Cowart, F. F., and Stearns, C. R., Jr.
1942. THE EFFECT OF CERTAIN FERTILIZER PRACTICES ON THE TIME OF MATURITY AND COMPOSITION OF GRAPEFRUIT AND ORANGES. Fla. State Hort. Soc. Proc. (1941) 54: 12–19.

(27) Crous, P. A.
1940–41. THE REDUCTION OF ACIDITY IN VALENCIAS BY THE USE OF ARSENICAL SPRAYS. Citrus Grower [So. Africa] No. 82, pp. [1], 3, 5, 7, 1940; No. 94, pp. [1], 3, 5, 7, 9, 1941.

(28) ———
1947. REDUCTION OF ACIDITY IN VALENCIAS. Citrus Grower [So. Africa] No. 156, pp. 8–9.

(29) Esselen, D. J., and Oberholzer, P. C. J.
1939. REDUCTION OF ACID IN VALENCIAS. EFFECT OF SUPERPHOSPHATE SPRAYS. Farming in So. Africa 14: 21–22.

(30) Finch, A. H., and McGeorge, W. T.
1940. STUDIES OF GRAPEFRUIT FERTILIZATION IN ARIZONA. Amer. Soc. Hort. Sci. Proc. (1939) 37: 62–67, illus.

(31) Florida Statutes Annotated.
1949. FLORIDA CITRUS CODE [OF 1949]. Ch. 25149, sec. 1–112, pp. 312–359.

(32) Forsee, W. T., Jr., and Neller, J. R.
1944. PHOSPHATE RESPONSE IN A VALENCIA GROVE IN THE EASTERN EVERGLADES. Fla. State Hort. Soc. Proc. 57: 110–115.

(33) Fudge, B. R.
1938. MAGNESIUM DEFICIENCY IN RELATION TO YIELD AND CHEMICAL COMPOSITION OF SEEDY AND COMMERCIALLY SEEDLESS VARIETIES OF GRAPEFRUIT. Fla. State Hort. Soc. Proc. 51: 34–43, illus.

(34) ———
1941. THE MINERAL COMPOSITION OF CITRUS JUICE AS INFLUENCED BY SOIL TREATMENT. Citrus Indus. 22 (10): 3, 6–7, 14–15.

(35) ———
1942. THE MINERAL COMPOSITION OF CITRUS JUICE AS INFLUENCED BY SOIL TREATMENT. Fla. State Hort. Soc. Proc. (1941) 54: 4–12.

(36) ——— and Fehmerling, G. B.
1940. SOME EFFECTS OF SOILS AND FERTILIZERS ON FRUIT COMPOSITION. Citrus Indus. 21 (9): 6–7, 11, 14–15.

(37) Gray, G. P., and Ryan, H. J.
1921. REDUCED ACIDITY IN ORANGES CAUSED BY CERTAIN SPRAYS. Calif. Dept. Agr. Monthly Bul. 10: 11–33.

(38) Grebinskii, S. O.
1940. THE EFFECT OF SOIL CONDITIONS, FERTILIZERS, CLIMATE AND OTHER FACTORS ON THE CHEMICAL COMPOSITION OF CITRUS FRUITS. Biokhim. Kul'tur. Rasteniĭ 7: 269–276. [Not seen; abstract in Chem. Abs. v. 35, columns 2926–2927. 1941.]

(38a) ———
1940. THE CHEMICAL DIFFERENCES IN DIFFERENT VARIETIES OF CITRUS FRUITS. Biokhim. Kul'tur. Rasteniĭ 7: 300–310. [Not seen; abstract in Chem. Abs. v. 35, column 2927. 1941.]

(39) Haas, A. R. C.
1948. EFFECT OF THE ROOTSTOCK ON THE COMPOSITION OF CITRUS TREES AND FRUIT. Plant Physiol. 23: 309–330.

(40) Halma, F. F.
1943. ROOTSTOCK INFLUENCE ON THE COMPOSITION OF VALENCIA ORANGE FRUIT. Amer. Soc. Hort. Sci. Proc. 42: 349–352, illus.

(41) ———
1944. QUALITY OF FRUIT FROM OWN-ROOTED AND BUDDED ORANGE TREES. Amer. Soc. Hort. Sci. Proc. 44: 223–226, illus.

(42) ———
1944. ROOTSTOCK INFLUENCE ON THE COMPOSITION OF VALENCIA ORANGE FRUITS. Calif. Citrog. 29: 211, illus.

(43) ———
1946. QUALITY OF FRUIT FROM OWN-ROOTED AND BUDDED ORANGE TREES. Calif. Citrog. 31: 236–237, illus.

(44) Hamner, K. C.
1945. MINOR ELEMENTS AND VITAMIN CONTENT OF PLANTS. Soil Sci. 60: 165–171.

(45) HARDING, P. L., and DYER, R. M.
1942. EFFECT OF THINNING ON SOME OF THE PHYSICAL AND CHEMICAL CHARACTERS OF VALENCIA ORANGES. Citrus Indus. 23 (8): 7, 10.
(46) ——— and FISHER, D. F.
1945. SEASONAL CHANGES IN FLORIDA GRAPEFRUIT. U. S. Dept. Agr. Tech. Bul. 886, 100 pp., illus.
(47) HODGSON, R. W., and EGGERS, E. R.
1938. ROOTSTOCK INFLUENCE ON THE COMPOSITION OF CITRUS FRUITS. Calif. Citrog. 23: 499, 531.
(48) INNES, R. F.
1946. FERTILIZERS EXPERIMENTS ON GRAPEFRUIT IN JAMAICA. Trop. Agr. [Trinidad] 23: 131–133.
(49) JESSEP, H. G.
1939. THE RAPID DETERMINATION OF SOLUBLE SOLIDS. Soc. Chem. Indus. Victoria Proc. 39: 180–183.
(50) JOACHIM, A. W. R., and PANDITTESEKERE, D. G.
1939. THE COMPOSITION OF LOCAL AND IMPORTED CITRUS FRUIT. Trop. Agr. [Ceylon] 93: 14–24.
(51) JONES, W. W.
1944. NITROGEN CONTROL PROGRAM. [REDUCTION OF NITROGEN IN SUMMER . . . FOR HIGHER QUALITY GRAPEFRUIT. .] Citrus Leaves 24 (5): 10–11, illus.
(52) ——— BITTERS, W. P., and FINCH, A. H.
1944. THE RELATION OF NITROGEN ABSORPTION TO NITROGEN CONTENT OF FRUIT AND LEAVES IN CITRUS. Amer. Soc. Hort. Soc. Proc. 45: 1–4, illus.
(53) ——— and PARKER, E. R.
1947. ASCORBIC ACID-NITROGEN RELATIONS IN NAVEL ORANGE JUICE, AS AFFECTED BY FERTILIZER APPLICATIONS. Amer. Soc. Hort. Sci. Proc. 50: 195–198, illus.
(54) ——— and PARKER, E. R.
1949. EFFECTS OF NITROGEN, PHOSPHORUS, AND POTASSIUM FERTILIZERS AND OF ORGANIC MATERIALS ON THE COMPOSITION OF WASHINGTON NAVEL ORANGE JUICE. Amer. Soc. Hort. Sci. Proc. 53: 91–102.
(55) LEWIS, W. E.
[1942.] ANALYSIS OF DATA RELATIVE TO THE MATURITY OF FLORIDA EARLY AND MIDSEASON COMMON SWEET ORANGES, SEASONS 1938, 1939, AND 1940. U. S. Agr. Market. Serv. [Unnumb. Pub.], 20 pp., illus. [Processed.]
(56) LORENZ, A. J., and ARNOLD, L. J.
1941. PREPARATION AND ESTIMATION OF CRUDE CITRIN SOLUTIONS (VITAMIN P) FROM LEMONS. Food Res. 6: 151–156, illus.
(57) MCCOLLAM, M. E.
1941. POTASH AND CITRUS CROPS. Calif. Citrog. 26: 253, 266, illus.
(58) ———
1943. POTASH FOR CITRUS CROPS IN CALIFORNIA. Better Crops With Plant Food 27 (7): 11–14, 49–50, illus.
(59) MACDOWELL, L. G.
1945. CHANGES IN FLORIDA FRUIT IN RECENT YEARS. Citrus Indus. 26 (1): 8–9.
(60) MARLOTH, R. H., and STOFBERG, F. J.
1939. EFFECT OF ARSENIC AND COPPER SPRAYS ON NAVEL ORANGES. Farming in So. Africa 14: 180–181.
(61) MARTIN, W. E.
1940. SOME EFFECTS OF CULTURAL PRACTICES UPON TREE COMPOSITION, YIELD AND QUALITY OF MARSH GRAPEFRUIT IN ARIZONA. Amer. Soc. Hort. Sci. Proc. (1939) 37: 68–75, illus.
(62) ———
1942. PHYSIOLOGICAL STUDIES OF YIELD, QUALITY, AND MATURITY OF MARSH GRAPEFRUIT IN ARIZONA. Ariz. Agr. Expt. Sta. Tech. Bul. 97, 48 pp., illus.
(63) MATUMOTO, S.
1939. BIOCHEMICAL STUDIES OF THE SATSUMA ORANGE. Chem. Soc. Japan Jour. 60: 1127–1148. [Not seen; abstract in Chem. Abs. v. 36, column 6256. 1942.]

(64) Miller, E. V., and Winston, J. R.
1942. JUICE COLOR AND QUALITY IN CERTAIN VARIETIES OF FLORIDA CITRUS FRUITS. Fla. State Hort. Soc. Proc. (1941) 54: 64–67.

(65) ——— Winston, J. R., and Fisher, D. F.
1941. A PHYSIOLOGICAL STUDY OF CAROTENOID PIGMENTS AND OTHER CONSTITUENTS IN THE JUICE OF FLORIDA ORANGES. U. S. Dept. Agr. Tech. Bul. 780, [32] pp., illus.

(66) Neller, J. R., and Forsee, W. T., Jr.
1942. FERTILIZER EXPERIMENTS IN AN ORANGE GROVE IN THE EASTERN EVERGLADES. Fla. State Hort. Soc. Proc. (1941) 54: 1–4.

(67) Neumark, S. D.
1938. THE CITRUS INDUSTRY OF SOUTH AFRICA. ITS NATIONAL AND INTERNATIONAL ASPECTS. 192 pp., illus. Johannesburg. (Thesis, M. Com., Univ. Witwatersrand).

(68) Parker, E. R., and Batchelor, L. D.
1942. EFFECT OF FERTILIZERS ON ORANGE YIELDS. Calif. Agr. Expt. Sta. Bul. 673, 39 pp., illus.

(69) Puche Alvarez, J.
1940. EL CONTENIDO DE ACIDO ASCORBICO Y EL PROCESO DE MADURACION EN ALGUNAS VARIEDADES DE NARANJA VALENCIANA. Ciencia [Mexico] 1: 159–161.

(70) Rakitin, Yu. V.
1945. ACCUMULATION OF ETHANOL AND ACETALDEHYDE IN RIPENING FRUITS. Biokhimiia 10: 373–378. [Not seen; abstract in Chem. Abs. v. 40, column 2903. 1946.]

(71) Richards, A. V.
1940. INFLUENCE OF ROOTSTOCK ON QUALITY OF CITRUS FRUIT. Trop. Agr. [Ceylon] 94: 354–361, illus.

(72) Rodriguez, E. M.
1938. CHEMICAL CONTROL IN HARVESTING ORANGES. Agronomia 3 (14): 51–52. [Not seen; abstract in Chem. Abs. v. 33, column 4338. 1939.]

(73) Ross, E.
1941. THE VITAMIN C, SOLIDS AND ACID IN ORANGE AND GRAPEFRUIT JUICES USED FOR CANNING PURPOSES. Citrus Indus. 22 (8): 5, 9, 12–13.

(74) ———
1942. THE VITAMIN C, SOLIDS AND ACID IN ORANGE AND GRAPEFRUIT JUICES USED FOR CANNING PURPOSES. Fla. State Hort. Soc. Proc. (1941) 54: 56–60.

(75) Roy, W. R.
1945. EFFECT OF POTASSIUM DEFICIENCY AND OF POTASSIUM DERIVED FROM DIFFERENT SOURCES ON THE COMPOSITION OF THE JUICE OF VALENCIA ORANGES. Jour. Agr. Res. 70: 143–169, illus.

(76) ——— and Bahrt, G. M.
1940. THE EFFECT OF ZINC, IRON, MANGANESE AND MAGNESIUM[,] APPLIED TO FRENCHED AND BRONZED ORANGE GROVES, ON THE VITAMIN C CONTENT OF ORANGES. Fla. State Hort. Soc. Proc. 53: 34–38.

(77) Schneider, J. J.
1946. NOMOGRAPH FOR THE DETERMINATION OF SOLUBLE SOLIDS ACID RATIO IN CITRUS PRODUCTS. Citrus Leaves 26 (5): 34, illus.

(78) Sinclair, W. B., and Bartholomew, E. T.
1944. EFFECTS OF ROOTSTOCK AND ENVIRONMENT ON THE COMPOSITION OF ORANGES AND GRAPEFRUIT. Hilgardia 16: 125–176, illus.

(79) ——— Bartholomew, E. T., and Ebeling, W.
1941. COMPARATIVE EFFECTS OF SPRAY AND HYDROCYANIC ACID FUMIGATION ON THE COMPOSITION OF ORANGE FRUITS. Jour. Econ. Ent. 34: 821–829, illus.

(80) ——— Bartholomew, E. T., and Ebeling, W.
1941. COMPOSITION OF THE JUICE OF ORANGE FRUITS FROM OIL-SPRAYED AND HCN-FUMIGATED TREES. Calif. Citrog. 26: 322, 346–348, illus.

(81) ——— and Eny, D. M.
1945. THE ORGANIC ACIDS OF LEMON FRUITS. Bot. Gaz. 107: 231–242, illus.

(82) ——— and Eny, D. M.
1946. THE ORGANIC ACIDS OF GRAPEFRUIT JUICE. Plant Physiol. 21: 140–147, illus.

(83) SINCLAIR, W. B., and ENY, D. M.
1947. ETHER-SOLUBLE ORGANIC ACIDS AND BUFFER PROPERTIES OF CITRUS PEELS. Bot. Gaz. 108: 398–407, illus.

(84) ——— and RAMSEY, R. C.
1944. CHANGES IN THE ORGANIC-ACID CONTENT OF VALENCIA ORANGES DURING DEVELOPMENT. Bot. Gaz. 106: 140–148, illus.

(85) SITES, J. W.
1944. SOURNESS IN GRAPEFRUIT IN RELATION TO SEASONAL VARIATIONS AND NUTRITIONAL PROGRAMS. Fla. State Hort. Soc. Proc. 57: 122–132, illus.

(86) ———
1948. INTERNAL FRUIT QUALITY AS RELATED TO PRODUCTION PRACTICES. Fla. State Hort. Soc. Proc. (1947) 60: 55–62.

(87) SKINNER, J. J., BAHRT, G. M., and HUGHES, A. E.
1934. INFLUENCE OF FERTILIZERS AND SOIL AMENDMENTS ON CITRUS TREES, FRUIT PRODUCTION AND QUALITY OF FRUIT. Fla. State Hort. Soc. Proc. 47: 9–17.

(88) SMITH, P. F., REUTHER, W., and GARDNER, F. E.
1949. PHOSPHATE FERTILIZER TRIALS WITH ORANGES IN FLORIDA. II. EFFECT ON SOME FRUIT QUALITIES. Amer. Soc. Hort. Soc. Proc. 53: 85–90.

(89) SOSA, A., and SANNIÉ, C.
1944. SUR LA COMPOSITION DE CITRUS TRIFOLIATA L. Soc. de Chim. Biol. Bul. 26: 457–461.

(90) STAHL, A. L., and CAIN, J. C.
1939. CITRUS MATURITY STUDIES. Fla. Agr. Expt. Sta. Ann. Rpt. 1938–39: 111.

(91) STEARNS, C. R., Jr., and SITES, J. W.
1943. FRUIT QUALITY STUDIES: (A) EFFECT OF MAGNESIUM AND OTHER NUTRITIONAL ELEMENTS UPON THE INTERNAL QUALITY OF GRAPEFRUIT. Fla. Agr. Expt. Sta. Ann. Rpt. 1942–43: 207–212.

(92) STEVENS, J. W., and BAIER, W. E.
1939. REFRACTOMETRIC DETERMINATION OF SOLUBLE SOLIDS IN CITRUS JUICES. Indus. and Engin. Chem., Analyt. Ed., 11: 447–449.

(93) THOMPSON, W. L., and SITES, J. W.
1945. RELATIONSHIP OF SOLIDS AND RATIO TO TIMING OF OIL SPRAYS ON CITRUS. Citrus Indus. 26 (5): 6–8, 14, illus.

(94) UNITED STATES BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE.
1937. SUBTROPICAL FRUIT INSECTS. *In* U. S. Bur. Ent. and Plant Quar. Ann. Rpt. 1936–37: 5–6.

(95) WEBBER, H. J., and BACHELOR, L. D., editors.
1943. THE CITRUS INDUSTRY. VOLUME I. HISTORY, BOTANY, AND BREEDING. 1,028 pp., illus. Berkeley and Los Angeles.

(96) WOOD, J. F., and REED, H. M.
[1936.] FACTORS AFFECTING THE MATURITY OF GRAPEFRUIT. Tex. Agr. Expt. Sta. Ann. Rpt. (1935) 48: 246.

(97) YOUNG, H. D.
1917. EFFECT OF FERTILIZERS ON THE COMPOSITION AND QUALITY OF ORANGES. Jour. Agr. Res. 8: 127–138.

VITAMINS

It is not necessary to repeat here the statements made early in this digest as to the importance of citrus fruits as a source of vitamin C (ascorbic acid). It is desirable, however, to review briefly five papers that bear on the subject. Lorenz (*51*)[20] in 1939 gave details of the history of the use of lemons in China and other parts of the world for the treatment of scurvy and other human ailments. He stated (*p. 140*): "The nutritional research story of vitamin C is virtually that of lemons. For a long time the two meant the same." Borsook (*14*) stated in 1942 that a balanced daily diet should contain 75 mg. of vitamin C. He based this on the standards set up by the national nutritional conference in 1941. He said further that most of the vitamin C comes from tomatoes and citrus fruits.

The Bureau of Human Nutrition and Home Economics, U. S. Department of Agriculture (*94*), recommended a daily allowance of ascorbic acid varying from 30 mg. for an infant less than 1 year old to 100 mg. for a boy 16 to 20 years old and 150 mg. for a woman during lactation. The daily allowance recommended for an average adult averages about 70 to 80 mg. The allowances were based on revised tables prepared by the National Research Council in 1948. According to Clark, Friend, and Burk (*17*) the amount of ascorbic acid available in our national food supply increased slightly from 1909 to the early 1930's and markedly after 1937, so that in 1945 the level was 39 percent higher than in 1930. They attributed much of the increase to the greater consumption of citrus fruits.

A survey by the Bureau of Human Nutrition and Home Economics (*96*) in 1948–49 of the citrus fruit consumed by city families indicated that 86.9 percent of the families interviewed had purchased some form of citrus fruit in the week they were interviewed. It was found that purchases of citrus fruits and products increased as the size of the family increased. Data given by the same bureau on nutritive value of diets of urban families in the United States indicate that 44.2 percent of the ascorbic acid was obtained from tomatoes and citrus fruits in 1948 (*95*).

VITAMIN C

EFFECT OF MINERAL NUTRITION

Not much published material has been found on the effect of mineral nutrition of citrus trees on the ascorbic acid content of the fruits. Two publications by workers at the Arizona Agricultural Experiment Station (Jones and others (*47*), 1944, and Jones, Van Horn, and Finch (*46*), 1945) reported results obtained from nitrogen fertilization of grapefruit. Jones and others found that fruits

[20] Italic numbers in parentheses refer to Literature Cited for Vitamins, p. 101.

from trees handled to give a low nitrogen content at harvest had 20 to 25 percent more ascorbic acid than fruits from trees with a higher nitrogen content. Jones, Van Horn, and Finch reported (*p. 469*) that—

the juice of the fruit which matured under low nitrogen conditions contained as much ascorbic acid at the end of the harvest season as did that of the high nitrogen plot at the beginning of harvest.

They further stated that there seem to be two factors that affect vitamin C concentration in plants: namely, sunlight, which tends to increase it, and luxuriant growth, which tends to reduce it. Under desert conditions, as in Arizona, light is not a limiting factor; hence nitrogen becomes the effective factor that conditions or limits the accumulation of sugars for conversion into ascorbic acid. Jones and his associates believed that, by simply not increasing the nitrogen level of the tree during the summer without attempting to reduce it, an improvement in fruit quality can be brought about. Jones and Parker (*44, p. 198*) reported in 1947 from work with navel oranges that when nitrogen is a limiting factor, that is, "when the limits of nitrogen supply are widened, there is a correlation, the ascorbic acid in the juice varying inversely with the nitrogen." In 1949 the same authors (*45*) reported the same inverse relation between ascorbic acid and nitrogen in their further tests. They also reported that the application of phosphorus tended to reduce the ascorbic acid concentration but that potassium appeared to cause a slight increase.

Reuther and others (*68*) reported in 1948 that in long-term phosphate fertilization trials with Valencia oranges in Florida on light sandy soils the fruit from the high-phosphate treatments had 14.6 percent less ascorbic acid than the fruit from the low treatments.

The tendency of nitrogenous fertilizers and phosphates to reduce the vitamin C content of citrus fruit was reported by Innes (*42*) in 1946 in Jamaica. It would be of interest to know what effect such fertilizers have on vitamin C content of both oranges and grapefruit in other producing regions.

Information on the importance of the minor elements in fertilizers was furnished by the work of Roy and Bahrt (*75*) in 1940 in Florida. They found that oranges from frenched trees (trees showing mottle-leaf or partial chlorosis) and from bronzed trees (trees showing wholesale yellowing of the leaves) yielded juice that contained subnormal quantities of ascorbic acid. Addition of zinc to the soil under frenched trees and of magnesium to soil in which bronzed trees were growing restored the ascorbic acid content of the fruit to the normal level.

Hamner (*30*) in 1945 in a paper on minor elements and vitamin content of plants made the comment (*p. 170*):

It seems probable that variations in the ascorbic acid content of plants such as might be encountered under field conditions are influenced so markedly by differences between varieties and by climatic conditions that the possible influence of soil conditions and fertilizer practices will be found to have little practical importance.

In regard to both carotene and ascorbic acid he considered it—

fortunate from a practical standpoint that results which have been obtained to date indicate that those treatments which are likely to give the highest crop yield per acre are also the ones most likely to give the highest vitamin yield per acre.

STABILITY

It is desirable that citrus fruits have a high vitamin C content and also that the vitamin be not greatly affected by commercial handling to which the fruit must be subjected. Results from cold-storage tests are conflicting. Hamersma (*28*, *29*) in 1938 reported from Union of South Africa that vitamin C in oranges is remarkably stable even after storage at 38° F. for 3 months. He found that the acid content does not affect the stability markedly, although if the acid content is high the vitamin C content is likely to be. Harding (*32*), in storage tests conducted in Florida in 1949, found, however, that there was a marked decrease in total acid and ascorbic acid in Valencia oranges during 16 weeks' storage at 32° and 38°. Bratley (*15*) reported in 1940 that vitamin C decreased considerably in tangerines stored on the market for 6 to 8 weeks at 32° to 35°. According to Dernovskaya-Zelentsova and Dylevskaya (*19*) in 1941 mandarin oranges wrapped in paper and packed in crates retained up to 95 percent of the original vitamin C content during 3 months' storage. These results seem to contradict those obtained by Bratley. The storage temperature used is not given. It must have been fairly low, however; otherwise the fruit would not have kept for 3 months.

Apparently very little work has been done on the stability of vitamin C in citrus fruits at room temperatures.

Mouriquand and Lavaud (*60*) in 1942 in France stated that loss of water during storage at room temperature and at 6° C. (42.8° F.) did not cause loss of vitamin C from the juice of lemons. Tsushi (*91*) during investigations on oranges and grapefruit in Japan, reported in 1946, found that after 1 month at ordinary storage the reduced vitamin C was 89 percent of the original quantity and the total vitamin C was 90 percent. The peel was found to contain four or five times as much vitamin C as the juice, but after 1 month its reduced vitamin C content was 57 percent of the original quantity and its total vitamin C content 59 percent. Sergeev (*79*) in U. S. S. R. reported in 1946 that storage in the light with access of air rapidly destroyed the vitamin, but storage in the dark without air for 90 days left 93.3 percent of the original content. The citrus industry of California doubtless has information on the behavior of the vitamin C of lemons at the rather mild storage temperature (55° to 58° F.) used for that fruit, but no statements have been seen concerning it. In view of the rather meager information it has been possible to present here, it is evident that the problem should be investigated more intensively than seems to have been done.

A question that arises in connection with the stability or lack of stability of vitamin C in storage is whether and to what extent there occur in citrus fruits substances that protect the vitamin from destruction. Somogyi (*85*) in U. S. S. R. reported in 1945 that citrus fruits, parsley, haws, tomatoes, and leeks contain relatively large quantities of something that protects ascorbic acid from oxidation during drying. The same author (*84*) also reported in the same year that the substance in lemons that protects ascorbic acid from degradation is the most active of all those substances found in plants; in 90 minutes in a 6-percent solution it inhibits completely the oxidation of ascorbic acid. This substance is considered to be of primary importance in connection with losses in vitamin C during drying. Its action is independent of whether vitamin C is being degraded by ascorbic oxidase, phenol polyphenolase, peroxidase, or copper.

If information could be obtained as to what factors—maturity of fruit, storage conditions, and length of storage—favor the retention of vitamin C, it should be valuable to the citrus industry and to consumers. Perhaps the most fundamental approach to the problem would be to determine the effect of the factors just enumerated on the presence or absence of protective substances such as those reported by Somogyi. In this connection it should be noted that Guild, Lockhart, and Harris (*27*) in their investigation of the stability of ascorbic and dehydroascorbic acid were dealing with solutions of the pure acids and worked with freshly prepared and with aged solutions. It is the old question of how far results obtained in vitro can be assumed to hold in vivo. Certainly, complicating factors are present in the latter case that are not present in the former.

EFFECT OF VARIOUS FACTORS

Maturity

Harding and Winston (*36*) in 1939, Harding, Winston, and Fisher (*37*, *38*) in 1939 and 1940, Harding (*31*) in 1944, and Harding and Fisher (*33*) in 1945 reported that the greatest amounts of ascorbic acid were always found in immature fruits of both grapefruit and orange. They reported also that as the fruits ripened the concentration of vitamin C per milliliter of juice usually decreased and the lowest values were found late in the season. Harding and Sunday (*34*) in 1949 reported a gradual decrease in the vitamin C content of Florida tangerines as ripening proceeds. However, on the basis of total vitamin C per fruit they found that the vitamin content tended to increase with the ripening of the fruit because the volume of juice per fruit increased during that period. As the fruit became overripe, there was a decrease in volume of juice as well as in concentration of vitamin C and then a sharp decrease in the total per fruit. Harding, Winston, and Fisher (*38*) in 1940 reported no correlation between the ascorbic acid content of orange juice and its taste.

Iwasaki and Komatu (*43*) in Japan reported in 1941 that the concentration of ascorbic acid in the pulp and rind of Satsuma oranges increases as the fruit ripens. Holmes, Patch, and Tripp (*40*) in 1943, Ugón and Bertullo (*92*) in 1944 in Uruguay, Metcalfe, Rehm, and Winters (*53*) in 1940 in Texas, and Puche Alvarez (*65*) in 1940 reported a gradual decrease in vitamin C content as ripening proceeds. In 1945 Ugón and Bertullo (*93*) stated that the values for ascorbic acid fluctuated very irregularly but tended to increase as the fruit ripened. The actual condition in their material is not made clear in their two reports.

French and Abbott (*24*) in 1940 stated that in Florida ripening had little effect on the vitamin C content of oranges. Hamersma (*29*) in 1938 in Union of South Africa reported no important variations in early and late pickings of oranges except those of two strains of Valencia in which the vitamin C content was lower in the late than in the early picking. Mélas-Joannidès (*52*) in Greece reported in 1939 that the ascorbic acid content of the less mature fruits was sometimes less than that of more mature fruits from the same tree.

Harding, Winston, and Fisher are the only ones of the authors cited who make a point of the fact that, although the concentration of ascorbic acid, expressed in grams per milliliter of juice, decreases as ripening proceeds, the total amount of the vitamin per fruit actually increases because of the increase in the volume of juice per fruit.

Harding (*31*) reported in 1944 that spraying grapefruit trees and their fruit once during the summer with lead arsenate at the rate of 1 pound to 100 gallons of water had no pronounced effect on the concentration of ascorbic acid in the juice of either the Marsh or the Duncan variety.

Winston (*97*) in studies on fruit from three calamondin trees found a decrease in ascorbic acid with increasing maturity in fruit from one tree, which was growing in a densely planted plot, and an increase in fruit from the other two trees, which were growing in the open. He attributed the differences in ascorbic acid in fruit from the different trees to differences in shade.

Rootstock

As is well known, the composition of citrus fruits is often affected significantly by the rootstock on which the fruit is grown. The effect extends to vitamin C as well as to total solids, total acid, and other constituents.

Sour orange was reported by Harding and Winston (*36*) and Harding, Winston, and Fisher (*37*, *38*) in 1939 and 1940 to be a better rootstock for Florida oranges, so far as vitamin C content was concerned, than rough lemon. The same was reported to a less marked degree for grapefruit by Harding and Fisher (*33*) in 1945 and by Smith, Caldwell, and Wiseman (*82*) in 1945 for Algerian tangerines grown in Arizona. Yofe and Rabinovitz (*99*) in 1938 in Palestine did not report any difference in the vitamin C content of Shamouti (Jaffa) oranges on rough lemon and sour orange rootstocks, but they reported both of these rootstocks superior to those of sweet lime and Baladi.

Variety

Harding and Winston (*36*) and Harding, Winston, and Fisher (*37*, *38*) in 1939 and 1940 reported that the ascorbic acid content was as high in early and midseason varieties of orange as in one late variety, Valencia, which has a long growing season. This fact, they believed, means that the production of ascorbic acid is connected with normal metabolism and that the vitamin is not merely a storage constituent of the fruit.

Su and Liu (*88*) in 1938 in China stated that, of five citrus fruits studied, Kwang-chu (orange) and pomelo are rich in ascorbic acid. The same authors (*89*) reported that the bioassay method confirmed the chemical method and showed that Kwang-chu is comparable with California Sunkist oranges.

Grebinskii (*25*) in 1940 reported that the vitamin C content of Chinese varieties of lemons varies from 37.4 to 69.0 mg. per 100 gm. of juice. Limes are like lemons in chemical composition except that they contain less vitamin C. The vitamin C content of Chinese oranges varied from 17.4 to 90.2 mg. per 100 gm. of juice and that of Caucasian oranges from 36.6 to 116.0 in Tillmans units.

Stahl and Cain (*86*) in 1939 in Florida stated that there was little change in the vitamin C content in the Hamlin, Parson Brown, and Pineapple varieties of oranges during ripening. The Pineapple variety contained about 10 percent more vitamin C than the Parson Brown; the Hamlin variety contained 10 percent less.

Sunlight

Harding and Winston (*36*) and Harding, Winston, and Fisher (*37*, *38*) found significantly greater amounts of ascorbic acid in oranges from outside branches well exposed to sunlight than in fruits from inside, shaded branches. Harding and Thomas (*35*) in 1942 reported the same to be true for exposed and shaded Marsh and Foster grapefruit.

Winston (*98*) in Florida reported in 1948 that vitamin C content was significantly higher in citrus fruit from outside branches, where the fruit was freely exposed to sunlight, than in fruit from inside, shaded branches. This was true for all the varieties of round oranges investigated, which included Parson Brown, Hamlin, Pineapple, Indian River, Seedling, and Valencia, as well as for Temple oranges and Dancy tangerines.

Sites and Reitz (*80*) reported in 1949 that unpublished data obtained by Sites, Hopkins, and Loucks in Florida in 1943 in preliminary studies on Valencia oranges and Duncan grapefruit showed that in general vitamin C content was higher in fruits taken from the outside of the tree than in those taken from the inside. Their data further showed a higher vitamin C content in fruits taken from the upper portions of the tree and from the south and west sides than in fruits from the lower part and the north and east sides.

Other Factors

Mélas-Joannidès (*52*) in 1939 in Greece, Hamersma (*28*, *29*) in 1938 in Union of South Africa, and French and Abbott (*24*) in 1940 in Florida reported wide variation in the vitamin C content of fruit from the same tree and from different trees of the same variety. Hamersma (*29*) reported significant differences in this respect between fruit from trees in the same orchard and from orchards in different localities. In his work significant differences in vitamin C content between trees and between localities were found to be correlated with differences in the acidity of the juice. The higher the acidity, the higher, in general, was the vitamin C content. Ross (*73*, *74*) reported in 1941 and 1942 the same relation in Florida fruit.

French and Abbott (*24*), on the other hand, reported no relation between the vitamin C content of Florida citrus fruit and geographical location. Apparently there is need for further investigation of this question.

Iwasaki and Komatu (*43*) in 1941 stated that the rind from the blossom end of an orange contains less ascorbic acid than that from the stem end but the pulp of both parts contains approximately the same amount. These authors and Mélas-Joannidès (*52*) reported that the outer rind (flavedo) contains more ascorbic acid than the inner, white part (albedo).

MISCELLANEOUS OBSERVATIONS

Harding, Winston, and Fisher (*38*) found no correlation between the ascorbic acid content of orange juice and its quality as judged by taste.

Smith, Ross, and Caldwell (*83*) in 1944 reported that the preparation of navel, Valencia, and Arizona sweet seedling oranges, Marsh grapefruit, and tangerines as segments, unstrained juice, strained juice, slices, and salad sections did not affect appreciably the vitamin C content of the portion consumed; but that, because of wastage an increasingly greater proportion of vitamin was lost when the fruit was prepared as segments, sliced pieces, unstrained juice, and strained juice. Storage of juice in an icebox for 24 hours after the fruit was reamed resulted in an average loss of 5 percent of the vitamin. Storage of whole oranges in an icebox for 30 days brought about a loss of about 5 percent of vitamin C. Holding fruit at room temperature for 11 days did not affect the quantity of reamed juice obtained, but the taste was not as fresh and there was more vitamin C. Schauss (*78*) in Iowa reported in 1945 that broccoli, cauliflower, strawberries, and citrus fruits are very good sources of vitamin C even after preparation and holding. Mirimanoff (*58*) in 1941 concluded that ground-up autoclaved and air-dried orange peel might be used as a source of vitamin C. It contained 200 mg. per 100 gm. Two other methods of preparation yielded products that contained much less vitamin C.

Ross (*73*, *74*) in 1941 and 1942 in Florida reported, as did Hamersma (*28*) in 1938 in southern Africa, that in orange juice high vitamin C tended to be associated with high acidity and low vitamin content with low acidity. Ignatius and De Wit (*41*) reported that in 1946 and 1947 the average vitamin C intake in the Netherlands was very inadequate in March and April and inadequate in December, January, February, and May. Potatoes supplied 65 percent, other vegetables 25 percent, and fruits 10 percent. Of this last 10 percent the greater part was supplied by citrus fruits and berries. Burton (*16*) in Oklahoma in 1938 reported that the "color added" process had no detectable effect on the ascorbic acid content.

