

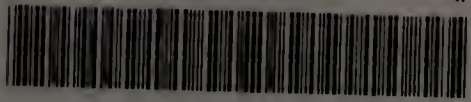


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A comparative evaluation of consumer units for the marketing of nearby grown tomatoes from the viewpoint of the producer, retailer, and consumer.

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A COMPARATIVE EVALUATION OF CONSUMER UNITS FOR THE
MARKETING OF NEARBY GROWN TOMATOES FROM THE
VIEWPOINT OF THE PRODUCER, RETAILER, AND CONSUMER

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OF NEARBY GROWN TOMATOES FROM THE VIEWPOINT OF THE
PRODUCER, RETAILER, AND CONSUMER.

BY

DONALD R. LAMBERT

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE MASTER OF SCIENCE DEGREE IN OLERICULTURE

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A Comparative Evaluation of Consumer Units for the Marketing
of Nearby Grown Tomatoes from the Viewpoint of the
Producer, Retailer, and Consumer.

INTRODUCTION

The prepackaging of vegetables is increasing every year. Consumers are not eating more in terms of pounds (14) but are purchasing more services. This has been made possible in part by a steady growth in real consumer income and technological changes in production and marketing. Local growers must now compete with a greater variety of fresh produce in the market because of these changes.

The phenomenal growth of the "supermarket" owes a great deal to "self-service" and prepackaging. In 1956 (24) supermarkets accounted for 58.9% of all grocery sales. Produce departments in 67% of the supermarkets (1) are fully "self-service" and 33% of all produce is prepackaged. The outlook is for a continued increase in produce packaging. Stokes (35) estimates that 60% of the 1956 fresh tomato crop, sold at retail, was packaged in consumer units.

The first visible packages for food products were made possible with the production of cellophane in 1924. During the next three decades many new films, packages, and methods were introduced into the picture. Today visibility enables consumers to buy tomatoes with confidence because they can

readily determine the quality and condition of the product. In the past, the quality of fresh packaged produce has not been uniform and this has been particularly true with pre-packaged tomatoes.

Local growers are faced with the problem of pre-packaging to meet the requirements of a changing market. To meet the needs of the local producer, packaging methods must be efficient, lend themselves to inexpensive equipment, and demand a minimum amount of skill.

In order to assist local growers with prepackaging problems, this study has been designed to investigate the effect of varying environmental factors such as temperature and ventilation as these relate to quality and shelf-life of prepackaged tomatoes. Plastics and paperboard containers were used in this study. With the paperboard containers, 300 MSAD cellophane, 300 LSAD cellophane, and cellulose acetate films were used for overwraps. The internal atmosphere of the packages was analyzed to determine the effect of varying levels of oxygen and carbon dioxide on tomatoes. A "super-market" in Amherst, Massachusetts, was selected for the consumer test and the study was conducted at the University of Massachusetts.

REVIEW OF LITERATURE

A quick look into the vegetable department of any "supermarket" will make one realize that prepackaging and "self-service" go hand and hand. In addition, prepackaging can increase sales, shelf-life, and profits. The outlook is for increased acceptance of this method of merchandising.

When one considers the variety of consumer packages for marketing tomatoes, he will realize that the search for a better package is a never ending one. Success or failure of any prepackaging venture today depends to a great extent on the selection of the appropriate package. In the prepackaging of fresh produce the observance of such fundamental requirements as temperature, respiration, ventilation, materials, and consumer desires are of basic importance.

Temperature

Early work by Wright, et al., (37) indicated that 55° F. was the lowest temperature at which tomatoes could be held for ripening and still obtain good color and flavor. The effects of chilling were found to be most noticeable with mature green fruits. Normal ripening followed in lots held at a temperature as low as 25° F. for 18 to 21 hours if this was followed by a favorable ripening temperature. Short periods of low temperature exposure tended to slow down the ripening when normal ripening temperatures were applied. Results showed that firm red ripe tomatoes kept best at

55° F. For maximum ripening, 60 to 70° F. was found to be most suitable.

In a later study Wright and Gorman (38) indicated that interior ripening processes are well under way in mature green tomatoes. Poor quality of green wraps, particularly in the winter months, was due to the presence of immature fruit and not to holding temperatures.

