13. Swanson, M. R., W. M. Walker, and T. R. Peck. 1970. Relationship between corn yield and chemical composition of ear leaf measured with different regression models. *Soil Sci. Plant Anal.* 1:123-130.
14. Tyler, G. 1976. Soil factors controlling metal ion absorption in the wood anemone *Anemone nemorosa*. *Oikos* 27:71-80.
15. Walker, W. M. and J. Pesek. 1963. Chemical composition of Kentucky bluegrass *(Poa pratensis)* as a function of applied nitrogen, phosphorus, and potassium. *Agron. J.* 55:247-250.
16. ——————, T. R. Peck, and S. G. Carmer. 1969. Relationship between soybean yields and leaf levels of 10 elements determined with different regression models. *Agron. J.* 61:413-416.
17. ——————, R. D. Voss, and T. R. Peck. 1971. Relationship between corn leaf composition and high and low yield levels. *Soil Sci. Plant Anal.* 2:389-397.
18. Worley, R. E., D. A. Hegwood, and S. A. Harmon. 1971. Effect of nitrogen, phosphorus, and potassium on yield and leaf analysis of southern pea. *J. Amer. Soc. Hort. Sci.* 96:532-533.

J. Amer. Soc. Hort. Sci. 104(6):751–754. 1979.

Losses in Fresh Tomatoes at the Retail and Consumer Levels in the Greater New York Area[1]

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Additional index words. wastage, marketing, diseases, decay, physiological disorders, injuries

Abstract. **Parasitic diseases were the main cause of losses at retail and consumer levels in fresh tomatoes (*Lycopersicon esculentum* Mill.) marketed in Greater New York in 1974-1977. Losses at the retail level (LRL) were 6.3 and 6.7% in prepackaged and loose fruits, respectively, and losses in consumer samples (LCL) were 7.9 and 4.7%, respectively. More than 60% of the LRL and 80% of the LCL resulted from diseases, principally alternaria, rhizopus, and gray mold rots and bacterial soft rot. Physical injuries and physiological disorders caused the remaining losses, the former being considerably more damaging.**

The fresh tomato is a leading produce commodity in tonnage and value in retail markets (8). From 63-73 thousand metric tons of fresh tomatoes are delivered annually to the Greater New York market for consumption by 18,000,000 area residents (10). Florida, California, and Mexico supply 70 to 75% of the fresh tomatoes for this market, and other southeastern and eastern states supply most of the remainder. Truck shipments have increased in recent years while rail shipments have declined. Tomatoes from distant domestic producing areas normally are in transit from 2 to 4 days when shipped by truck and almost twice that long when transported by rail. Mexican tomato shipments are transported by both means and may be in transit a week or longer.

While intensive research has been devoted towards improving fresh tomato quality (2, 3), very little has been published on actual losses of fresh tomatoes; and what has been reported is outdated. Federal inspectors found a 4 to 6% loss in fresh tomato rail arrivals at Pittsburgh during 1957-1961 (9). Friedman (1) reported a 7% tomato retailing loss by a large food chain organization in 1956. Miller (7) found a 7% kitchen loss in a 1934 survey of tomato losses from disease in Knoxville, Tennessee. Losses in ripening and repacking rooms were estimated to be 10 to 12% in 1965 (9). A trade publication reported that up to one quarter of all tomatoes shipped are lost in marketing channels (8).

Because of such limited and outdated information, a 3-year study was conducted in the Greater New York area to obtain a more comprehensive and up-dated account of the nature and extent of losses in fresh tomatoes after they arrive in terminal markets. We believe that the findings for this large market area will be applicable to other large markets receiving tomatoes from all parts of the country. The results of this study could then be used by researchers and the trade to develop realistic guidelines towards the goal of reducing losses and improving the quality of tomatoes purchased by consumers.

Materials and Methods

Tomatoes retailed loose or prepackaged were studied every week in 8 Greater New York supermarkets for 3 years, starting in October, 1974. At least 2 stores each in low, middle, and high income areas cooperated in the study. Florida supplied the selected stores with 57.2% of the prepackaged and 46.8% of the loose-packaged fruits during the study. California followed with 16.7% prepackaged and 23.9% loose; Mexico, with 9.6% prepackaged and 13.0% loose; other domestic states, 10.1% prepackaged and 10.7% loose; unknown sources, 6.4% prepackaged and 4.6% loose; and Ohio, 1.0% loose fruits that were greenhouse-grown.