TABLE 5.—*Vitamin C contents of citrus fruits as reported by various authors*

Reference	Date	State or country	Kind of fruit, variety, part, or size	Vitamin C content
				I. U./100 gm.
Anonymous (*1*)	1945	Argentina	Tangerine	41.87
			Orange	72.50
Anonymous (*2*)	1947	Australia	Orange	(1)
Bär (*6*)	1939	Peru	Mountain orange	11.76
				Mg./100 gm.
Barron (*7*)	1940	do	Orange [2]	50
				Mg./cc.
Daniel and Rutherford (*18*)	1937	Florida	Orange	0.32–0.62
			Grapefruit	[3] 0.32
			Perrin lemon [4]	[3] 0.32
				Mg./100 gm.
French (*23*)	1939	do	Peel, early-market grapefruit	20–30
				Mg./cc.
Hamersma (*29*)	1938	Union of South Africa	Orange	0.38–0.83
Harding, Winston, and Fisher (*38*)	1940	Florida	Valencia orange	[5] 63.0–30.0
			Seedling orange	[6] 58.0–47.0
			Pineapple orange	[6] 48.0–42.0
			Hamlin orange	[6] 48.0–36.0
Metcalfe, Rehm, and Winters (*53*)	1940	Texas	Marsh grapefruit	36.4
			Marsh pink grapefruit	32.4
			Red blush grapefruit	32.7
			Marsh seedless grapefruit	32.0
			Foster pink grapefruit	34.3
			Duncan grapefruit	37.7
			Navel orange	41.1
			Valencia orange	42.3
			Hamlin orange	50.0
			Jaffa orange	46.9
			Pineapple orange	54.2
			Temple orange	52.4

Munsell (*61*)	1945	Puerto Rico	Orange	46.3–66.2
			Lime	23.1–38.1
			Lemon	29.3–35.6
			Sweet lime	26.3
			Sour orange	73.0
			Spanish lime	6.7
			Grapefruit	35.6–52.9
Puche Alvarez (*65*)	1940	Mexico	Valencia orange [7]	0.48–0.61
			Washington Navel [7]	0.54–0.66
				Mg./100 gm.
Quinones, Guerrant, and Dutcher (*66*)	1944	United States	Orange	35–44
Rauen, Devescovi, and Magnani (*67*)	1943	Italy	Orange flavedo [8]	175–192
			Orange albedo [8]	86–194
			Orange flesh [8]	44.9–73.2
Ribeiro (*69*)	1944	Brazil	Natal orange	86
			Seleta orange	63
			Pera orange	52
			Grapefruit	57
			Lemon	49
			Sweet lemon	67
			Persian sweet lemon	47
			Galego lemon	21
				Mg./cc.
Ross (*73*)	1941	Florida	Orange	0.67–0.42
			Grapefruit	0.49–0.35
				Mg./100 gm.
Sergeev (*79*)	1946	U. S. S. R.	Orange, bitter	48.5
			Orange, small	37.0
			Orange, large	54.5
			Orange juice	45.0
Smith, Caldwell, and Wiseman (*82*)	1945	Arizona	Dancy tangerine	16–65
			Algerian tangerine	32–91
Tsushi (*91*)	1946	Japan	Onshu orange	36.9

[1] See table 6.
[2] From markets in Lima.
[3] About.
[4] Content decreased by about 40 percent after 2 months' storage.
[5] December to July.
[6] August to March.
[7] From Spain.
[8] Italian.

The vitamin C contents of citrus fruits, according to various authors, are summarized in table 5.

Data on the monthly variation of the ascorbic acid content of fresh oranges published by the Commonwealth Food Control and the Council for Scientific and Industrial Research (Australia) (*2*) in 1947 are presented in table 6. So far as known to the writers this kind of tabulation has not been published anywhere else. It should be borne in mind that the growing seasons are the opposite from those in this country, because Australia is in the southern hemisphere.

TABLE 6.—*Monthly variation in ascorbic acid in fresh oranges from Griffith, New South Wales*

Variety and month picked	Ascorbic acid in—		
	Juice	Inner rind	Outer rind
	Mg./100 ml.	*Mg./100 gm.*	*Mg./100 gm.*
Washington Navel:			
April	72	64	193
May	67	65	211
June	69	85	278
July	68	84	268
August	68	89	280
September	74	125	325
Late Valencia:			
August	70	83	260
September	67	84	236
October	64	59	218
November	61	56	216
December	55	48	183
January	51	40	141
February	48	36	119

PROVITAMIN A

The concentration of carotene (provitamin A) in oranges was determined by Taylor and Witte (*90*). They reported in 1938 that juice of Florida and California varieties of orange differed widely in average content of carotenoid pigments. No pronounced seasonal trends in carotene content were found in any of the varieties. Average values for Florida and California were as follows:

Variety and State:	Samples (*number*)	Carotene (*mg. per liter*)
Valencia oranges, California	14	1.65
Washington Navel oranges, California	68	1.07
Valencia oranges, Florida	34	.57
Pineapple oranges, Florida	32	.34
Assorted varieties, Florida	16	.32

From a study of plastid pigments in citrus rinds, Miller, Winston, and Schomer (*56*) reported in 1940 that fully colored tangerine and Temple orange rinds contained a larger quantity of carotenoid pigments than the rinds of the mature green fruit. Their results with Parson Brown, Pineapple, and Valencia oranges showed that as the chlorophyll decreased the carotenoids increased and that they continued to increase after the chlorophyll had disappeared. Pineapple oranges from the northeast side of the tree had a higher carotenoid content than those from the southwest side.

Sammartino (*77*) stated in 1939 that the content of carotene of Italian oranges on the market varied from 0.0184 to 0.0371 mg., values which are claimed to be higher than those for oranges from the United States. Determinations were made by the method of Guilbert (*26*).

Miller and Winston (*54*) and Miller, Winston, and Fisher (*55*) in 1941 said that from September to March early and midseason Florida oranges showed a gradual increase in carotenoid pigments. In Valencia oranges pigments in the juice increased up to February or March after which time they usually declined. Miller and his associates also found that the vitamin A potency of Florida oranges not only varies with the variety but increases during the maturing season. Mandarin oranges are much higher in vitamin A potency than other types. Miller and Winston (*54, p. 221*) made the comment: "It would seem desirable to make a greater use of the Mandarin type of oranges as a dietary supplement for both man and animals if not as a source of pure carotene or other precursors of vitamin A."

Smith, Caldwell, and Farrankop (*81*) in 1945 reported that Algerian and Dancy tangerines, contained respectively 0.12 and 0.295 mg. of carotene per 100 gm. in the edible portions. The juice generally contained about half as much carotene as the flesh. Tangerines picked from the north and east sides of trees contained about 25 percent more carotene than those picked from the south and west sides.

In 1947 Booth (*13*) reported that his animal feeding experiments indicated that the vitamin A activity of the ester of citronin, the orange-peel pigment, is less than 10 percent of that of beta-carotene and is probably nil.

Natarajan and Mackinney (*63*) in 1948 reported that Valencia orange juice contains a very small proportion of pigments with absorption characteristics like those of alpha- or beta-carotene. In 1948 Sadana and Ahmad (*76*) reported that in the pulp and rinds of 14 varieties of Indian oranges *(Citrus aurantium)* they found xanthophylls, kryptoxanthin, neokryptoxanthin, K-carotene, and beta-carotene. Total active pigments in terms of beta-carotene varied from 2.4 to 4.4 gammas [21] per gram for the pulp and 4.9 to 40.7 gammas per gram for the rind; in terms of vitamin A potency this amounted to 4.0 to 7.3 international units per gram in pulp and 8.2 to 67.8 in the rind.

RIBOFLAVIN AND OTHER VITAMINS

In 1941 Lanford, Finkelstein, and Sherman (*49*) stated that, when compared either per 100 gm. or per 100 calories of fresh edible material, citrus fruits, banana, and tomato appear richer in riboflavin content than apples and pears. Grapefruit contained 20 gammas per 100 gm. and oranges 27.8.

[21] 1 gamma=1/1,000 mg.

890503—51—7

The thiamine and riboflavin contents of citrus fruits were investigated by Bailey and Thomas (*4*). They stated in 1942 that the mean thiamine (vitamin B_1) content of Florida citrus fruits in micrograms per 100 ml. of juice expressed by pressure was for Pineapple oranges 65, Valencia oranges 70, seeded grapefruit 35, seedless grapefruit 32, and tangerines 69. The riboflavin (vitamin G) expressed as gammas per 100 ml. of juice was for Pineapple orange 16, Valencia orange 15, seeded grapefruit 12, and seedless grapefruit 11. The concentration of thiamine and riboflavin in micrograms per fruit of different sizes is shown in the following tabulation:

Fruit:	*Thiamine*	*Riboflavin*
Orange (size 176):		
Pineapple	80	20
Valencia	91	20
Grapefruit (size 70)	81–85	27
Tangerine (size 150)	45	—

Escudero and others (*22*) in 1942 reported the thiamine and riboflavin contents in gammas per 100 gm. of various citrus fruits as follows:

Fruit:	*Thiamine*	*Riboflavin*
Lemon	111	8
Mandarin	105	23
Orange	130	34

The nicotinic acid in all cases was less than 25 gammas per 100 gm. In a paper published in 1945 Escudero and others (*21*) reported on the vitamin content of 37 lots of various Argentine fruits. They found that the quantities of the vitamins present were very similar to those reported from other countries.

A compilation of the vitamin values of foods appears in a publication by Booher, Hartzler, and Hewston (*12*) issued in 1942. The highest value for vitamin G in fresh citrus fruits, as listed by these authors, is 27.8 gammas per 100 gm. in one sample of sweet oranges; the highest value given for vitamin B_1 is 122 gammas per 100 gm. in one sample of the pulp of tangerines.

METHODS OF ANALYSIS

It seemed desirable in the digests of potato literature (*72*) issued in 1949 and tomato literature now being prepared[22] to include a section on methods of analysis. In these are listed particularly papers in which the authors pointed out possible errors in the determination of vitamin C or other vitamins or described improved methods for determining them. The same procedure is followed in this digest.

DeWitt and Sure (*20*) in 1938 reported that the concentration of substances in citrus juices that reduce methylene blue was proportional to the concentration of ascorbic acid and all reducing properties were destroyed by reactions destroying ascorbic acid.

---

[22] ROSE, D. H., and COOK, H. T. HARVESTING, HANDLING, AND TRANSPORTATION OF FRESH TOMATOES. . . . U. S. Dept. Agr. Bibliog. Bul. [In preparation.]

They concluded that ascorbic acid is the sole component which reduces methylene blue under experimental conditions.

A rapid photometric method for the determination of ascorbic acid in plant materials was described by Morell (*59*) in 1941. The method consists essentially in (1) plotting a calibration curve from colorimetric determinations on solutions containing known concentrations of ascorbic acid and (2) comparing determinations on solutions for which the concentration was unknown with points on this curve. Methods of preparing test solutions from plant materials were described.

Stevens (*87*) in 1938 described an iodine titration method for the estimation of ascorbic acid in citrus juices. The method was said to have advantages for more or less routine control work over the 2,6-dichlorophenolindophenol method. The two methods gave, on the average, nearly identical results with citrus juices. Ballentine (*5*) reported in 1941 that the use of 0.01 N potassium iodate in titrating ascorbic acid is more accurate than the Stevens method and more rapid than the several modifications of the Tillmans method.

Mélas-Joannidès (*52*) reported that the juice of citrus fruits contains substances other than ascorbic acid that reduce iodine. She found that the iodometric method always gave larger values for ascorbic acid than those obtained by the 2,6-dichlorophenol-indophenol method except in the case of lemons. These results were said to agree perfectly with those reported by Bessey and King (*11*).

Lampitt and Baker (*48*) in 1942 in England reported that in preparing orange drinks about 65 percent of the total ascorbic acid of the whole orange is obtained by extraction of thin slices including the peel with sugar sirup. Only 31 percent of the total ascorbic acid is obtained when the juice is obtained by rotary squeezing.

Loeffler and Ponting (*50*) in 1942 described a rapid method of determining ascorbic acid in fresh, frozen, or dehydrated fruits and vegetables, which they summarized as follows (*p. 848*):

> Ascorbic acid can be determined quickly in fruits and vegetables, whether fresh, frozen, or dehydrated, by disintegrating the sample with dilute metaphosphoric acid in a high speed cutter and measuring the decolorizing effect of the extracted ascorbic acid on indophenol dye with a photoelectric colorimeter.

Details are given in the paper.

Bessey (*10*) in 1944 stated that after several years' experience in many laboratories he knew of no evidence that dehydroascorbic acid or other reducing substances except ascorbic acid occur in fresh or commercial canned citrus fruits or tomatoes. Comparison of the indophenol method with the independent (furfural) method of Roe (*70*), published in 1936, when applied to these products gives satisfactory checks. A technique that was described in detail and recommended follows essentially that of Bessey and King (*11*), published in 1933, which was modified in 1936 by Musulin and King (*62*) and in 1938 by Bessey (*9*).

Bedford and McGregor (*8*), on the other hand, reported in 1948 that they found a significant amount of dehydroascorbic acid in fresh vegetables. This was markedly decreased by scalding, but it increased again during frozen storage. Cooking the frozen vegetables almost completely destroyed the dehydroascorbic acid present.

These two conflicting statements of Bessey (*10*) in 1944 and of Bedford and McGregor (*8*) in 1948 raise the question of what significance is to be attached to reports of the presence of dehydroascorbic acid in fresh plant material.

Harris and Olliver (*39*) stated in 1942 that the amount of dehydroascorbic acid normally found in fresh fruits and vegetables was too small to be of practical significance. The large amount of dehydroascorbic acid reported by certain workers was ascribed to failure to prevent oxidation during extraction. The same suggestion was made in 1942 by Paech (*64*) in Germany.

Guild, Lockhart, and Harris (*27*) in 1948 reported a lack of agreement between the 2,6-dichlorophenolindophenol method of Bessey (*9*), published in 1938, and the 2,4-dinitrophenylhydrazine method of Roe and Kuether (*71*), published in 1943, for the determination of ascorbic acid in foods. From a study of freshly prepared and of aged solutions of ascorbic acid and dehydroascorbic acid, they concluded that the Roe method probably measures the ascorbic acid originally present in the fresh sample and that the Bessey method measures only what is biologically active at the time of analysis. Conditions under which the two acids are stable or unstable are discussed in some detail. Dehydroascorbic acid was found to be the more unstable.

In 1948 an anonymous reviewer (*3*) considered it doubtful whether either the Roe (dinitrophenylhydrazine) or the Bessey (dye) method is entirely suitable for the determination of dehydroascorbic acid. Actually the measurement of dehydroascorbic acid in foods has a limited and doubtful value, at least if the food must be cooked before consumption, since this substance is readily destroyed by such treatment.

Mills, Damron, and Roe (*57*) in 1949 reported results obtained by a method that permits the simultaneous determination of ascorbic acid, dehydroascorbic acid, and diketogulonic acid in the same tissue filtrate. They found only 0.6 mg. per 100 gm. of dehydroascorbic acid in grapefruit and none in lemons, limes, or oranges. Dehydroascorbic acid and diketogulonic acid are both oxidation products of ascorbic acid. Dehydroascorbic acid is antiscorbutically active, diketogulonic acid is not.

In view of the results of these later investigations it apparently remains to be proved that what is sometimes reported as dehydroascorbic acid in fresh tissue was not the result of the extraction procedure, which oxidized ascorbic acid to dehydroascorbic acid.

Zscheile and Porter (*100*) in 1947 described analytical methods for determining carotenes of *Lycopersicon* species and strains.

LITERATURE CITED FOR VITAMINS

(1) Anonymous.
1945. TABLES OF THE VITAMIN VALUES OF EDIBLE VEGETABLE PRODUCTS. Inst. Nac. Nutr. [Buenos Aires], Pubs. CNP 29: 9–55. [Not seen; abstract in Chem. Abs. v. 40, column 5851. 1946.]

(2) ———
1947. THE ASCORBIC ACID AND CAROTENE CONTENT OF SOME AUSTRALIAN FRUITS AND VEGETABLES. Austral. Council Sci. and Indus. Res., Jour. 20: 1–8. (Compiled from data of Commonwealth Food Control and the Council for Scientific and Industrial Research.)

(3) ———
1948. ASCORBIC AND DEHYDROASCORBIC ACID ANALYSES. Nutr. Rev. 6: 206–207.

(4) Bailey, M. I., and Thomas, A. W.
1942. THE THIAMINE AND RIBOFLAVIN CONTENTS OF CITRUS FRUITS. Jour. Nutr. 24: 85–92.

(5) Ballentine, R.
1941. DETERMINATION OF ASCORBIC ACID IN CITRUS FRUIT JUICES. Indus. and Engin. Chem., Analyt. Ed., 13: 89.

(6) Bär, J. A.
1939. EVALUATION OF VITAMIN C IN SOME OF OUR MOUNTAIN FRUITS. Rev. Cienc. [Peru] 41: 503–509. [Not seen; abstract in Chem. Abs. v. 34, column 4477. 1940.]

(7) Barron, A. G.
1940. THE VITAMIN C CONTENTS OF FRUITS, VEGETABLES AND MILK WHICH ARE CONSUMED IN LIMA. Soc. Quím. Peru Bol. 6 (1): 5–18. [Not seen; abstract in Chem. Abs. v. 34, column 5187. 1940.]

(8) Bedford, C. L., and McGregor, M. A.
1948. DEHYDROASCORBIC ACID IN FROZEN AND COOKED FROZEN VEGETABLES. Science 107: 251–252.

(9) Bessey, O. A.
1938. A METHOD FOR THE DETERMINATION OF SMALL QUANTITIES OF ASCORBIC ACID AND DEHYDROASCORBIC ACID IN TURBID AND COLORED SOLUTIONS IN THE PRESENCE OF OTHER REDUCING SUBSTANCES. Jour. Biol. Chem. 126: 771–784.

(10) ———
1944. REPORT ON [THE DETERMINATION OF] ASCORBIC ACID (VITAMIN C) IN CITRUS FRUITS AND TOMATOES. Assoc. Off. Agr. Chem. Jour. 27: 537–540.

(11) ——— and King, C. G.
1933. THE DISTRIBUTION OF VITAMIN C IN PLANT AND ANIMAL TISSUES, AND ITS DETERMINATION. Jour. Biol. Chem. 103: 687–698.

(12) Booher, L. E., Hartzler, E. R., and Hewston, E. M.
1942. A COMPILATION OF THE VITAMIN VALUES OF FOODS IN RELATION TO PROCESSING AND OTHER VARIANTS. U. S. Dept. Agr. Cir. 638, 244 pp.

(13) Booth, V. H.
1947. VITAMIN A ACTIVITY OF ORANGE PEEL PIGMENT. Biokhimiia 12: 21–25. [In Russian. English summary, p. 25.]

(14) Borsook, H. C.
1942. OUR FOOD: AS SCIENCE NOW REGARDS IT. PART ONE. Calif. Citrog. 28: 30, 44–45, illus.

(15) Bratley, C. O.
1940. LOSS OF ASCORBIC ACID (VITAMIN C) FROM TANGERINES DURING STORAGE ON THE MARKET. Amer. Soc. Hort. Sci. Proc. (1939) 37: 526–528, illus.

(16) Burton, H. B.
1938. THE VITAMIN C CONTENT OF ORANGES. Okla. Acad. Sci. Proc. (1937) 18: 36–38.

(17) Clark, F., Friend, B., Burk, M. C.
1947. NUTRITIVE VALUE OF THE PER CAPITA FOOD SUPPLY, 1909–45. U. S. Dept. Agr. Misc. Pub. 616, 36 pp., illus. [Processed.]

(18) Daniel, E. P., and Rutherford, M. B.
1937. ASCORBIC ACID CONTENT OF A NUMBER OF CITRUS FRUITS. Jour. Agr. Res. 54: 689–693.

(19) Dernovskaya-Zelentsova, G. L., and Dylevskaya, V. G.
1941. STABILITY OF VITAMIN C IN STORED BERRIES AND MANDARIN ORANGES. Sci. Inst. Vitamin Res. U. S. S. R. Proc. 3 (1): 284–288. [Not seen; abstract in Chem. Abs. v. 36, column 2943. 1942.]

(20) DeWitt, J. B., and Sure, B.
1938. A STUDY OF CERTAIN REDUCING SUBSTANCES IN CITRUS FRUITS. Food Res. 3: 351–358.

(21) Escudero, A., Herraiz, M. L., Alvarez Herrero, H. G. de, and others.
1945. THE CONTENT OF CAROTENE, THIAMIN, RIBOFLAVIN, ASCORBIC ACID, AND NICOTINIC ACID OF SOME SAMPLES OF FRUITS OF THE 1943 HARVEST. Rev. Asoc. Argentina Dietol. 3 (9): 67–72. [Not seen; abstract in Chem. Abs. v. 39, column 4989. 1945.]

(22) Escudero, P., Escudero, A., Herraiz, M. L., and Alvarez Herrero, H. G. de.
1942. THIAMINE, RIBOFLAVIN AND NICOTINIC ACID OF SOME ARGENTINE CITRUS FRUITS. Inst. Nac. Nutr. [Buenos Aires], CPa5: 19–23. [Not seen; abstract in Chem. Abs. v. 39, column 1233. 1945.]

(23) French, R. B.
1939. THE INVESTIGATION OF VITAMIN C CONTENT OF FLORIDA FRUITS AND VEGETABLES. Fla. Agr. Expt. Sta. Ann. Rpt. 1938–39: 85.

(24) ——— and Abbott, O. D.
1940. INVESTIGATION OF THE VITAMIN C CONTENT OF FLORIDA FRUITS AND VEGETABLES. I. EFFECTS OF MATURATION AND OF COLD STORAGE ON THE VITAMIN C POTENCY OF ORANGES AND GRAPEFRUIT. Jour. Nutr. 19: 223–232, illus.

(25) Grebinskiĭ, S. O.
1940. THE CHEMICAL DIFFERENCES IN DIFFERENT VARIETIES OF CITRUS FRUITS. Biokhim. Kul'tur. Rasteniĭ 7: 300–310. [Not seen; abstract in Chem. Abs. v. 35, column 2927. 1941.]

(26) Guilbert, H. R.
1934. DETERMINATION OF CAROTENE AS A MEANS OF ESTIMATING THE VITAMIN A VALUE OF FORAGE. Indus. and Engin. Chem., Analyt. Ed., 6: 452–454.

(27) Guild, L. P., Lockhart, E. E., and Harris, R. S.
1948. STABILITY OF SOLUTIONS OF PURE ASCORBIC ACID AND OF DEHYDROASCORBIC ACID. Science 107: 226–227.

(28) Hamersma, P. J.
1938. THE STABILITY OF VITAMIN C IN SOUTH AFRICAN ORANGES. Farming in So. Africa 13: 426.

(29) ———
1938. THE VITAMIN-C CONTENT OF SOUTH AFRICAN ORANGES AND ITS STABILITY OVER STORAGE PERIODS, SOME EXCEEDING THREE MONTHS, AT APPROXIMATELY 38° F. Union So. Africa Dept. Agr. & Forestry, Sci. Bul. 163, 53 pp.

(30) Hamner, K. C.
1945. MINOR ELEMENTS AND VITAMIN CONTENT OF PLANTS. Soil Sci. 60: 165–171.

(31) Harding, P. L.
1944. SEASONAL CHANGES IN THE ASCORBIC ACID CONCENTRATION OF FLORIDA GRAPEFRUIT. Amer. Soc. Hort. Sci. Proc. 45: 72–76.

(32) ———[23]
1949. STORAGE OF FLORIDA ORANGES. ORLANDO, FLORIDA—1949. U. S. Bur. Plant Indus., Soils, and Agr. Engin., H. T. & S. Off. Rpt. 219, [48] pp., illus. [Processed.]

(33) ——— and Fisher, D. F.
1945. SEASONAL CHANGES IN FLORIDA GRAPEFRUIT. U. S. Dept. Agr. Tech. Bul. 886, 100 pp., illus.

(34) ——— and Sunday, M. B.
1949. SEASONAL CHANGES IN FLORIDA TANGERINES. U. S. Dept. Agr. Tech. Bul. 988, 59 pp., illus.

(35) ——— and Thomas, E. E.
1942. RELATION OF ASCORBIC ACID CONCENTRATION IN JUICE OF FLORIDA GRAPEFRUIT TO VARIETY, ROOTSTOCK, AND POSITION OF FRUIT ON THE TREE. Jour. Agr. Res. 64: 57–61.

[23] Available generally only in the larger libraries of the country.

(36) Harding, P. L., and Winston, J. R.
1939. THE ASCORBIC ACID (VITAMIN C) CONTENT OF JUICE OF THE PRINCIPAL VARIETIES OF FLORIDA ORANGES. Fla. State Hort. Soc. Proc. 52: 90–95, illus.

(37) ——— Winston, J. R., and Fisher, D. F.
1939. SEASONAL CHANGES IN THE ASCORBIC ACID CONTENT OF JUICE OF FLORIDA ORANGES. Amer. Soc. Hort. Sci. Proc. (1938) 36: 358–370.

(38) ——— Winston, J. R., and Fisher, D. F.
1940. SEASONAL CHANGES IN FLORIDA ORANGES. U. S. Dept. Agr. Tech. Bul. 753, 89 pp., illus.

(39) Harris, L. J., and Olliver, M.
1942. VITAMIN METHODS. 3. THE RELIABILITY OF THE METHOD FOR ESTIMATING VITAMIN C BY TITRATION AGAINST 2:6-DICHLOROPHENOLINDOPHENOL. 1. CONTROL TESTS WITH PLANT TISSUES. Biochem. Jour. 36: 155–182, illus.

(40) Holmes, A. D., Patch, J. A., and Tripp, F.
1943. THE RELATION OF SEASON, WEIGHT AND PRICE TO THE VITAMIN C CONTENT OF ORANGES. New. England Jour. Med. 228: 8–11.

(41) Ignatius, J. G. W., and Wit, W. de
1948. THE SUPPLY OF VITAMIN C BY CONSUMPTION OF POTATOES, VEGETABLES AND FRUIT IN THE YEARS 1946 AND 1947. Voeding 9: 254–262. [In Dutch. English summary, pp. 261–262.]

(42) Innes, R. F.
1946. FERTILIZERS EXPERIMENTS ON GRAPEFRUIT IN JAMAICA. Trop. Agr. [Trinidad] 23: 131–133.

(43) Iwasaki, Y., and Komatu, T.
1941. ASCORBIC ACID CONTENT OF CITRUS FRUITS. Agr. Chem. Soc. Japan, Jour. 17: 427–432. [Not seen; abstract in Chem. Abs. v. 36, column 3570. 1942.]

(44) Jones, W. W., and Parker, E. R.
1947. ASCORBIC ACID-NITROGEN RELATIONS IN NAVEL ORANGE JUICE, AS AFFECTED BY FERTILIZER APPLICATIONS. Amer. Soc. Hort. Sci. Proc. 50: 195–198, illus.

(45) ——— and Parker, E. R.
1949. EFFECTS OF NITROGEN, PHOSPHORUS, AND POTASSIUM FERTILIZERS AND OF ORGANIC MATERIALS ON THE COMPOSITION OF WASHINGTON NAVEL ORANGE JUICE. Amer. Soc. Hort. Sci. Proc. 53: 91–102.

(46) ——— Van Horn, C. W., and Finch, A. H.
1945. THE INFLUENCE OF NITROGEN NUTRITION OF THE TREE UPON THE ASCORBIC ACID CONTENT AND OTHER CHEMICAL AND PHYSICAL CHARACTERISTICS OF GRAPEFRUIT. Ariz. Agr. Expt. Sta. Tech. Bul. 106, pp. [455]–484, illus.

(47) ——— Van Horn, C. W., Finch, A. H., and others.
1944. A NOTE ON ASCORBIC ACID: NITROGEN RELATIONSHIPS IN GRAPEFRUIT. Science 99: 103–104, illus.

(48) Lampitt, L. H., and Baker, L. C.
1942. ASCORBIC ACID IN ORANGES. Nature [London] 149: 271.

(49) Lanford, C. S., Finkelstein, B., and Sherman, H. C.
1941. RIBOFLAVIN CONTENTS OF SOME TYPICAL FRUITS. Jour. Nutr. 21: 175–177.

(50) Loeffler, H. J., and Ponting, J. D.
1942. ASCORBIC ACID. RAPID DETERMINATION IN FRESH, FROZEN, OR DEHYDRATED FRUITS AND VEGETABLES. Indus. and Engin. Chem., Analyt. Ed., 14: 846–849, illus.

(51) Lorenz, A. J.
1939. DIETETIC HISTORY OF THE LEMON. Calif. Citrog. 24: 122, 138–140, illus.

(52) Mélas-Joannidès, Z.
1939. L'ACID ASCORBIQUE DANS LE JUS DE FRUITS DU GENRE CITRUS, EN GRÈCE. Soc. de Chim. Biol. Bul. 21: [809]–813.

(53) Metcalfe, E., Rehm, P., and Winters, J.
1940. VARIATIONS IN ASCORBIC ACID CONTENT OF GRAPEFRUIT AND ORANGES FROM THE RIO GRANDE VALLEY OF TEXAS. Food Res. 5: 233–240.

(54) Miller, E. V., and Winston, J. R.
1941. SEASONAL CHANGES IN THE CAROTENOID PIGMENTS IN THE JUICE OF FLORIDA ORANGES. Amer. Soc. Hort. Sci. Proc. 38: 219–221.

(55) Miller, E. V., Winston, J. R., and Fisher, D. F.
1941. A PHYSIOLOGICAL STUDY OF CAROTENOID PIGMENTS AND OTHER CONSTITUENTS IN THE JUICE OF FLORIDA ORANGES. U. S. Dept. Agr. Tech. Bul. 780, [32] pp., illus.

(56) ——— Winston, J. R., and Schomer, H. A.
1940. PHYSIOLOGICAL STUDIES OF PLASTID PIGMENTS IN RINDS OF MATURING ORANGES. Jour. Agr. Res. 60: 259–267, illus.

(57) Mills, M. B., Damron, C. M., and Roe, J. H.
1949. ASCORBIC ACID, DEHYDROASCORBIC ACID, AND DIKETOGULONIC ACID IN FRESH AND PROCESSED FOODS. Analyt. Chem. 21: 707–709, illus.

(58) Mirimanoff, A.
1941. CONTRIBUTION À LA PROPHYLAXIE DE L'HYPOVITAMINOSE C DANS LA POPULATION. Schweiz. Apoth. Ztg. 79: [333]–336.

(59) Morell, S. A.
1941. RAPID PHOTOMETRIC DETERMINATION OF ASCORBIC ACID IN PLANT MATERIALS. Indus. and Engin. Chem., Analyt. Ed., 13: 793–794, illus.

(60) Mouriquand, G., and Lavaud, J.
1942. SUR LA TENEUR DES CITRONS EN ACIDE ASCORBIQUE A DIFFÉRENTS STADES DE LEUR CONSERVATION. Soc. de Biol. [Paris] Compt. Rend. 136: 599–601.

(61) Munsell, H. E.
1945. ASCORBIC ACID CONTENT OF FRUITS OF PUERTO RICO WITH DATA ON MISCELLANEOUS PRODUCTS. Food Res. 10: 42–51.

(62) Musulin, R. R., and King, C. G.
1936. METAPHOSPHORIC ACID IN THE EXTRACTION AND TITRATION OF VITAMIN C. Jour. Biol. Chem. 116: 409–413.

(63) Natarajan, C. P., and Mackinney, G.
1948. CAROTENOID PIGMENTS OF VALENCIA ORANGE JUICE. Fruit Prod. Jour. and Amer. Food Mfr. 28: 119.

(64) Paech, K.
1942. THE ASCORBIC ACID CONTENT AND ITS VARIATIONS IN FOODS DERIVED FROM PLANTS. Forschungsdienst, Sonderh. 16: 283–290. [Not seen; abstract in Chem. Abs. v. 37, column 3522. 1943.]

(65) Puche Alvarez, J.
1940. EL CONTENIDO DE ACIDO ASCORBICO Y EL PROCESO DE MADURACION EN ALGUNAS VARIEDADES DE NARANJA VALENCIANA. Ciencia [Mexico] 1: 159–161.

(66) Quinones, V. L., Guerrant, N. B., and Dutcher, R. A.
1944. VITAMIN CONTENT OF SOME TROPICAL FRUITS, THEIR JUICES AND NECTARS. Food Res. 9: 415–417.

(67) Rauen, H. M., Devescovi, M., and Magnani, N.
1943. DER VITAMIN C-GEHALT ITALIENISCHER ORANGEN UND DARAUS HERGESTELLTER PULPEN. Ztschr. f. Untersuch. der Lebensmtl. 85: 257–266.

(68) Reuther, W., Gardner, F. E., Smith, P. F., and Roy W. R.
1949. A PROGRESS REPORT ON PHOSPHATE FERTILIZER TRIALS WITH ORANGES IN FLORIDA. Fla. State Hort. Soc. Proc. (1948) 61: 44–60, illus.

(69) Ribeiro, O. F.
1944. VITAMIN C IN BRAZILIAN CITRUS FRUITS. An. Assoc. Quím. Brasil 3: 40–43. [Not seen; abstract in Chem. Abs. v. 38, column 6413. 1944.]

(70) Roe, J. H.
1936. THE DETERMINATION OF ASCORBIC ACID AS FURFURAL AND A COMPARISON OF RESULTS OBTAINED BY THIS METHOD AND BY INDOPHENOL TITRATION. Jour. Biol. Chem. 116: 609–619.

(71) ——— and Kuether, C. A.
1943. THE DETERMINATION OF ASCORBIC ACID IN WHOLE BLOOD AND URINE THROUGH THE 2,4-DINITROPHENYLHYDRAZINE DERIVATIVE OF DEHYDROASCORBIC ACID. Jour. Biol. Chem. 147: 399–407, illus.

(72) Rose, D. H., and Cook, H. T.
1949. HANDLING, STORAGE, TRANSPORTATION, AND UTILIZATION OF POTATOES. . . . U. S. Dept. Agr. Bibliog. Bul. 11, 163 pp., illus.

(73) Ross, E.
1941. THE VITAMIN C, SOLIDS AND ACID IN ORANGE AND GRAPEFRUIT JUICES USED FOR CANNING PURPOSES. Citrus Indus. 22 (8): 5, 9, 12–13.

(74) Rose, E.
1942. THE VITAMIN C, SOLIDS AND ACID IN ORANGE AND GRAPEFRUIT JUICES USED FOR CANNING PURPOSES. Fla. State Hort. Soc. Proc. (1941) 54: 56–60.

(75) Roy, W. R., and Bahrt, G. M.
1940. THE EFFECT OF ZINC, IRON, MANGANESE AND MAGNESIUM[,] APPLIED TO FRENCHED AND BRONZED ORANGE GROVES, ON THE VITAMIN C CONTENT OF ORANGES. Fla. State Hort. Soc. Proc. 53: 34–38.