Scott's and Hawes' (34) results indicate that a critical range of ripening exists between 55 and 60° F. This agrees with work conducted by Wright, R. C., et al. and Wright and Gorman (38). This work was carried out on pink, medium ripe, and ripe tomatoes held at 32, 38, 45, 55, 72, and 88° F. and checked at 0, 2, 4, 7, 9, 11, and 14 days of storage. Between 45 and 55° F. pink and medium ripe lots showed signs of slow ripening. Color was inhibited at 88° F. and developed most rapidly at 72° F.

In a study by Sayre, et al., (31) (32) it was shown that temperature determines the color of the fruits. The pigments responsible for the color of tomato fruits in various stages of maturity are chlorophyll (green), carotene (yellow), and lycopene (red). Above 86° F. lycopene breaks down and only carotene develops which results in an orange ripe fruit.

Early investigation by Rosa (30) linked the incidence of decay with prolonged exposure to low temperature prior to being placed at normal ripening temperatures. He also noted that less mature fruit was more susceptible to decay as a

result of exposure to low temperature. When held only for 3 to 5 days at 32 to 40° F. little or no increase in decay resulted. Most decay in tomatoes is due to a fungus (2) (39), which develops in tomatoes held below 50° F. for more than 3 to 5 days.

Scott's and Hawes' (34) results support the above (30) (2) (39) and point out that breakdown or decay did not occur in fruits showing color when they were subjected to a period of low temperature. In addition, when tomatoes were subjected to prolonged periods of high or low temperatures, off flavors were noted.

Respiration

Hardenburg, R. E., (21) emphasized that vegetables are living things and therefore carry on processes characteristic of living things. The utilization of oxygen and the evolution of carbon dioxide and heat can not be overlooked. The more perishable a product is the higher the rate of respiration. Refrigeration is the key to slowing this process.

Hardenburg, R. E., (20) states that as soon as the oxygen concentration is reduced from 21% to 1 to 3%, the normal respiration is cut in half. This results in anaerobic respiration with the production of alcohol and carbon dioxide. Carbon dioxide concentration may rise to 20 to 40% and cause the package to swell. Even before the product shows visible signs of breakdown, undesirable flavors and colors have developed which make it unsalable.

Some early studies conducted by Brooks, C., (9) showed that the exchange of gases was made almost entirely through the stem scar of the fruit. The skin of the tomato is practically impermeable to gases. An increase of carbon dioxide was noted in the internal atmosphere along with retarded ripening when the stem scar was sealed with wax proving the impermeability of the tomato skin to gases.

The work of Clendenning, K. A., (12) (13) agrees with the results of Brooks, C., (9) in that the stem scar area is where nearly all the gas exchange takes place. In addition to the inhibition of color development waxing increased the incidence of mold and physiological disorders.

Ventilation

The necessity of ventilation to prevent anaerobic respiration was clearly shown by Hardenburg, R. E., (20) and Platenius, H., (27) in their work. Hardenburg recommended at least two 1/4-inch holes to prevent anaerobic respiration in a film package weighing one to two pounds or less.

Later work by Hardenburg, R. E., (21) showed the importance of ventilation for prepackaged produce. The amount of ventilation was found to be dependent upon the respiration rate. Low temperatures will reduce the amount of ventilation necessary, but low temperatures cannot be depended upon in marketing. It was noted that all films used must be ventilated because they restrict the passage of oxygen. The necessity for ventilation is substantiated by Scott, L. E.,

and J. E. Hawes (34), Claypool, L. L., (11) and Allen, A. S., and N. Allen (8).

Gas Analysis

Some striking results were obtained by Scott, L. E. and S. Tewfik (33) when they analyzed the atmosphere of pre-packaged tomatoes. Packages were stored for four days at 72° F. They contained 500 grams of fruit with an atmospheric volume of 500 to 600 ml. The internal atmosphere of only those packages wrapped in 300 PL cellophane and "Lumarith" were low in carbon dioxide and high in oxygen. (300 PL Cellophane 5.5% carbon dioxide and 12.8% oxygen - "Lumarith" 2.8% carbon dioxide and 15.7% oxygen.) Those packages with "Lumarith" and 300 PL Cellophane did not have any off flavor. The other types of cellophanes tested ranged from a low oxygen content of .4% to a high carbon dioxide level of 18.9% and had a fermented acid taste that made them inedible.