The loose tomatoes were delivered to the stores in jumble-packed 10-, 20-, 25-, or 30-lb. (4.5, 9.1, 11.4, or 13.6 kg) fiberboard cartons either directly from growing areas or from terminal market repacking plants. Tomatoes from California and Mexico were frequently delivered in 18- or 20-lb. (8.2 or 9.1 kg) wooden lugs also. A relatively few 8-lb. (3.6 kg) baskets from Ohio and some half-bushel baskets from nearby farms were also delivered. The prepackaged tomatoes arrived at the stores in 9-, 10-, or 12-oz (255, 284, or 340 g) consumer packages, 30 to a master fiberboard container. Each package consisted of an oblong, open-frame plastic tray, in which 3 or 4 fruits placed in a single row were overwrapped with a plastic film that was heat-sealed but not air tight.

The stores were visited each week, and the percentages of retail losses were based on the volumes displayed and/or sold by our cooperators during 1 to 5 days. The fruits were culled jointly by USDA and store personnel. When the parasitic or physiological causes for culling could not be readily identified in the store, the culled fruits were brought to our laboratory for a more detailed examination. Standard procedures of phytopathology were employed to positively identify such defects.

During the weekly visits, 3 to 5 prepackaged units and/or 6 to 10 loose tomatoes were purchases in each store for the

[1]Received for publication March 22, 1979.
The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper must therefore be hereby marked *advertisement* solely to indicate this fact.

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purpose of determining the nature and extent of losses consumers normally would experience. Not all of the stores retailed both loose and prepackaged fruits simultaneously. The samples were brought to our laboratory and held at room temperature (19-21°C) until ripe. Most fruits usually ripened within 3 days; a few required up to 6 days. The tomatoes were examined daily. Ripe fruits were sized individually by means of a template and grouped into 3 classes by diameter: up to 5.7 cm; 5.7 to 7.0 cm; and more than 7.0 cm. Sound fruits and those with small trimming losses were cut transversely in half and scored for internal bruising damage. Five degrees of internal bruising were scored, based upon the cross-sectional involvement and severity of damage to locular tissue and adjacent walls. Locular tissues were considered damaged when the gelatinous matrix with seeds was slightly discolored or cloudy. The damage was considered severe when the gelatinous tissue was dry and discolored, stringy, or watery and the seeds were displaced from the placenta. We rated fruit damage as follows: 1 = up to 25% of the locular tissues damaged; 2 = up to 25% of the locular tissues severely damaged or 25% to 50% of the locular tissues damaged; 3 = 25 to 50% of the locular tissues severely damaged or 50 to 75% of the locular tissues damaged; 4 = 75% of the locular tissues severely damaged or 75 to 100% of the locular tissues damaged; 5 = 75 to 100% of the locular tissues severely damaged.

Results and Discussion

About 12,900 kg (159,000 fruits) of prepackaged and 19,400 kg (120,900 fruits) of loose tomatoes were displayed or sold during our 3-year test in retail stores. Of the latter fruit, 45% was not repacked but delivered to stores directly from producing areas or after passing through a food-chain's distribution center. Retail losses (LRL) in prepackaged and loose fruits were 808 kg and 1,298 kg, respectively. Parasitic diseases, mainly rots, caused 2/3 of the LRL of the former and almost 3/5 of the LRL of the latter fruits (Table 1). Mechanical injuries, field scars, and freezing damage were responsible for 24 and 30% of the LRL in prepackaged and loose fruits, respectively. Non-parasitic physiological disorders, mainly overripeness, chilling, growth cracks, and internal browning, accounted for the remaining LRL. Much of the LRL in loose tomatoes (62%) came from non-repacked fruit.