(76) Sadana, J. C., and Ahmad, B.
1948. OBSERVATIONS ON THE CAROTENOID PIGMENTS OF DIFFERENT VARIETIES OF ORANGES. Jour. Sci. & Indus. Res. [India] 7B: 96–100, illus.

(77) Sammartino, U.
1939. THE CAROTENE CONTENT OF ITALIAN ORANGES. Ricera Sci. [Roma] 10: 884–885. [Not seen; abstract in Chem. Abs. v. 34, column 4822. 1940.]

(78) Schauss, V.
1945. ASCORBIC ACID CONTENT OF FRUITS AND VEGETABLES USED IN AN INSTITUTION. Amer. Dietet. Assoc. Jour. 21: 364, 366.

(79) Sergeev, G. K.
1946. BITTER ORANGE FRUIT AS VITAMIN C SOURCE. Voenno-Med. Zhur. 1946 (7/8): 50–51. [Not seen; abstract in Chem. Abs. v. 42, column 2032. 1948.]

(80) Sites, J. W., and Reitz, H. J.
1949. THE VARIATION IN INDIVIDUAL VALENCIA ORANGES FROM DIFFERENT LOCATIONS OF THE TREE AS A GUIDE TO SAMPLING METHODS AND SPOT-PICKING FOR QUALITY. I. SOLUBLE SOLIDS IN THE JUICE. Amer. Soc. Hort. Sci. Proc. 54: 1–10, illus.

(81) Smith, M. C., Caldwell, E., and Farrankop, H.
1945. TANGERINES[,] THEIR PRO-VITAMIN A VALUE. Ariz. Agr. Expt. Sta. Mim. Rpt. 70, 5 pp. [Processed.]

(82) ——— Caldwell, E., and Wiseman, H.
1945. TANGERINES[,] THEIR ASCORBIC ACID CONTENT AND FACTORS THAT AFFECT IT. Ariz. Agr. Expt. Sta. Mim. Rpt. 72, 7 pp. [Processed.]

(83) ——— Ross, W., and Caldwell, E.
1944. THE COMPARATIVE VITAMIN C VALUES OF ARIZONA CITRUS FRUITS OF DIFFERENT VARIETIES AND SIZES WHEN PREPARED FOR CONSUMPTION IN SEVERAL DIFFERENT WAYS. Ariz. Agr. Expt. Sta. Mim. Rpt. 62, 15 pp. [Processed.]

(84) Somogyi, J. C.
1945. ACTIVE SUBSTANCES WHICH INHIBIT OXIDATION OF ASCORBIC ACID, AND THEIR MODE OF ACTION. Helvetica Physiol. Pharmacol. Acta C15–16. [Not seen; abstract in Chem. Abs. v. 40, column 407. 1946.]

(85) ———
1945. VERSUCHE ÜBER WIRKSTOFFE, DIE DEN ASKORBINSÄUREABBAU HEMMEN. III. MITTEILUNG. Ztschr. f. Vitaminforsch. 16: 134–168, illus.

(86) Stahl, A. L., and Cain, J. C.
1939. CITRUS MATURITY STUDIES. Fla. Agr. Expt. Sta. Ann. Rpt. 1938–39: 111.

(87) Stevens, J. W.
1938. ESTIMATION OF ASCORBIC ACID IN CITRUS JUICES. AN IODINE TITRATION METHOD. Indus. and Engin. Chem., Analyt. Ed., 10: 269–271.

(88) Su, Tsu-Fei, and Liu, D. Y.
1938. HUNAN LOCAL FOOD PRODUCTS. I. THE CHEMICAL COMPOSITION AND VITAMIN C CONTENT OF HUNAN CITRUS FRUITS. Chinese Med. Jour. 54: 40–44. [Not seen; abstract in Chem. Abs. v. 33, column 1012. 1939.]

(89) ——— and Liu, D. Y.
1938. HUNAN LOCAL FOOD PRODUCTS. II. THE ANTISCORBUTIC ACTIVITY OF THE HUNAN KWANG-CHU (ORANGE). Chinese Med. Jour. 54: 44–50. [Not seen; abstract in Chem. Abs. v. 33, column 1012. 1939.]

(90) Taylor, A. L., and Witte, P. J.
1938. CAROTENE IN ORANGES. Indus. and Engin. Chem., Indus. Ed., 30: 110–[111], illus.

(91) TSUSHI, D.
1946. STUDIES ON VITAMIN C IN CITRUS FRUITS. I. VITAMIN C CONTENT OF THE ONSHU ORANGE AND JAPANESE GRAPEFRUIT. Osaka Munic. Res. Inst. Dom. Sci. Rpt. 17: 90–120. [Not seen; abstract in Chem. Abs. v. 41, column 4865. 1947.]

(92) UGÓN, N. A., and BERTULLO, W.
1944. DEGREE OF MATURITY OF CITRUS FRUITS COMPARED WITH THEIR VITAMIN C CONTENT. Arch. Soc. Biol. Montevideo 11: 139–158. [Not seen; abstract in Chem. Abs. v. 38, column 5880. 1944.]

(93) ——— and BERTULLO, W.
1945. DEGREE OF MATURITY OF CITRUS FRUITS COMPARED WITH THEIR RICHNESS IN VITAMIN C. An. Asoc. Quím. Farm. Uruguay 47 (1): 5–22. [Not seen; abstract in Chem. Abs. v. 40, columns 965–966. 1946.]

(94) UNITED STATES BUREAU OF HUMAN NUTRITION AND HOME ECONOMICS.
1948. HELPING FAMILIES PLAN FOOD BUDGETS. U. S. Dept. Agr. Misc. Pub. 662, 16 pp. [Processed.]

(95) ———
1949. NUTRITIVE VALUE OF DIETS OF URBAN FAMILIES. UNITED STATES, SPRING 1948 AND COMPARISON WITH DIETS IN 1942. U. S. Bur. Human Nutr. and Home Econ., 1948 Food Consumption Surveys Prelim. Rpt. 12, 25 pp. [Processed.]

(96) ———
1950. CITRUS FRUIT CONSUMED BY CITY FAMILIES. U. S. Bur. Human Nutr. and Home Econ., Commod. Sum. Rpt. 8, 15 pp., illus. [Processed.]

(97) WINSTON, J. R.
1943. SEASONAL CHANGES IN THE JUICE OF THE CALAMONDIN IN FLORIDA. Amer. Soc. Hort. Sci. Proc. 43: 84–90, illus.

(98) ———
1948. VITAMIN C CONTENT AND JUICE QUALITY OF EXPOSED AND SHADED CITRUS FRUITS. Fla. State Hort. Soc. Proc. (1947) 60: 63–67.

(99) YOFE, J., and RABINOVITZ, N.
1938. VITAMIN C IN CITRUS FRUITS, SEASON 1936/37. Hadar 11: 137–138, illus.

(100) ZSCHEILE, F. P., and PORTER, J. W.
1947. ANALYTICAL METHODS FOR CAROTENES OF LYCOPERSICON SPECIES AND STRAINS. Analyt. Chem. 19: 47–51, illus.

TRANSPORTATION

Since the time of investigations by Powell (*26*)[24] on the marketing of citrus fruits grown in California (reported in 1908), the United States Department of Agriculture has conducted numerous studies on the transportation of these fruits from all the major citrus-growing areas of the country. Most of this work, however, has been done since about 1928. Problems investigated have included (1) the use of various kinds of refrigeration and ventilation service, (2) the efficiency of different kinds of refrigerator cars, (3) methods of loading, (4) methods of wrapping the fruit, (5) use of different kinds of containers, and (6) prevention of decay in transit by means of antiseptic washes and treated wrappers.

In 1936 Mann and Cooper (*22*) discussed and summarized the results of investigations on the transportation of oranges from California to New York during the period from 1928 to 1933. Since then numerous other investigations on the same subject have been made by the Department. The results of tests on half-stage (upper-half-bunker) icing were published in 1943 by Mann, Gorman, and Hukill (*24*) and reports on other phases of the investigations have been issued. Many of the latter have been released to shippers, carriers, and other agencies who cooperated in the tests. A number of the reports are in the form of typed or processed summaries available only in the files of the Bureau of Plant Industry, Soils, and Agricultural Engineering, Beltsville, Md.

The value of three outstanding practices or methods for the transportation of citrus fruits has been demonstrated by the work done since 1933. These are half-stage icing, the use of fan cars, and controlled ventilation during the shipment of winter oranges from central and southern California to eastern markets. Half-stage icing and fan cars are used not only for citrus fruits but also for a variety of other fruits and vegetables.

In 1946, 1947, and 1948 the Department cooperated with the Association of American Railroads in transportation tests designed to compare the efficiency of standard end-bunker cars, standard end-bunker cars with fans under the floor racks (fan cars), and overhead-bunker cars. These three types of cars were used in tests with several kinds of fruits and vegetables. Only those tests that dealt with citrus fruits are discussed here. These cooperative tests are usually called A. A. R.–U. S. D. A. tests. The results of the Department's work on these and other problems in the transportation of citrus fruits are reviewed in this section. Before that review is begun a few terms that must be used are defined.

---

[24] Italic numbers in parentheses refer to Literature Cited for Transportation, p. 122.

DEFINITIONS

A standard end-bunker car is a refrigerator car of the type that has been used by American railroads for many years. At each end it has an ice compartment, or bunker, which can be left open or closed. It can be closed by manipulation of plugs that fit into openings at the top of the bunker and hinged hatch covers, or ventilators, that fit down over the plugs. These covers can be raised and held at various angles above the plugs. The car has slatted floor racks that hold the load 3 to 5 inches off the floor.

A fan car is the same in construction as a standard end-bunker car except that it has a set of Preco fans under the floor racks next to each bunker. Because of the size of the fans, the floor racks are 7½ inches high. These fans are driven by a belt connected to a friction pulley on the car wheels. When they are in the "on" position and the car is in motion, they set up air circulation. The direction of the circulation is the reverse of the natural circulation, the cooled air being delivered out of the top-bunker opening and over the top of the load. This results in more effective cooling and uniform temperatures throughout the load.

An overhead-bunker car has 8 to 10 ice bunkers in the ceiling, each with its own plug and hatch cover. With this arrangement of bunkers the air circulates from top to bottom of the car instead of lengthwise as in end-bunker cars.

Half-stage icing refers to filling only the upper half of the bunkers with ice. Cars are equipped with ice grates that can be dropped into position halfway between bottom and top if the bunker is used for this service.

Standard refrigeration means filling the bunkers with ice at every regular icing station from shipping point to destination. Modified icing service may refer to initial icing without re-icing en route (Rule 240) or to initial icing with or without re-icing at the first icing station and with re-icing at specified stations once, twice, or three times in transit. Another modified icing service, used extensively, requires that a car be pre-iced (Rule 239). The bunkers may be replenished after loading and re-iced up to three times in transit if desired.

Standard ventilation for citrus shipments means that the ventilators will be closed when the outside temperature reaches 32° F. and opened when it rises above 32°.

Special ventilation means that the vents will be manipulated at specified points in accordance with specified outside temperatures other than 32° F. (standard ventilation) or they will remain open or closed to a given place in transit or to destination.

Combination ventilation means that the vents will be manipulated in accordance with special ventilation for part of the transit period and in accordance with standard ventilation for the remainder of the period.

A transportation test is one in which the cars are accompanied by observers from shipping point to destination. These observers take temperature readings of the air and load in the cars by means of two kinds of equipment. One type of equipment consists of electric resistance thermometers attached to a cable inside the car and a reading box which can be attached to the end of the cable coming out at the top of the car. Readings with this equipment can be taken only when the train is standing. The other type of equipment was developed specially for the series of A. A. R.–U. S. D. A. transportation tests. It consists of copper-constantan thermocouples as the sensitive element and of Brown Electronic Pyrometers for the readings. This system was connected to a selector-switch box mounted on top of the test car, and by means of special cables it was connected to instruments in the business car. Contact with any thermocouple in any test car was made by means of two sets of hand-operated selector switches, one to select the car and the other to select the desired thermocouple in that car. With this equipment, temperature in any part of any test car could be obtained whether the train was moving or standing. Power to operate the switches was furnished by 24-volt batteries, and the instruments were operated by a 110-volt Diesel generator set, which also charged the batteries.

A shipping test is one in which the cars are not accompanied by observers. In such a test, record of load temperatures in transit is obtained by means of small recording thermographs placed in test packages in the load or by observers stationed along the route taken by the cars. These observers take temperature readings by means of reading boxes and electric resistance thermometers installed in the cars at the shipping point. All the temperature records are obtained without opening the car doors.

REFRIGERATION SERVICES FOR DIFFERENT SEASONS

Powell (*26*) in 1908 and Mann and Cooper (*22*) in 1936 reported the need for immediate and rapid cooling of citrus fruits in order to reduce decay during shipment. This is important throughout all seasons of the year, but is especially so during the hot summer months. Protective services used in transit are selected with this fundamental requirement in mind and therefore vary with the season. They include refrigeration, ventilation, or a combination of these. The work covering transit temperatures is discussed on the basis of seasonal need; that is, summer, fall, winter, and spring.

SUMMER

The earliest shipments of citrus from California were made under standard refrigeration as it was felt that the lowest possible temperature was required to maintain the fruit in acceptable condition. Early work of the Department, as reported by Powell (*26*) in 1908, indicated the desirability of rapid cooling of the fruit after picking in order to prevent decay. This work also showed that the precooling materially reduced the refrigeration required during transit. Similar work reported by Mann and Cooper (*22*) in 1936 formed the basis for establishing a modified icing service calling for one re-icing in transit. Adequate precooling, either in the warehouse or in the car immediately after loading, has resulted in a great reduction in the amount of refrigeration required in transit. Thus there have been considerable savings for the shipper and the carriers.

To decrease further the weight of ice to be carried, extensive tests in nonfan cars were conducted on half-stage icing during the period from 1936 to 1941. The results of some of this work reported by Mann, Gorman, and Hukill in 1943 (*24*) showed that, with properly precooled fruit, half-stage icing gives more rapid cooling and as satisfactory fruit temperatures in transit as full-bunker icing. This was again shown in the work of Harvey and others (*9*) in December 1947. Similar results were obtained by Mallison in 1939 (*20*) with citrus fruits shipped from Florida. He found, however, that half-stage icing is not adequate without re-icing for loads not properly precooled in hot weather, which usually prevails in Florida in late June.

As the efficiency of refrigeration in a refrigerator car is dependent upon the air circulation, considerable work had been done prior to 1941 by the Department and others to develop means of increasing this circulation. Wind-driven fans and others driven by mechanical means from the car wheels were tested for a number of years (*21*). The only fan, however, to come into commercial use was the Preco, described on page 108. With forced-air circulation much more rapid cooling is obtained and temperatures throughout the load are more nearly uniform.

Many tests have been run comparing cars with forced-air circulation (fan cars) with those having none; these have confirmed the advantages of the use of the fans. The fans can also be used for precooling in the car by attaching a portable electric motor or a gasoline engine and using the ice in the bunkers. A great deal of information on precooling with car fans and other equipment was presented by Pentzer, Asbury, and Barger (*25*) in 1945. All types of icing services including half-stage icing gave better results with fans. Some of these results are reported in the following: Mann, Gorman, and Hukill (*24*), 1943; Mann and Embree,[25] 1943; Rygg and others (*30*), 1946; Harvey and others (*15*), 1944; Harvey, Embree, and Wiant,[26] 1944; Winston and Bratley (*33*), 1946; Bratley and Harding (*2*), 1946; and Harvey and others (*9*), 1948.

It may thus be seen that through the use of fan cars, proper selection of a modified icing service, and adequate precooling, either in the warehouse or in the car, citrus fruits may be shipped satisfactorily through the hottest months of the year without resort to the more expensive transit icing services.

Optimum lemon storage temperatures range from 55° to 60° F., and it is considered unnecessary and possibly harmful to the fruit to ship it at temperatures normally used for oranges. As lemons have been shipped under refrigeration service similar to that used for oranges, work was started in the summer of 1948 by Harvey,

---

[25] MANN, C. W., and EMBREE, G. L. REFRIGERATION AND VENTILATION TEST 1943—CALIF. [CALIFORNIA TO NEW YORK, FEBRUARY AND MARCH 1943.] [U. S. Bur. Plant Indus., Soils, and Agr. Engin. Unpublished Report.] [54] pp., illus. [1943.] [Typed.]

[26] HARVEY, E. M., EMBREE, G. L., and WIANT, J. S. SHIPPING TEST OF WASHINGTON NAVEL ORANGES FROM SOUTHERN CALIFORNIA TO NEW YORK. [APRIL AND MAY 1944.] U. S. Bur. Plant Indus., Soils, and Agr. Engin., [Off. Rpt.], [151] pp., illus. 1944. [Processed.] (In cooperation with Calif. Fruit Growers Exch.)

Atrops, and Hruschka (*7*) to determine the most economical and desirable icing service for lemons. The preliminary results indicate that this commodity has been refrigerated more than necessary and that a substantial saving can probably be made by using less expensive icing services, particularly in the summer.

FALL

Although weather conditions in the fall usually moderate considerably from those of the hot summer period, refrigeration is still needed for fall shipments, because the temperatures of fruit of the late-fall or early-winter harvest are as high as those of some of the nonprecooled summer loads. The reason is that much of the fruit is "sweated" to bring up the color; thereby the loading temperature is raised to 65° to 80° F. As this is done just prior to shipping, the advantage of the relatively lower outside-air temperatures in November and December (lower 50's and upper 40's, respectively) is lost, as was shown by Harvey and others (*14*) in 1945. As rapid cooling is important, these generally nonprecooled loads should be loaded in pre-iced cars. During this transition period, outside-air temperatures are not usually low enough so that standard or combination ventilation service can be used to advantage. When properly precooled loads are available, however, it is possible by judicious use of advance weather information to take advantage of favorable weather conditions that may exist.

WINTER

For many years winter shipments of oranges (Washington Navel) from California moved under standard refrigeration or some modified form of ice refrigeration, both of which are expensive and of value mainly for oranges shipped during the warmer parts of the year.

Refrigeration or initial cooling, however, is needed for these shipments, because of the usually high loading temperatures of the fruit resulting from the "sweating" process previously mentioned. The problem of finding a less expensive form of refrigeration was studied as early as 1930 by the Department in cooperation with the California Fruit Growers Exchange, and the study has been carried on more intensively in recent years. As has been pointed out, rapid initial cooling of the load is important from the standpoint of control of decay. This means therefore that such cooling must take place either prior to shipping or during the first part of the transit period.

The use of the cold mountain or desert air encountered during the first day or two in transit from California was studied by Mann and Gorman [27] in 1937 and by Mann [28] [29] in 1938 and 1940. It was

---

[27] MANN, C. W., and [GORMAN, E. A., Jr.] REPORT OF ORANGE AND PEAR TRANSPORTATION TEST 1937—4. [CALIFORNIA TO NEW YORK, DECEMBER 1937.] [U. S. Bur. Plant Indus. Unpublished Report.] 41 pp., illus. [1938.] [Typed.]

[28] MANN, C. W. REPORT OF ORANGE TRANSPORTATION TEST 1938—4. [CALIFORNIA TO NEW YORK, DECEMBER 1938.] [U. S. Bur. Plant Indus. Unpublished Report.] 33 pp., illus. [1939.] [Typed.]

[29] MANN, C. W. REPORT OF ORANGE VENTILATION AND REFRIGERATION TEST, 1940—8. [CALIFORNIA TO NEW YORK, DECEMBER 1940.] [U. S. Bur. Plant Indus. Unpublished Report.] [41] pp., illus. [1941.] [Typed.]

found that keeping the ventilators open when the outside air was down as low as 20° F. afforded considerable additional cooling of the fruit during the first part of the transit period without much danger from freezing. Under standard ventilation, in which the vents are closed at 32°, much of this cooling effect is never gained.

As a result of this early work and to bring the benefits of this special ventilation to the attention of shippers, further intensive studies were made during the shipping seasons of 1944–45, 1945–46, and 1946–47 by Harvey and others of the Department (*11*, *14*, *16*), in cooperation with the California Fruit Growers Exchange. The results of these tests were quite significant showing that in general, and despite unseasonably warm weather during some of the tests, the cooling of the load by combination ventilation was more rapid and more satisfactory during the first 5 days than that by ice refrigeration. During the remainder of the trip, however, ice refrigeration produced lower temperatures. As noted before, prompt cooling at the beginning of the transit period is more important than an equal amount of cooling during the latter part.

Because of facts brought out by the cooperative investigations Heydenfeldt (*18*), of the California Fruit Growers Exchange, wrote a circular of instructions to shippers. He stated:

> The recent inclusion in the tariff of the "Combination Ventilation" rule is one result of the investigations. Under this rule, vents may be open above 20 degrees and closed at 20 degrees or lower in the areas west of Ogden and Salt Lake City, Utah; El Paso, Texas; and Belen, New Mexico; standard ventilation thereafter. This rule may be used to advantage instead of shipping under standard ventilation where vents are closed at 32 degrees and opened above 32 degrees.

Attention was called to the fact that during much of the time when winter shipments are in transit the cooling effect of the cold outside air has been greater than the cooling effect of ice. This fact and the saving of the cost of ice are the reasons for the favorable reaction of California orange shippers to controlled ventilation. It was also pointed out, as was done by Harvey and others (*11*, *14*, *16*) in the Department publications, that this service must be used with discretion, due consideration being given to outside temperatures likely to be encountered and to the load temperatures at critical times en route.

Only four of these tests included fan cars, because of their scarcity at the time; therefore little information was obtained on the effect of fans on load temperatures. The data for the fan cars showed that there was a more uniform temperature through the load than in cars without fans, indicating the desirability of further study of the use of fan cars in combination ventilation service.

When weather or other conditions are not favorable for shipping winter oranges under the combination ventilation service and refrigeration is desirable, it is practicable to employ half-stage icing with whatever icing rule the shipper prefers, as reported by Harvey and others (*8*) in 1948. This means a saving of 22 percent of the full-bunker-icing-service cost for practically equivalent refrigeration.

Although the transit period is not as long for Florida fruit as for the California fruit, it is still important to reduce the temperature quickly after harvesting and packing to avoid the development of decay. Properly precooled fruit may be shipped during the winter months under the "free icing," or special, refrigeration service (Item 80P) to the eastern seaboard destinations not more than 5 days distant and by Item 81 to destinations in the District of Columbia, Virginia, and certain "central western" States. Preliminary studies on this service were reported by Winston in 1942 (*31*). A more intensive study was being made during the winter of 1949–50, but a report has not been made yet. The value of half-stage icing during the winter when some refrigeration may be necessary, particularly for nonprecooled fruit, was again demonstrated in the studies by Winston (*31*). Standard ventilation, while effective under certain conditions, is bound to give varying and uncertain results because of the varying weather conditions (*34*). Very little difference was noted in the arrival condition of precooled loads in pre-iced cars and in cars iced at varying times after loading (*31*).

SPRING

The spring shipping season is one of transition between strictly winter and hot summer weather. Therefore, the refrigeration or shipping service that can be used to best advantage depends largely on the general weather conditions and the loading temperatures of the fruit. While combination ventilation is not likely to prove successful during this period, half-stage icing in conjunction with other modified icing services has proved very successful. Where fan cars are available they should always be moved with the fans operating. Item 80P, or "free icing," can still be used to advantage during this period for Florida shipments when loading temperatures permit.

PRECOOLING

Precooling may be defined as the rapid reduction of the commodity temperature to that desired for transit by the removal of field heat either in appropriate cooling rooms prior to loading or in the car immediately after loading and before the transit period begins. The relation of adequate precooling to proper transit temperatures and economies in transit refrigeration has already been pointed out. Because of the importance of this operation, it is emphasized further. Adequate precooling of citrus means bringing the fruit temperature down to 50° F. or below in all parts of the load. For fruit that has been kept for several days in a cold-storage room this is no problem; but for fruit precooled in the car or overnight in a room cooler it is very important to allow sufficient time for all of the fruit to cool thoroughly. As reported by Mallison (*20*) in 1939, many commercial precooling operations are not continued for a long enough time to cool the load properly. For room coolers adequate air circulation and proper stacking of the fruit are important. Considerable information on precooling methods and equipment was presented by Pentzer, Asbury, and Barger (*25*).

890503—51—8

As reported by Ryall and Winston (*29, p. 12*) in 1943:

> The time required to cool a load depends on the size of the load, the initial fruit temperatures, the rate and volume of air movement, the refrigerating capacity of the cooling medium, and the air temperature outside the car.

Although it is desirable to precool all loads to 50° F. or below, the final temperature should be determined in part by the type of refrigeration service to be used en route. If either "free icing" or no ice is to be used, fruit temperatures should be brought down to near 40°, whereas for more complete refrigeration temperatures up to 50° should be satisfactory. The use of car fans in precooling has been found to give as good results as portable fans placed in the ice bunker or in the body of the car or as mobile precooling units mounted on trucks in common use in Florida.

In California the greater part of citrus precooling is done in warehouses and most of the car precooling is done at central cooling plants by the railroads. Comparatively little research on precooling has been conducted there in recent years. In the discussion of refrigeration services for the various seasons the value of proper precooling and its effect on transit conditions were pointed out.

Investigations in Texas, reported by Lutz (*19*) in 1940, showed that cooling grapefruit in conjunction with half-stage icing gave satisfactory temperatures at less cost than loading the fruit warm and shipping it under full-bunker icing. In 1945 Ryall and Ramsey [30] reported that precooled citrus shipped under Rule 240 (initial ice only) reached Chicago in as good or better condition and with generally lower temperatures than that loaded warm and shipped under standard refrigeration. Ryall and Ramsey (*28*) in 1945 emphasized the importance of precooling citrus fruit prior to shipment from Texas.

A number of studies of precooling made in Florida were reported by Mallison (*20*) in 1939; Winston, Mallison, and Bratley (*34*) in 1940; Winston and Bratley (*32*) in 1941; Winston (*31*) in 1942; and Ryall and Winston (*29*) in 1943. They all show the value of precooling in reducing decay in transit and permitting the use of modified refrigeration in transit.

HEAVY LOADING

In regard to heavy loads, Harvey [31] stated that, under pressure from the Office of Defense Transportation and other offices, heavy loading was tried with most perishable commodities from the very beginning of World War II. In anticipation of the coming situation, tests of heavy loading of oranges were already under way a year or two before the war. The first heavy loading of oranges (three full layers high, that is, 693 boxes instead of 462) was made in December 1938. In 1940 the United States Horticultural Field Laboratory at Pomona, Calif., tested more than 50 heavy orange loads, ranging from 684 to 693 boxes. This extremely heavy loading was considered unfeasible on account of the great amount of crate breakage in transit and the inefficient refrigeration. The

[30] Unpublished data of A. L. Ryall and G. B. Ramsey.

[31] Correspondence.

next step was the trial of many types of deck loads in which the boxes in the third layer were not placed on end. From these trials emerged the final standard heavy orange load of 561 boxes (462 in the first 2 layers plus a deck load of 3 boxes on their backs across the car times 33, or 99 boxes with a single braced channel through the deck layer 20¾ inches wide).

Mann and Embree (*23*) in 1942 reported on four tests conducted in 1940 and 1941 to develop satisfactory methods of refrigeration of the heavy loads of oranges. The results of these tests showed the importance of thorough precooling or of using fan cars in shipping warm fruit in heavy loads (693 boxes). Mann and Embree concluded that the precooling period at railroad precooling plants should be lengthened from 8 to 12 hours and that baffles should be used to direct the cold air through the load.

Two other transportation tests were conducted by Mann and Embree with oranges and lemons shipped from California to New York in 1943. These tests were concerned with methods of loading these fruits in accordance with Office of Defense Transportation General Order 18, which required that shipments in standard nailed boxes be loaded not less than three layers high; two layers, each box placed on end, and the top layer, each box placed on its bottom or side, each layer to be the same length and width as the floor space of the car. One test was conducted early in 1943 [32] and the work continued with another test in June.[33] The investigators reached the following conclusions as to stowage and refrigeration.

Deck layers (top) with boxes stowed crosswise carried best. Channel braces were best, and spacing the boxes of the deck layer was best when the boxes were loaded crosswise. Shifting and breakage in the bottom layers (on end) were definitely reduced by turning the boxes so that the bulges faced the nearest wall. Scotch strips (short, horizontal strips nailed to the top end of the second-layer wall box to hold it out from the wall) proved to be at least as effective as Pierce poles (horizontal strips on wall at middle of second-layer box to hold it from side) for bracing the second layer of boxes away from the walls in lemon loads 7 boxes wide when the strips were placed beneath the deck-layer boxes. The solid 646-box load, 8 wide, 2 high (on end), although employing no stripping or bracing, showed no shifting or breakage and proved satisfactory for commercial loads.

There were no significant differences in the transit refrigeration of oranges resulting from different methods of stowing in the same type of car. Refrigeration was affected more by size of load, type of car, and icing service used. As in previous tests, the overhead-bunker car showed lower average temperatures and less variation of temperatures throughout the load than standard end-bunker cars loaded in the same manner.

In precooled cars of lemons, deck layers 3 boxes wide stowed crosswise cooled faster and remained cooler through the trip than

---

[32] See footnote 25 p. 110.

[33] MANN, C. W., and EMBREE, G. L. CALIFORNIA CITRUS 1943—TEST 2. [CALIFORNIA TO NEW YORK, JUNE AND JULY 1943.] [U. S. Bur. Plant Indus., Soils, and Agr. Engin. Unpublished Report.] [54] pp., illus. [1943.] [Typed.]

did comparable shipments with deck-layer boxes placed lengthwise. Because of the shape and arrangement of the hatches, the standard-length overhead-bunker car could not be properly connected to the regular precooling ducts; this resulted in the fruit being precooled only half as much as that in regular end-bunker cars.

The heavy lemon load evolved more or less independently of the Department from 1934 to the beginning of World War II. The original load (348 boxes) was 2 layers high and 6 boxes across the car (with horizontal spacing bars (Pierce poles) at each side of the car to keep the load centered and braced) and 29 stacks long. The next changes in development of the present lemon load (464 boxes) were to use first 7 boxes across the car and then 8. Use of 8 made a solid compact load. The refrigeration attained with this type of load was not investigated until 1948. A test in August of that year, reported by Harvey, Atrops, and Hruschka (*7*), indicated that adequate refrigeration throughout the load was possible by the use of several of the icing services available. Similar results were obtained in cooler weather when this test was repeated in May 1949 and again in June and July (Harvey and others (*6*, *10*)).

In 1947 Winston, Ramsey, and Wiant [34] conducted a transportation test with citrus fruit shipped from Florida to Chicago and New York. They found in this one test that use of double-deck loads of oranges was of little advantage in cars sent to New York but of decided advantage in those sent to Chicago. The reason for this difference was not known. Transit temperatures were about the same in the solid loads as in the double-deck loads. Crushing and flattening of fruit were not an important cause of loss in the solid loads. On arrival there was no significant difference in decay between the fruit in 4/5-bushel bags treated with diphenyl, each containing five 8-pound mesh bags, and that in four similar bags nontreated and each with holes about 5/8 inch in diameter.

COMPARISON OF CARS

One of the greatest improvements in refrigeration cars has been the development and use of the forced-air circulating fan. A great number of tests have showed the value of such fans in precooling, in rapid cooling, and in establishing more uniform load temperatures during transit. See Bratley and Harding (*2*), 1946; Rygg and others (*30*), 1946; Harvey and others (*15*), 1944; and Harvey, Embree, and Wiant,[35] 1944.

Overhead-bunker cars were compared with standard end-bunker cars both with and without fans. In January 1944 Harvey and others (*15*) conducted two shipping tests on the refrigeration of Washington Navel oranges and reported that overhead-tank-bunker cars gave less cooling than standard and fan cars under similar icing services. Also in 1944 Harvey, Embree, and Wiant [36] found that the fan car gave the best performance after the transit

[34] Unpublished data of J. R. Winston, G. B. Ramsey, and J. S. Wiant.

[35] [36] See footnote 26, p. 110.

period began, but that the overhead-bunker car cooled more quickly during the first 1½ days while the cars were being switched and the fans were generally inoperative. The temperature spread in the overhead-bunker car was considerably less than in the standard nonfan car. Other tests (*2*, *30*, *33*) confirmed these findings. In addition, average temperatures in fan cars were generally lower than in overhead-bunker cars.

Studies of the effect of different thicknesses of insulation on car performance were made in two tests on citrus fruits in cooperation with the Association of American Railroads. One test was with warm grapefruit shipped from Texas to Pittsburgh in April 1947 (*27*). Six special fan cars differing only in insulation thickness, which varied from 3 to 3½ inches to 6 to 7 inches, were used in this test. The test showed very little difference between cars in either ice meltage or fruit temperature. The main function of the ice was to absorb the field heat from the warm load, and a comparatively small percentage was lost by leakage. The weather was cool during the greater part of the test; this would tend to minimize heat leakage.

The other test was with oranges shipped from California to New York in July 1947 (*17*). The same cars as in the Texas test, as well as new standard cars with 4 to 4½ inches of insulation, were used. Warehouse-cooled fruit was loaded in this test. Ice-meltage records showed that there was some slight correlation between the amount of ice meltage and the amount of insulation. The meltage generally decreased as the insulation increased, but not in direct proportion to the thickness of insulation. These tests indicated that the 4- to 4½-inch insulation now being used in new cars gives sufficient protection for all fresh commodities.

Winston, Ramsey, and Wiant [37] found in 1947 that use of double-deck cars in the shipment of bagged citrus fruit from Florida appears to have some advantage in the prevention of crushing and bruising, especially when cars are subject to rough handling. Fruit temperatures obtained were similar to those in standard nonfan cars.

Cars utilizing dry ice to cool a secondary refrigerant (Broquinda System) were tested by Winston and Mallison [38] in 1940. While satisfactory temperatures were obtained with precooled fruit, there was not enough refrigeration to properly precool a warm load. Recent developments in cars of this type, although not tested by the Department, indicate that the performance has been improved.

SUBSTITUTE CONTAINERS

During World War II the shortage of wooden containers for the shipment of fruits and vegetables was responsible for investigations to determine whether available substitutes could be used satisfactorily.

---

[37] Unpublished data of J. R. Winston, G. B. Ramsey, and J. S. Wiant.

[38] [WINSTON, J. R., and MALLISON, E. D.] INVESTIGATIONS ON THE REFRIGERATION OF FLORIDA CITRUS 1940—1–4. [FLORIDA TO NEW YORK AND OTHER NORTHERN DESTINATIONS.] U. S. Bur. Plant Indus., [Off. Rpt.] 4 v. 1940. [Processed.]

Fiberboard containers and wire-bound crates were studied and the results were reported by Ryall, Bratley, and Wiant in 1943.[39] In one test they found no difference in the condition of the fruit at destination. They found considerable breakage of the slats of the crates, which in their opinion was due in part to rough handling at time of loading, in part to actual failure of the crates that might have occurred even with more careful handling, and in part to heavy loading in one of the cars (crates stowed 6 high). In a shipping test with Texas grapefruit in standard wooden boxes and fiberboard cartons, they found that about half of the bottom-layer cartons showed some buckling of the side walls near the end that was on the floor racks. In some of these cartons, fruits next to the badly bent side walls were bruised. Bruising, presumably due to squeezing at time of lidding, was also found in fruits next to the lids of wooden crates. The amount of bulge in the lids of the cartons seemed to be satisfactory to the trade. The cartons were stowed on end, but Ryall, Bratley, and Wiant felt they might have buckled less by pressure if they had been stowed on the side.