Allen, A. S. and N. Allen (8) conducted some work on mature green, pink and ripe tomatoes along the same lines and obtained similar results. The fact that oxygen permeability of the film is not enough in sealed packages is re-emphasized in this paper.

Types of Films Used

Cellulose acetate and cellophane 300 LSAD are commonly used as film overwraps for tomatoes. In all cases they should be ventilated if they are to be used for fresh produce. The studies of Allen, A. S. and N. Allen (8) and Scott, L. E. and Tewfik (33) support this statement.

Cellophane's limited dimensional stability should not be overlooked. Allen, A. S. and N. Allen (8) stressed the role of fogging and wrinkling in their study and its relationship with film permeability. They also showed that the incidence of mold and decay is higher in films with a low water vapor transmission rate. This can be controlled to a great extent by ventilation.

Acetate's dimensional stability and gas and moisture permeability made it a highly desirable film for fresh produce. Scott, L. E. and Tewfik (33) still believe it is advisable to ventilate cellulose acetate film and not to rely on the permeability of any film. Allen, A. S. and N. Allen (8) also recommend ventilation of cellulose acetate film. The differences in the rate of ripening between non-ventilated and ventilated cellulose acetate packages of mature green tomatoes held at 65 to 75° F. for ten days is clearly shown in their report.

Types of Containers

While in the past most of the packages were of paperboard, plastics are now moving into the field. The demand for full visibility is bringing about changes in paperboard trays to give them more visibility (3). The sizes of packages holding 3, 4, or 5 tomatoes as reported by Robertson, B. C. (29) runs around 115 different sized packages. Investigation has shown that there is a good possibility of establishing a limited number of standard sizes.

Consumer Survey

The growth of packaging in the past few years has been very rapid. Even as late as 1948, Easmussen, P. P. (28) indicated only a small volume of vegetables were being pre-packaged. Gaylord, F., et al., (17) and Hauck, C. W. (22) point to the expanding use of prepackaging and the willingness of the consumer to accept prepackaged produce.

A study of consumer packaging in the Northeast by Godwin, M. R. (18) in 1951 reveals that the reaction of the consumer to prepackaged produce varies from one area to another. He recommends caution in shifting to the pre-packaging of fruits and vegetables. During the summer pre-packaging met with more consumer resistance.

In Texas, Sorensen, H. B., et al., (36) found that there was little variation in sales within a 1 to 7 cent price premium for bulk tomatoes when offered along with packaged tomatoes. At the 7 cent premium per pound the sale of bulk tomatoes dropped only 6% to 34%. This contradicts the idea that package sales would take a great drop as the price differentials with bulk tomatoes were narrowed to 1 cent a pound. Spoilage of bulk tomatoes was found to be three times greater than that of prepackaged tomatoes. (9.4% vs. 2.7%.) In all three income areas (high, low, and medium) sales of packaged tomatoes exceeded bulk sales. Stores in the high income area sold more bulk tomatoes and those in the medium income led in the sale of prepackaged tomatoes.

The role of visibility in promoting sales is emphasized in a report by Hauck, C. W. (22) in which he ranked inadequate visibility third in order of frequency of complaints by consumers. Lee, W. A. (25) also reported that despite a three cent premium for tomatoes offered in transparent plastic tubes it was found that they sold more readily than tomatoes in paperboard tubes with less visibility.

A Du Pont survey in 1951 (4) again indicated the importance of visibility when it revealed that 36% of all housewives liked to inspect their purchases because they lacked confidence in prepackaged produce. The 1955 Du Pont survey (6) re-emphasized the importance of visibility. "Of all cellophane packaged items purchased 77.3% were as a result of store decisions as compared to 70.8% for all items in all types of packages." In another consumer survey by Du Pont (5) in 1956 around 52% preferred prepackaged produce as compared with 45% in 1950. It also showed that 46% preferred bulk tomatoes and 44% preferred prepackaged tomatoes.

MATERIALS AND METHODS

Tomatoes for this experiment were obtained from three sources. Some red ripe, prepackaged, shipped in tomatoes were purchased in a local market for some of the early work. Later greenhouse tomatoes were obtained from the Olericulture Department greenhouse. When field tomatoes were ready they were used for the remainder of the tests. No attempt was made to select one variety for this experimental work.