The losses in the consumer samples (LCL) were determined from 958 kg (9800 fruits) of prepackaged and 1,055 kg (6,250 fruits) of loose tomatoes. About 80% of the total loss in both kinds of consumer samples was due to disease (Table 1). Of the prepackaged fruits, 26% were defective enough to require trimming; and of these fruits, 2 in 3 were diseased. Trimming was necessary for 30% of the loose tomatoes, and disease was involved in 55% of those trimmed. Physical injuries and physiological disorders accounted for almost 15 and 5%, respectively, of the LCL in prepackaged and loose fruits. Excluding overripeness, these defects were similar to, but individually less damaging than those affecting retail culls.

Table 1. Wastage of fresh tomatoes in Greater New York retail stores and in consumer samples (1974-1977).

Location of loss and type of packaging	Causes of loss (% by weight) Diseases	Physical injuries	Physiological disorders	Total
Retail				
Prepackaged	4.2ab^{z}	1.5a	0.6a	6.3a
Loose	3.8b	2.0a	0.9a	6.7a
Consumer				
Prepackaged	6.5a	1.1a	0.3a	7.9a
Loose	3.8b	0.7a	0.2a	4.7b

^{z}Mean separation within columns by Duncan's multiple range test, 5% level.

Diseases caused significantly higher losses in the prepackaged than in the loose fruit consumer samples. Some of these diseases probably had their start in the repackaging plant. Infections are ofttimes unnoticed because of their size or position in the tray or by being masked by the film overwrap. Diseased tomatoes in bulk displays are more likely to be culled out by store clerks because of their high visibility and ease of removal. A tomato in the prepackaged tray would have to be obviously rotted to prompt breakage of the package for its removal.

More internal bruising was found in consumer samples of loose tomatoes than in prepackaged tomatoes. The larger size of the loose fruits (over 7.0 cm avg diameter) and bulk retailing made them more vulnerable to mechanical damage than the smaller-sized prepackaged fruits (6.5 cm avg diameter). The internal bruise index was 2.7 for loose tomatoes, averaging 2.4 for Florida fruits and 3.1 for Mexican fruits. The bruise index for prepackaged fruits was less (2.1), averaging 1.9 for Florida fruits and 3.1 for Mexican fruits. About 1% of all tomatoes were sufficiently bruised internally to warrant trimming. While the resultant waste, 0.1 and 0.2% by weight of prepackaged and loose tomatoes, respectively, was insignificant, many of the fruits we judged edible were adversely affected in appearance and flavor by internal bruising. McColloch found that bruising increased with each handling step in marketing and that the deleterious effect of internal bruising on tomato quality is often undetected externally (5).

Retail losses, mostly from disease, were highest for prepackaged tomatoes from the eastern states, and the lowest for Florida fruits (Table 2). Freeze damage and mechanical injuries caused an inordinately high loss (4.0%) in prepackaged fruits from eastern states. Freeze damage was a leading cause of loss due to physical injury in prepackaged fruits from California and unknown sources. The freeze damage resulted from refrigeration breakdowns in stores, delivering tomatoes with frozen foods, exposing unprotected fruits to freezing temperatures outdoors, and the displacement of a few prepackaged units to frozen food displays by thoughtless store patrons.

While no significant differences in disease or LCL in prepackaged tomatoes were found among sources, Florida and California fruits had smaller losses than fruits from the other sources of supply (Table 2). When LRL and LCL are combined, losses approximated 10% in prepackaged tomatoes from Florida and exceeded 17% in the prepackaged fruits from other sources of supply.

Loose tomatoes from Mexico and the eastern states had high LRL (Table 3). Mechanical injuries contributed substantially to these losses, especially to fruits from nearby sources of supply. Tomatoes delivered to stores in bulk from local farms were generally riper than those from other areas, lacked protective packaging, and were thus more vulnerable to mechanical damage.

Disease was the main cause of LCL in loose tomatoes from all sources of supply and these losses were consistently lower than those in consumer samples of prepackaged tomatoes (Table 3). The greatest LCL were found in tomatoes from Mexico, which when combined with LRL were about double the combined losses (LRL plus LCL) of tomatoes from either California, Florida, or Ohio.

LRL and LCL were highest in tomatoes from nearly all sources of supply during the last year of our study. The increase in 1976-77 relative to the respective averages for the previous 2 years was about 50% for LRL and 90% for LCL. A higher disease incidence was mainly responsible for the sharp increases.