In 1943 Bratley and Winston [40] conducted shipping tests to determine the usefulness of fiberboard containers as substitutes for regular nailed crates for the transportation of Florida citrus fruit. They found that fiberboard boxes stood up fairly well in transit but that cooling was generally slower than in nailed crates. Subsequent handling of the fiberboard boxes during stacking, displaying, and loading on the trucks revealed a number of weaknesses. Many of the boxes came apart at the lock, and the lids of still others fell off. Purchasers reported that the boxes were not strong enough to stack properly.

When bagged late-season Washington Navel oranges were shipped on top of the second layer of wooden crates, Bratley [41] found that there was little crushing, but bruising and decay were high. The upper layer of crates was slow in cooling and the pads placed on the boxes to protect the bagged oranges were difficult to keep in place. Bratley concluded that late-season navel oranges cannot be shipped in solid loads, because of the crushing and bruising in the bottom layers. More satisfactory results, however, might be obtained on shorter hauls and with less mature fruit.

Bratley and Winston [42] in a series of tests with Florida oranges shipped in wooden crates, mesh bags, and paper bags found that the bags stood up very well but that there was considerably more split and decayed fruit in them than in wooden crates.

---

[39] Correspondence and unpublished data of A. L. Ryall, C. O. Bratley, and J. S. Wiant.

[40] BRATLEY, C. O., and WINSTON, J. R. TESTS FOR COMPARING THE HANDLING, CARRYING AND STORAGE QUALITIES OF CITRUS FRUIT WHEN PACKED IN REGULAR AND SUBSTITUTE CONTAINERS. FLORIDA CITRUS; 1943, TESTS 5 AND 6. U. S. Bur. Plant Indus., Soils, and Agr. Engin., [Off. Rpt.], 5 pp. [1943.] [Processed.]

[41] BRATLEY, C. O. REPORT ON THE ARRIVAL CONDITION OF . . . CALIFORNIA NAVEL ORANGES, PART OF WHICH WERE PACKED IN BAGS. LA VERNE, CALIF. TO NEW YORK, N. Y., MARCH 16–27, 1944. U. S. Bur. Plant Indus., Soils, and Agr. Engin., [Off. Rpt.], [4] pp., illus. [1944.] [Processed.]

[42] Correspondence and unpublished data of A. L. Ryall, C. O. Bratley, and J. S. Wiant.

Bratley and Winston (*4*) in 1945 conducted a shipping test to determine the suitability of the "Friday pack" container as a substitute for bushel crates and standard citrus crates for the shipment of oranges from Florida to northern markets. The "Friday pack" container is of fiberboard and contains cupped trays made of papier mâché. The authors found that there was considerably less than 0.5 percent decay in both kinds of packages, and that the amounts of aging in fiberboard packages and wooden packages were about the same. Weight loss was heavier in the wooden crates. "Friday pack" containers that became dented or otherwise distorted in transit regained their shape well when stacked for the auction display.

The main difficulty with substitute containers (fiberboard) appeared to be their tendency to become distorted under pressure, often accompanied by an increase in bruising. If they became wet, they were likely to come apart. In general, fruit packed in them cooled slowly. The breakage of slats in the wire-bound boxes shipped may have been due to the use of poor material in making the boxes. Bags tended to shift considerably.

WRAPPING AND WAXING TESTS

Another shortage that became acute during World War II was that of paper for wrapping fruits. The United States Department of Agriculture was requested by the Office of Defense Transportation to determine whether paper wrappers were necessary for certain fruits, including citrus.

CALIFORNIA

In 1944 Bratley and Harvey (*3*) conducted a shipping test with wrapped and naked-pack (unwrapped) lemons from California to New York to determine weight losses in transit under these two methods of packing. Waxed and unwaxed fruits and two types of boxes were tried. Bratley and Harvey found that the naked, unwaxed fruits lost considerably more weight than any of the others. There was a slight difference in the weight loss of unwrapped fruit receiving the two wax treatments. There was no significant difference in weight loss between the fruit receiving the two wax treatments when the fruit was wrapped. The unwaxed fruits that were wrapped lost slightly less weight than the naked fruits that were waxed. Thus, the data indicated the value of waxing the fruit to cut down weight loss but that wrapping unwaxed fruit is more effective in preventing loss in weight than waxing alone.

From the standpoint of appearance, the lots of wrapped fruit treated with wax were the best. They possessed the glossiest finish. Naked unwaxed fruit had the poorest appearance of all. The packs of such fruit were markedly slack and badly jumbled. The packs of waxed fruit were less slack and jumbled, but they nevertheless had a poor appearance. None of the wrapped lots was jumbled, and they were only slightly slack.

Waxing had no beneficial effect on the buttons. In fact, there was some indication that the treatments increased the number of black buttons.

In 1944 Harvey, Embree, and Bratley (*13*) conducted a series of shipping tests to obtain data relative to shrinkage, decay, and other losses in wrapped and naked-pack lemons during transit from California to New York and a holding period thereafter equivalent to the time normally required for the fruit to reach the consumer. They concluded that the use of tissue wrappers on lemons affords desirable protection against shrinkage during transit and the subsequent marketing period. Other advantages from the use of tissue wrappers were protection against smudging of sound fruits by decaying ones and against chafing of fruit in contact with the sides and lids of the boxes. The total advantage was such that one may regard the use of tissue wrappers as essential if grade A lemons are to be made available to eastern consumers. In the "strong" market prevailing during the 1944 season when this work was done there was no sales-price differential between wrapped and naked-pack lemons, but in a "weak" or even a normal market such a differential undoubtedly could be anticipated. Waxing treatments proved to be distinct aids in reducing shrinkage and in improving the appearance of lemons, but they were not an adequate substitute for tissue wrappers.

Harvey and Bratley (*12*) in 1945 made a shipping test with Washington Navel oranges from southern California to New York, to compare the effects of waxing and wrapping. As in the test made from California in 1944 wrappers were more effective in controlling moisture loss than any of the waxing treatments alone. The diphenyl wrappers were somewhat more effective than plain wrappers. Harvey and Bratley stated (*p. 14*):

> In this, as in other shipping tests on citrus fruit where the behavior of wrapped and naked packs are compared, wraps were shown to contribute such advantages that under normal marketing conditions they should not be voluntarily ignored. Although waxing treatments were not found to be adequate substitutes for tissue wraps, they definitely reduce shrinkage and improve the appearance of the fruit. The reduced shrinkage and improved appearance varies somewhat with the method of application of the waxes, and of other factors the specific consideration of which was out of the scope of this test.

Weight loss in transit in all lots was less than 2 percent. Pitting and decay were not consistently related to any of the treatments. Diphenyl wrappers reduced decay to about one-half that found in other lots. Aging was reduced by all waxing treatments but not as much as by the tissue wrappers alone.

It is of interest to note that in a 1944 shipping test with Washington Navel oranges, Harvey, Embree, and Wiant [43] found that a car containing naked-pack fruit had a very good cooling rate; this car was not exactly comparable with the other cars in the test, because of its lower initial fruit temperature and differences in icing. In general, the rate of cooling and the temperature spread (between top and bottom layers) were more satisfactory than in any of the cars packed with wrapped fruit except the fan car.

Harvey and Bratley [44] concluded in 1945 from the results of a wrapping and waxing test with California oranges that wax treat-

---

[43] See footnote 26, p. 110.

[44] Unpublished data of E. M. Harvey and C. O. Bratley.

ments were not of much significance in preventing weight loss and that diphenyl wrappers did not decrease weight loss of sound fruit. The lower weight loss observed in fruit in diphenyl wrappers that developed decay may have meant that the decay was less advanced than in fruit with untreated wrappers. Fruit treated with a wax that gave it a high gloss or shine had a fresher appearance than unwaxed fruit or fruit treated with other waxes.

FLORIDA

Winston and Bratley [45] conducted storage tests with Florida oranges with different kinds of wrappers such as might be used for fruit destined for overseas shipment. Their results can be summarized in part as follows: After 2 weeks in storage about one-third as much decay occurred in fruit in diphenyl wrappers in lined crates as in that wrapped in plain tissue. After 4 weeks in storage decay had increased slightly but still remained less in fruit in diphenyl wrappers. The average total loss in weight during transit, 2 weeks' storage, and 1 week's subsequent holding period was 6.1 percent in fruit in plain wrappers, 6.4 percent in that in diphenyl wrappers, 1.3 percent in that in plain wrappers in foil-lined crates, and 1.1 percent in that in diphenyl wrappers in foil-lined crates. After 4 weeks' storage, the values for weight loss were 7.9, 7.9, 2.4, and 1.9 percent, respectively. No unusual flavors, not even the flavor of diphenyl, were detected by a panel of tasters.

In a test made since the end of World War II, Winston and others [46] in 1947 found that kraft-paper overwrap bags greatly retarded the refrigeration of oranges moving from Florida to New York. Loss from crushing of fruit in bottom layers of loads was not materially affected by the use of the paper bags. Crushing seemed to be due more to the weight of the load than to lack of protection where 8-pound mesh bags rested on crates and excelsior. The kraft-paper bags reduced moisture loss during the holding period (after arrival at New York) and thereby considerably reduced aging. Comparison of the fruit from crates and from mesh bags with and without kraft-paper overwrap bags showed no difference in freshness of appearance, but there was somewhat more decay in fruit in mesh bags without overwrap bags than in those with them. In a 1946 test fruit in treated mesh bags showed only a little more decay than that in untreated mesh bags.[47]

MISCELLANEOUS TESTS

In 1942 Bratley and Winston [48] conducted a shipping test with one car of limes moving from Florida to New York. Their results and conclusions were summarized as follows:

---

[45] [Winston, J. R.], and Bratley, C. O. wrapping tests with florida oranges for overseas shipment. U. S. Bur. Plant Indus., Soils, and Agr. Engin., [Off. Rpt.], 2 pp., illus. [1944.] [Processed.]

[46] Unpublished data of J. R. Winston, J. Kaufman, H. W. Hruschka, and J. S. Wiant.

[47] Unpublished data of J. R. Winston, J. Kaufman, and C. O. Bratley.

[48] Bratley, C. O., and Winston, J. R. shipping test with limes under refrigeration. [U. S. Bur. Plant Indus., H. T. & S. Off. Rpt. 95], 5 pp. 1942. [Unpublished.]

Except for the limes in the two bottom layers of cartons, the fruit in the car was too yellow for best demand on arrival. From the temperature record it is evident that this coloring was due to delay in cooling the load. Only during the last 2 or 3 days of the trip did the temperature at the top doorway position become low enough to retard coloring. Rapid cooling was undoubtedly hindered by blocking of the vertical channels in the load.

Any system of hastening the cooling of the load would help retain the green color of the fruit. Care should be taken, however, to lower as small a part of the load as possible below the danger point of 42° F. Precooling the fruit to 45° to 50° either before or after loading would undoubtedly be helpful. Half-stage icing of pre-cooled loads might be helpful in maintaining circulation of cold air without lowering the temperature of the bottom-layer packages too much. Each of these systems should be tried experimentally. Further work should be done also on the relation of temperature to color development, decay, rind break-down, and stylar-end break-down.

Mann and Gorman [49] found that for all practical purposes the method of refrigerating a ship's hold by the circulation of cooled air during a transportation test from California to New York seemed quite adequate for oranges sent to ship's side by iced refrigerator car. The fruit in this cargo compared favorably with similar fruit shipped by iced refrigerator car, arriving at destination on the same date. Brown staining of California Valencia oranges is evidently increased by some other condition than low temperature and is possibly connected with rate of air movement.

Carne (*5*) in 1948 reported that the life of good oranges aboard ship is probably about 25 to 30 days in ventilated storage and a maximum of about 15 to 20 days at high temperatures. If ventilation is not adequate or the fruit more mature, the safe periods will be much shorter. The Australian Citrus Advisory Council (*1*) in 1938 advised that whenever possible fruit shipped for export to New Zealand should not be warmer than 53° F. at time of loading aboard ship.

LITERATURE CITED FOR TRANSPORTATION [50]

(1) Australian Citrus Advisory Council.
1938. CITRUS INDUSTRY. ADVICE ON THE PICKING, HANDLING AND PACKING OF ORANGES INTENDED FOR EXPORT TO NEW ZEALAND. So. Austral. Dept. Agr. Jour. 41: 1016–1017.

(2) Bratley, C. O., and Harding, P. L.
1946. TRANSPORTATION TEST WITH GRAPEFRUIT FROM FLORIDA TO NEW YORK, MAY 2–6, 1946. U. S. Bur. Plant Indus., Soils, and Agr. Engin., [Off. Rpt.], [11] pp., illus. [Processed.] (A. A. R.–U. S. D. A. Test No. 1.)

---

[49] [Mann, C. W.], and Gorman, E. A., Jr. OCEAN TRANSPORTATION TEST OF CALIFORNIA VALENCIA ORANGES [VIA S. S. CITY OF SAN FRANCISCO]. LOS ANGELES, CALIFORNIA (10–16–38) TO NEW YORK, NEW YORK (10–31–38). [U. S. Bur. Plant Indus. Unpublished Report.] [21] pp., illus. 1938. [Typed].

[50] H. T. & S. [Handling, Transportation, and Storage] reports and those of A. A. R.–U. S. D. A. [Assoc. of Amer. Railroads–U. S. Dept. of Agr.] are available generally only in the larger libraries of the country.

(3) BRATLEY, C. O., and HARVEY, E. M.
1944. WEIGHT LOSS IN WRAPPED AND NAKED PACK LEMONS. REPORT ON SHIPPING TESTS FROM PUENTE, CALIF., TO NEW YORK, N. Y., MAY 26–JUNE 8, 1944. U. S. Bur. Plant Indus., Soils, and Agr. Engin., H. T. & S. Off. Rpt. 145, [6] pp. [Processed.] (In cooperation with Calif. Fruit Growers Exch.)

(4) ——— and WINSTON, J. R.
1945. TEST FOR COMPARING THE HANDLING AND CARRYING QUALITIES OF CITRUS FRUIT WHEN PACKED IN REGULAR AND SUBSTITUTE CONTAINERS. [FEBRUARY 1945.] U. S. Bur. Plant Indus., Soils, and Agr. Engin., H. T. & S. Off. Rpt. 152, 7 pp., illus. [Processed.]

(5) CARNE, W. M.
1948. NON-REFRIGERATED FRUIT EXPORTS. Citrus News 24: 6–7, 15.

(6) HARVEY, E. M., ATROPS, E. P., and FRIEDMAN, B. [A.]
1949. TESTS ON THE REFRIGERATION OF LEMONS IN TRANSIT FROM CALIFORNIA TO NEW YORK. [JUNE AND JULY 1949.] U. S. Bur. Plant Indus., Soils, and Agr. Engin., H. T. & S. Off. Rpt. 217, [20] pp., illus. [Processed.]

(7) ——— ATROPS, E. P., and HRUSCHKA, H. W.
1948. TRANSPORTATION TEST WITH LEMONS FROM SOUTHERN CALIFORNIA TO NEW YORK AUGUST 18 TO 27, 1948. U. S. Bur. Plant Indus., Soils, and Agr. Engin., H. T. & S. Off. Rpt. 195, [40] pp., illus. [Processed.]

(8) ——— ATROPS, E. P., KAUFMAN, J., and others.
1948. SHIPPING TESTS WITH WASHINGTON NAVEL AND VALENCIA ORANGES UNDER HALF-STAGE AND FULL-BUNKER REFRIGERATION FROM SOUTHERN CALIFORNIA [TO NEW YORK,] MAY AND JUNE 1948. U. S. Bur. Plant Indus., Soils, and Agr. Engin., H. T. & S. Off. Rpt. 193, [29] pp., illus. [Processed.] [In cooperation with Calif. Fruit Growers Exch.]

(9) ——— ATROPS, E. P., MACRILL, J. R., and WAID, W. C.
1948. SHIPPING TESTS WITH WASHINGTON NAVEL ORANGES UNDER HALF-STAGE AND FULL-BUNKER REFRIGERATION FROM TULARE COUNTY, CALIF. [TO NEW YORK], DECEMBER 1947. U. S. Bur. Plant Indus., Soils, and Agr. Engin., H. T. & S. Off. Rpt. 187, [26] pp., illus. [Processed.] [In cooperation with Calif. Fruit Growers Exch.]

(10) ——— ATROPS, E. P., REDIT, W. H., and FRIEDMAN, B. A.
1949. TRANSPORTATION TEST WITH LEMONS FROM SOUTHERN CALIFORNIA TO NEW YORK MAY 18 TO 27, 1949. U. S. Bur. Plant Indus., Soils, and Agr. Engin., H. T. & S. Off. Rpt. 214, [28] pp., illus. [Processed.]

(11) ——— ATROPS, E. P., WIANT, J. S., and others.
1947. SHIPPING TESTS WITH WASHINGTON NAVEL ORANGES UNDER CONTROLLED AND STANDARD VENTILATION AND ICE REFRIGERATION [TO NEW YORK] FROM TULARE COUNTY CALIFORNIA, DECEMBER 1946[,] AND SOUTHERN CALIFORNIA, FEBRUARY 1947. U. S. Bur. Plant Indus., Soils, and Agr. Engin., H. T. & S. Off. Rpt. 181, [52] pp., illus. [Processed.] (In cooperation with Calif. Fruit Growers Exch.)

(12) ——— and BRATLEY, C. O.
1945. COMPARISON OF WAXING AND WRAPPING WASHINGTON NAVEL ORANGES IN A SHIPPING TEST FROM SOUTHERN CALIFORNIA TO NEW YORK, N. Y. APRIL–MAY, 1945. U. S. Bur. Plant Indus., Soils, and Agr. Engin., H. T. & S. Off. Rpt. 158, [27] pp., illus. [Processed.]

(13) ——— EMBREE, G. L., and BRATLEY, C. O.
1944. COMPARISON OF WRAPPED AND NAKED-PACK LEMONS IN SHIPPING TESTS FROM SOUTHERN CALIFORNIA TO NEW YORK, N. Y. 1944. U. S. Bur. Plant Indus., Soils, and Agr. Engin., H. T. & S. Off. Rpt. 147, [22] pp. [Processed.] (In cooperation with Calif. Fruit Growers Exch.)

(14) ——— EMBREE, G. L., BRATLEY, C. O., and others.
[1945.] SHIPPING TESTS WITH WASHINGTON NAVEL ORANGES UNDER CONTROLLED AND STANDARD VENTILATION AND ICE REFRIGERATION FROM TULARE COUNTY AND SOUTHERN CALIFORNIA [TO NEW YORK], DECEMBER, JANUARY, AND FEBRUARY, 1944–45. U. S. Bur. Plant Indus., Soils, and Agr. Engin., H. T. & S. Off. Rpt. 163, [51] pp., illus. [Processed.] (In cooperation with Calif. Fruit Growers Exch.)

(15) HARVEY, E. M., EMBREE, G. L., PENTZER, W. T., and BRATLEY, C. O.
[1944.] COMPARATIVE REFRIGERATION SHIPPING TESTS OF WASHINGTON NAVEL ORANGES FROM TULARE COUNTY, CALIFORNIA, TO NEW YORK, N. Y. [JANUARY 1944.] U. S. Bur. Plant Indus., Soils, and Agr. Engin., [H. T. & S. Off. Rpt. 144], [24] pp., illus. [Processed.]

(16) ——— PENTZER, W. T., BRATLEY, C. O., and others.
[1946.] SHIPPING TESTS WITH WASHINGTON NAVEL ORANGES UNDER CONTROLLED AND STANDARD VENTILATION AND ICE REFRIGERATION FROM TULARE COUNTY CALIFORNIA [TO NEW YORK], NOVEMBER AND DECEMBER, SEASON OF 1945–46. U. S. Bur. Plant Indus., Soils, and Agr. Engin., H. T. & S. Off. Rpt. 170, [21] pp. [Processed.] (In cooperation with Calif. Fruit Growers Exch.)

(17) ——— REDIT, W. H., and RYGG, G. L.
1947. TRANSPORTATION TEST WITH PRECOOLED VALENCIA ORANGES SHIPPED FROM ORANGE COUNTY, CALIFORNIA[,] TO NEW YORK, N. Y.[,] JULY 2 TO 14, 1947. U. S. Bur. Plant Indus., Soils, and Agr. Engin., [Off. Rpt.], [27] pp., illus. [Processed.] (A. A. R–U. S. D. A. Test No. 17.)

(18) HEYDENFELDT, F. F.
1949. BULLETIN ON MODIFIED VENTILATION. Calif. Fruit Growers Exch., Field Serv. Dept. Cir. 765, [1] p. [Processed.]

(19) LUTZ, J. M.
1940. INVESTIGATIONS ON THE PRECOOLING AND TRANSPORTATION OF TEXAS GRAPEFRUIT MARCH 1940. U. S. Bur. Plant Indus., H. T. & S. Off. Rpt. 40, 14 pp., illus. [Processed.]

(20) MALLISON, E. D.
1939. INVESTIGATIONS ON THE PRECOOLING AND TRANSPORTATION OF FLORIDA CITRUS FRUITS—MAY AND JUNE 1939. U. S. Bur. Plant Indus., H. T. & S. Off. Rpt. 34, 66 pp., illus. [Processed.]

(21) ——— GORMAN, E. A., Jr., and HUKILL, W. V.
1937. PROTECTION OF APPLES AND PEARS IN TRANSIT FROM THE PACIFIC NORTHWEST DURING THE WINTER MONTHS. U. S. Dept. Agr. Tech. Bul. 550, 55 pp., illus.

(22) MANN, C. W., and COOPER, W. C.
1936. REFRIGERATION OF ORANGES IN TRANSIT FROM CALIFORNIA. U. S. Dept. Agr. Tech. Bul. 505, 88 pp., illus.

(23) ———and EMBREE, G. L.
1942. HEAVY LOADING OF ORANGES. Calif. Citrog. 28: 32–33, 56, illus.

(24) ——— GORMAN, E. A., Jr., and HUKILL, W. V.
1943. STAGE ICING IN THE REFRIGERATION OF ORANGES IN TRANSIT FROM CALIFORNIA. U. S. Dept. Agr. Tech. Bul. 857, 37 pp., illus.

(25) PENTZER, W. T., ASBURY, C. E., and BARGER, W. R.
1945. PRECOOLING CALIFORNIA GRAPES AND THEIR REFRIGERATION IN TRANSIT. U. S. Dept. Agr. Tech. Bul. 899, 64 pp., illus.

(26) POWELL, G. H.
1908. THE DECAY OF ORANGES WHILE IN TRANSIT FROM CALIFORNIA. U. S. Bur. Plant Indus. Bul. 123, 79 pp., illus.

(27) REDIT, W. H.
1947. TRANSPORTATION TEST WITH WARM GRAPEFRUIT SHIPPED FROM HARLINGEN, TEXAS TO PITTSBURGH, PA. AND POINTS EAST APRIL 23 TO MAY 1, 1947. U. S. Bur. Plant Indus., Soils, and Agr. Engin., [Off. Rpt.], [34] pp., illus. [Processed.] (A. A. R.–U. S. D. A. Test No. 16.)

(28) RYALL, A. L., and RAMSEY, G. B.
1945. AN EVALUATION OF PRECOOLING AND TRANSIT PROTECTIVE SERVICES FOR TEXAS CITRUS FRUIT. [TEXAS TO CHICAGO, 1945.] U. S. Bur. Plant Indus., Soils, and Agr. Engin., H. T. & S. Off. Rpt. 159, [44] pp., illus. [Processed.]

(29) ——— and WINSTON, J. R.
1943. EFFECTIVENESS OF DIFFERENT METHODS OF CAR- PRECOOLING OF ORANGES IN FLORIDA, 1942. U. S. Bur. Plant Indus., Soils, and Agr. Engin., H. T. & S. Off. Rpt. 97, [21] pp. [Processed.]

(30) RYGG, G. L., HALLER, M. H., BRATLEY, C. O., and WIANT, J. S.
1946. TRANSPORTATION TEST WITH ORANGES—COLTON, CALIF. TO NEW YORK CITY JULY 17–28, 1946. U. S. Bur. Plant Indus., Soils, and Agr. Engin., [Off. Rpt.], [24] pp., illus. [Processed.] (A. A. R.–U. S. D. A. Test No. 6.)

(31) WINSTON, J. R.
[1942.] REFRIGERATION OF FLORIDA PRECOOLED ORANGES IN TRANSIT. A COMPARISON OF THE EFFECT OF ICING REFRIGERATOR CARS BEFORE AND AFTER LOADING. U. S. Bur. Plant Indus., H. T. & S. Off. Rpt. 96, 9 pp. [Processed.]

(32) ——— and BRATLEY, C. O.
1941. INVESTIGATIONS ON THE PRECOOLING AND TRANSPORTATION OF FLORIDA CITRUS FRUIT—1940–41. (Summary . . .) [U. S. Bur. Plant Indus.,] H. T. & S. Off. Rpt. 79, 6 pp. [Processed.]

(33) ——— and BRATLEY, C. O.
1946. TRANSPORTATION TEST WITH GRAPEFRUIT AND ORANGES FROM FLORIDA TO NEW YORK, MAY 16–20, 1946. U. S. Bur. Plant Indus., Soils, and Agr. Engin., [Off. Rpt.], [11] pp., illus. [Processed.] (A. A. R.–U. S. D. A. Test No. 2.)

(34) ——— MALLISON, E. D., and BRATLEY, C. O.
1940. INVESTIGATIONS ON THE PRECOOLING AND TRANSPORTATION OF FLORIDA CITRUS FRUIT—1939–40. SUMMARIZED REPORT. U. S. Bur. Plant Indus., H. T. & S. Off. Rpt. 49, 141 pp. [Processed.]

POSTHARVEST DISEASES AND THEIR CONTROL

Diseases take a heavy toll of citrus fruits in the packing house, in storage, in transit, and in the hands of retailers and consumers. Some, such as brown rot, may develop to a recognizable degree in the groves; others, such as stem-end rot, develop in transit and even later from latent infections that took place while the fruit was on the tree. Decays caused by the blue and green molds usually result from infection of wounds made during harvesting, handling, and processing. Losses from citrus diseases during transit in shipments of oranges, tangerines, and grapefruit to New York City during the period 1935–42 are shown by Wiant and Bratley (*190*).[51]

The literature on citrus diseases is voluminous, but fortunately it was rather well summarized up to 1936 by Fawcett in his book "Citrus Diseases and Their Control" (*49*), and up to 1948 by Fawcett and Klotz in volume 2 of "The Citrus Industry" (*19a, ch. 11*). Rose and others (*150*) in 1943 summarized what was known up to that time about blemishes caused by insects and diseases that are encountered during the handling, storage, transportation, and marketing of citrus fruits in the United States. Klotz and Fawcett (*96*) in 1948 published the second edition of their illustrated handbook of citrus diseases. All of these publications are well illustrated in color.

In some instances it was necessary to digest articles published before 1938, in order to give readers a better understanding of the significance of recent articles. Reviews of certain articles published since 1948 have been included, but the search for such articles is incomplete. For information on diseases not mentioned in this digest the reader is referred to Fawcett (*49*), Fawcett and Klotz (*19a, ch. 11*), Rose and others (*150*), and Klotz and Fawcett (*96*).

DISEASES AND INJURIES

ACORN DISEASE

Acorn disease, also sometimes called pink nose, of citrus fruit is probably the same as the crazy top, or stubborn, disease of citrus trees, according to Klotz and Fawcett (*96*) and Fawcett, Perry, and Johnston (*51*). It is caused by a virus, *Citrivir pertinaciae,* and occurs in Arizona and California (*96*). Haas, Klotz, and Johnston (*65*) in 1944 said that this disease was first observed on a few trees in West Ontario, Calif., in 1937 and that since then it had increased at an alarming rate. It probably is spread by budding (*51, 96*).

The name is derived from the acorn shape of some of the late-season fruits from diseased trees. Some fruits from diseased trees are not affected, and the symptoms are less evident in some seasons than in others. The acorn shape is due to the uneven thickness of the

[51] Italic numbers in parentheses refer to Literature Cited for Postharvest Diseases and Their Control, p. 165.

rind, which is normal at the stem end and then abruptly decreases in thickness toward the stylar end. The thin rind at the end is very thin and is subject to attack by rot fungi. The stylar end of affected navel oranges assumes a pinkish color, which gives rise to the name "pink nose." A blue color is present in the albedo of the thin part of the rind of affected grapefruit.

Fruits affected with acorn disease are poor in quality and should be culled. The juice from the blossom half of such fruit is more acid and contains less reducing sugars than juice from the stem half; the reverse is true in normal fruit. There is a marked reduction in dry matter of the peel of the tip half of acorn-affected fruits. Diseased fruits also have a bitter taste and a disagreeable odor (*51, 65, 96*).

ALGAL FRUIT SPOT

Winston (*193*) reported a spotting of Lue Gim Gong oranges in Florida in 1937 by the alga *Cephaleüros (virescens) mycoidea*. This alga is rather commonly found on numerous hosts in Florida and affects the limbs, twigs, and leaves of citrus trees. It had not been reported previously on the fruit.

The fruit spots were dark brown to nearly black and slightly raised and averaged about 1 mm. in diameter. The margins were irregular to acutely pointed. The spots penetrated three or four cells deep into the flavedo.

No decay caused by the algal infection developed in samples held at 80° F. No infections were observed in the next crop. Winston concluded that the unusual development on the fruit in 1937 was due to the abundant growth of the alga in 1936 when the blooms that set the 1937 fruits opened.

ALTERNARIA ROT

Alternaria rot, which is found in practically all lemon-growing areas, ranks second to the blue and green mold rots in importance as a storage and market disease (*150*). It is caused by *Alternaria citri* and probably by other species of *Alternaria*. Bliss and Fawcett (*28*) stated in 1944 that on the basis of their morphological studies *A. citri* and *Stemphylium citri* appear to be identical.

Alternaria rot may extend down the center of the fruit and finally may result in a soft break-down and collapse; it may be semipliable and occur at the stem ends; or it may be dry, firm, and black and at the navel end of navel oranges. It is usually considered a disease of old or physiologically weak fruit.

The center-rot type of decay starts as a blackening of the button end, and then the tissues of the central axis and sometimes of the inner rind blacken. The fungus proceeds through these tissues from the stem end to the stylar end, and there is very little external indication of the disease. Finally the entire rag breaks down and the interior becomes a lead-brown slimy mass. Later the discoloration begins to show through the rind as a translucent, dark-colored area and soon afterward the entire rind is broken down.

The end-rot type of decay is characterized by browning of the exterior as well as of the interior tissues, starting at the button.

The affected tissues are at first leathery pliable and later soft pliable.

Black rot of navel oranges is primarily an orchard disease. It starts at the stylar or navel end and spreads up through the core. Spores of the causal fungus probably enter through imperfections at the navel.

It is generally recognized that weak fruit is especially susceptible to alternaria rot. Fawcett (*49, p. 433*) said:

> Observations have repeatedly shown that old fruit held for a long time on the tree before picking or in storage after picking or both is most apt to have large percentages of this decay. It is also a common observation that the "tree-ripe" fruits tend to have more Alternaria rot in a given time than that when picked in the "green," "light green," or "silver" stage.

Rose and others (*150*) said the same and in addition noted that the high temperatures used for ethylene treatment or curing favor the development of the disease. Chapman and Brown (*38*) reported that navel oranges from nutritionally unbalanced trees grown in high-potash, low-calcium nutrient solutions had considerable *Alternaria* infection.

Harvey (*67*) concluded from storage studies with Eureka lemons in California that there is a definite stage, which he called decay break, near which lemons changed from a physiological condition of almost complete immunity to *Alternaria* to a state of extreme susceptibility. The length of time lemons could be held in storage before decay break was reached depended on their stage of maturity when stored, the time of picking, the year, and the conditions in storage. After decay break was reached, the rate of decay was rapid and rather uniform. Harvey considered that a given lot of lemons had reached the decay break when 2 percent of the fruits showed visible signs of alternaria decay. Two percent with visible alternaria decay indicated that 3 percent were actually infected. Harvey found that there was a correlation between the condition of the buttons and the subsequent development of alternaria decay weeks later. He established standards whereby the behavior of lemons in storage could be predicted by an initial inspection and one or more later inspections, depending on whether the lemons were tree-ripe, silver, or light green.

Kessler and Allison (*82*), working in California, reported in 1948 that lemons treated with 2,4-D (200 to 1,000 p.p.m.) before storage did not develop alternaria or other decay during 4 months' storage and the buttons remained intact and green; 9 percent of the untreated fruit showed alternaria decay, 60 to 75 percent black buttons, and 20 to 22 percent internal decline. Stewart (*165*) in the same year reported considerably reduced incidence of black buttons and alternaria decay of stored lemons and grapefruit treated with 2,4-D or 2,4,5-T during the 3 months before harvest or in the packing house. He also found that light-green lemons dipped for 2 minutes in a lanolin emulsion containing 500 to 1,000 p.p.m. acid equivalent of the butyl ester of 2,4-D before storage showed no black buttons or decay after 115 days' storage at 58° to 60° F. and 88 percent relative humidity; 3 percent of them showed black buttons and none of them showed decay after 162 days' storage; and treated green lemons remained free from both troubles. Green lemons treated with 2,4-D vapor for 69 hours showed a decrease of decay and black buttons. Stewart suggested that the chemical acts by delaying maturity of the abscission, or separation, layer between the button and the fruit.

ANTHRACNOSE

Anthracnose, caused by species of *Colletotrichum*, is characterized by rind spots, rot, or tear stain on various kinds of citrus fruits. It occurs in the citrus-growing areas of many countries. Averna Saccá (*7*) in 1940 reported that anthracnose causes considerable damage to sweet oranges along the coast of São Paulo, Brazil. Pittman (*127*) listed anthracnose as one of the principal diseases of lemons in Australia. Adam and others (*3*) found that 89.4 percent of the latent fungus infections of oranges in Australia are caused by *Colletotrichum gloeosporioides*, one of the anthracnose fungi.

Colletotrichum gloeosporioides causes anthracnose of orange, lemon, and grapefruit; *Gloeosporium limetticolum* affects lime; and *G. foliicolum* is the cause of anthracnose on tangerine and Satsuma orange in Japan (*49*).

Anthracnose may manifest itself as mere blemishes or as spots ½ inch or more in diameter. At first the spots are reddish brown, but later they turn dark brown or black. They vary from shallow depressions to fairly deep pits or cankers. The fungus penetrates the rind and invades the pulp, causing a rot and imparting a bitter, disagreeable flavor. The affected external tissues are soft, pliable, and brown to black. Inside the fruit, the decay advances slowly through the core, inner rind, and pulp.

The tear stain type of anthracnose is characterized by a dull-reddish, reddish-green, or brown stain that occurs in streaks or bands on the fruit.

Anthracnose spots probably start in most cases at slight injuries on overripe fruit or on fruit that has been weakened by poor growing conditions. Since the causal fungus is common on dead twigs, there is usually an abundance of inoculum present. Baker (*9*) found that in Trinidad young fruits were infected almost as soon as they were set and that the fungus then remains latent and invisible until the fruits reach an advanced stage of ripening.