In this study three stages of maturity were utilized. (35) These were the mature green, turning tomato or "breaker," and the firm, ripe tomato. A mature green tomato is characterized by a heightened gloss without red color, less hairiness, the development of a jelly-like substance in the locules, and seeds that are hard enough to be pushed aside and not cut by a sharp knife in slicing. "The turning tomato or "breaker" shows from a trace of yellow or red color around the blossom (stylar) end up to 50 per cent color." A firm, ripe tomato is well colored but not at optimum ripeness.

Temperature

Two different temperatures were maintained for this experimental work. Those tomatoes subjected to room temperature were held at 70° F. and direct sunlight was prevented from reaching the tables on which the packaged tomatoes were placed. To keep a check on the temperature a Dickson Minicorder (Type 1-II) with a temperature range of 0 - 100° F.

was used. This instrument recorded temperatures for seven day periods. A mechanically refrigerated walk-in box maintained from 55 to 60° F. was also used in this study.

Since the respiration rate of red ripe tomatoes at 60° F. may increase five fold over those held at 40° F., it was decided to check the temperature of prepackaged tomatoes with thermocouples. (39) Four wires were inserted into one tomato in each of four packages. Open bottom, cushion tubes and standard paperboard tubes overwrapped with 300 LSAD and 300 MSAD cellophane and cellulose acetate were checked. Similar tests were also carried out with molded plastic trays. The thermocouples were placed in the blossom end near the surface, in the shoulder near the surface, in the side near the surface, and in the center to determine the hot spot.

Containers

The following containers were used in these tests:

1. Rectangular packages with a transparent window.
2. Clear plastic tubes made of "Polyflex."
3. Molded plastic trays.
4. Open bottom cushion tubes.
5. Larger overwrap trays holding two pounds.

The adaptability of these containers in meeting the needs of local growers was investigated. Cushioned open-bottom tubes, overwrapped with 300 LSAD and 300 MSAD cellophane and

cellulose acetate were used in the gas analysis determinations. These tests were carried out when the tomatoes had reached the red ripe stage. Both ventilated and non-ventilated packages of tomatoes were tested after ripening at room temperature or in the refrigerated box. The rate of ripening, amount of condensation, condition of the package and film, tomato quality and flavor were noted in one series of tests.

Gas Analysis

A "Haldane-Type" gas analysis apparatus (7) (19) (15) (16) was used to determine the level of carbon dioxide and oxygen. A 10% solution of potassium hydroxide (23) was used to absorb the carbon dioxide. Potassium pyrogallate (26) to absorb oxygen was produced by first mixing 300 grams of potassium hydroxide to 200 cc. of water. This should give a solution with a specific gravity of 1.55. To each 100 cc. of the concentrated alkali, 15 grams of pyrogallic acid were added. Mineral oil was used to protect the solutions from atmospheric air.

Packages to be tested were opened under a solution of calcium chloride (26) with a specific gravity of 1.44. In this solution carbon dioxide is only 1/16th as soluble as in water. The gas was collected under an inverted funnel submerged in the solution. The gas then displaced the solution from an inverted test tube that was placed over the end of the funnel but under the surface of the solution. A rubber

stopper, with connections of glass and rubber tubing, was then inserted in the test tube under the surface of the solution. The collected atmosphere was removed from the test tube by lowering the mercury column. Another solution of calcium chloride flowed into the test tube containing the gas sample as each sample was withdrawn.

The apparatus was flushed three times with the sample gas before a test was conducted on any sample. In determining the concentration of carbon dioxide and oxygen, the gas sample was passed through the respective solutions until two successive readings did not differ.

Consumer Survey

The consumer test was run for approximately two weeks. A "supermarket" in Amherst, Massachusetts, was chosen to indicate consumer reaction to the packages displayed. Open bottom cushion tubes with a 300 LSAD cellophane overwrap and molded plastic trays holding four tomatoes were put on display. A molded pulp tray with a cellophane overwrap used by the store was also on sale at the same time. Approximately 25 packages of each type were maintained in the display at all times.

The three packages used in this test were sold at three different prices. The molded plastic tray sold at 19¢ per package, the cushion tube for 17¢ per package, and the store trays at 15¢ per pound. The cushion tube and molded plastic tray contained approximately a pound of tomatoes.