Losses in tomatoes from the principal sources of supply, i.e., Florida and California, showed that they differed significantly

Table 2. Greater New York retail store and consumer sample losses in prepackaged tomatoes from various growing areas (1974-1977).

Source	Causes of loss (% by weight)							
	Diseases		Physical injuries		Physiological disorders		Total	
	Retail	Consumer	Retail	Consumer	Retail	Consumer	Retail	Consumer
Florida	2.7b[z]	5.8a	0.6	0.8	0.2	0.2	3.4b	6.8a
California	6.3ab	6.1a	2.9	1.0	1.1	0.1	10.2ab	7.1a
Mexico	4.2ab	8.5a	1.4	1.5	1.2	0.8	6.8ab	10.8a
Eastern States	9.0a	8.4a	4.0	0.5	0.9	0.7	13.9a	9.6a
Unknown	5.2ab	7.1a	2.4	2.7	1.2	0.4	8.8ab	10.3a

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

Table 3. Greater New York retail store and consumer sample losses in loose tomatoes from various growing areas (1974-1977).

Source	Causes of loss (% by weight)							
	Diseases		Physical injuries		Physiological disorders		Total	
	Retail	Consumer	Retail	Consumer	Retail	Consumer	Retail	Consumer
Florida	2.7b[z]	3.8ab	1.6	0.7	0.5	0.2	4.9b	4.8ab
California	3.4ab	2.9ab	1.6	0.3	1.0	0.1	6.0ab	3.3ab
Mexico	7.1a	6.4a	2.7	1.0	1.6	0.3	11.4a	7.8a
Eastern States[y]	5.3ab	2.9ab	3.7	0.9	1.3	0.3	10.3ab	4.1ab
Unknown	3.6ab	3.3ab	1.5	0.6	1.8	<0.1	6.9ab	3.9ab
Ohio[x]	2.2b	1.1b	2.2	0.2	1.4	0	5.8ab	1.3b

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

[y]Included a small quantity of fruit from Arkansas.

[x]Greenhouse-grown fruit.

Table 4. Nature and extent of losses in Florida (FL) and California (CA) tomatoes marketed in Greater New York, 1974-1977.

Nature of loss	Loss (% by weight)							
	Retail				Consumer			
	Pre-packaged		Bulk		Pre-packaged		Bulk	
	FL	CA	FL	CA	FL	CA	FL	CA
Parasitic								
Alternaria rot	1.2	2.6	1.3	1.2	1.4	1.3	1.2	0.8
Bacterial soft rot	0.6	0.9	0.4	0.5	1.9	1.8	1.2	1.0
Rhizopus soft rot	0.5	1.0	0.3	0.2	1.6	1.5	1.0	0.5
Gray mold rot	0.1	0.6	0.1	0.9	0.1	1.0	<0.1	0.5
Anthracnose	0.1	0.3	<0.1	0.1	0.1	0.1	<0.1	0.0
Sour rot	0.1	0.2	0.4	0.1	0.2	0.1	0.2	0.0
Others[z]	0.1	0.7	0.2	0.4	0.5	0.3	0.2	0.1
Subtotal	2.7	6.3	2.7	3.4	5.8	6.1	3.8	2.9
Injuries								
Mechanical	0.3	1.0	0.9	1.0	0.3	0.3	0.2	0.2
Freezing	0.2	1.5	0.5	0.3	0.4	0.5	0.3	0.1
Others[y]	0.1	0.4	0.3	0.3	0.1	0.1	0.2	<0.1
Subtotal	0.6	2.9	1.6	1.6	0.8	1.0	0.7	0.3
Physiological								
Overripe	0.1	0.7	0.2	0.3	<0.1	<0.1	<0.1	<0.1
Chilled	<0.1	0.3	0.2	0.7	0.1	<0.1	0.1	<0.1
Others[x]	0.1	0.1	0.1	<0.1	0.1	<0.1	<0.1	<0.1
Subtotal	0.2	1.1	0.5	1.0	0.2	0.1	0.2	0.1
Total	3.4*	10.2*	4.9	6.0	6.8	7.1	4.8	3.3

*Difference significant at 5% level.