Suggested control measures are pruning out dead branches as far as practical, promoting good growing conditions, spraying as for melanose control (143), avoiding injuries to the fruit, picking the fruit before it is overmature, avoiding long storage, and using transit temperatures below 50° F. (*7, 49, 96, 150*).

BLACK PIT

Black pit occurs mostly on lemons, but to some extent on oranges and grapefruit. It has been found in nearly all citrus-growing areas except Florida, Brazil, and tropical places with very high temperatures. It is caused by the bacterial organism *Phytomonas syringae* (*96*). Mezzetti (*108*) in 1939 described a bacterial pitting of oranges and lemons in Sicily resembling black pit and reported that *P. syringae* was isolated from the lesions. Although distributed widely, black pit is of only relatively minor importance in the United States and is rarely seen on the market.

The spots usually start at injuries that occur while the fruit is on the tree, but they may enlarge in storage. They may be merely small pits or specks or sunken spots, ¼ to ½ inch in diameter, and light to dark brown at first and then black.

Smith and Klotz (*161, 162*) in 1945 reported the occurrence in some California lemon and Valencia orange groves of fruit spots that averaged much larger than the usual black pits. Cultures yielded a bacterial organism typical of *Phytomonas syringae* but more virulent. Maturity of the fruit and virulence of the organism seem to determine the size of the spots.

According to Fawcett (*49*) windstorms accompanied by rain and followed by cool, moist atmospheric conditions supply ideal conditions for infection and development of black pit. Enlargement of the spots takes place most rapidly at 62.6° F. and is retarded by temperatures of about 83° and above.

Preventive measures are not ordinarily considered necessary.

BLACK SPOT

Black spot was first described in Australia in 1895. Fawcett (*49*) in 1936 gave its distribution as Australia, China, Japan, and South Africa and said that it appears to be unknown in other citrus areas of the world. Since then it has been reported in Batavia, Dutch East Indies, by Muller (*118*) and in Brazil by Averna Saccá (*8*). Reports by Wager (*183, 184, 185*) indicate that it is becoming more widely distributed in South Africa. First found in the mist belt of Natal in 1929, it has caused extensive damage in recent years in other parts of Natal and in most of the citrus-growing sections of the Transvaal. McCleery (*105*) estimated that black spot causes a greater economic loss in New South Wales, Australia, than any other disease of any crop. Blackford (*27*) said that black spot is the commonest of the four major citrus diseases in Queensland.

Black spot is caused by *Phoma citricarpa* (*49*). Kiely (*83, 87*) in 1948 and 1949 in Australia showed that the perfect stage of *P. citricarpa* is *Guignardia citricarpa*, which he described as a new species. A variety, *P. citricarpa* var. *mikan*, occurs in Japan (*49*).

Blackford (*27*) said that all kinds of citrus may become infected, but that black spot is seldom found on Washington Navel oranges and grapefruit. Wager (*182*) stated that in South Africa smooth lemons are the most susceptible but that rough lemons, grapefruit, mandarins, and Valencia oranges are also affected. Navel oranges became infected if allowed to stay on the tree until the weather became warm. Kiely (*84*) reported that black spot is most serious on Valencia oranges in New South Wales and that lemons and grapefruit are affected to a lesser extent under the central coast conditions. Mandarins and Washington Navel oranges are affected on the north coast, where the winter weather is warmer at the time the fruit is maturing. Kiely (*83*) found the black spot fungus on native Australian shrubs and cultivated plants of nine different families.

Black spot appears first as small reddish-brown spots on the surface of the fruit. As the spots become older, they are depressed at the center and have raised reddish-brown margins. The center becomes light tan to brown. Finally the spots darken and become nearly black. Pycnidia sometimes develop in the lighter colored area. The spots vary in diameter from 1/25 to 1/3 inch. The leaves and twigs, as well as the fruit, are affected. Kiely (*83*) found the ascigerous stage developing over the surface of dead leaves.

For a long time it was thought that the chief source of infection were pycnidiospores of *Phoma citricarpa,* which developed in the spots on mature fruit. Kiely (*83*) demonstrated, however, that ascospores of the perfect stage, *Guignardia citricarpa,* formed in the dead leaves were an important source of infection.

Muller (*118*) stated that in Batavia the fungus is confined to the upper layers of the peel while the fruit remains on the tree, but that it rapidly penetrates the peel and pulp after picking and extensive rot develops in transit. McCleery (*105*) found that much infection occurs soon after blossoming, but the fruit may appear healthy as long as 12 months afterward. The principal infection period probably lasts about 20 weeks after blossoming. Wager (*182, 183*) reported that latent infection was widespread in South Africa. The fruit became infected while quite small, but spots did not develop until the fruit began to mature and color when the weather became warm. Kiely (*83*) also said that infections can become established in young fruits and leaves but remain latent for months. He noted that mature lesions never develop on fruit on young trees, but that they develop on fruit of 8- to 10-year-old trees in the coastal area of New South Wales. Because of the latent infections, serious losses in transit and on the market may occur in fruit that shows little or no sign of infection when packed (*49*).

Black spot in South Africa was at first confined to the mist belt, but Wager (*182*) reported that in 1945 and 1946 it caused severe damage in many other parts of South Africa in spite of the exceptionally dry spring weather.

Wager (*182*) found that oranges kept at 80° F. developed black spot lesions in 4 days and within 2 weeks all the fruits were severely spotted. No spots developed in 3 weeks on oranges kept at 60°. Wager also found that badly spotted fruits incubated at 40°, 70°, and 85° developed an average of 2, 11, and 21 new spots per fruit, respectively, by the end of 1 week and 2, 5, and 4 more spots, respectively, by the end of the second week. This indicated little further development on fruit in cold storage. The same author (*182*) reported that new spots did not develop in cold storage in 5 weeks, but developed rapidly when the same fruits were exposed to room temperature.

Kiely (*85*) and Wager (*182, 183*) recommended spraying with bordeaux mixture plus white oil for control. Wager also recommended picking as early as possible in infected orchards, picking fruit on the sunny side of the tree first, inducing early ripening by spraying with lead arsenate every third year, and avoiding use of nursery trees from infected areas.

BLUE MOLD AND GREEN MOLD ROTS

Blue mold rot, caused by *Penicillium italicum*, and green mold rot, caused by *P. digitatum*, are probably the commonest of those on citrus fruits in the packing house, in transit, in storage, and on the market. They are not often found on fruit on the tree. A white mold which produces white-chalky spore masses and resembles *P. digitatum* except for color has been found frequently in California (*49*). Wei (*188*) reported a white-colony strain of *Penicillium* in China and named it *P. italicum* var. *alba*.

Blue and green molds may occur separately or in mixtures with each other or with other rot fungi. Savastano and Fawcett (*154*) in 1929 showed that the rate of decay caused by mixtures of several fungi may be different from that caused by any one alone. For instance, the rate of decay is accelerated when *Oospora citri-aurantii* is present with the blue or green mold fungi, but *Botrytis cinerea* has a retarding effect. Gemmell (*58*) in 1939 stated that *Penicillium digitatum* and *O. citri-aurantii* grew more rapidly in mixed than in pure cultures. His studies indicated that *P. digitatum* produces a thermostable substance connected with nitrogen metabolism that stimulates the growth of *Oospora* and that the latter removes metabolic staling substances that would inhibit growth of *P. digitatum*.

The early stage of either blue or green mold rot is characterized by soft, watery spots in the rind ¼ to ½ inch in diameter. Under favorable conditions, the diameter may become 1½ to 2 inches in about 24 to 36 hours. Usually blue mold spots enlarge more slowly than those caused by green mold. The decayed areas eventually are covered with a white mold on which blue or olive-green spore masses are formed. The spore mass of blue mold is powdery or velvety and is surrounded by a narrow band of white mycelium, which in turn is surrounded by a well-defined, soft, water-soaked band. The spore mass of the green mold has a wrinkled surface and is surrounded by a broad zone of white mycelium and an indefinite band of softened rind. Spores of the green mold form only on the surface, but those of the blue mold form also in the flesh, sometimes even in the center of the fruit. Wrappers adhere closely to fruits rotted by green mold, but not to those rotted by blue mold.

If the humidity is low or moderate, an affected fruit shrinks to a wrinkled, dry, spore-covered mummy, but if it is high other molds and bacteria may enter the fruit and cause it to flatten into a soft, decomposing mass.

In addition to causing decay, *Penicillium digitatum* forms ethylene, which causes increased respiration and more rapid coloring of healthy fruit in storage. Biale (*21*, *22*) in 1940 published the results of tests of a number of common molds—*P. digitatum*, *P. italicum*, *Sclerotinia sclerotiorum*, *Oospora* sp., *Alternaria* sp., and *Aspergillus niger;* he found that volatile emanations from a single moldy lemon infected with *P. digitatum* increased the rate of respiration and caused rapid yellowing and shedding of stem ends of 50 to 60 sound fruits. Similar results were obtained with cultures on potato-dextrose broth. Volatile products from *P. italicum* produced very slight effect and the other fungi tested had no effect. In 1941 Biale and Shepherd (*24*) reported that a single lemon infected with green mold caused an 80-percent increase in respiration of 500 lemons. Production of volatiles was greatest at 14.5° C.; higher temperatures of 20° to 25° did not increase it and 2.5° inhibited emanations of volatiles. Biale and Shepherd (*24*) and Miller, Winston, and Fisher (*111*) showed that the emanations from green-mold-affected fruit produced epinasty in test plants (pea, potato, and tomato), which indicated the presence of ethylene. Biale (*23*), Miller, Winston, and Fisher (*111*), and Rohrbaugh and MacRill (*149*) stated that the emanations from decaying lemons in storage reduce the storage life of other fruit in the same container or even in the same room because of the increased rate of respiration.

Most of the blue and green mold infections take place through wounds that result from careless harvesting and packing methods, too high a bulge on the packed boxes, rough handling, and other causes. The blue mold fungus, however, can grow through the uninjured skin of citrus fruits and consequently spreads to uninjured fruits from fruits already affected with the fungus. Green mold frequently infects fruit through the decayed areas started by blue mold.

The importance of avoiding injuries through which infection may take place is generally recognized. Winston (*194, p. 6*) wrote: "The very foundation of decay control is careful handling; in fact, there is no substitute for it." Rose and others (*150, p. 21*) stated:

> The control of blue mold and green mold rots depends first of all on careful handling throughout the harvesting, packing, and marketing processes, in order to keep the fruit as free as possible from skin breaks and bruises.

Careful handling is also advocated by Huelin (*77*) and Kiely (*86*) in Australia. Recommendations to California lemon pickers by the California Fruit Growers Exchange (*35*) are as follows:

1. Avoid leaving long sharp or jagged stems that are apt to damage other fruit.
2. Avoid clipper injuries. Make two cuts—the first at least ¼ inch from the button and the second next to the button.
3. Place ladders carefully against the trees.
4. Transfer fruit carefully from picking bag to field box.
5. See that box contains no sand, gravel, or twigs.

Meckstroth (*107*) and Hopkins and Loucks (*71*) in 1944 and Miller, Winston, and Cubbedge (*110*) in 1949 reported that removal of the buttons by pulling or abscission increased the subsequent development of green mold.

Littauer (*1*) in Palestine reported that there is a definite correlation between the number of spores on the fruit and the amount of decay and recommended more care in sanitation such as cleaning field boxes and packing houses. Tomkins (*170*) had more decay in fruit sprayed with spores than in uninoculated fruit. Klotz and Fawcett (*96*) said that the percentage of decay is directly proportional to the concentration of spores in the air and on equipment. They recommended dumping and cleaning in a separate room to avoid contaminating the processing and packing rooms. They also indicated that some packing houses were being disinfected with chlorine gas (3 oz. per 1,000 cu. ft.) at the start of the packing season or by atomizing with pine oil emulsion or some of the quaternary ammonium compounds. In experiments in South Africa Van der Plank and Rattray (*138*) found that removing green-mold-infected oranges from the boxes did not alter the subsequent development of decay. Rose and others (*150*) stated that sorting is effective if it is done after the mold is so far advanced as to show the green or blue color provided the fruit is not carelessly handled and contaminated during the sorting process. If the decay is in an early stage, there are probably even smaller spots present that will become visible later.

Both molds grow best at 75° F. and are checked by lower temperatures. Storage at 59° delays development of the decay about 5 or 6 days and 50° adds another 5 or 6 days to the salable life of the fruit. At 40° to 50° the development of mold is practically negligible during the ordinary handling period for citrus fruit. The blue mold fungus can develop slowly at temperatures that are low enough to inhibit green mold completely (*150*). Tomkins (*170*) stated that storage at 5° C. (41° F.) is preferable to storage at 10° to 18° C. (50° to 64° F.). Van der Plank, Rattray, and Crous (*139*) in South Africa reported that storage of lemons at 40° F. retarded decay but that decay progressed at a faster rate when the fruit was removed to a higher temperature. Australian workers (*5, 6*) reported that the penicillium rots were controlled best by temperatures of 37° to 42°.

Curing at relatively high temperatures has been observed to reduce the incidence of blue and green molds. Winston (*195*) stated that fruit subjected to the high temperatures required for the degreening treatment are less susceptible to penicillium rot than similar fruit held at ordinary air temperatures. Hopkins and Loucks (*76*) said that at the beginning of the season in Florida when the fruit is fully green and requires long periods (60 to 72 hours) in the coloring rooms, the percentage of fruit infected by *Penicillium* is low because of the curing action. They gave data from commercial samples showing a reduction of mold from 38.2 to 9.4 percent by the curing process. Their experiments showed that the beneficial effects of curing were obtained either with or without ethylene. Trout, Tindale, and Huelin (*173*) in Australia found that sweating (curing) for 3 to 5 days at 78° to 90° F. and 50 to 80 percent relative humidity did not control *P. digitatum* if the fruits were inoculated before sweating, but if they were sweated first, loss from subsequent inoculation was much less, 70 percent of them being decayed when inoculation was before sweating but only 2 percent when it was afterward. Nattrass (*122*) indicated that wilting would aid in eliminating losses from *P. digitatum* and *P. italicum* in Cyprus citrus fruit for export.

In Australia (*5*) preliminary sweating at 70° to 90° F. reduced wastage from mold, but the effect varied from year to year, from grove to grove, with maturity of the fruit and with conditions before picking. In one lot of oranges, it was found that increased loss of water from curing beyond 3 to 4 percent led to increased waste. Van der Plank, Rattray, and Crous (*139*) found that in South Africa a temperature of 60° resulted in good curing and the fruit had more juice.

The conclusions of various workers about the effect of time of picking on losses from penicillium rots is contradictory. Trout, Tindale, and Huelin (*173*) in Australia found that fruit picked in September developed mold more rapidly than fruit picked in July. Van der Plank, Rattray, and Crous (*139*) found that in South Africa maturity at picking affected decay, the riper fruits being more susceptible. Shiff (*158*) reported that in Palestine fungus rots, in which he included penicillium rot, were worse on fruit picked in March than on fruit picked in January. However, Tomkins (*170*) working with Jaffa (Palestine) oranges, found that decay by green mold was greater in early-season (November) fruit than in late-season (March and May) fruit. In storage tests he found that fruit picked in May developed mold sooner than fruit picked in March.

According to Shiff (*158*) blue and green molds in Palestine were worse on oranges from trees budded on sweet lime than on those from trees budded on sour orange rootstock.

Much work has been done on the use of antiseptic treatments for the control of blue and green mold rots. Since these treatments are also directed against other diseases, they are discussed on pages 154 to 165.

BOTRYTIS, OR GRAY MOLD, ROT

Botrytis rot is primarily a storage and transportation disease, but it may occur to some extent in orchards. It is most common on lemon and orange, but may also cause decay of other kinds of citrus fruit. This disease has been reported in Italy, Palestine, Russia (U. S. S. R.), Australia, and South Africa (*49*).

The fungus causing botrytis rot is usually considered to be *Botrytis cinerea*. Fawcett (*49*) listed *B. citricola* as causing a similar disease in Italy and Brazil and *B. vulgaris* as causing one in Spain.

In the early stages of botrytis rot the decaying tissues are firm, but later they become leathery and pliable. The affected surface of a lemon becomes drab or cinnamon brown and later may turn buff or dark brown. The color of the affected surface of an orange is medium to dark yellowish brown. Under moist conditions the affected part becomes covered with a mass of gray spores. The rind, core, and membranes are invaded by the fungus more rapidly than the pulp and eventually the fruit collapses. Savastano and Fawcett (*154*) found that in mixed infections *Botrytis cinerea* had a retarding effect on the decay caused by *Penicillium italicum* or *P. digitatum*.

The fungus that causes botrytis rot lives on decaying leaves, twigs, and fruit and on vegetable matter in the soil; and the spores are spread by rain, wind, insects, and other means.

Klotz, Calavan, and Zentmyer (*94*) reported that blossom infection reduced the set of fruit and that spraying with bordeaux mixture increased fruit set 35 percent. Fawcett (*49*) said that decay starts at the button, on the cut stem, or at injuries and also that the fungus can grow from bits of organic matter through the uninjured rind. He stated that infection sometimes results from the fungus growing from infected petals into the rind of fruit on which the petals fall. Klotz, Calavan, and Zentmyer (*94*) in 1946 were unable to infect lemons by contact with diseased petals in moist chambers, but Klotz and Fawcett (*96*) in 1948 said that mature Valencia oranges are occasionally infected by the fungus growing from fallen petals that lodge on the fruit. They said that in storage the disease spreads principally by contact.

According to Fawcett (*49*), citrus fruits may become entirely rotted by *Botrytis* within 2 weeks or less at 60° to 70° F., but the fungus is able to develop slowly at temperatures as low as 32°. Bocharova (*29*), working in the U. S. S. R., reported that *B. cinerea* was able to grow at −5° C. but that low-temperature storage of citrus fruits restricted the proteolytic activity of the fungus.

For control, Klotz and Fawcett (*96*) recommended not leaving boxes of fruit long on the ground in moist weather, preventing injuries to the fruit, keeping the fruit free from moist organic matter, washing it in hot water as for brown rot, avoiding excessive humidity in the storage rooms, and frequent inspection and removal of decaying fruit during long storage. Bocharova (*29*) reported that the disease can be controlled by selection and careful packing of the fruit and by refrigeration.

BROWN ROT

Brown rot is a serious disease of lemons and other citrus fruits that occurs in groves, in packing houses, and in storage. It has been reported in all the principal citrus-growing countries of the world. Fawcett (*49*) listed the following species of *Phytophthora* as causes of brown rot: *P. citrophthora, P. parasitica, P. palmivora, P. hibernalis, P. syringae,* and *P. citricola*. To these Frezzi (*53, 54*) in Argentina added *P. boehmeriae* and *P. megasperma*. Wager (*181*) in 1942 reported that he had obtained brown rot in lemon and orange by inoculation with *P. cactorum, P. cinnamomi, Pythium ultimum, P. debaryanum, P. irregulare,* and *P. vexans*.

According to Fawcett (*49*) brown rot first attracted serious attention in California in 1901–5 when it seriously threatened the lemon industry. Perfection of control measures has reduced the losses caused by it. The potential seriousness of brown rot is illustrated by a report in 1940 of a loss of 40 percent in a shipment of oranges from the Cook Islands to New Zealand (*124*). Parham (*125*) reported that *P. hibernalis* was first observed in Fiji in 1941 when it destroyed the entire orange crop. Nadel-Schiffmann (*120*) isolated *P. hibernalis* from Shamouti oranges in Palestine in 1945 and showed that it was pathogenic to apple, eggplant, tomato, and potato as well as to orange, lemon, and grapefruit. Deva Rajan and Aiyappa (*43*) reported heavy losses caused by *P. palmivora* in India. Klotz (*91*) in 1944 stated that brown rot, caused by species of *Phytophthora,* had been causing unusually severe losses to lemons and navel and Valencia oranges in California since 1938, because of the wet winters and lack of spray protection and tree care.

The first indication of brown rot is a slight discoloration of the rind. In mature, fully colored lemons the affected rind takes on various shades of drab and brown. The decay is leathery, and the affected fruit does not soften rapidly. Since the juice of the lemon is too acid for the causal organism, growth is usually confined to the rind, core, and tissues between the segments. A white delicate surface mold occurs only under very humid conditions. Affected tissues give off a characteristic, rather penetrating, aromatic odor.

The fungi that cause brown rot live in the orchard soils. Some of them attack the tree trunks and cause brown rot gummosis and foot rot. Much of the fruit infection is caused by the motile spores splashed by rain onto the leaves and fruit. Usually only the fruits 3 to 4 feet from the ground are infected, but some infection may occur 20 or 30 feet from the ground. Infected fruits may carry spores into the washing tank and cause infections that develop in storage or in transit. The disease may also spread by contact of one fruit with another.

Klotz and Fawcett (*95*) in 1941 stated that *Phytophthora citrophthora* and *P. parasitica* are killed in the upper 2 inches of the soil by temperatures over 110° F., but that when fall rains come spores from greater depths germinate and infect the fruit on the lower branches.

According to Fawcett (*49*), the optimum temperature for *Phytophthora citrophthora* is 80.6° F. This fungus grows fairly well at 56.3° to 86°, but slowly or not at all below 45.5°. The time required for visible appearance of infection after fruit is dipped in a swarm-spore suspension is 6 days at 55.3°, 3 days at 60.8°, 2½ days at 66.2°, 2 days at 72.5°, and 3 days at 78.8°. No infection occurred at 84.2° and 90°. The minimum, optimum, and maximum temperatures for growth of *P. parasitica* are 44.6°, 89.6°, and 96.8°, respectively.

Wager (*181*) in 1942 reported that inoculation tests with species of *Phytophthora* and *Pythium* isolated from citrus roots in California showed that *Phytophthora citrophthora, P. parasitica, P. palmivora,* and *P. cactorum* produce brown rot in orange and lemon fruits with or without wounding. *P. syringae, P. megasperma,* and *P. cinnamomi* infected only through wounds. *Pythium ultimum* and *P. debaryanum* produced infection in a few cases without wounds, but they grew rapidly when the fruit had been wounded. *P. irregulare* behaved similarly, but it was less virulent. *P. vexans* infected only wounded fruit.

Control of brown rot can be obtained by spraying with copper fungicides in the orchard, by sorting out visibly affected fruit, and by treating the fruit in hot water or in hot or cool antiseptic solutions.

Fawcett (*49*) in 1936 stated that good control of brown rot in the orchard can be obtained by spraying the ground and lower branches with 6–6–100 bordeaux mixture. If hydrocyanic acid gas fumigation is to be done in the orchard, he suggested using less copper or a spray composed of 1 pound of copper sulfate, 12 pounds of zinc sulfate, 6 pounds of hydrated lime, and 100 gallons of water. Greig (*62*) in New Zealand in 1942 recommended an autumn spray of 3–4–50 bordeaux. Morris, Klotz, and Sokoloff (*117*) obtained satisfactory commercial control by spraying a 4-foot skirt of the tree with 1–1–100 bordeaux. The weaker spray caused less injury than 6–6–100 bordeaux. Addition of 5 pounds of zinc sulfate to the 1–1–100 formula decreased copper injury. Klotz (*89*) recommended 1–1–100 bordeaux in orchards where cyanide fumigation is practiced and otherwise 6–6–100 bordeaux. Klotz and Fawcett (*95*) stated in 1941 that for proper protection the bordeaux must be applied just before or just after the first rain. In very wet seasons Klotz (*89*) recommended an additional application at the end of January or February. Klotz and Fawcett (*95*) stated that the zinc sulfate, copper sulfate, and lime mixture seemed promising as a means of avoiding damage from cyanide fumigation. In 1943 Klotz (*90*) reported that tetrachloropara-benzoquinone at concentrations of ¼ to 1 pound per 100 gallons gave good control of brown rot and did not aggravate fumigation injury. Klotz and Parker (*97*) in 1945 stated that in order to reduce risk of copper injury it would be preferable to use a dilute spray several times rather than a single strong spray once.

Greig (*62*) in New Zealand recommended pruning to give a clearance of about 3 feet between the lower branches and the ground and stirring the soil frequently. Fawcett (*49*) suggested that tall weeds or other plants growing up through and touching the lower branches be cut and allowed to lie on the soil. He also warned against placing the picked fruit on the soil or leaving boxes of fruit on the soil during rainy or foggy periods.

Klotz (*91*) in 1944 said that the effectiveness of the hot-water treatment in the packing house should be reemphasized as it will save many fruits that are newly infected when picked. The hot-water treatment consists of immersing the fruit 2 to 4 minutes in water at 115° to 120° F. Hot or cold solutions of 1¾ percent anhydrous sodium carbonate (soda ash) or 1 to 2 pounds of copper sulfate in 1,000 gallons of water may also be used (*96*). According to Klotz (*89*), chemicals are unnecessary for brown rot control if the temperature of the water is 117° to 120°. He found that the fungus penetrates to a depth of 0.024 inch in 24 hours at 70°. Treatment in a hot soda-ash-soap solution was effective 24 hours after inoculation, but its effectiveness decreased after 24 hours and when treatment was delayed 36 hours 95 percent of the fruit decayed. Hot-water treatment was most effective in winter when packing-house temperatures were 50° to 55° and spore germination was less rapid. Klotz and Fawcett (*95*) and Klotz (*90*) reported that hot-water treatment was still effective up to 30 hours after infection. Klotz (*90, 91*) warned against treating when the fruit (particularly lemon) is cold and turgid, because of the injury caused by liberation of toxic rind oil under such conditions. Klotz and Fawcett (*96*) recommended conditioning lemons before treating with hot water by holding them for 36 to 48 hours after picking if they are picked during a period of dry weather or 4 days if they are picked during a wet period. Oranges are less sensitive to rind injury than lemons, but they should be conditioned at least 1 day before treating. Cold antiseptic solutions prevent infection of sound fruit by spores in the wash water, but they are not effective if the fungus has penetrated the skin.

DOTHIORELLA ROT

Dothiorella rot is a leathery stem-end rot of citrus fruit similar to that caused by *Phomopsis* or *Diplodia*. The fungus that causes this disease is the imperfect stage of *Botryosphaeria ribis*. Fawcett (*49*) said that it is identical with *Dothiorella gregaria*, the cause of melaxuma of walnut and rot of avocado. Reichert and Hellinger (*146*) in Palestine isolated *Dothiorella* from a black rot of orange and from a tip-end rot of banana. These isolates were successfully cross-inoculated, and the authors concluded from this and cultural studies that the fungi were identical and identified them as *D. gregaria*. According to Fawcett (*49*), this fungus has a wide host range and is widely distributed throughout the world. Conditions favoring this rot and methods of control are similar to those for diplodia and phomopsis stem-end rots.

FUSARIUM ROT

Fusarium rot is a minor disease. Klotz and Fawcett (*96*) stated that *Fusarium lateritium*, *F. solani*, and *F. fructigenum* have been found causing decay of citrus in California and that these and other species affect citrus fruits in other countries. They described the decay as semipliable to soft, starting usually at the stem end, but sometimes at the stylar end, of mature fruit.

Ghatak (*59*) isolated two strains of *Fusarium moniliforme* from a soft rot that affects Kamela oranges on the Calcutta market in the winter. The rot manifested itself on the rind as semipliable, light-brown, water-soaked areas that subsequently enlarged and developed white patches bearing conidia. The whole surface of an affected fruit finally became covered with a white encrustation, and the orange became a pulpy mass. Infection was entirely through wounds.

GRANULATION

In 1939 Turrell and Bartholomew (*175*) described granulation as a condition in citrus fruits, chiefly oranges, in which the juice vesicles become hardened, enlarged, colorless, and highly refractive and finally collapse. A description similar to this was given by Winston (*195*) in 1950. For many years such fruit, especially in California, was said to be "crystallized." According to Bartholomew, Sinclair, and Turrell (*17*) in 1941, granulation has been reported and accurately described in nine foreign countries and probably occurs in one or more varieties wherever citrus is grown. It occurs in all the citrus-producing areas in the United States but is most troublesome in Florida and California. It is most common in Valencia oranges, but it also occurs in Hamlin, Parson Brown, and Temple oranges and in tangerines.

Bartholomew and Sinclair (*11, p. 163*) reported in 1938 that according to their data—

> low temperatures may cause granulation to appear or increase in amount in fruits that are predisposed to granulation anyway but not in those that are not predisposed to granulate.

A comprehensive discussion of granulation, together with results from experimental work, was presented in 1941 by Bartholomew, Sinclair, and Turrell (*17*). They reported that spraying Valencia orange trees with lime reduced granulation in the fruits. Large fruits are more likely to be granulated than small ones, and they have a lower content of soluble solids. The carotene concentration in the juice sacs decreases as granulation progresses. The pectin content of granulated juice sacs is considerably higher than that of normal ones. The cause of granulation is unknown, but the process seems to be governed by growth factors. Certain rootstocks may increase the amount of granulation, but the relation to rootstock may not be the same in different localities. F. E. Gardner [52] stated that granulation is most noticeable in fruit from trees on rough lemon than sour orange or other rootstocks.

Granulation is found more often in fruits from the inside and the north side of the tree than in fruits from any other part of the tree. Parker, Rounds, and Cree (*126*) in 1943 reported no clear relation between granulation or poor fruit color and the number of irrigations. Bartholomew, Sinclair, and Ebeling (*16*) reported, in 1943 also, that granulation in citrus fruits may be affected to some extent by certain rootstocks but that climate and other factors seem to be more important. Hydrocyanic acid gas fumigation had no effect on granulation or juice quality, but oil sprays increased granulation and decreased total soluble solids. Granulation reduced total juice content but increased the juice—or the water—content of the juice sacs. Granulated fruits were lower in sugars and acids and higher in salts (potassium, calcium, and others) than normal fruits. Bartholomew and Sinclair (*12*) reported also, in 1944, that oil sprays increase the amount and severity of granulation in Valencia oranges and decrease the soluble constituents.

In 1947 Bartholomew and Sinclair (*14, 15*) gave it as their opinion, based on observation and experimental results, that the prevention of granulation by bud selection would be a matter of mere chance, because of the difficulty of finding a bud or limb sport whose progeny would not produce granulation. This, they thought, would be true even if selection and culling were done through several generations.

The latest articles seen on granulation are those by Bartholomew, Sinclair, and Turrell (*18, 19*), published in 1948. In these the authors summarized the results of 17 years of investigation on the granulation of Valencia oranges in California. Most of these results had already been presented in the papers reviewed previously.

About the only additional statements needed are from their summaries: (1) "Granulation is not caused by a fungus, virus, or

---

[52] Correspondence.

bacterium, but is definitely related to the growth activity of the tree and fruit. The more rapid and luxuriant the growth the more granulation" (*19, p. 14*); and (2) although the incidence of granulation is governed by growth factors—climate, amount of soil moisture, insecticides, and rootstocks—it is recommended (*18, p. 325*) that buds for new Valencia trees be taken "from trees that were low producers of granulation *when they were young*."

HYDROCYANIC ACID GAS FUMIGATION INJURY

Injury caused by hydrocyanic acid gas fumigation varies with the age of the fruit, climatic conditions, and other factors. A common type of injury is the formation of spots or pits that may be deep or only slightly sunken. Sometimes the albedo collapses in irregular areas, but the flavedo, or colored, tissues remain intact although depressed. Sometimes the surface of the fruit is scabby. Fruits from trees fumigated just before or during blossoming have ridged, bumpy, thick rind (*96*). Sinclair and Lindgren (*160*) reported that the ridging, also called "coxcombing," is due to an irregular and excessive growth of the outer peel. The highest percentage of navel and Valencia oranges was affected when the trees were fumigated in February. Lemons were affected more if fumigated from late January through April.

MELANOSE

Melanose, a superficial, raised brown blemish of the skin of citrus fruit, is especially important on grapefruit grown in Florida and other Gulf States and also causes considerable damage to oranges. It occurs in all citrus-growing sections of the United States and in many other parts of the world. Blackford (*27*) in 1943 said that it is the second most important disease of citrus in Queensland, Australia. According to Ruehle and Kuntz (*151*), melanose is among the most important fungus diseases occurring in Florida citrus groves. Klotz and Fawcett (*96*) stated that it is important in Florida, but minor in California. Melanose does not spread in transit, but the blemish lowers the market grade of the fruit.

Melanose is caused by *Diaporthe citri*, one of the fungi that causes stem-end rot. Wehmeyer (*187*) reduced *D. citri* to synonomy with *D. medusaea*. The imperfect stage of the melanose fungus is *Phomopsis citri*.

Melanose affects the leaves, young twigs, and fruits of various citrus plants. On the fruit it causes small, brown, raised spots, or pustules, varying in diameter from $\frac{1}{50}$ to $\frac{1}{25}$ inch. The spots sometimes coalesce and form rather large scablike patches known as "mud-cake" melanose. The affected surface feels somewhat like rough sandpaper. This roughness distinguishes melanose from rust mite damage. Sometimes the melanose markings occur in streaks called "tear streaks." These streaks probably result from spores deposited by drops of water from dew or light rains running down the sides of the fruit. Melanose differs from the pimple stage of exanthema (ammoniation or copper deficiency) in being dark brown surrounded by gray instead of dark reddish brown. By means of a hand lens it can be seen that the melanose pustules are cracked away from the surrounding healthy skin and those of exanthema either are not cracked or are cracked across the top.

In damp weather the melanose fungus produces an abundant supply of spores on the twigs and branches of citrus trees. The fungus can attack only young tissue. According to Burger (*33*) and Burger, DeBusk, and Briggs (*34*) fruits are immune after about June 1. Winston, Bowman, and Bach (*196*) concluded in Florida that fruits of the February and March bloom become practically immune in May and seldom are susceptible after June 10. They stated that the young fruits gradually become more resistant and that orange and grapefruit develop immunity when they reach a diameter of 1½ inches and 2½ inches, respectively. Ruehle and Kuntz (*151*) found that the diameter of grapefruit should be 3 inches before the fruit can be considered immune. The fungus in the spots on the fruit usually dies long before the fruit matures.

Klotz and Fawcett (*96*) stated that the disease is important only in places that have abundant summer rainfall, such as in Florida, and that it is unimportant in places, like California, where the summers are dry. Fawcett (*49*) said that melanose is important in New South Wales, where there are rains during the susceptible period, but not in South Australia, where the weather is dry when the fruit is young and susceptible. Blackford (*27*) reported that melanose is worse in the damp coastal part of Queensland than inland, where it is drier. Rhoads (*148*) said that in Florida infection of the fruits was favored by 2 or 3 days of rainy weather.

Rhoads (*148*) reported that grapefruit is more susceptible than orange to melanose in Florida. Klotz and Fawcett (*96*) stated that most commercial varieties of citrus are susceptible but that melanose is more noticeable on grapefruit because of the smoothness of the skin.