The tomatoes were checked each day to maintain the display and any packages that showed signs of overmaturity were removed.

RESULTS

Hot Spot

The temperature in the center of the tomato was never more than one or two degrees Fahrenheit below room temperature and then followed room temperature very closely. The position of the tomato in a four-tomato package did not have any influence on the temperatures recorded. Any tomato in the packages used would give a reliable indication of temperature fluctuation in the packages.

Containers

Some of the larger overwrap trays holding two pounds of tomatoes could be used satisfactorily without an overwrap. It was found that colored adhesive tapes could be used to keep the tomatoes in the containers.

Clear plastic tubes made of "Polyflex" (Plax Corp.) were investigated. These tubes develop a permanent crease if they are compressed tightly in the master shipping container. If this material was purchased by the roll and made into packages on the farm, it would be too time consuming. If the cementing is done carelessly the result is an unattractive smeared unit.

Condensation in the plastic tube often obscured visibility of the tomatoes. Punching holes in the tubes for more ventilation was not completely satisfactory.

A rectangular package with a transparent window proved to be unsatisfactory because the interlocking paperboard ends made the reuse of this container impossible once it was opened.

The molded plastic tray was easily and cheaply assembled. A stapler was the only equipment needed to seal the package. Sufficient ventilation was provided through the seam in the package to allow proper ripening and prevent the production of off flavors. The level of carbon dioxide and oxygen in this package was found to be the same as the atmospheric level. In this study condensation was not a problem with this package.

Open bottom cushion tubes were found to be difficult and slow to wrap (300 LSAD and 300 MSAD cellophane and cellulose acetate) by hand methods. It was found that two $\frac{1}{4}$ -inch holes for ventilation were necessary to promote proper ripening and prevent the development of off flavors.

Gas Analysis I

Table I gives the results of the gas analysis for mature green tomatoes held for fourteen days at 70° F. All of the packages that were ventilated showed normal ripening and were in the firm, red ripe stage at the end of fourteen days. In all of the non-ventilated packages an off flavor

TABLE I

Concentration of Oxygen and Carbon Dioxide in Packages of
Mature Green Tomatoes Held for Fourteen Days at 70° F.

Type of Film	Ventilation	Percent Carbon Dioxide	Percent Oxygen
300 LSAD	Yes	0.4	20.6
300 LSAD	Yes	0.4	20.8
300 LSAD	Yes	0.4	20.8
Average		<u>0.4</u>	<u>20.7</u>
300 LSAD	No	7.1	5.5
300 LSAD	No	5.4	3.8
300 LSAD	No	14.1	1.0
Average		<u>8.8</u>	<u>3.4</u>
300 MSAD	Yes	0.4	20.8
300 MSAD	Yes	0.4	20.7
300 MSAD	Yes	0.4	20.8
Average		<u>0.4</u>	<u>20.8</u>
300 MSAD	No	13.9	6.4
300 MSAD	No	12.3	9.4
300 MSAD	No	9.7	11.4
Average		<u>11.9</u>	<u>9.0</u>
Cellulose Acetate	Yes	0.4	20.7
Cellulose Acetate	Yes	0.4	20.8
Cellulose Acetate	Yes	0.4	20.5
Average		<u>0.4</u>	<u>20.6</u>
Cellulose Acetate	No	1.3	19.9
Cellulose Acetate	No	5.4	11.3
Cellulose Acetate	No	3.2	11.6
Average		<u>3.2</u>	<u>11.6</u>

could be detected. Even those in the non-ventilated cellulose acetate packages were slightly off flavored when compared to those in the ventilated cellulose acetate packages.

The 300 LSAD cellophane film showed some wrinkling that detracted from the appearance of the package. Those units with 300 MSAD cellophane showed slightly more wrinkling. The appearance of the cellulose acetate was superior to both of the other films.

The only package in the 300 LSAD cellophane group showing color contained 7.1% carbon dioxide and 5.5% oxygen. The other two packages in the group showed no sign of color. These two were mottled and some mold was developing on the stem scar.

With non-ventilated 300 MSAD cellophane film only one package of tomatoes was beginning to color with the concentration of oxygen at 11.4% and carbon dioxide at 9.7%. In the other two units the tomatoes were still green.