[z]Cladosporium, fusarium, phytophthora, pencillium, phomopsis, and unidentified rots, nailhead spot, early blight, bacterial spot, bacterial necrosis and virus mottling in both states. Additionally, late blight and phoma rot in Florida fruits; pleospora rot in California fruits.

[y]Field scars, insect and chemical injuries.

[x]Internal browning, growth cracks, blossom-end rots, and deformed fruits.

only in the LRL of prepackaged fruits (Table 4) – the LRL were substantially higher for the California tomatoes. The kinds of diseases in prepackaged fruits from both states were essentially the same. Much of the retail loss (LRL) was due to alternaria rot (*Alternaria tenuis* Auct.), bacterial soft rot (*Erwinia carotovora* (L. R. Jones) Holland), and rhizopus soft rot (*Rhizopus stolonifer* (Fr.) Ehr.). Gray mold rot (*Botrytis cinerea* Pers. ex Fr.) also contributed significantly to the loss in California fruits, especially in the fall months. Mechanical injuries, overripeness, and freezing damage that occurred on the market also contributed to the higher retail loss in prepackaged tomatoes from California.

In a recent study (4), California researchers reported that 11% of commercially packed tomatoes were unmarketable at the time they left a California packinghouse for retail sale within the state. Physical damage was the primary defect in the fruits at the packinghouse and in the cullage of the same fruit lots later at retail. Our findings in New York showed rots to be the chief cause of retail loss in prepackaged California tomatoes. The high incidence of physical damage reported by the California workers would account for our findings, since infection of the tomatoes by pathogens is enhanced by physical injuries and long transit times required for transcontinental shipments. However, retail cullage of the loose tomatoes in our study showed insignificant difference between California and Florida fruits. We assume that the vapor pressure was higher within the prepackaged units and therefore more favorable for disease development than the ambient vapor pressures surrounding loose tomatoes in the store.

In our study, California tomatoes were handled by our test stores from June to December, Florida tomatoes from November to June. The marketing season for tomato crops from these states could have profoundly influenced the magnitude of loss sustained by both crops in our tests, especially at retail. Decay and overripeness are more likely to occur during warm or hot marketing periods, and chilling injury to tomatoes marketed in winter. We identified chilling injury principally by the failure of mature tomatoes to ripen properly. Some chilled fruits infected by *Alternaria* were placed in the disease category. Alternaria rot commonly occurs on chilled tomatoes (6).

About 25% of all tomatoes in consumer samples of Florida and California fruits required trimming. In the Florida samples, 15% and 18% of all prepackaged and loose fruits, respectively, were diseased; and the corresponding values for California fruits were 18% and 14%. On most mechanically injured fruits, trimming losses seldom exceeded 10g per fruit. The soft rots, especially rhizopus and bacterial, were generally more extensive and occasionally involved whole fruits. Alternaria rot occurred more frequently but was usually localized and shallow.

By extrapolating our loss data obtained on tomatoes from all sources of supply, annual LRL in Greater New York would range from 4,100 to 4,500 metric tons and the annual LCL would range from 4,300 to 5,000 metric tons. Thus the combined LRL and LCL would range from 8,400 to 9,500 metric tons depending upon the volumes delivered to the Greater New York market in any 1 year (10).

Our data reveal that disease is the greatest contributor to losses of fresh tomatoes on the market. The identification of these diseases and their magnitude indicate that current field disease control measures are generally effective against diseases that formerly caused considerable losses on the market (6). Much of the loss in our study was caused by pathogens that are innocuous in the field. These pathogens inhabit packinghouses, transit vehicles, ripening rooms and wholesale and retail storages. Tomatoes must be physically injured to be invaded by many of these organisms. The decays and the physical damage found in our study indicate that fresh tomatoes are frequently mishandled in marketing channels. To minimize physical injuries and the related losses that ensue, we, like previous researchers (1, 4, 5, 6), emphasize the need for careful handling of tomato fruits at all stages of marketing.