Rose and others (*150*) gave spraying once or twice with 3–3–50 bordeaux mixture and cutting out dead wood as control measures in Florida. Klotz and Fawcett (*96*) suggested spraying with 3–4–50 or stronger bordeaux plus 1 percent oil about 10 to 20 days after the blossoms drop. They also suggested pruning out dead wood and twigs, but did not consider it commercially economical. Kuntz and Ruehle (*100*) in 1938 stated that a combined pruning and spraying program produces the best results. In 1940 they (*151*) presented such a program varied according to the age of the orchard and the presence or absence of scab. Rhoads (*148*) in 1940 recommended a 3–3–100 bordeaux plus 5 to 10 pounds of sulfur 2 to 3 weeks after petals fall followed by a second application 4 weeks later if blooming is prolonged. He found that basic copper sulfate, copper ammonium silicate, and cuprous oxide were practically equal in efficiency to bordeaux and did not have the tendency to increase insect infestation. Blackford (*26*) in Australia found that 3–80 cuprous oxide gave just as good control as bordeaux. He also said that it was safer to fumigate after spraying with cuprous oxide, probably because the fungicide washes off quicker. Voorhees (*179*) found in spraying trials in Florida in 1939–42 that proprietary copper compounds were equal to 3–3–100 bordeaux when used at a rate equivalent to ¾ pound of metallic copper per 100 gallons. Reducing the amount of copper decreased the control of melanose accordingly. Suit (*167*) reported that organic fungicides did not give good control of melanose.

OLEOCELLOSIS, OR OIL SPOTTING

Oleocellosis, or oil spotting, is a spotting of the rind caused by the action of liberated rind oil on the surface cells. It is most commonly found on lemon and lime, but may affect other citrus fruits, especially orange, that are picked early in the fall while they are still green and immature.

The spots may be green, yellow, or brown and irregular or circular in shape; they are usually not more than ½ inch in diameter. Because the tissues between the oil glands are slightly sunken, the glands stand out prominently. The green spots develop on fruits damaged while they are still green, the green color being retained in the affected tissues after the rest of the surface has turned yellow. The yellow spots develop on fruits that have already colored before being affected by the toxic rind oil. The brown color develops in the green or yellow spots when they become older or if the damage was especially severe (*49*, *96*, *150*).

Oleocellosis may follow bruising that takes place either while the fruit is on the tree or in the process of harvesting and packing.

It has been generally observed that in California the green spot stage of oleocellosis usually occurs during the late fall and early spring when there are frequent rains and fog. The probable reasons for the seasonal occurrence are the turgid condition of the fruit, which makes it more subject to injury and liberation of rind oil, the greater toxicity of the oil under moist conditions, and the higher oil content of the rind in the fall. It has also been generally observed that the severity of oleocellosis differs from one grove to another.

Wardlaw and Leonard (*186*) reported up to 12 percent of the grapefruit in Trinidad affected with oleocellosis, or goose-flesh as they called it. They found that more developed on fruit picked at 7 a.m. than at 10 a.m. and also that the amount varied with the length of the "quailing" (wilting) period before the fruit was transported to the packing shed. They recommended avoiding picking fruit in the rain and not picking it before 10 a.m. Miller and Winston (*109*) reported in 1943 that green spotting was especially evident on early oranges in Florida after they had been colored by the ethylene treatment. Their studies, which were conducted in 1941 and 1942, had shown that green spotting was greatest on oranges picked at sunrise, less on those picked at noon, and least on fruit picked at sunset. Also spotting was greatest in October and decreased to January. Miller and Winston concluded that the greater damage in the morning was due to the greater turgidity of the fruit as a result of slower transpiration at night, the oil vesicles of the turgid fruit being more susceptible to rupture and release of toxic oil. They recommended picking in the afternoon instead of in the morning.

Scurti (*157*) in Italy concluded from microscopical observations under normal and polarized light that a form of oleocellosis that occurs on oranges in refrigerated storage is caused by unequal temperatures and inadequate ventilation. He noted that excessive quantities of oil are produced and that instead of volatilizing it corrodes the cuticle and dissolves the wax. Corrosion is followed by dehydration and depression of the tissues. Scurti attributed the brown discoloration to enzymatic oxidation.

Klotz (*90, 91*) and Klotz and Fawcett (*96*) cautioned not to treat citrus fruits (particularly lemon) with hot water when they are cold and turgid because of the risk of injury by liberation of toxic rind oil.

SCAB

Citrus scab is caused by several species of *Elsinoë,* the imperfect stage of which is *Sphaceloma.* Sour orange scab is caused by *Elsinoë fawcetti;* sweet orange fruit scab by *E. australis;* and Tyrons, or Australian, citrus scab by *Sphaceloma fawcettii* var. *scabiosa.*

Sour orange scab is especially severe on sour orange and is commercially important on lemon, grapefruit, Satsuma orange, Tahiti lime, and tangelo. It occurs rarely on some sweet orange varieties and on one variety of kumquat (*49, 96, 150*). In the United States it occurs in Florida and Texas, but not in California. It is present in many other countries where the citrus-growing areas are moist and warm in the summer.

Sweet orange fruit scab is found on sweet orange varieties, especially those that usually are resistant to *Elsinoë fawcetti. E. australis,* the causal fungus, was formerly known only in South America, where it occurs in Brazil, Argentina, Paraguay, and Uruguay (*49, 81*). Castellani (*37*) found it in Eritrea in 1948 and suspected that it was introduced during World War II on oranges sent from South America. In 1938 Jenkins (*80*) reported it on lemons brought into this country from Paraguay. Bitancourt and Jenkins (*25*) reported on their study of the life history of *E. australis* and its connection with the imperfect stage in 1939.

Tyrons, or Australian, scab is widely distributed in the moist citrus-growing areas of Australia. The causal fungus is probably the one that causes scab in New Zealand (*49*).

The earliest symptoms on the fruit are small, raised areas in the rind, which are whitish at first and later turn pinkish or tan. The protuberances may be single or they may coalesce and form large, raised gray or tan-colored scabs. If the fruits are infected while young they may become misshapen because of the numerous warty outgrowths. On grapefruit, the skin around the scabby areas tends to remain green.

Scab makes the fruit unsightly and less valuable on the market. It does not spread in transit or in storage.

According to Fawcett (*49*), a temperature range of about 59° to 73.4° F., sufficient moisture, and young susceptible tissues are essential for infection.

Control is obtained by spraying with bordeaux mixture in the orchards. Klotz and Fawcett (*96*) recommended an application of

890503—51—10

6–6–100 bordeaux plus 1 percent oil emulsion just before growth starts in the spring followed by a second application when at least two-thirds of the blossoms have fallen. Schiel (*155*) in Argentina obtained control by two applications of bordeaux, the first just before flowering and the second when at least three-fourths of the petals had fallen. Similar recommendations were given by Ruehle and Thompson (*152*).

SCLEROTIUM BATATICOLA ROT

Littauer and Gutter (*102*) reported in 1946 that they had isolated *Sclerotium bataticola* from a decaying orange found in a grove in Palestine. The decayed area was light brown, resembling that caused by *Diplodia*, and extended along the segments from the button to the stylar end. The affected areas later became black, because of the formation of numerous, minute black sclerotia on the surface and sometimes in the albedo and core. The fruit remained pliable. *Sclerotium bataticola* from sweet lemon roots, potato tubers, *Cupressus* sp., *Musa* sp., *Arachis hypogea,* and *Persea gratissima* produced the same decay when inoculated into Shamouti oranges.

According to Fawcett (*49*), R. Weindling and P. A. Miller obtained infection of citrus fruit with this fungus in inoculation tests in California, but naturally infected fruit had not been observed.

SEPTORIA SPOT

Septoria spot has been reported on citrus fruits of various kinds grown in many citrus-growing areas throughout the world. It is usually considered of minor importance (*49, 150*). However, Fawcett and Klotz (*50*) and Woglum and Lewis (*201*) in 1940 and 1941 reported severe damage to Valencia orange, lemon, and grapefruit in California, and Pittman (*127*) listed it as one of the principal diseases of lemon in Australia in some years.

The disease is attributed to several species of *Septoria* (*S. citri, S. limonum,* and *S. depressa*).

In the early stages the lesions are very small depressions about $\frac{1}{12}$ inch in diameter and not deeper than the oil glands. Later they become about $\frac{3}{8}$ inch in diameter and $\frac{1}{8}$ inch in depth. When small, the pits are light tan to buff-colored; but they may become dark brown or black as they become larger. The pits are surrounded by a narrow greenish margin, which becomes reddish brown as the fruit matures and colors. Pycnidia of the causal fungus are formed in some of the spots.

Woglum and Lewis (*201*) attributed the severe spotting of grapefruit in California in 1940 to the succession of wet, warm winters, followed by humid weather in the spring. They noted that septoria spot had been present for years but had not caused much damage until the weather conditions just described prevailed. In Australia (*2*) showery weather was blamed for the development of septoria spot in the Murrumbidgee irrigation district in 1942. Fawcett and Klotz (*50*) in California and Pittman (*127*) in

Australia noted that septoria spot was prevalent in the inland citrus-growing sections and less important near the coast.

Control in the orchard can be obtained by spraying with bordeaux mixture, by adding copper sulfate to the whitewash in places where that material is used, or by spraying with zinc-lime spray or zinc-copper-lime mixture. Fawcett and Klotz (*50*) found that spore germination was completely inhibited by a 41-hour exposure to the materials just listed. In Australia spraying with 5–5–100 and 2½–2½–100 bordeaux and copper oxychloride plus ½ gallon of white oil beginning late in March gave almost complete control of septoria spot on navel oranges, while about 50 percent of the fruits on unsprayed trees were infected. Woglum and Lewis (*201*) recommended spraying in November and December for control but found that further development could be stopped even after the disease had started by spraying in February and March.

SOOTY BLOTCH

Sooty blotch is caused by the superficial growth of a black mold over the surface of the fruit. The fungus does not penetrate the rind, and the damage consists of making the fruit unattractive in appearance. Unlike sooty mold, sooty blotch occurs independently of honeydew secretions by insects.

Sooty blotch in Florida and South Africa has been attributed to *Gloedes pomigena*. Van der Plank (*129*) said that G. R. Bates stated that sooty blotch in eastern Transvaal is caused by *Stomiopeltis citri*. According to Fawcett (*49*), sooty blotch in Brazil is caused by *Stomiopeltis citri* and *Sirothyrium citri*.

This disease is favored by shade and moist atmospheric conditions. Van der Plank (*129*) stated that in South Africa it was found first in the damper sections of the northern and eastern Transvaal, along the Natal coast, and around Pietermaritzburg and that these sections are still the most severely affected.

According to Fawcett (*49*), sooty blotch is not sufficiently important to warrant control measures except in South Africa. Crous (*42*) reported that control of sooty blotch first received notice in South Africa in 1933, when a few individual packers started using bleaching solutions to clean the fruit. In 1935 the disease was very serious and big packing houses were in difficulty, because of the large amount of badly blotched fruit. As a result, improvements were made in the bleaching solutions and apparatus for treating fruit. Although the superficial fungus growth can be easily removed by wiping the fruit with a wet cloth, the bleaching treatment is necessary under South African conditions to remove the black fungus from the pores. The bleach treatment is discussed in detail on page 161.

SOUR ROT

Sour rot is caused by the fungus *Oospora citri-aurantii*. Lemon and lime are most commonly affected, but other kinds of citrus fruit may also be attacked. Viennot-Bourgin and Brun (*178*) in 1944 observed sour oranges from southern France affected with sour rot on Paris markets. Up to 30 percent wastage due to sour rot was reported in 1940 in a shipment of oranges from the Cook Islands to New Zealand (*124*).

Tissues infected by *Oospora* are at first water-soaked, slightly raised, and dark buff yellow. The fungus hyphae then grow through the skin and form a thin water-soaked cream-colored mat on the surface. The decay is extremely soft. Finally an affected fruit collapses into "a putrid, sour, dirty, leaking, maggot-filled mass of mud" (*96, p. 21*).

The fungus apparently gains entrance through injuries, weakened buttons, and tissues already infected by other fungi. Overmature fruit or fruit that has been held in storage a long time is most susceptible. Fresh fruit is difficult to infect even when wounded. When *Oospora* is mixed with other fungi such as the blue or the green mold, rotting is usually more rapid than when either fungus is present by itself (*58, 154*). Once *Oospora* has become established, it can spread by contact from diseased to healthy fruit.

STEM-END ROT

The common name "stem-end rot" as ordinarily used refers to the rot caused by either *Phomopsis citri* or *Diplodia natalensis*. Other rots of the stem end are caused by *Alternaria, Collototrichum, Pleospora,* and *Dothiorella*. The perfect stages of the common stem-end rot fungi are *Diaporthe citri* and *Physalospora rhodina*. *Phomopsis citri* also causes melanose, a surface blemish of the fruit (p. 142). Stem-end rot is especially destructive to citrus fruit grown in the Gulf States and the West Indies and occurs to varying extents in many other citrus-growing areas of the world. Although found occasionally in California, it is of no economic importance in that State. *Diplodia natalensis* attacks numerous plants other than citrus. Ramsey, Heiberg, and Wiant (*142*) isolated it from Texas-grown Crystal Wax onions collected on the Chicago and New York markets and demonstrated by inoculations that it also would produce stem-rot of orange. The results of cultural studies and inoculations indicated that *Diplodia* isolates from avocado, coconut, peanut, sweetpotato, and watermelon are also probably the same species as the *Diplodia* on orange and onion. Minz and Ben-Meir (*115*) reported that *Diplodia natalensis* isolates from *Acacia farnesiana,* groundnut, *Cereus straussii,* quince, loquat, *Euphorbia grandidens, Ficus elastica, F. nitida,* walnut, apple, mango, and mulberry were pathogenic to citrus. They concluded that *Diplodia* from almost any source is potentially dangerous to oranges.

The stem-end rot caused by either *Phomopsis* or *Diplodia* is characterized by a pliable leathery condition of the rind and softening of the underlying pulp, usually at the stem end, but sometimes at injuries on the side of the fruit. There is little discoloration in the early stages, but later the affected rind turns tan to brown and sometimes black. The discoloration caused by *Diplodia* is usually darker than that caused by *Phomopsis*.

The rot caused by either fungus progresses rapidly down the spongy core, where the segments join, and along the inner white part of the rind. Progress is less rapid in the juice sacs. Diplodia rot usually progresses more rapidly than phomopsis rot according to Fawcett (*49*) and Brooks (*30, 32*). If the rot reaches the stylar end through the core before one-third of the rind has been invaded it is usually caused by *Diplodia*. In a dry atmosphere the fruit may dry down to a mummified mass, but under moist conditions the surface of the fruit may become covered with a dark feltlike mycelial growth.

Affected fruits have a flat somewhat bitter taste and an unpleasant, rancid odor. Those affected with the diplodia stem-end rot usually have a stronger odor than those affected with phomopsis rot.

Phomopsis usually occurs abundantly on the recently killed bark of small twigs and fruit stems. *Diplodia* usually develops in or on the dead bark of larger twigs and limbs. Infection of the stem button takes place while the fruit is on the tree, but active growth from the button into the rind and flesh usually does not take place until after the fruit is clipped from the tree.

Winston (*192*) in 1936 and Winston and Meckstroth (*197*) showed that pulled grapefruit, unless very ripe, is affected less by stem-end rot than clipped fruit, the amount of infection depending on how completely all stem parts were removed from the fruits. Hopkins and Loucks (*72*) in 1944 reported that they found no significant difference in amounts of rot in pulled and clipped oranges. However, the percentage of fruit with the calyx entirely removed was not large and in the light of Winston and Meckstroth's work this could account for their failure to get a difference. The same authors (*104*) in 1946 reported that removal of the calyx decreased stem-end rot of oranges caused by *Phomopsis* but not that caused by *Diplodia*.

Voorhees (*180*) made histological studies of orange buttons to determine more accurately the mode of entry of the stem-end rot fungi. He concluded that they may enter through any part of the button, but usually enter through the cut stem. Similar conclusions were reached by Brooks (*32*). Nadel (*119*) in 1944 sectioned buttons of Shamouti oranges. She found no mycelium in the inner tissues of the buttons of freshly picked fruit. However, she found it superficially in the axil of sepals, within the torn necrotic tissue where petals and stamens had been attached, and on other external parts. Nadel concluded that the presence of such mycelium constitutes a source of inoculum for latent infection.

Minz (*114*) concluded that diplodia stem-end rot in Shamouti oranges is caused by spores lodged in the stem-end region. These germinate as the season advances and penetrate slightly into the tissue of the fruit through its base. Minz found the fungus present on the stem as early as 2 weeks after fruit set in May. The incidence of latent *Diplodia* infections increased as the season progressed and was highest at the end of the season (March and April). *Diplodia* was concentrated mainly in the base of the fruit at that time.

Littauer, Nadel-Schiffmann, and Minz (*103*) in investigations of the mode of infection of oranges by *Diplodia* found that all wound infections on different parts of the stem end gave positive results when the oranges were held at 18° to 19° C. and 80 to 90 or even 100 percent relative humidity, but that without wounding results were variable. The percentage of rot was higher and the incubation period was shorter on fruit cut with Harvey clippers, which pinched the stalk off and left a rough surface, than on fruit cut with clippers that cut like scissors and left a smooth surface. All wound inoculations through the rind were successful, but surface inoculations without wounding were successful only when mass-culture inoculum was used and the humidity was high. In an accompanying anatomical study of the course of penetration of *Diplodia* by the same authors (*121*), it was shown that the fungus could be found in sections of tissues surrounding the infection courts 2 days after inoculation of the wounded rind, 5 days after inoculation of sepals and base of the fruit without wounding, and 9 days after inoculation of the cut fruitstalk. In the first stages of fungus penetration, although an abundance of mycelium was present in the tissues, the inoculated stem and rind remained healthy. The former remained green and fresh and the latter firm and not discolored.

Hildebrand (*70*), working in Florida, in 1947 reported findings similar to those reported by Nadel in 1944. His histological studies of the button region of fruits in all stages of development demonstrated the presence of mycelium and spores of the stem-end rot fungi around, on, and under the calyx lobes, but never below the cork layer of attacked fruits. After the fruits were picked, the mycelium penetrated from the outer button tissues into the deeper button tissues and then into the fruit. Miller, Winston, and Cubbedge (*110*) in 1949 reported much more stem-end decay in stored Pineapple oranges with buttons than in those with buttons removed. Winston and Roberts (*200*) reported that stem-end rot of ethylene-treated and color-added fruit was decreased by the washing, polishing, and grading processes, probably because the buttons were removed.

Fawcett (*49*) gave the optimum temperature for *Diplodia natalensis* as 30° C. and that for *Phomopsis citri* as 23°. He stated that some high temperature strains of *Diplodia* grow at 36° to 37°. Winston (*195*) and Rose and others (*150*) stated that in Florida *Diplodia* is the more common cause of stem rot in the warmer months and that *Phomopsis* occurs more frequently in the cooler months. The development of stem-end rot, especially that caused by *Diplodia,* is favored by the high temperatures used in the ethylene-gassing chambers. Littauer (*101*) reduced the incidence of stem-end rot from 37 to 39 down to 2.8 percent by lowering the storage temperature from 18° to 15°. Minz, Nadel-Schiffmann, and Littauer (*116*) found that the most favorable temperatures for diplodia rot development in Shamouti oranges ranged from 18° to 35°. Development of the rot was slow and erratic at 14°, and none developed at 7°. Rose and others (*150*) stated that temperatures of 40° to 45° F. are necessary to control stem-end rots in transit. Klotz and Fawcett (*96*) and Fawcett (*49*) recommended temperatures of 45° to 50°.

Rose and others (*150*) stated that at ordinary temperatures the crest of the rot in fruit that appeared sound when packed is reached 10 to 20 days after packing. Minz, Nadel-Schiffmann, and Littauer (*116*) found that at 30° C. the incubation period in oranges inoculated with *Diplodia* was 2 to 4½ days and that the fruit was completely decayed in 6 to 8½ days. At 18° the incubation period in oranges picked in December and March was 14 and 4 days, respectively, and the time required for complete decay was 10 and 7 days, respectively.

Rose and others (*150*) stated that immature fruit is very resistant to stem-end rot, whereas dead-ripe fruit is very susceptible. Minz, Nadel-Schiffmann, and Littauer (*116*) said that the incidence of diplodia rot increases with advancing maturity of the fruit. Data from their tests show that the length of the incubation period and the time required to rot the fruit completely was shorter with the more mature fruit. Winston (*194, p. 5*) said, "All citrus fruit becomes progressively more susceptible to stem-end rot as the ripening season advances."

It is well known that stem-end rot is increased when fruit is given the ethylene-coloring treatment. Brooks (*31*) in 1943 said that 27 percent of the oranges treated with ethylene for 42 hours at 82° F. and 87 to 92 percent relative humidity and then stored at 70° for 14 days developed diplodia stem-end rot, but that only 2.5 percent of the controls developed it. Winston and Meckstroth (*197*) stated in 1944 that the ethylene treatment increases susceptibility of lemons to rapid infection by stem-end rot. *Phomopsis* was responsible for most of the rot in nongassed lemons, whereas diplodia rot was stimulated by the ethylene treatment. Loucks and Hopkins (*104*) in 1946 stated that the ethylene treatment did not significantly increase phomopsis rot, but that it did increase rot caused by *Diplodia*. Voorhees (*180*) also found that *Diplodia* is the fungus responsible for increase of stem-end rot in ethylene-treated fruit. Brooks (*32*) in 1944 reported nine times as much stem-end rot in ethylene-treated oranges as in untreated oranges 2 weeks after harvest and three times as much after another 3 weeks. The increase was due almost entirely to infection by *Diplodia*. Voorhees advanced three possible reasons for the increased stem-end rot after ethylene treatment: (1) Higher temperatures of the ethylene room; (2) aging and weakening of the buttons; and (3) stimulation of the germination of *Diplodia* spores. He considered aging of the buttons the most important factor. Hopkins and Loucks (*76*) in 1948 reported on tests to determine whether ethylene actually increased diplodia stem-end rot or the increase following the degreening treatment was due merely to the effect of high temperature and high humidity. Their data indicate that the ethylene stimulates the development of diplodia stem-end rot.

The chemical treatments used for the control of stem-end rot are also used for the control of other diseases and therefore are discussed on pages 154 to 165.

SULFUR INJURY

Sulfur injury on the fruit is caused by lime-sulfur spray or sulfur dusts and is characterized by slightly sunken spots irregular in outline and varying in diameter from 3/8 to 1 inch. The epidermal cells are killed, turn gray, and later may crack. They are often invaded by *Phomopsis*, *Diplodia*, or *Colletotrichum*. Another type of sulfur injury that has been observed in California is characterized by hard, firm brown spots with gum pockets under the white portion of the rind (*150*). Turrell and others (*175b*) concluded that solid sulfur particles on the surface of dusted fruit volatilize at high temperatures and the gas penetrates the rind. They stated that the principal factor in sulfur injury is intensity of sun radiation and that high humidity, warm air, and lack of air movement are secondary.

Turrell and Chervenak (*175a*) and Turrell (*174*) in 1949 and 1950 reported that experiments with radioactive sulfur showed that elemental sulfur vapor penetrates lemon peel and produces compounds similar to those produced by fruit in contact with elemental sulfur. They suggested that the sulfur is incorporated in the tissue proteins. Turrell stated (*p. 56*) :

> Elemental sulphur dust appears to lower the critical temperature at which citrus fruits are injured by absorption of sunlight. The principal factors influencing this temperature in the external environment are: (*a*) intensity of sun radiation, (*b*) temperature of the air, (*c*) vapor density of the air. Injury occurs when the outgoing energy does not balance the incoming energy at a point below the critical temperature. Air temperature and vapor density regulate the rate of outgoing energy.

WATER SPOT

Water spot is a type of rind break-down that causes serious losses of navel oranges in protracted rainy periods. Practically all the literature has been on this trouble in California, but water spot probably occurs to some extent in other sections when conditions are favorable. Cass-Smith, Owen, and Harvey (*36*) in 1941 reported a condition resembling water spot on mature navel oranges in Western Australia, where 30 inches or more of rain (80 percent of the annual total) falls during the ripening and harvesting period.

Water spot usually occurs in the tissues surrounding the navel, next to wounds, and on the shoulder portion of the stem half. The affected areas become water-soaked in appearance and later either become brown, dry, and sunken or are invaded and decayed by rot organisms such as blue or green mold (*49*).

Klotz and others (*93*) noted that serious economic losses occur from water spot in orchards in the eastern Los Angeles and western San Bernardino districts when several days of continuous rain occur during January to April. Klotz, Stewart, and Bumgardner (*98*) said that hot weather, rain, and high humidity are important factors in development of rind break-down. They noted that fruits with incipient spotting at harvest developed definite spots after washing, fumigation, and ethylene treatment.

It has been shown that water spot results from the imbibition of water by the albedo, or white part, of the rind during foggy or rainy periods. The water is absorbed through slight cracks or other injuries or through imperfections in the rind at the navel. Swelling of the tissues causes further cracking and absorption of more water. Klotz and Turrell (*99*) in 1939 and Turrell and Klotz (*176*) in 1940 concluded from a study of the rind structure and composition that the capillary spongelike structure of the rind, together with the hydrophilic and osmotic properties of its cells, is important in the development of water spot. Internal liberation of toxic rind oil caused by the effect of water-soaking on the semipermeability of the oil glands and decay by blue and green molds are important secondary factors in ultimate break-down. No correlation was found between the density of oil glands or stomata and incidence of water spot. Growth cracks and fresh mechanical or chemical injuries were considered the most effective avenues of entrance for water.

Scott and Baker (*156*) in 1947 studied the anatomy of navel oranges. They found no significant differences between navel oranges and other types that would explain the susceptibility of the former to water spot. They suggested that the epidermis is structurally weak and that excessive water absorption during winter rains upsets the critical balance between epidermal extension and increase in volume of underlying tissues. Klotz and Basinger (*92*) in 1938 observed that fruit with large open convolutions at the navel or with growth cracks, fruit in an advanced stage of maturity, and varieties with weak rinds such as Thomson Navel are very susceptible. Chapman and Brown (*38*) found that fruits from nutritionally unbalanced trees growing in high-potash, low-calcium sand and solution cultures showed considerable water spot.

Fruit affected with water spot often rots in the orchard before it is picked. However, under dry conditions the affected tissues dry and may escape notice in the packing house. Such fruit is especially subject to rot in transit (*150*).

It is generally recognized that water spot is increased by spraying the trees and fruit with oil except miscible oil mixed with lime-sulfur. Ebeling, Klotz, and Parker (*45*) reported that 32.1 percent of the fruits sprayed with the usual light medium oil were affected with water spot, 21.8 percent when sprayed with a light toxic oil, and 5 to 10.8 percent when sprayed with a miscible oil plus lime-sulfur or ammonium polysulfide or with nonoil sprays or when fumigated. Cass-Smith, Owen, and Harvey (*36*) in Australia reported three times as much water spot on fruit from trees sprayed with white spray oil as on that from unsprayed trees. Bartholomew and Sinclair (*13*) concluded from their experiments that the increased water spot on fruit from trees sprayed with oil was not caused by changing the quantity of oil in the peel.

Klotz and Basinger (*92*) reported in 1938 that water spot could be reduced by spraying with a paraffin wax emulsion. Klotz and others (*93*) found that spraying with parathion gave good control of red scale and fruit sprayed with this material showed 43 percent less water spot than fruit sprayed with oil. Reduction in incidence of water spot was also obtained by spraying with 2,4-D.

Cass-Smith, Owen, and Harvey (*36*) reported that water spot was increased by continual heavy applications of fertilizers high in available nitrogen. Klotz and others (*93*) concluded from their experiments that there is little possibility of changing the resistance or susceptibility to a practical degree by differential applications of nitrogen, potassium, phosphorus, organic matter, or other soil amendments.

For control Klotz and others (*93*) advised fumigating with cyanide instead of using oil sprays, harvesting early, reducing the humidifying effect of cover crops by mowing, controlling weeds, and using nitrogen fertilizers conservatively.

DETECTION OF BLEMISHES AND DISEASES BY X-RAYS AND ULTRAVIOLET LIGHT

Harvey (*68*) reported in 1937 that internal defects of citrus fruits can be detected by X-ray inspection and that 75 to 150 boxes per hour can be sorted by that means. Minz (*113*) in Palestine investigated the use of ultraviolet light for making early diagnosis of blemishes of oranges. He concluded that ultraviolet light is perhaps of value in detecting fruit blemishes, but not fruit rots.

CHEMICAL TREATMENTS FOR CONTROLLING POSTHARVEST DECAY

Postharvest treatments are effective and important means of controlling decay of citrus fruits. These treatments are applied during the washing process, as fumigants during the degreening process, in storage, or in transit; chemicals also are impregnated in fruit wrappers and box liners and mixed with the wax. The packing-house treatments, however, are supplements to, not substitutes for, disease control in the orchard, careful handling, and proper refrigeration.

Although the treatments now being used aid in reducing decay they are not completely effective under all conditions and against all diseases. Consequently, studies are being continued by investigators in many citrus-producing areas of the world in an effort to find new materials and methods that will more effectively control decays of citrus fruits and not be harmful to the consumer. Winston and others (*199*) in 1949 issued a report on screening tests conducted with more than 1,300 chemicals in an effort to find more effective fungicides that would be safe to use to prevent decay of citrus during the postharvest period.

BORAX AND OTHER BORON MATERIALS

Borax is probably the antiseptic most generally used to reduce decay in citrus fruit. It came into general use soon after publication by Fulton and Bowman (*55*) in 1924 and by Barger and Hawkins (*10*) in 1925 of the results of their investigations in which they showed that blue mold and stem-end rots can be reduced by treating the fruit in solutions of borax. Winston (*191*) in 1935 reported the results of further investigations on the borax treatment. The borax treatment has been found to be effective and is used in other countries as well as in the United States.

Fulton and Bowman (*55*) used 5- and 10-percent solutions of borax in their investigations and Barger and Hawkins (*10*) used a 2.5-percent solution. Winston (*191*) found that at least an 8-percent solution is necessary for best results. Klotz and Fawcett (*96*) in 1948 recommended a 5- to 8-percent solution of borax for oranges and grapefruit, but not for lemons. Winston (*195*) stated in 1950 that a 5- to 8-percent solution is used commercially. Loucks and Hopkins (*104*) in Florida used a 5-percent solution in their work on stem-end rot control. Hwang, Chow, and Ching (*78*) in China reported good control of blue mold with a 6-percent borax solution. Tzereteki and Tchanturia (*177*) in the U. S. S. R. reported good control of penicillium rot with an 8-percent solution.

Fulton and Bowman (*55*) compared the effectiveness of 5-percent solutions of boric acid and of borax for the control of blue mold and found that boric acid was less effective. Winston (*191*) tested 3.2- and 5-percent solutions of boric acid and a 5-percent solution of a mixture of 8 parts of borax and 1 part of boric acid. He found that boric acid alone or in combination with borax injured the rind of orange, grapefruit, and tangerine, causing a brown sunken area, usually around the stem, to develop in about 16 days. Winston (*195*) stated in 1950 that a mixture of 2 parts of borax and 1 part of boric acid is sometimes used in place of borax alone because it is more soluble, but that this combination is apt to injure the rind of fruit that has barely reached legal maturity. Klotz and Fawcett (*96*) recommended a mixture containing 4 percent borax and 2 percent boric acid as a substitute for borax alone.

Fidler and Tomkins (*52*) in England found that solutions containing 1 or 2 percent borax plus 1 percent sodium hydroxide were as effective against green mold as 5 percent borax. They said that the boron ion is more effective against green mold if it is in alkaline solution. In Australia decay was reduced by washing with a solution containing 1 percent sodium hydroxide and 8 percent borax (*5*).

Winston (*191*) obtained reduction of decay with solutions containing sodium metaborate, potassium metaborate, or potassium tetraborate comparable with that obtained with borax when the chemical was used at a concentration of the boron ion equivalent to that in an 8-percent borax solution. The sodium metaborate solution, however, caused slight discoloration of the rind around the stem in some cases. According to Winston (*195*), anthracnose often develops in such an injury.

Wei and Hu (*189*) in China compared the effect of a locally produced crude grade of borax with that of pure borax and concluded that the crude grade was more effective.

In the tests by Fulton and Bowman (*55*) and Barger and Hawkins (*10*) the treating solutions were used at temperatures of 120° to 122° F. to facilitate dissolving the borax and because wash-water temperatures of 115° to 120° were already being used in California to control brown rot. Winston (*191*), working with a 5-percent solution of borax, found no significant difference in control of decay when temperatures of 80°, 90°, 100°, 110°, and 120° were used. Apparently the main function of the higher temperatures is to keep the borax in solution. Hall (*66*) in Australia used a solution at 110° to 120°, and Winston (*195*) in 1950 stated that a temperature of about 110° is used commercially.

The length of treatment used by various workers has varied from a momentary dip to immersion for 5 or 10 minutes. Winston's studies (*191*) showed that an instantaneous dip was as effective as a 5-minute dip if the borax was not washed off immediately. His tests indicated that to be most effective the borax should not be washed off for at least 6 to 8 hours. Under present commercial procedures (*195*) the fruit is rinsed as it emerges from the borax tank, and therefore borax is not in contact with the fruit long enough to be very effective against stem-end rot; it is fairly effective against green mold. Tzereteki and Tchanturia (*177*) in the U. S. S. R. and Hwang, Chow, and Ching (*78*) in China used 5-minute immersions in their tests. Rattray (*144*) in the Union of South Africa obtained the best control of blue mold with a 4- to 5-minute immersion in an 8-percent solution of borax at 110° F.

The time when the treatment is applied has an important effect on the effectiveness of the borax treatment. Fulton and Bowman (*55*) showed that the borax treatment was less effective if delayed several hours after the fruit was inoculated with blue mold spores. Winston (*191*) reported that treating after coloring was much less effective in reducing losses from stem-end rot than treating before coloring. Brooks (*30*) reported that only 2 percent of the fruit treated with borax before ethylene degreening showed stem-end rot after holding 14 days whereas 7 percent of fruit treated after degreening showed it. In 1944 (*32*) he reported that borax applied after a 42- to 45-hour ethylene treatment was less than half as effective as that applied before.

Some workers have reported that borax treatment may cause rind injury. An Australian report (*5*) contained information that the borax treatment increases storage spot. Huelin (*77*), also in Australia, reported injury from treating with 4- to 8-percent solutions of borax. Fidler and Tomkins (*52*) in England indicated injury from a 5-percent borax solution. Godfrey and Ryall (*61*) in Texas found that borax hastens wilting or shriveling of lemons especially of the thin-skinned Meyer variety. However, Winston and Meckstroth (*197*) reported that an 8-percent solution of borax did not injure the rind in their tests with pulled and clipped fruits.

The borax treatment is not equally effective against some citrus-decaying fungi. Fulton and Bowman (*55*) and Winston (*191*) obtained marked reduction of stem-end rot whether caused by *Phomopsis* or *Diplodia* and blue mold rot. Barger and Hawkins (*10*) found that borax was not as effective against green mold rot as against blue mold rot. Fawcett (*49*) reported that borax or a mixture of borax and boric acid is much more effective against green mold rot than against blue mold rot. Although sometimes effective against both green and blue mold, only green mold is controlled in some lots of fruit and the blue mold then spreads faster than usual. Winston (*194*) reported that borax is more effective against diplodia stem-end rot than against phomopsis stem-end rot, but that boric acid is more effective against phomopsis stem-end rot than against diplodia stem-end rot.