Tomatoes in only one of the non-ventilated cellulose acetate units were colored unevenly. (Oxygen at 11.3% and carbon dioxide at 5.4%). The tomatoes in the other two packages were evenly colored. Table I shows that the last two packages mentioned had a lower concentration of carbon dioxide and a higher oxygen concentration.

Gas Analysis II

In Table II the results of the gas analysis for mature green tomatoes held for 31 days at 55 to 60° F. are

TABLE II

Concentration Of Oxygen and Carbon Dioxide in Packages of Mature Green Tomatoes Held for Thirty-one Days at 55 to 60° F.

Type of Film	Ventilation	Percent Carbon Dioxide	Percent Oxygen
300 LSAD	Yes	0.4	20.8
300 LSAD	Yes	0.4	20.8
300 LSAD	Yes	0.4	20.6
Average		0.4	20.7
300 LSAD	No	1.3	18.9
300 LSAD	No	1.7	18.5
300 LSAD	No	2.1	18.0
Average		1.7	18.5
300 MSAD	Yes	0.4	20.7
300 MSAD	Yes	0.4	20.5
300 MSAD	Yes	0.4	21.0
Average		0.4	20.7
300 MSAD	No	3.7	17.4
300 MSAD	No	5.1	15.6
300 MSAD	No	6.7	13.9
Average		5.2	15.6
Cellulose Acetate	Yes	0.4	20.9
Cellulose Acetate	Yes	0.4	20.8
Cellulose Acetate	Yes	0.4	20.8
Average		0.4	20.8
Cellulose Acetate	No	1.3	19.3
Cellulose Acetate	No	1.3	19.8
Cellulose Acetate	No	1.7	19.2
Average		1.4	19.4

given. In this test the 300 MSAD cellophane was unsatisfactory because of the development of condensation and the slackness of the film.

Only the ventilated acetate packages developed an even red color. In these packages the oxygen and carbon dioxide levels were normal but the tomatoes had a noticeable off flavor. Non-ventilated cellulose acetate containers had tomatoes with a yellow-green color. Table II shows that the level of oxygen and carbon dioxide is not normal. (Normal oxygen 20.9% and carbon dioxide 0.03%.)

All the packages with 300 LSAD were slack and condensation was evident but not as serious as the packages wrapped with 300 MSAD cellophane. Ventilating packages developed a light pink color on the blossom end. Tomatoes in units without ventilation were unevenly colored.

Units wrapped with 300 MSAD cellophane had tomatoes with mold growing on the stem scar. They also were unevenly colored. The tomatoes developed a color ranging from a yellow-green to a pale pink on the blossom end. One package contained tomatoes that were much greener and Table II reveals that this package had the highest carbon dioxide level and the lowest oxygen level (carbon dioxide 6.7% and oxygen 13.9%).

Gas Analysis III

Table III presents the results of the gas analysis for oxygen and carbon dioxide in packages of turning (or

TABLE III

Concentration of Oxygen and Carbon Dioxide in Packages of Turning (or "Breaker") Tomatoes Held for Five Days at 70° F.

Type of Film	Ventilation	Percent Carbon Dioxide	Percent Oxygen
300 LSAD	Yes	2.8	18.4
300 LSAD	Yes	1.6	19.6
300 LSAD	Yes	2.2	19.4
Average		<u>2.2</u>	<u>19.1</u>
300 LSAD	No	12.3	2.1
300 LSAD	No	16.7	1.1
300 LSAD	No	15.1	1.4
Average		<u>14.7</u>	<u>1.5</u>
300 MSAD	Yes	0.8	20.9
300 MSAD	Yes	1.3	20.2
300 MSAD	Yes	1.3	20.4
Average		<u>1.1</u>	<u>20.5</u>
300 MSAD	No	20.8	2.5
300 MSAD	No	21.3	3.3
300 MSAD	No	19.5	3.7
Average		<u>20.5</u>	<u>3.2</u>
Cellulose Acetate	Yes	0.5	20.3
Cellulose Acetate	Yes	0.5	20.9
Cellulose Acetate	Yes	0.5	20.8
Average		<u>0.5</u>	<u>20.7</u>
Cellulose Acetate	No	7.0	10.0
Cellulose Acetate	No	9.6	9.6
Cellulose Acetate	No	9.0	7.3
Average		<u>8.5</u>	<u>9.0</u>

"breaker") tomatoes held for five days at 70° F. Both 300 LSAD cellophane and cellulose acetate were free from wrinkling but the 300 MSAD cellophane showed slight wrinkling. The tomatoes in all ventilated packages were well colored. Only the non-ventilated units presented an off flavor problem.