Literature Cited

1. Friedman, B. A. 1960. Market diseases of fresh fruits and vegetables. *Econ. Bot.* 14:145-156.
2. Kader, A. A., L. L. Morris, M. A. Stevens, and M. Albright-Holton. 1978. Composition and flavor quality of fresh market tomatoes as influenced by some postharvest handling procedures. *J. Amer. Soc. Hort. Sci.* 103:6-13.
3. ———— and M. A. Stevens. 1976. Solving the tomato flavor problem. *Western Grower & Shipper* 47(3), p. 6, 7.
4. MacLeod, R. F., A. A. Kader, and L. L. Morris. 1976. Damage to fresh tomatoes can be reduced. *Calif. Agr.* 30:(12):11-12.
5. McColloch, L. P. 1962. Bruising injury of tomatoes. U.S. Dept. of Agr. Mktg. Res. Rpt. 513.
6. ————, H. T. Cook, and W. R. Wright. 1968. Market diseases of tomatoes, peppers, and eggplants. U. S. Dept. Agr., Agr. Handb. 28.
7. Miller, P. R. 1935. Fruit and vegetable losses in market and kitchen caused by plant diseases. *Plant Dis. Rptr.* Supplement 88.
8. Seelig, R. A. 1968. Towards better tomatoes. United Fresh Fruit & Vegetable Assoc. Handb.
9. United States Department of Agriculture. 1965. Losses in agriculture. U. S. Dept. Agr., Agr. Handb. 291.
10. ————. 1975-1978. Fresh fruit and vegetable unloads in eastern cities. U. S. Dept. Agr., AMS, FVUS (1974, 1975, 1976, 1977).

J. Amer. Soc. Hort. Sci. 104(6):754–759. 1979.

Yield Response of Four Fresh Market Tomato Cultivars after Acute Ozone Exposure in the Seedling Stage[1]

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Additional index words. Lycopersicon esculentum, air pollution

Abstract. **Seedlings of 'Fantastic', 'Homestead 24', 'Walter' and 'Heinz 1439' tomato (*Lycopersicon esculentum* Mill.) were exposed to ozone 6 times between the 2nd and 5th week after emergence. Early total, marketable, and U.S. No. 1 yield were reduced when plants were exposed to 40 pphm ozone for 2 hours for all cultivars, except for 'Walter' in one trial. Early marketable yield of the most sensitive cultivar, 'Fantastic', was reduced an average of 14.7 metric tons/ha per year at 40 pphm ozone for 2 hours. Effect on early yield of 10 pphm ozone for 8 hours and 40 pphm for 1 hour was influenced by cultivar and year. Early yield was affected more by ozone concentration than by dose. Season marketable yield was unaffected by early acute ozone fumigation except for 'Homestead 24' at 40 pphm ozone for 2 hours in 1976. Fruit quality and fruit weight were not appreciably influenced by acute ozone exposure.**

Sensitivity to ozone (O_3) has been studied in tomato and within *Lycopersicon* species (1-8). Of 1200 entries from *Lycopersicon esculentum, Lycopersicon pimpinellifolium* (Just.) Mill., *Lycopersicon hirsutum* Hum. & Bonpl. and *Lycopersicon peruvianum* (L.) Mill., 2 cultivars and 4 plant introductions, all from *L. esculentum* were identified by Clayberg (1, 2) as tolerant. Gentile et al (3) found *L. esculentum* was the most tolerant *Lycopersicon* species of 5 tested and *L. pimpinellifolium* was the most sensitive. Most research concerning cultivar sensitivity has involved an evaluation of foliar injury at the 6th leaf stage and older (3).

In a California study involving 11 locations tomato yields decreased as the ambient O_3 dosage increased (6, 7). Tomato yields were also reduced at one location in New York where

[1]Received for publication August 10, 1978. Paper No. 5718 of the Journal Series of the North Carolina Agricultural Research Service, Raleigh.
The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper must therefore be hereby marked *advertisement* solely to indicate this fact.

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[4]The authors express gratitude to Dr. Herbert J. Kirk, formerly Department of Statistics, now of the SAS Institute, Raleigh, N. C. for statistical assistance and to Paul N. Lineberger, Department of Horticultural Science and Tommy N. Gray, Department of Plant Pathology for their technical assistance.