Godfrey and Ryall (*61*) in Texas reported good control of stem-end rot of lemon with borax, but unsatisfactory control of green mold rot. In their tests sodium metaborate consistently reduced stem-end rot and usually reduced green mold rot.

When the borax treatment first came into use there was considerable concern over the quantity of borax carried on or in the fruit and its possible effect on the consumer. Fulton and Bowman (*55*) estimated that a single medium-sized orange dipped in a 5-percent solution of borax may retain 0.4 grain of dried borax on its surface. Dunn and Bloxam (*44*) found 50 to 330 p.p.m. of boric acid in the peel of orange and 20 to 80 p.p.m. in the pulp. Since they found none on the surface of the fruit, they concluded that it occurred naturally in the fruit in the quantities found. Furlong (*56*) reported in 1948 that the boron content of orange peel was increased by treating in a borax solution in proportion to the concentration of the solution and the length of treatment. The peel of untreated oranges had a boron content of 0.75 p.p.m. The boron contents were 1.22, 2.06, and 2.51 p.p.m., respectively, after treatment in 1-, 2-, and 3-percent borax solutions. There was no increase in boron content when the fruit was washed within an hour after treatment. The boron content increased less in the pulp than in the peel.

Haas (*64*) in California found that the boron content of orange juice varies with the boron content of the soil. Treatment of the soil with boron increased the water-soluble boron content of the fruit.

SODIUM ORTHO-PHENYLPHENATE AND RELATED CHEMICALS

Sodium ortho-phenylphenate has come into commercial use in recent years for treating citrus fruit in the packing house. It is quick-acting and effective, but not as safe for the fruit as borax. According to Van der Plank and Rattray (*133*), the effectiveness of this chemical against green mold rot was first recorded by J. N. Sharma in South African Patent No. 1255/35 in 1935. Van der Plank and Rattray (*133*) reported in 1939 good control of green mold rot in citrus fruit in South Africa with 0.3- to 0.5-percent solutions without injury to the fruit. The fact that no heating of the solution was necessary gave the phenylphenate an advantage over the borax treatment, and the action of the disinfectant was not greatly dependent on how long the fruit was immersed. The alkalinity of the solution, however, had to be carefully controlled as injury resulted if it was not alkaline enough or if too much alkali was added. Van der Plank and Rattray concluded from preliminary trials that sodium ortho-phenylphenate is also useful as a general disinfectant for lug boxes and packing-house equipment.

Hwang and Klotz (*79*), in their tests in California on the toxicity of various chemical solutions to spores of *Penicillium italicum* and *P. digitatum*, found that 0.15 percent sodium ortho-phenylphenate was among the most effective of the chemicals they tested at temperatures below 100° F. Brooks (*30*) in 1942 reported that sodium ortho-phenylphenate was a promising material for treating citrus fruit. In his tests only 2 to 4 percent of the fruit treated with a 1.2-percent solution for 2 minutes at 100° F. 1 to 3 days after removal from the ethylene room and then washed showed stem-end rot after being held 14 days at 70° as compared with 20 percent of the untreated fruit. At higher temperatures this strength caused injury to the fruit. Nearly as good control was obtained at 90° with the 1.2-percent solution, and slightly better results were obtained with a 2-percent solution at 80° than with a 1.2-percent one at 100°. Brooks reported that 1.2 percent in the water phase of a water-wax emulsion at 100° caused no injury and gave better control of stem-end rot than any other treatment used.

Miller, Winston, and Meckstroth (*112*) reported that treating with 2 percent sodium ortho-phenylphenate for 2 minutes at 110° F. controlled citrus decay, but injured the rind. They practically eliminated the injury by adding 1 part by weight of commercial formaldehyde (37 percent) to 4.5 parts of the ortho-phenylphenate. Under commercial conditions this mixture was effective only when applied as a warm flood spray. It was not effective as a mist spray. The mixture was also effective when applied with the wax emulsion. In that case it should be mixed with the water diluent.

Winston (*195*) recommended in 1950 that the concentration of sodium ortho-phenylphenate be not more than 1 to 1¼ percent and not less than ¾ percent and that it be used at room temperature. He stated that the rind injury caused by this antiseptic is in the form of small, reddish splotches that may not develop until 10 to 15 days after the treatment. He said that these blemishes ordinarily are not commercially important.

Godfrey and Ryall (*61*) obtained good control of stem-end rot of lemons with sodium ortho-phenylphenate, but poor control of green mold. However, the rind was injured where the chemical dried and this injury was not prevented by the addition of formaldehyde. It was, therefore, necessary to rinse the fruit after treatment.

A number of related chemicals have been used by various workers, but sodium ortho-phenylphenate has been the most satisfactory from the standpoint of effectiveness, ease of application, and safety to the fruit. Van der Plank and Rattray (*135*) reported that in tests against fungi growing on potato-dextrose agar at 65° F. ortho-phenylphenol was toxic to *Alternaria citri, Colletotrichum gloeosporioides, Diplodia natalensis, Phomopsis citri,* and *Sclerotinia libertiana* at 0.005 to 0.01 percent; to *Trichoderma lignorum* at 0.002 to 0.005 percent; to *Penicillium digitatum* at 0.002 to 0.003 percent; and to *P. italicum* at 0.01 to 0.02 percent.

Van der Plank and Rattray (*133*) reported that ortho-phenylphenol is more apt to injure the rind than its sodium salt, sodium ortho-phenylphenate, and that it has the further disadvantages that it is only slightly soluble in water and that its effectiveness is dependent on the temperature and the length of treatment.

Stearns (*163*) reported commercial control of stem-end rot in overripe Valencia and mature Hamlin and Parson Brown oranges by treatment with 0.75 percent Dowicide 2 (95 percent trichlorophenol) dissolved in an organic-solvent-water mixture.

Rattray (*145*) reported that sodium ortho-phenylphenate was more effective against green mold rot than sodium trichlorophenate and tetrachlorophenol.

Gates (*57*) reported good control of rot in oranges with 2 to 3 percent sodium ortho-phenylphenate and with 1 to 4 percent ortho-aminophenol.

Macintosh (*106*) reported in 1945 that experiments with animals at the National Institute for Medical Research in London showed that the mean lethal dose of ortho-phenylphenol was 0.5 gm. per kilogram of body weight for cats and 3 gm. for rats. Sublethal doses usually produced no signs of poisoning. Chronic administration to rats over a period of 32 days produced no signs of ill health and no significant effect on the hemoglobin or white-cell level. Macintosh concluded that the toxicity was so low that there was no danger to the consumer from the quantities that would be eaten with treated fruit.

The use of antiseptics in impregnated fruit wrappers is discussed on page 164.

DIPHENYL

Tomkins (*168*) in 1936 reported that losses from green mold rot of oranges could be reduced by use of paper wrappers impregnated with diphenyl. Farkas (*46*) conducted extensive shipping tests with oranges from Palestine to England in 1937–38 to determine the value of diphenyl wrappers for the control of rots caused by *Penicillium digitatum, P. italicum,* and *Diplodia natalensis.* He found that the use of diphenyl wrappers extended the keeping period and that, even when decay did start, the fruit remained dry and did not contaminate adjacent sound oranges. The same author (*47*) in 1939 reported that in two consignments of second-grade oranges to England the average decay in lots wrapped in diphenyl-impregnated paper was 1.5 and 0.37 percent as compared with 9 and 9.57 percent, respectively, in the fruits wrapped in untreated paper. Oranges wrapped in the impregnated wrappers and stored 4½ months showed less than 2 percent loss while those wrapped in untreated wrappers were almost a total loss. Farkas and Aman (*48*) in 1940 reported that a concentration of 0.08 mg. per liter of air stopped development of *P. digitatum, P. italicum,* and *Diplodia* sp., but that the spores and older hyphae continued to grow when the diphenyl was removed.

Ramsey, Smith and Heiberg (*143*) tested the effect of diphenyl vapor on the growth of 10 citrus pathogens. They found that the action of the chemical was fungistatic instead of fungicidal and that the fungi resumed growth on removal from the vapors. They concluded from their tests that diphenyl vapors would be effective in checking rots caused by *Penicillium italicum, P. digitatum, Botrytis cinerea, Diplodia natalensis,* and *Phomopsis citri.* Heiberg and Ramsey (*69*) in further studies with 52 fruit and vegetable pathogens confirmed the earlier work regarding the fungistatic characteristic of diphenyl and the wide variation in its effects on different organisms.

Godfrey and Ryall (*61*) in Texas obtained a substantial reduction of stem-end rot and green mold rot of lemons by the use of diphenyl wrappers. Hopkins and Loucks (*75*) in Florida reported that diphenyl fruit wrappers and box liners greatly reduced stem-end rot and mold of oranges and grapefruit.

Farkas (*46*) reported that only a slight odor of diphenyl could be detected on diphenyl-wrapped oranges after 2 to 3 weeks in storage and that chemical analysis revealed only 0.1 mg. in the peel. Tomkins and Isherwood (*172*) reported only 4 to 20 mg. of diphenyl per 100 gm. of peel (approximately that from one orange) in fruit that had been stored in wrappers each impregnated with 100 mg. of diphenyl. Farkas (*47*) reported that no ill effects followed oral administration of 16 mg. of diphenyl to a 160-gm. rat over a period of 20 weeks or of 90 mg. to a 2.5-kg. monkey over a period of 17 weeks. Macintosh (*106*) in laboratory animal tests found that the toxicity of diphenyl was very low and that the minute quantities absorbed by oranges from wrappers would not endanger consumers. Up to 1 gm. per kilogram of body weight did not have any visible ill effect on cats. Daily doses of 2, 20, and 200 mg. of diphenyl in nut oil per kilogram of body weight fed for 4 weeks to male white rats weighing 35 to 75 gm. did not cause any signs of ill health, and the hemoglobin content and total and differential counts of white blood cells remained normal.

Steyn and Rosselet (*166*) in 1949 described a photometric method for determining diphenyl in orange that is sensitive enough to determine as little as 0.2 p.p.m.

Diphenyl is commercially impregnated in fruit wrappers, paper sacks, and box liners (*195*).

NITROGEN TRICHLORIDE GAS

Klotz (*88*) reported that *Penicillium digitatum* and *P. italicum* were controlled in California by fumigating with a mixture of nitrogen trichloride and air. Klotz and Fawcett (*96*) in 1948 recommended 6 to 14 mg. of nitrogen trichloride gas per cubic foot of air for 3 to 6 hours in storage rooms with loose fruit and in closed cars with packed fruit for preventing blue mold and green mold rots of oranges; 5 mg. of gas for 3 hours once or twice weekly for oranges in the precooler; and 1 to 2 mg. for 4 hours one or more times weekly for lemons and grapefruit in storage and the same dosage in cars.

In a report from Australia (*4*) in 1937 it was stated that fumigating wounded and unwounded Washington Navel oranges with nitrogen trichloride reduced decay by 76.2 and 58.5 percent, respectively.

Littauer (*101*) in Palestine in 1947 reported control of decays caused by *Diplodia natalensis*, *Penicillium digitatum*, and *P. italicum* by fumigating Shamouti oranges with nitrogen trichloride. The best results were obtained from two successive applications of 7 mg. of gas per cubic foot of air for 6 hours at 2-day intervals. This treatment reduced rotting during 5 weeks' storage at 18° C. by 80 to 90 percent. The gas was almost as effective at 15° as at 18°.

Ryall and Godfrey (*61, 153*) in tests in Texas found that nitrogen trichloride in concentrations of 0.003 to 0.04 p.p.m. applied two to four times for 2- to 6-hour periods during degreening reduced stem-end and green mold rots materially. They found that the gas treatment used in conjunction with an antiseptic dip reduced rot better than either the dip or the gas alone.

CHLORINE BLEACHING SOLUTIONS

Chlorine solutions have come into commercial use in South Africa as combination antiseptic and bleaching solutions for oranges affected with sooty blotch. According to Crous (*42*) a few South African packers started using bleaching treatments in 1933. In 1939 he described the use of the "double eusol solution," which consisted of ¼ pound each of chloride of lime and boric acid in 1 gallon of water. The fruit was treated 30 seconds to 1½ minutes depending on the intensity and abundance of the blotching; it was then rinsed and the lugs were stacked for 24 hours for the fruit to dry before it was packed. Forced hot- or cold-air dryers were used in the larger plants.

In 1940 Naude (*123*) reported that the addition of 3.2 ounces of soda ash to a solution containing 4 ounces of chloride of lime and 2 to 4 ounces of boric acid per gallon resulted in a more stable solution of higher bleaching efficiency than the eusol bleaches. A cheaper solution that proved to be as effective as the eusol or the eusol-soda-ash mixture consisted of equal parts of chloride of lime and sodium bicarbonate. Naude recommended that the baths containing bleaching solutions be kept in a cool place and preferably be constructed of wood or cement as sunlight, iron, and galvanized iron decompose them rapidly. If metal tanks or tubs are used, he recommended that they be painted with an acid-resistant paint.

Van der Plank, Van Wyk, and Van Niekerk (*141*) in 1940 reported that sooty blotch was removed from citrus fruits by use of a mixture of 10 to 12 ounces of sodium bicarbonate to 1 pound of chloride of lime. They said that stronger solutions were unstable and that plants adapted to use the weak solutions were most economical of material. They considered the eusol solution (chloride of lime and boric acid) too slow.

Van der Plank (*128*) in the same year said that the use of bleaching solutions to remove sooty blotch from citrus fruits had become a standard practice in South Africa. He stated that a suitable bleaching solution of chloride of lime and sodium bicarbonate would bleach sooty blotch in about 35 seconds.

Van der Plank and Van Niekerk (*130, 131*) stated that calcium hypochlorite may be used in place of bleaching powder and that it saves sodium bicarbonate, is cheaper, and is easily prepared.

Van der Plank (*129*) found that with solutions prepared from constant proportions of bleaching powder, sodium bicarbonate, and sodium carbonate, the average length of treatment required to remove sooty blotch from the fruit is inversely proportional to the concentration of available chlorine. The rate of bleaching increased about 1.5 times for every 10° C. rise in temperature of the solution over the range 21.7° to 46.1°. In studies on the effect of acidity, Van der Plank found that at pH 7.6 to 9.8 the time required for bleaching was doubled for every increase of 1.4 in pH. Below pH 7.6 the effect of acidity was less and it disappeared almost completely at pH 6, at which reaction the hypochlorites exist almost entirely as free undissociated hypochlorous acid.

SODIUM CARBONATE AND SODIUM BICARBONATE

According to Fawcett (*49*) and Klotz and Fawcett (*96*), sodium carbonate or soda ash and sodium bicarbonate are often used in the wash water in California packing houses. Sodium carbonate is usually used at concentrations of 1¼ to 1¾ percent in hot water and sodium bicarbonate in concentrations of 2½ to 3 percent. These materials aid in washing the fruit and control brown rot and are partially effective against blue and green mold rots. Wei and Hu (*189*) in China reported that treating with 3 percent sodium carbonate only slightly reduced infection of oranges by blue mold and stem-end rot fungi.

SODIUM HYDROXIDE

The use of sodium hydroxide with borax was discussed on page 155. In addition, Fidler and Tomkins (*52*) found that dipping oranges in a 2-percent solution of sodium hydroxide reduced green mold rot as effectively as treating with a 5-percent solution of borax and caused less injury to the skin.

GROWTH REGULATORS

Reference has already been made under alternaria rot to the work of Kessler and Allison (*82*) on the effect of 2,4-D and of Stewart (*165*) on the effect of 2,4-D and 2,4,5-T. Guiscafre-Arrillaga (*63*) in Louisiana found that germination of spores of *Penicillium digitatum* suspended in 0.1- to 0.3-percent solutions of Dow 2,4-D Weed Killer (70 percent 2,4-D acid plus 30 percent sodium bicarbonate) and Du Pont 83 percent 2,4-D Weed Killer (83.5 percent sodium salt of 2,4-D) was only 14 percent as compared with 82 to 91 percent germination in the checks. Fumes from the ethyl ester of 2,4-D arrested growth of the germ tubes. On an average only 10 percent of oranges dipped in 0.1- to 0.5-percent solutions of these compounds showed decay after they were held for 3 weeks as compared with more than 50 percent of the untreated fruit. Considerable reduction in decay was also obtained by sprinkling 10 gm. of the dry chemical under a layer of filter paper in the bottom of a container of fruit or by placing filter paper soaked in 10 cc. of undiluted ester under the fruit.

THIOUREA AND OTHER CHEMICALS

Although the antiseptics discussed herein have given excellent control of stem-end and blue and green mold rots and other diseases, they should not be used commercially until animal-toxicity tests have proved beyond any doubt that they will not make the treated fruit harmful to consumers. Toxicity tests have already

shown that thiourea is harmful in quantities that are taken up by the treated fruits.

Childs and Siegler (*39*) in 1944 reported that 0.1 to 0.2 percent of thiourea dissolved in corn-meal agar inhibited growth of *Diplodia natalensis* and that 0.01 to 0.02 percent inhibited that of *Phomopsis citri* and *Penicillium digitatum*. In tests with oranges they obtained approximately 50-percent control by dipping the fruit in a 1-percent solution of thiourea and more than 90-percent control by dipping it in a 4-percent solution. Control was increased when the treating solution was allowed to dry on the fruits before they were washed and brushed. In other tests with 5 percent thiourea 2.4 percent of the thiourea-treated fruits, 1.2 percent of those treated with thiourea plus wax emulsion, and 34.5 percent of the untreated fruits had decayed after 18 days' storage. Urea failed to reduce decay, and therefore Childs and Siegler concluded that this indicated that the sulfur part of thiourea was important to its fungicidal action.

The same authors (*40*) in 1945 reported that decay in oranges was reduced from 32.9 to 1.7 percent, from 32.6 to 10.5 percent, and from 42.2 to 7.5 percent, respectively, by immersing the fruit for 2 to 5 seconds in 5-percent solutions of thioacetamide, 8-hydroxyquinoline sulfate, and 2-aminothiazole. They noted that the amino group and sulfur are common to the chemical structure of these compounds and thiourea and are probably essential for fungicidal activity. In 1946 Childs and Siegler (*41*) stated that momentary dips in a 5-percent thiourea or thioacetamide solution or an 8-percent quinsol solution reduced the incidence of stem-end and blue and green mold rots in Florida oranges from 40 to 2 percent or even less. Equally good results were obtained when a 5-percent concentration of thiourea, thioacetamide, or quinsol was used in the water phase of wax emulsions. They found that the fungicidal activity was linked with penetration of the fruit tissues. Colorimetric analysis showed 12 p.p.m. of thiourea in the juice and 20 p.p.m. in the rind.

Stearns (*164*) stated that thiourea penetrates the rind and appears in the juice 2 or 3 weeks after treatment. He stated further that thiourea has a physiological effect on the thyroid gland and that it is essential to know how much is in the juice of treated fruits. He described a method of analyzing the fruit for small amounts.

Hopkins and Loucks (*73*) reported that the average thiourea content of juice from treated oranges was 4 to 29 p.p.m., depending on the treatment. It was least when the fruit was rinsed after treatment and greatest when the chemical was incorporated in wax.

Hopkins and Loucks (*74*) in 1947 and Winston, Meckstroth, and Roberts (*198*) in 1948 reported good control of decay of oranges in Florida by treating the fruit with 2-aminopyridine. In the tests reported by Hopkins and Loucks total decay of oranges was reduced from 26.7 to 8.4 percent and from 78 to 8 percent by treating the buttons with a 3-percent solution. In these tests 2-aminopyridine gave somewhat better control than thiourea. Oranges dipped in a 1-, 2-, or 3-percent solution and not rinsed showed 16, 10, or 10 percent decay, respectively, after 2 weeks and untreated fruit showed 73 percent decay. Control was also obtained when the fruit was dipped in a 3-percent solution and rinsed thoroughly after standing 1 hour. In Winston's tests decay of oranges was reduced from 73.8 percent in the check to 5.8 percent in fruit treated in a 5-percent solution and to 4.2 percent in fruit treated in a 10-percent solution. A similar reduction was obtained when the same concentrations were used in wax emulsion. Winston also found that 2-aminopyridine impregnated in paper checked decay in seedling and Valencia oranges.

Siegler and Childs (*159*) investigated the possibility of using water-insoluble antiseptics with the idea that they might not be taken up by the fruit in sufficient quantity to be harmful to the consumer. They used isopropanol (isopropyl alcohol) as a solvent because of its low cost and relative safety from the standpoint of rind injury. They reported promising control with diphenyl sulfoxide, benzhydrol, and phenylurethane.

Godfrey and Friend (*60*) reported in 1940 that a 1–1,000 tincture of sodium ethylmercuri-thiosalicylate (merthiolate) applied to the stem end of lemons with a stamp pad completely controlled diplodia stem-end rot during a 3-week holding period while 84 percent of the untreated fruits developed the rot. Almost as complete control was obtained with 1–1,500 strength. Total immersion for 2 minutes in a 1–10,000 solution gave 99 to 100 percent control in treated fruit in late-season tests while 27 to 35 percent of the untreated fruit developed decay. Sulfomerthiolate and sodium p-ethylmercuri-thiophenylsulfonate were also effective when applied by the stamp-pad method. **These chemicals are definitely dangerous to consumers and are not approved for commercial use.**

Reichert and Littauer (*147*) in 1937 described the control of decays of Palestine oranges caused by *Diplodia* and *Penicillium* spp. by applying a drop of iodine solution to the stem end of each orange with a pipette. The method was based on the fact that the chief point of infection is the stem end. The solution consisted of 13 gm. of iodine, 10 gm. of potassium iodide, 200 cc. of water, and 800 cc. of alcohol. In tests in 1936 the treatment reduced stem-end rot in inoculated fruit during 4 weeks' storage from 52 to 13.5 percent. The method, although effective, is probably practical only in small-scale operations.

IMPREGNATED FRUIT WRAPPERS AND OTHER PACKING MATERIALS

Reference has been made in the discussions of various antiseptics to their use for impregnating fruit wrappers, box liners, and paper sacks. Tomkins (*168*) in 1936 reported that in his tests iodine-impregnated wrappers controlled decay, but the iodine was too volatile, stained the packing yellow, and was injurious to some fruits. He concluded that of the substances tested diphenyl was best.

Van der Plank and Rattray (*132, 137*) reported that lightly oiled wrappers had no effect on orange or grapefruit. They stated that moistureproof crystalline waxed paper reduced weight loss but caused pitting of grapefruit and increased losses from mold. Van der Plank and Rattray (*134*) reported that wrappers impregnated with ortho-phenylphenol reduced penicillium decay in stored oranges from 5 percent in the control to 0.8 to 3.2 percent, but that severe scalding occurred at all strengths used. Bates (*20*) reported that *Penicillium digitatum* was controlled by wrappers impregnated with ortho-phenylphenol, but unless the chemical was used at a very low concentration it injured the rind. He reported that the injury was preventable by incorporating a glyceride oil, such as olive or groundnut oil, in the wrappers. Van der Plank and Rattray (*136*) and Van der Plank, Rattray, and Van Wyk (*140*) also reported that glyceride oils with ortho-phenylphenol reduced injury considerably. Tomkins (*169*) was able to reduce the injury by using mineral oil. Tomkins (*171*) reported that wrappers impregnated with 0.1 gm. of ortho-phenylphenol and 0.1 gm. of either benzidine or hexamine reduced decay of oranges by *Penicillium digitatum* and did not cause injury.

Hwang, Chow, and Ching (*78*) reported good control of blue mold by wrapping the fruit in paper impregnated with copper and tung oil.

Diphenyl-impregnated fruit wrappers, box liners, and other items have come into rather wide commercial use in recent years. Tomkins (*168*) and Farkas (*46, 47*) reported excellent results in shipments of citrus fruit from Palestine to England. In the United States Winston (*195*) said that diphenyl-impregnated wrappers, box and bag liners, and separator sheets are used commercially. Also pulverized diphenyl sprinkled in kraft-paper bags at the time of packing has proved effective. Winston said that ¼ to ⅓ ounce per crate is the minimum dose for decay control.

LITERATURE CITED FOR POSTHARVEST DISEASES AND THEIR CONTROL

(1) Anonymous.
1940. Research work in citrus wastage. Hadar 13: 21, 26. (Reviews work of F. Littauer.)

(2) ———
1943. Septoria spot of citrus. Agr. Gaz. N. S. Wales 54: 120.

(3) Adam, D. B., McNeil, J., Hanson-Merz, B. M., and others.
1949. The estimation of latent infection in oranges. Austral. Jour. Sci. Res., Ser. B., 2: [1]–18, illus.

(4) Australia. Council for Scientific and Industrial Research.
1937. Citrus packing house investigations. *In* Austral. Council Sci. and Indus. Res., Ann. Rpt. (1936–37) 11: 58–59.

(5) ———
1939. Fruit storage investigations.—(i) Citrus fruits.—(a) Report of citrus research officer. *In* Austral. Council Sci. and Indus. Res., Ann. Rpt. (1938–39) 13: 63.

(6) ———
1940. Investigations at Melbourne in co-operation with the Victorian Department of Agriculture. *In* Austral. Council Sci. and Indus. Res., Ann. Rpt. (1939–40) 14: 59.

(7) Averna Saccá, R.
1940. Sobre a fórma ascofora (Glomerella sp.) que encontrei em algumas folhas de laranjeira doce no Guarugá. Rev. de Agr. [São Paulo] 15: [463]–467, illus.

890503—51—12

(8) Averna Saccá, R.
1940. PUSTULAS PRETAS SOBRE LARANJAS DOCES PRODUSIDAS PELO PHOMA CITRICARPA. Rev. de Agr. [São Paulo] 15: [468]–474, illus.

(9) Baker, R. E. D.
1938. STUDIES IN THE PATHOGENICITY OF TROPICAL FUNGI. II. THE OCCURRENCE OF LATENT INFECTIONS IN DEVELOPING FRUITS. Ann. Bot. [London] (n. s.) 2: [919]–931.

(10) Barger, W. R., and Hawkins, L. A.
1925. BORAX AS A DISINFECTANT FOR CITRUS FRUIT. Jour. Agr. Res. 30: 189–192.

(11) Bartholomew, E. T., and Sinclair, W. B.
1938. FURTHER STUDIES ON THE RELATION OF LOW TEMPERATURES TO GRANULATION. Calif. Citrog. 23: 163, 192.

(12) ——— and Sinclair, W. B.
1944. GRANULATION AND JUICE QUALITY IN VALENCIAS AS AFFECTED BY INSECTICIDES. Calif. Citrog. 30: 4–5.

(13) ——— and Sinclair, W. B.
1945. NAVEL ORANGE PEEL OIL AND WATER SPOT. Calif. Citrog. 30: 266–267.

(14) ——— and Sinclair, W. B.
1947. BUD SELECTION AND GRANULATION. Calif. Citrog. 32: 94, 106, 123–124, illus.

(15) ——— and Sinclair, W. B.
1947. BUD SELECTION AND GRANULATION. Citrus Leaves 27 (1): 8–11, illus.

(16) ——— Sinclair, W. B., and Ebeling, W.
1943. CITRUS FRUIT QUALITY. Citrus Leaves 23 (12): 14, 16.

(17) ——— Sinclair, W. B., and Turrell, F. M.
1941. GRANULATION OF VALENCIA ORANGES. Calif. Agr. Expt. Sta. Bul. 647, 63 pp., illus.

(18) ——— Sinclair, W. B., and Turrell, F. M.
1948. GRANULATION OF VALENCIA ORANGES. Calif. Citrog. 33: 322–325.

(19) ——— Sinclair, W. B., and Turrell, F. M.
1948. GRANULATION OF VALENCIA ORANGES. Citrus Leaves 28 (1): 14–15.

(19a) Batchelor, L. D., and Webber, H. J., editors.
1948. THE CITRUS INDUSTRY. VOLUME II. PRODUCTION OF THE CROP. 933 pp., illus. Berkeley and Los Angeles.

(20) Bates, G. R.
1939. RECENT DEVELOPMENTS IN THE PROCESSING OF RHODESIAN ORANGES. Rhodesia Sci. Assoc. Proc. 37: 29–35.

(21) Biale, J. B.
1940. EFFECT OF EMANATIONS FROM SEVERAL SPECIES OF FUNGI ON RESPIRATION AND COLOR DEVELOPMENT OF CITRUS FRUITS. Science 91: 458–459.

(22) ———
1940. EFFECT OF VAPORS FROM MOLDY FRUITS ON COLORING AND RESPIRATION OF LEMONS. Calif. Citrog. 25: 186, 212., illus.

(23) ———
1948. RESPIRATION OF CITRUS FRUITS IN RELATION TO METABOLISM OF FUNGI. II EFFECTS OF EMANATIONS OF PENICILLIUM DIGITATUM, SACC. ON LEMONS AT DIFFERENT STAGES OF RIPENESS. Amer. Soc. Hort. Sci. Proc. 52: 187–191, illus.

(24) ——— and Shepherd, A. D.
1941. RESPIRATION OF CITRUS FRUITS IN RELATION TO METABOLISM OF FUNGI. I. EFFECTS OF EMANATIONS OF PENICILLIUM DIGITATUM, SACC., ON LEMONS. Amer. Jour. Bot. 28: 263–270, illus.

(25) Bitancourt, A. A., and Jenkins, A. E.
1939. CICLO EVOLUTIVO DE "ELSINOË AUSTRALIS BITANCOURT & JENKINS", AGENTE DA VERRUGOSE DA LARANJA DOCE. Inst. Biol. [São Paulo] Arq. 10: [129]–146, illus. [English summary, pp. 140–142.]

(26) Blackford, F. W.
1941. THE ESTABLISHMENT OF A HOME-MADE CUPROUS OXIDE MIXTURE AS A CITRUS FUNGICIDE IN SOUTHERN QUEENSLAND. Queensland Agr. Jour. 56: 4–33, illus.

(27) ———
1943. FOUR MAJOR DISEASES OF CITRUS. Queensland Agr. Jour. 57: 353–358, illus.

(28) BLISS, D. E., and FAWCETT, H. S.
1944. THE MORPHOLOGY AND TAXONOMY OF ALTERNARIA CITRI. Mycologia 36: 469-502, illus.
(29) BOCHAROVA, Z. Z.
1941. DISEASES OF CITRUS FRUIT IN STORAGE. I. BOTRYTIS CINEREA ON STORED CITRUS FRUIT. Microbiology 8: 1187-1194. [In Russian. English summary, p. 1194.] (Not seen; abstract in Chem. Abs. v. 35, column 3351. 1941.)
(30) BROOKS, C.
1942. THE HARE AND THE TORTOISE OF CITRUS STEM-END ROT; THE COMPARATIVE BEHAVIOUR OF DIPLODIA AND PHOMOPSIS. Fla. State Hort. Soc. Proc. (1941) 54: 61-63.
(31) ———
1943. PREVENTION OF STEM-END ROT. Fla. State Hort. Soc. Proc. (1942) 55: 61-69, illus.
(32) ———
1944. STEM-END ROT OF ORANGES AND FACTORS AFFECTING ITS CONTROL. Jour. Agr. Res. 68: 363-381, illus.
(33) BURGER, O. F.
1923. MELANOSE CONTROL. Fla. Grower 28 (20): 7, 17.
(34) ——— DEBUSK, E. F., and BRIGGS, W. R.
1923. PRELIMINARY REPORT ON CONTROLLING MELANOSE AND PREPARING BORDEAUX-OIL. Fla. Agr. Expt. Sta. Bul. 167, pp. 123-140, illus.
(35) CALIFORNIA FRUIT GROWERS EXCHANGE.
1943. INSTRUCTIONS TO LEMON PICKERS. Calif. Citrog. 28: 144, illus.
(36) CASS-SMITH, W. P., OWEN, R. C., and HARVEY, H. L.
1941. WATER SPOT OF NAVEL ORANGES IN RELATION TO THE APPLICATION OF WHITE OIL SPRAYS AND VARIOUS OTHER ORCHARD PRACTICES. West. Austral. Dept. Agr. Jour. (Ser. 2) 18: 267-284, illus.
(37) CASTELLANI, E.
1948. LA SCABBIA DELLE ARANCE IN ERITREA. Riv. di Agr. Subtrop. e Trop. 42: [145]-150, illus.
(38) CHAPMAN, H. D., and BROWN, S. M.
1942. SOME FUNGAL INFECTIONS OF CITRUS IN RELATION TO NUTRITION. Soil Sci. 54, 303-312, illus.
(39) CHILDS, J. F. L., and SIEGLER, E. A.
1944. EXPERIMENTAL CONTROL OF ORANGE DECAYS WITH THIOUREA. Phytopathology 34: 983-985.
(40) ——— and SIEGLER, E. A.
1945. COMPOUNDS FOR CONTROL OF ORANGE DECAYS. Science 102: 680.
(41) ——— and SIEGLER, E. A.
1946. CONTROLLING ORANGE DECAY. Indus. and Engin. Chem., Indus. Ed., 38: 82-87.
(42) CROUS, P. A.
1939. THE TREATMENT OF SOOTY BLOTCH ON CITRUS FRUITS. Citrus Grower [So. Africa] No. 67, pp. 9, 11-13, illus.
(43) DEVA RAJAN, M. R., and AIYAPPA, K. M.
1944. LEAF-FALL AND FRUIT-ROT DISEASE OF ORANGES. Indian Farming 5: 512-513.
(44) DUNN, J. T., and BLOXAM, H. C. L.
1929. BORIC ACID IN ORANGES. Analyst 54: 28-29.
(45) EBELING, W., KLOTZ, L. J., and PARKER, E. R.
1938. EXPERIMENTS ON NAVEL WATER SPOT. Calif. Citrog. 23: 410, 434-436, illus.
(46) FARKAS, A.
1938. THE PRACTICAL APPLICATION OF IMPREGNATED WRAPPERS AGAINST FUNGAL DECAY OF CITRUS FRUIT. Hadar 11: 261-267, illus.
(47) ———
1939. CONTROL OF WASTAGE OF CITRUS FRUIT BY IMPREGNATED WRAPPERS, ON A COMMERCIAL SCALE. Hadar 12: 227-231.
(48) ——— and AMAN, J.
1940. THE ACTION OF DIPHENYL ON PENICILLIUM AND DIPLODIA MOULDS. Palestine Jour. Bot., J. Ser., 2: 38-45, illus.
(49) FAWCETT, H. S.
1936. CITRUS DISEASES AND THEIR CONTROL. Ed. 2, 656 pp., illus. New York and London.