Some of the ventilated packages showed signs of yellow mottling but otherwise these tomatoes had a good red color. The tomatoes in non-ventilated units were poorly colored and had an orange tint.

When a non-ventilated 300 MSAD cellophane film was used as an overwrap the tomatoes did not develop any color. The green tomatoes had a mottled appearance and there was some evidence of mold on the stem scar. The ventilated packages did develop an even, red color.

The packages with ventilated cellulose acetate produced tomatoes that were red and evenly colored. The tomatoes in non-ventilated units were red but did show some greenish-yellow mottling. A look at the concentration of oxygen and carbon dioxide in Table III indicates the reason for this development.

Gas Analysis IV

Table IV shows the concentration of oxygen and carbon dioxide in packages of turning (or "breaker") tomatoes held for seventeen days at 55 to 60° F. In this test only cellulose acetate film was free of serious wrinkling. Both of the cellophane films were seriously wrinkled. Tomatoes in

TABLE IV

Concentration of Oxygen and Carbon Dioxide in Packages of Turning (or "Breaker") Tomatoes Held for Seventeen Days at 55 to 60° F.

Type of Film	Ventilation	Percent Carbon Dioxide	Percent Oxygen
300 LSAD	Yes	0.4	20.1
300 LSAD	Yes	0.4	20.8
300 LSAD	Yes	0.4	20.8
Average		<u>0.4</u>	<u>20.6</u>
300 LSAD	No	2.5	15.8
300 LSAD	No	2.9	11.6
300 LSAD	No	2.9	15.1
Average		<u>2.8</u>	<u>14.1</u>
300 MSAD	Yes	0.4	20.5
300 MSAD	Yes	0.4	20.6
300 MSAD	Yes	0.4	20.8
Average		<u>0.4</u>	<u>20.6</u>
300 MSAD	No	7.5	10.0
300 MSAD	No	5.4	15.0
300 MSAD	No	8.1	10.2
Average		<u>7.0</u>	<u>11.7</u>
Cellulose Acetate	Yes	0.4	20.7
Cellulose Acetate	Yes	0.4	20.7
Cellulose Acetate	Yes	0.3	20.6
Average		<u>0.4</u>	<u>20.7</u>
Cellulose Acetate	No	2.1	18.0
Cellulose Acetate	No	2.6	16.2
Cellulose Acetate	No	2.1	18.3
Average		<u>2.3</u>	<u>17.5</u>

all of the ventilated packages were well colored. The flavor of the tomatoes in the ventilated packages was superior to the non-ventilated units. Off flavors were noticeable in all non-ventilated packages.

Condensation was very heavy on packages of tomatoes overwrapped with 300 LSAD cellophane. This was found in both ventilated and non-ventilated units. The condensation had moistened the paperboard containers to the point where they were soft and the glued surfaces were separating. Close inspection of tomatoes in these packages was impossible because of condensation. Mold was also starting to grow on the stem scars of tomatoes in ventilated and non-ventilated packages. Tomatoes in non-ventilated units were not as well colored as those in ventilated packages. The stem end of most of the tomatoes in the non-ventilated packages was still green.

Those units overwrapped with 300 MSAD cellophane were also covered with condensation on their inner surfaces. These paperboard containers were soft and separated like those wrapped with 300 LSAD cellophane. Molds were found on the stem scar of the tomatoes in both ventilated and non-ventilated packages. Ripening had advanced only slightly in the non-ventilated packages.

The cellulose acetate film was by far the best appearing film. No sign of condensation was evident in ventilated and non-ventilated packages. The tomatoes were well colored

in the ventilated units but there was some evidence of slight mottling of the tomatoes in the non-ventilated packages. The extent of this mottling was negligible and would not detract from its salability.

Gas Analysis V

The concentration of oxygen and carbon dioxide in packages of red ripe tomatoes held for five days at 70° F. is shown in Table V. All the tomatoes held at this temperature (70° F.) were overripe. The three types of film used (300 MSAD and 300 LSAD cellophane and cellulose acetate) were free from wrinkling in both ventilated and non-ventilated packages. Condensation was not a problem in any of the units.