(50) Fawcett, H. S., and Klotz, L. J.
1940. septoria spot of citrus fruits. Calif. Citrog. 26: 2, illus.
(51) ——— Perry, J. C., and Johnston, J. C.
1944. the stubborn disease of citrus. Calif. Citrog. 29: 146–147, illus.
(52) Fidler, J. C., and Tomkins, R. G.
1939. dipping for the control of fungal rotting in citrus fruit. [Gt. Brit.] Food Invest. Bd. Rpt. 1938: 189–190.
(53) Frezzi, M. J.
1941. phytophthora boehmeriae, causante de la podredumbre morena de los frutos cítricos, en la república argentina. Rev. Argentina de Agron. 8: 200–205, illus.
(54) ———
1942. podredumbre morena de los frutos cítricos y parásitos que la producen en corrientes, argentina. Rev. Argentina de Agron. 9: 216–220, illus.
(55) Fulton, H. R., and Bowman, J. J.
1924. preliminary results with the borax treatment of citrus fruits for the prevention of blue mold rot. Jour. Agr. Res. 28: 961–968, illus.
(56) Furlong, C. R.
1948. the effect of dipping in borax solutions on the boron content of oranges. Analyst 73: 498–500.
(57) Gates, C. M.
1949. preliminary tests of fungicidally active compounds for the control of stem-end rot of oranges. Citrus Indus. 30 (12): 11–14.
(58) Gemmell, A. R.
1939. synergism in fruit-rotting fungi. Chron. Bot. 5: 41–42.
(59) Ghatak, P. N.
1938. investigations on orange rot in storage. i. orange rot due to two strains of fusarium moniliforme sheldon. Indian Bot. Soc. Jour. 17: 141–148, illus.
(60) Godfrey, G. H., and Friend, W. H.
1940. diplodia stem-end rot of lemons controlled with sodium ethyl mercuri thiosalicylate. Science 91: 94–95.
(61) ——— and Ryall, A. L.
1948. the control of transit and storage decays in texas lemons. Tex. Agr. Expt. Sta. Bul. 701, 24 pp., illus.
(62) Greig, A. M. W.
1942. preventing infection in citrus fruit. Orchardist of N. Z. 15 (6): 3.
(63) Guiscafre–Arrillaga, J.
1948. sensitivity of penicillium digitatum to 2,4-dichlorophenoxy-acetic acid. U. S. Bur. Plant Indus., Soils, and Agr. Engin., Plant Dis. Rptr. 32: 248–250. [Processed.]
(64) Haas, A. R. C.
1945. boron in citrus trees. Plant Physiol. 20: 323–343, illus.
(65) ——— Klotz, L. J., and Johnston, J. C.
1944. acorn disease in oranges. Calif. Citrog. 29: 148, 168–169, illus.
(66) Hall, E. G.
1938. the storage of oranges. Agr. Gaz. N. S. Wales 49: 558, 618–620, 667–668.
(67) Harvey, E. M.
1946. changes in lemons during storage as affected by air circulation and ventilation. U. S. Dept. Agr. Tech. Bul. 908, 32 pp., illus.
(68) Harvey, R. B.
1938. the x-ray inspection of internal defects of fruits and vegetables. Amer. Soc. Hort. Sci. Proc. (1937) 35: 156–157.
(69) Heiberg, B. C., and Ramsey, G. B.
1946. fungistatic action of diphenyl on some fruit and vegetable pathogens. Phytopathology 36: 887–891.
(70) Hildebrand, E. M.
1947. stem-end rot fungi attack immature citrus fruit. (Abstract) Phytopathology 37: 433.

(71) HOPKINS, E. F., and LOUCKS, K. W.
1944. PULLING VERSUS CLIPPING OF ORANGES IN RESPECT OF LOSS FROM STEM-END ROT AND BLUE MOLD. Fla. State Hort. Soc. Proc. 57: 80–86, illus.

(72) ——— and LOUCKS, K. W.
1944. PULLING VERSUS CLIPPING OF ORANGES IN RESPECT TO LOSS FROM STEM-END ROT AND BLUE MOLD. Fla. Agr. Expt. Sta. Ann. Rpt. 1943–44: 213–214, illus.

(73) ——— and LOUCKS, K. W.
1946. STUDIES ON THIOUREA FOR STEM-END ROT CONTROL. Fla. Agr. Expt. Sta. Ann. Rpt. 1945–46: 164–166.

(74) ——— and LOUCKS, K. W.
1947. EXPERIMENTAL CHEMICAL TREATMENTS AND THE PREVENTION OF DECAY IN CITRUS FRUITS. Citrus Indus. 28 (6): 12–14.

(75) ——— and LOUCKS, K. W.
1947. THE USE OF DIPHENYL IN THE CONTROL OF STEM-END ROT AND MOLD IN CITRUS FRUITS. Citrus Indus. 28 (10): 5–9, illus.

(76) ——— and LOUCKS, K. W.
1948. A CURING PROCEDURE FOR THE REDUCTION OF MOLD DECAY IN CITRUS FRUITS. Fla. Agr. Expt. Sta. Bul. 450, 26 pp., illus. (In cooperation with Fla. Citrus Comn.)

(77) HUELIN, F. E.
1942. THE HANDLING AND STORAGE OF AUSTRALIAN ORANGES, MANDARINS, AND GRAPEFRUIT. Austral. Council Sci. and Indus. Res., Bul. 154, 60 pp., illus.

(78) HWANG, L., CHOW, C. M., and CHING, I.
1946. FURTHER STUDY ON STORAGE EXPERIMENTS OF KWANGSI SHA-TIEN PUMMELO (CITRUS GRANDIS OSBECK) WITH SPECIAL REFERENCE TO DISEASE CONTROL. Kwangsi Agr. 6: 12–25. [In Chinese. English summary, pp. 23–25.]

(79) ——— and KLOTZ, L. J.
1938. THE TOXIC EFFECT OF CERTAIN CHEMICAL SOLUTIONS ON SPORES OF PENICILLIUM ITALICUM AND P. DIGITATUM. Hilgardia 12: 1–38, illus.

(80) JENKINS, A. E.
1938. ELSINOË ON LEMON FRUITS FROM PARAGUAY. Phytopathology 28: 73–75, illus.

(81) ——— and BITANCOURT, A. A.
1939. ILLUSTRAÇÕES DAS DOENÇAS CAUSADAS POR "ELSINOË" E "SPHACELOMA" CONHECIDAS NA AMERICA DO SUL ATÉ JANEIRO DE 1936. Inst. Biol. [São Paulo] Arq. 10: [31]–60, illus. [English summary, pp. 53–54.]

(82) KESSLER, K. L., and ALLISON, J. R.
1948. USE OF GROWTH REGULATORS ON LEMONS IN STORAGE. Calif. Citrog. 34: 24–25, 28, illus.

(83) KIELY, T. [B.]
1948. GUIGNARDIA CITRICARPA N.SP. AND ITS RELATIONSHIP TO THE BLACK SPOT DISEASE OF CITRUS IN COASTAL ORCHARDS OF NEW SOUTH WALES. Austral. Inst. Agr. Sci. Jour. 14: 81–83, illus.

(84) ———
1949. BLACK SPOT OF CITRUS IN NEW SOUTH WALES COASTAL ORCHARDS. Agr. Gaz. N. S. Wales 60: 17–20, illus.

(85) ———
1949. BLACK SPOT OF CITRUS. RECOMMENDATIONS FOR CONTROL ON THE CENTRAL COAST OF NEW SOUTH WALES. Agr. Gaz. N. S. Wales 60: 137–139, illus.

(86) ———
1949. BLUE AND GREEN MOULD ROTS OF CITRUS FRUITS. Agr. Gaz. N. S. Wales 60: 465–466, illus.

(87) ———
1949. PRELIMINARY STUDIES ON GUIGNARDIA CITRICARPA, N. SP.: THE ASCIGEROUS STAGE OF PHOMA CITRICARPA M. ALP. AND ITS RELATION TO BLACK SPOT OF CITRUS. Linn. Soc. N. S. Wales Proc. (1948) 73: 249–292, illus.

(88) KLOTZ, L. J.
1936. NITROGEN TRICHLORIDE AND OTHER GASES AS FUNGICIDES. Hilgardia 10: 27–52, illus.

(89) Klotz, L. J.
1941. BROWN ROT OF CITRUS FRUIT. IMPORTANT FACTORS IN ITS CONTROL IN ORCHARD AND PACKING HOUSE. Calif. Citrog. 27: 6, 23, illus.

(90) ———
1943. PHYTOPHTHORA INFECTIONS OF CITRUS. Calif. Citrog. 28: 200–201, 220–221, illus.

(91) ———
1944. BROWN ROT AND GUMMOSIS INFECTIONS CAUSING SERIOUS LOSSES. Calif. Citrog. 29: 116, illus.

(92) ——— and Basinger, A. J.
1938. WATER SPOT OF NAVEL ORANGES. Calif. Citrog. 23: 115, illus.

(93) ——— Boyce, A. M., Chapman, H. D., and others.
1949. WATER SPOT OF NAVEL ORANGES. Calif. Citrog. 34: 122–126, illus. (Condensed version of Calif. Agr. Expt. Sta. leaflet.)

(94) ——— Calavan, E. C., and Zentmyer, G. A.
1946. THE EFFECT OF BOTRYTIS ROT ON LEMONS. Calif. Citrog. 31: 247, 262, illus.

(95) ——— and Fawcett, H. S.
1941. BROWN ROT AND GUMMOSIS. FURTHER STUDIES ON THE FUNGI CAUSING THESE DISEASES IN CITRUS TREES AND FRUIT. Calif. Citrog. 26: 114, 142–143, illus.

(96) ——— and Fawcett, H. S.
1948. COLOR HANDBOOK OF CITRUS DISEASES. Ed. 2, rev. and expanded, 119 pp., 51 col. pls. Berkeley and Los Angeles.

(97) ——— and Parker, E. R.
1945. SUGGESTIONS FOR CONTROLLING BROWN ROT, EXANTHEMA, AND SEPTORIA SPOT OF CITRUS. Calif. Citrog. 31: 20.

(98) ——— Stewart, W. S., and Bumgardner, R. J.
1947. RIND SPOT AND DROP OF VALENCIA ORANGES. Calif. Citrog. 33: 36–37, illus.

(99) ——— and Turrell, F. M.
1939. RIND STRUCTURE AND COMPOSITION IN WATER SPOT OF NAVEL ORANGE. Calif. Citrog. 25: 45, 56–57, illus.

(100) Kuntz, W. A., and Ruehle, G. D.
1938. SPRAYING AND PRUNING FOR MELANOSE CONTROL. Fla. State Hort. Soc. Proc. 51: 89–102.

(101) Littauer, F.
1947. CONTROL OF DIPLODIA STEM-END ROT AND MOULDS IN SHAMOUTI ORANGES WITH NITROGEN TRICHLORIDE (DECCO PROCESS). Palestine Jour. Bot., R. Ser., 6: [205]–218.

(102) ——— and Gutter, J.
1946. SCLEROTIUM BATATICOLA TAUBENHAUS AS CAUSAL AGENT OF A ROT OF SHAMOUTI ORANGES. Palestine Jour. Bot., R. Ser., 5: 261–262, illus.

(103) ——— Nadel-Schiffmann, M., and Minz, G.
1947. THE MODE OF INFECTION OF SHAMOUTI ORANGES BY DIPLODIA. Palestine Jour. Bot., R. Ser., 6: [158]–164.

(104) Loucks, K. W., and Hopkins, E. F.
1946. A STUDY OF THE OCCURRENCE OF PHOMOPSIS AND OF DIPLODIA ROTS IN FLORIDA ORANGES UNDER VARIOUS CONDITIONS AND TREATMENTS. Phytopathology 36: 750–757, illus.

(105) McCleery, F. C.
1939. BLACK SPOT OF CITRUS. A BRIEF SUMMARY OF CONTROL EXPERIMENTS, 1925–39. Agr. Gaz. N. S. Wales 50: 618–622, illus.

(106) Macintosh, F. C.
1945. THE TOXICITY OF DIPHENYL AND O-PHENYL-PHENOL. Analyst 70: 334–335.

(107) Meckstroth, G. A.
1944. PULLING VERSUS CLIPPING OF FLORIDA ORANGES. Citrus Indus. 25 (11): 9, 12, 18.

(108) Mezzetti, A.
1939. RICERCHE SULL' EZIOLOGIA DELLA "PITICCHIA BATTERICA" DEI FRUTTI DI LIMONE. [Roma] R. Staz. di Patol. Veg. Bol. 19: 189–221, [251]–292, illus.

(109) Miller, E. V., and Winston, J. R.
1943. green-spotting in relation to time of day that early oranges are [picked]. Citrus Indus. 24 (11): 7, 14–15, illus.; 24 (12): 12, 18, illus.
(110) ——— Winston, J. R., and Cubbedge, R. H.
1949. a physiological study of post-harvest abscission in pineapple oranges. Amer. Soc. Hort. Sci. Proc. 53: 158–162.
(111) ——— Winston, J. R., and Fisher, D. F.
1940. production of epinasty by emanations from normal and decaying citrus fruits and from penicillium digitatum. Jour. Agr. Res. 60: 269–277, illus.
(112) ——— Winston, J. R., and Meckstroth, G. A.
1944. studies on the use of formaldehyde and sodium ortho-phenylphenate in the control of decay in citrus fruits. Citrus Indus. 25 (10): 3, 15, 18.
(113) Minz, G.
1940. early diagnosis of jaffa orange blemishes and diseases by means of ultra-violet rays. Palestine Jour. Bot., R. Ser., 3: [259]–262.
(114) ———
1946. diplodia natalensis, its occurrence on flowers, button, and stem-end of shamouti orange, and its relation to stem-end rot and fruit drop. Palestine Jour. Bot., R. Ser., 5: [152]–168, illus.
(115) ——— and Ben-Meir, Y.
1944. pathogenicity of diplodia from various hosts to citrus fruits. Palestine Jour. Bot., R. Ser., 4: [162]–165.
(116) ——— Nadel-Schiffmann, M., and Littauer, F.
1947. the incubation period and rate of development of diplodia in shamouti oranges. Palestine Jour. Bot., R. Ser., 6: [165]–169, illus.
(117) Morris, H. I., Klotz, L. J., and Sokoloff, V. P.
1941. brown rot control and copper injury. report of a field experiment on lemons. Calif. Citrog. 26: 284, illus.
(118) Muller, H. R. A.
1939. overzicht van de belangrijkste citrus-ziekten in nederlandsch-indië. [Dutch East Indies] Alg. Proefsta. v. Landb., Meded. 34, 42 pp., illus. [English summary, pp. 40–42.]
(119) Nadel, M.
1944. anatomical study of the button of shamouti oranges in relation to stem-end rot. Palestine Jour. Bot., R. Ser., 4: [166]–170, illus.
(120) Nadel-Schiffmann, M.
1947. phytophthora hibernalis. Palestine Jour. Bot., R. Ser., 6: [148]–157, illus.
(121) ——— Minz, G., and Littauer, F.
1947. anatomical study of the button and rind of shamouti oranges in relation to the mode of infection by diplodia. Palestine Jour. Bot., R. Ser., 6: [170]–173, illus.
(122) Nattrass, R. M.
1937. citrus wastage, a reminder. Cyprus Agr. Jour. 32: 74–78.
(123) Naude, C. P.
1940. removal of sooty blotch from oranges. Union So. Africa Dept. Agr. and Forestry, Bul. 212, 13 pp.
(124) New Zealand. Department of Scientific and Industrial Research.
1940. wastage in citrus fruits. *In* New Zeal. Dept. Sci. and Indus. Res., Ann. Rpt. (1939–40) 14: 54.
(125) Parham, B. E.
1942. brown rot of citrus (phytophthora hibernalis). Fiji Dept. Agr. Jour. 13: 28.
(126) Parker, E. R., Rounds, M. B., and Cree, C. B.
1943. orchard practices in relation to yield and quality of valencia oranges. parts 1 and 2. Calif. Citrog. 28: 226–227, 238–239, 242, 260, 268–269, illus.
(127) Pittman, H. A. J.
1949. principal diseases of lemons in victoria and their control. Victoria Dept. Agr. Jour. 47: 117–122, illus.

(128) PLANK, J. E. VAN DER.
1940. THE USE OF MIXTURES OF CHLORIDE OF LIME AND SODIUM BICARBONATE TO REMOVE SOOTY BLOTCH FROM CITRUS FRUITS. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Ann. Rpt. 1938–39: 98–103, illus.

(129) ———
1945. THE USE OF HYPOCHLOROUS ACID AND ITS SALTS IN CITRUS PACKHOUSES FOR BLEACHING SOOTY BLOTCH AND AS DISINFECTANTS AGAINST MOULD. Union So. Africa Dept. Agr. and Forestry, Sci. Bul. 241, 60 pp., illus.

(130) ——— and NIEKERK, O. T. VAN.
1940. NOTES ON THE BLEACHING OF SOOTY BLOTCH FROM ORANGES. Citrus Grower [So. Africa] No. 83, pp. [1], 3.

(131) ——— and NIEKERK, O. T. VAN.
1941. BLEACHING OF SOOTY BLOTCH FROM ORANGES. Farming in So. Africa 16: 27–28.

(132) ——— and RATTRAY, J. M.
1938. THE USE OF WAXED AND OIL-TREATED CITRUS WRAPS AND OF WAX AND OIL EMULSIONS. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Rpt. 1936–37: 151–153.

(133) ——— and RATTRAY, J. M.
1939. TWO NEW DISINFECTANTS FOR CITRUS. Citrus Grower [So. Africa] No. 65, pp. 13–14.

(134) ——— and RATTRAY, J. M.
1939. THE USE OF WRAPS IMPREGNATED WITH O-PHENYL PHENOL AGAINST DECAY IN ORANGES. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Rpt. 1937–38: 142–145, illus.

(135) ——— and RATTRAY, J. M.
1940. THE RELATIVE EFFICACY OF O-PHENYL-PHENOL AGAINST VARIOUS CITRUS-ROTTING FUNGI IN CULTURE. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Ann. Rpt. 1938–39: 88.

(136) ——— and RATTRAY, J. M.
1940. THE USE OF WRAPS IMPREGNATED WITH O-PHENYL-PHENOL AGAINST MOULD IN CITRUS FRUITS. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Ann. Rpt. 1938–39: 88–93.

(137) ——— and RATTRAY, J. M.
1940. THE EFFECT OF LIGHTLY OILED CITRUS WRAPS ON THE BEHAVIOUR OF ORANGES IN STORE. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Ann. Rpt. 1938–39: 122–124.

(138) ——— and RATTRAY, J. M.
1940. A NOTE ON THE EFFECT OF REPACKING NAVEL ORANGES AND ITS BEARING ON THE QUESTION OF THE SPREAD OF P. DIGITATUM BY [CONTACT]. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Ann. Rpt. 1938–39: 124–125.

(139) ——— RATTRAY, J. M., and CROUS, P. A.
1940. THE STORAGE OF LEMONS. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Ann. Rpt. 1938–39: 110–122.

(140) ——— RATTRAY, J. M., and WYK, G. F. VAN.
1940. THE USE OF WRAPS CONTAINING O-PHENYLPHENOL FOR CITRUS FRUITS. Jour. Pomol. and Hort. Sci. 18: 135–144.

(141) ——— WYK, G. F. VAN, and NIEKERK, O. T. VAN.
1940. REMOVAL OF SOOTY BLOTCH FROM CITRUS FRUITS. THE USE OF MIXTURES OF CHLORIDE OF LIME AND SODIUM BICARBONATE. Farming in So. Africa. 15: 201–202.

(142) RAMSEY, G. B., HEIBERG, B. C., and WIANT, J. S.
1946. DIPLODIA ROT OF ONIONS. Phytopathology 36: 245–251, illus.

(143) ——— SMITH, M. A., and HEIBERG, B. C.
1944. FUNGISTATIC ACTION OF DIPHENYL ON CITRUS FRUIT PATHOGENS. Bot. Gaz. 106: 74–83, illus.

(144) RATTRAY, J. M.
1936. CITRUS WASTAGE INVESTIGATIONS, 1934. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Rpt. 1934–35: 154–160, illus.

(145) RATTRAY, J. M.
1939. DIPPING EXPERIMENTS WITH ORANGES. Union So. Africa Dept. Agr. and Forestry Low Temp. Res. Lab., Capetown, Rpt. 1937–38: 170–176.

(146) REICHERT, I., and HELLINGER, E.
1938. DOTHIORELLA ROT OF BANANAS AND ORANGES IN PALESTINE. Palestine Jour. Bot., R. Ser., 2: [79]–88, illus.

(147) ——— and LITTAUER, F.
1937. A NEW METHOD OF CONTROL OF WASTAGE IN ORANGES. Hadar 10: 141–142, 144–145, illus.

(148) RHOADS, A. S.
1940. THE CAUSE AND CONTROL OF MELANOSE. Citrus Indus. 21 (6): 5, 9, 12, illus.

(149) ROHRBAUGH, P. W., and MACRILL, J. R.
1943. ETHYLENE IN LEMON STORAGE ROOMS. Calif. Citrog. 28: 118, illus.

(150) ROSE, D. H., BROOKS, C., BRATLEY, C. O., and WINSTON, J. R.
1943. MARKET DISEASES OF FRUITS AND VEGETABLES: CITRUS AND OTHER SUBTROPICAL FRUITS. U. S. Dept. Agr. Misc. Pub. 498, 57 pp., illus.

(151) RUEHLE, G. D., and KUNTZ, W. A.
1940. MELANOSE OF CITRUS AND ITS COMMERCIAL CONTROL. Fla. Agr. Expt. Sta. Bul. 349, 54 pp., illus.

(152) ——— and THOMPSON, W. L.
1939. COMMERCIAL CONTROL OF CITRUS SCAB IN FLORIDA. Fla. Agr. Expt. Sta. Bul. 337, 47 pp., illus.

(153) RYALL, A. L., and GODFREY, G. H.
1948. DIP AND GAS TREATMENTS FOR THE REDUCTION OF POST-HARVEST DECAY IN TEXAS LEMONS. Phytopathology 38: 1014–1018, illus.

(154) SAVASTANO, G., and FAWCETT, H. S.
1929. A STUDY OF DECAY IN CITRUS FRUITS PRODUCED BY INOCULATIONS WITH KNOWN MIXTURES OF FUNGI AT DIFFERENT CONSTANT TEMPERATURES. Jour. Agr. Res. 39: 163–198, illus.

(155) SCHIEL, E.
1942. LA LUCHA CONTRA SPHACELOMA AUSTRALIS, PARÁSITO DEL MANDARINO EN LA PROVINCIA DE SANTA FE. Rev. Argentina de Agron. 9: 19–27, illus.

(156) SCOTT, F. M., and BAKER, K. C.
1947. ANATOMY OF WASHINGTON NAVEL ORANGE RIND IN RELATION TO WATER SPOT. Bot. Gaz. 108: 459–475, illus.

(157) SCURTI, J.
1949. SULLA OLEOCELLOSI DELLE ARANCE E SULLE MODIFICAZIONI ISTOLOGICHE CHE LA CARATTERIZZANO. [Italy] Min. dell'Agr. e Foreste, Ann. della Sper. Agr. (n. s.) 3 (1): [179]–193, illus.

(158) SHIFF, M.
1939. THE INFLUENCE OF ORCHARD CONDITIONS ON THE INCIDENCE OF WASTAGE IN PALESTINIAN ORANGES. Hadar 12: 233–236.

(159) SIEGLER, E. A., and CHILDS, J. F. L.
1947. ISOPROPANOL-SOLUBLE COMPOUNDS IN CONTROLLING STEM-END DECAY OF ORANGES. Phytopathology 37: 399–402.

(160) SINCLAIR, W. B., and LINDGREN, D. L.
1943. RIDGES AND SECTORS INDUCED IN THE RIND OF CITRUS FRUITS BY FUMIGATION WITH HYDROCYANIC ACID. Plant Physiol. 18: 99–106, illus.

(161) SMITH, C. O., and KLOTZ, L. J.
1945. A MORE VIRULENT BLACK PIT ORGANISM ON CITRUS. Calif. Citrog. 30: 303, illus.

(162) ——— and KLOTZ, L. J.
1945. A MORE VIRULENT BLACK PIT ORGANISM ON CITRUS. Phytopathology 35: 942–943, illus.

(163) STEARNS, C. R., Jr.
1945. INVESTIGATIONS OF MELANOSE AND STEM-END ROT OF CITRUS FRUIT. Fla. Agr. Expt. Sta. Ann. Rpt. 1944–45: 158.

(164) ———
1946. PACKINGHOUSE RESEARCH. Fla. Agr. Expt. Sta. Ann. Rpt. 1945–46: 160–161

(165) Stewart, W. S.
1948. Effect of plant growth regulators on stored citrus fruit. Calif. Citrog. 34: 58, 80–84, illus.

(166) Steyn, A. P., and Rosselet, F.
1949. Quantitative photometric determination of diphenyl in orange peel. Analyst 74: 89–95, illus.

(167) Suit, R. F.
1949. Recent experiments on melanose control with reference to organic fungicides and dormant sprays. Citrus Indus. 30 (2): 8, 18.

(168) Tomkins, R. G.
1936. Wraps for the prevention of rotting of fruit. [Gt. Brit.] Food Invest. Bd. Rpt. 1935: 129–131.

(169) ———
1937. Treated wraps for the prevention of rotting. [Gt. Brit.] Food Invest. Bd. Rpt. 1936: 149–151.

(170) ———
1939. The rotting of oranges by green mould. [Gt. Brit.] Food Invest. Bd. Rpt. 1938: 184–186, illus.

(171) ———
1939. Treated wraps for the prevention of fungal rotting. [Gt. Brit.] Food Invest. Bd. Rpt. 1938: 186–189.

(172) ——— and Isherwood, F. A.
1945. The absorption of diphenyl and o-phenyl-phenol by oranges from treated wraps. Analyst 70: 330–333.

(173) Trout, S. A., Tindale, G. B., and Huelin, F. E.
1938. The storage of oranges with special reference to locality, maturity, respiration, and chemical composition. Austral. Council Sci. and Indus. Res., Pam. 80, 59 pp., illus.

(174) Turrell, F. M.
1950. A study of the physiological effects of elemental sulphur dust on citrus fruits. Plant Physiol. 25: 13–62, illus.

(175) ——— and Bartholomew, E. T.
1939. Structural and microchemical changes in granulated orange vesicles. Calif. Citrog. 24: 88, 110, illus.

(175a) ——— and Chervenak, M.
1949. Metabolism of radioactive elemental sulfur applied to lemons as an insecticide. Bot. Gaz. 111: [109]–122, illus.

(175b) ——— Cuneo, F., Slack, D., and Carns, H.
1943. Factors in injury to citrus by sulphur dusts. Calif. Citrog. 28: 286–287, 302, 306–307, 310–311, illus.

(176) ——— and Klotz, L. J.
1940. Density of stomata and oil glands and incidence of water spot in the rind of Washington navel orange. Bot. Gaz. 101: 862–871, illus.

(177) [Tzereteki, L. Y., and Tchanturia, N. N.]
1939. [Diseases of citrus fruits in storage.] Sovet. Bot. 1939 (3): 111–115.

(178) Viennot-Bourgin, G., and Brun, J.
1945. Sur la présence du "sour-rot" des agrumes en France. Rev. Bot. Appl. et d'Agr. Trop. 25: 10–15, illus.

(179) Voorhees, R. K.
1943. A comparison of some copper fungicides in controlling citrus melanose. Citrus Indus. 24 (12): 5–8, 14–15, illus.

(180) ———
1944. Investigations of melanose and stem-end rot of citrus fruit. Fla. Agr. Expt. Sta. Ann. Rpt. 1943–44: 188–191, illus.

(181) Wager, V. A.
1942. Pythiaceous fungi on citrus. Hilgardia 14: 535–548, illus.

(182) ———
1946. Preliminary investigations on the black spot disease of citrus. Farming in So. Africa 21: 770–772, illus.

(183) ———
1948. The black spot disease of citrus. Farming in So. Africa 23: 386–390, illus.

(184) WAGER, V. A.
1948. THE DISTRIBUTION OF THE BLACK SPOT FUNGUS IN SOUTH AFRICA. Citrus Grower [So. Africa] No. 174, p. 4, illus.

(185) ———
1949. THE OCCURRENCE OF THE BLACK-SPOT FUNGUS IN THE CITRUS AREAS OF SOUTH AFRICA. Farming in So. Africa 24: 367–369, 374, illus.

(186) WARDLAW, C. W., and LEONARD, E. R.
1939. STORAGE INVESTIGATIONS WITH TRINIDAD GRAPEFRUIT, 1938–39. Trop. Agr. [Trinidad] 16: 208–215, illus.

(187) WEHMEYER, L. E.
1933. THE GENUS DIAPORTHE NITSCHKE AND ITS SEGREGATES. Mich. Univ. Studies, Sci. Ser. v. 9., 349 pp., illus.

(188) WEI, C. T.
1939. STORAGE DISEASES OF SWEET ORANGES IN SZECHUAN. Nanking Jour. (Agr. Sci.) 9: 239–268, illus.

(189) ——— and HU, K. H.
1941. A PRELIMINARY REPORT ON THE CONTROL OF STORAGE ROTS OF SWEET ORANGE. Nanking Jour., Sect. C, 11 (3): 79–102, illus.

(190) WIANT, J. S., and BRATLEY, C. O.
1948. SPOILAGE OF FRESH FRUITS AND VEGETABLES IN RAIL SHIPMENTS UNLOADED AT NEW YORK CITY, 1935–42. U. S. Dept. Agr. Cir. 773, 62 pp.

(191) WINSTON, J. R.
1935. REDUCING DECAY IN CITRUS FRUITS WITH BORAX. U. S. Dept. Agr. Tech. Bul. 488, 32 pp., illus.

(192) ———
1936. A METHOD OF HARVESTING GRAPEFRUIT TO RETARD STEM-END ROT. U. S. Dept. Agr. Cir. 396, 8 pp., illus.

(193) ———
1938. ALGAL FRUIT SPOT OF ORANGE. Phytopathology 28: 283–286, illus.

(194) ———
1948. DECAY OF FLORIDA CITRUS FRUITS AND ITS CONTROL. Citrus Indus. 29 (2): 5–9, 22–23, 26, illus.

(195) ———
1950. HARVESTING AND HANDLING CITRUS FRUITS IN THE GULF STATES. U. S. Dept. Agr. Farmers' Bul. 1763, 67 pp., illus. (Revised.)

(196) ——— BOWMAN, J. J., and BACH, W. J.
1927. CITRUS MELANOSE AND ITS CONTROL. U. S. Dept. Agr. Dept. Bul. 1474, 63 pp., illus.

(197) ——— and MECKSTROTH, G. [A].
1944. DECAY CONTROL IN FLORIDA LEMONS. Citrus Indus. 25 (2): 6–7, 10, 18–19, 22.

(198) ——— MECKSTROTH, G. A., and ROBERTS, G. L.
1948. 2-AMINO-PYRIDINE, A PROMISING INHIBITOR OF DECAY IN ORANGES. Citrus Indus. 29 (3): 5–7, 16–17.

(199) ——— MECKSTROTH, G. A., ROBERTS, G. L., and CUBBEDGE, R. H.[53]
1949. FUNGICIDAL SCREENING TESTS FOR THE CONTROL OF DECAY IN FLORIDA ORANGES. U. S. Bur. Plant Indus., Soils, and Agr. Engin., H. T. & S. Off. Rpt. 201, 26 pp. [Processed.]

(200) ——— and ROBERTS, G. L.
1945. EFFECT OF CERTAIN PACKING HOUSE PRACTICES ON DECAY, RIND BREAKDOWN AND JUICE QUALITY OF FLORIDA ORANGES. Citrus Indus. 26 (3): 10, 14–15, 22.

(201) WOGLUM, R. S., and LEWIS, H. C.
1941. GRAPEFRUIT DAMAGE FROM SEPTORIA. Calif. Citrog. 26: 367, 394, illus.

---

[53] Available generally only in the larger libraries of the country.

INSECT DAMAGE AFFECTING MARKET QUALITY

Insect damage to citrus fruit occurs almost entirely in the growing crop. With few exceptions all the control measures are applied in the orchard, but discolorations, russeting, and deformities of the fruit caused by mites and thrips, the presence of scale on the fruit, and scars left by chewing insects lower the market grade and result in reduced prices. In the lower Rio Grand Valley in Texas the presence of the Mexican fruit fly makes it necessary to treat the fruit at certain times of the year before it may be shipped in interstate commerce.

Rose and others (*7*) [54] in 1943 described the damage, as it appears on the market, caused by scales, citrus rust mite, thrips, chewing insects, and larvae of the orange tortrix. Further information on these and other insect pests of citrus may be found in the excellent reports by Watson and Berger (*10*), Quayle (*5, 6*), A. M. Boyce in volume 2 of "The Citrus Industry" (*1, ch. 14*), and Ebeling (*3*). Much of the recent literature is cited by Boyce. Papers not cited by Boyce which are of interest are the thesis by Bedford (*2*) in 1943 on the biology and economic importance of the citrus thrips in the Union of South Africa, the circular by McGregor (*4*) in 1944 on the citrus thrips, and the recently published Farmers' Bulletin by Spencer and Osburn (*8*) on the citrus rust mite.

Directions for the vapor-heat and the low-temperature treatments of grapefruit and oranges required by the Mexican fruit fly quarantine were published in the Service and Regulatory Announcements series of the United States Bureau of Entomology and Plant Quarantine in 1941 (*9*).

LITERATURE CITED FOR INSECT DAMAGE AFFECTING MARKET QUALITY

(1) Batchelor, L. D., and Webber, H. J., editors.
1948. THE CITRUS INDUSTRY. VOLUME II. PRODUCTION OF THE CROP. 933 pp., illus. Berkeley and Los Angeles.

(2) Bedford, E. C. G.
1943. THE BIOLOGY AND ECONOMIC IMPORTANCE OF THE SOUTH AFRICAN CITRUS THRIPS, SCIRTOTHRIPS AURANTII FAURE. Pretoria Univ. Ser. II: Nat. Sci. No. 7, 68 pp., illus. Pretoria. (Thesis, M. A.).

(3) Ebeling, W.
[1950.] SUBTROPICAL ENTOMOLOGY. 747 pp., illus. San Francisco.

(4) McGregor, E. A.
1944. THE CITRUS THRIPS, MEASURES FOR ITS CONTROL, AND THEIR EFFECT ON OTHER CITRUS PESTS. U. S. Dept. Agr. Cir. 708, 12 pp., illus.

(5) Quayle, H. J.
1938. INSECTS OF CITRUS AND OTHER SUBTROPICAL FRUITS. 583 pp., illus. Ithaca, New York.

[54] Italic numbers in parentheses refer to Literature Cited for Insect Damage Affecting Market Quality.

(6) QUAYLE, H. J.
1941. CONTROL OF CITRUS INSECTS AND MITES. Calif. Agr. Col. Ext. Cir. 123, 31 pp., illus.

(7) ROSE, D. H., BROOKS, C., BRATLEY, C. O., and WINSTON, J. R.
1943. MARKET DISEASES OF FRUITS AND VEGETABLES: CITRUS AND OTHER SUBTROPICAL FRUITS. U. S. Dept. Agr. Misc. Pub. 498, 57 pp., illus.

(8) SPENCER, H., and OSBURN, M. R.
1950. CONTROL OF THE CITRUS RUST MITE. U. S. Dept. Agr. Farmers' Bul. 2012, 8 pp., illus.

(9) UNITED STATES BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE.
1941. ANNOUNCEMENTS RELATING TO MEXICAN FRUITFLY QUARANTINE (NO. 64). U. S. Bur. Ent. and Plant Quar., Serv. and Regulat. Announc. 148, pp. 73–74.

(10) WATSON, J. R., and BERGER, E. W.
1937. CITRUS INSECTS AND THEIR CONTROL. Fla. Univ. Agr. Ext. Bul. 88, 135 pp., illus. (Revision of Bul. 67.)

☆U. S. GOVERNMENT PRINTING OFFICE : 1951 890503

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C.—Price 40 cents