Fruits in non-ventilated units of 300 LSAD and 300 MSAD cellophane had developed some soft spots. Only one package of tomatoes wrapped in cellulose acetate showed any soft spots.

Gas Analysis VI

Table VI gives the concentration of carbon dioxide and oxygen in packages of red ripe tomatoes held for five days at 55 to 60° F. At this lower temperature range all of the tomatoes were in excellent condition. None of these tomatoes developed soft spots.

Cellulose acetate film was the best appearing film of the group. A slight amount of fogging developed in both the ventilated and non-ventilated packages wrapped with

TABLE V

Concentration of Oxygen and Carbon Dioxide in Packages of
Red Ripe Tomatoes Held for Five Days at 70° F.

Type of Film	Ventilation	Percent Carbon Dioxide	Percent Oxygen
300 LSAD	Yes	0.4	20.5
300 LSAD	Yes	0.4	20.8
300 LSAD	Yes	0.4	20.8
Average		<u>0.4</u>	<u>20.7</u>
300 LSAD	No	8.4	4.6
300 LSAD	No	8.4	5.9
300 LSAD	No	5.5	15.3
Average		<u>7.6</u>	<u>8.6</u>
300 MSAD	Yes	0.4	20.6
300 MSAD	Yes	0.4	20.8
300 MSAD	Yes	0.4	20.8
Average		<u>0.4</u>	<u>20.7</u>
300 MSAD	No	12.3	8.8
300 MSAD	No	13.2	6.8
300 MSAD	No	17.9	3.8
Average		<u>14.5</u>	<u>6.5</u>
Cellulose Acetate	Yes	0.4	20.7
Cellulose Acetate	Yes	0.4	20.6
Cellulose Acetate	Yes	0.4	20.9
Average		<u>0.4</u>	<u>20.7</u>
Cellulose Acetate	No	1.3	19.8
Cellulose Acetate	No	4.6	13.7
Cellulose Acetate	No	5.1	13.5
Average		<u>3.6</u>	<u>15.6</u>

TABLE VI

Concentration of Oxygen and Carbon Dioxide in Packages of
Red Ripe Tomatoes Held for Five Days at 55 to 60° F.

Type of Film	Ventilation	Percent Carbon Dioxide	Percent Oxygen
300 LSAD	Yes	0.4	20.5
300 LSAD	Yes	0.4	20.8
300 LSAD	Yes	0.4	20.8
Average		<u>0.4</u>	<u>20.7</u>
300 LSAD	No	2.9	13.8
300 LSAD	No	2.9	11.3
300 LSAD	No	3.0	12.0
Average		<u>2.9</u>	<u>12.3</u>
300 MSAD	Yes	0.4	20.5
300 MSAD	Yes	0.4	20.6
300 MSAD	Yes	0.4	20.5
Average		<u>0.4</u>	<u>20.5</u>
300 MSAD	No	4.2	16.5
300 MSAD	No	4.6	16.7
300 MSAD	No	5.1	16.5
Average		<u>4.7</u>	<u>16.6</u>
Cellulose Acetate	Yes	0.4	20.8
Cellulose Acetate	Yes	0.4	20.7
Cellulose Acetate	Yes	0.4	20.5
Average		<u>0.4</u>	<u>20.6</u>
Cellulose Acetate	No	0.4	20.7
Cellulose Acetate	No	1.7	19.0
Cellulose Acetate	No	1.2	20.1
Average		<u>1.1</u>	<u>20.0</u>

cellulose acetate, but it did not restrict visibility.

Cellulose acetate film was again free of wrinkling.

The packages wrapped with 300 LSAD cellophane showed some wrinkling, giving the packages a slack appearance. Both ventilated and non-ventilated packages had a little more condensation than the cellulose acetate packages.

The packages with 300 MSAD cellophane developed enough fogging to restrict visibility. Wrinkling developed to such an extent that it detracted from the appearance of the package.

Consumer Survey

The following results were obtained regarding consumer reaction to three different types of packages in a local "supermarket" in Amherst, Massachusetts:

1. That the consumer associates both the molded plastic tray and the open bottom cushion tube with shipped-in tomatoes.
2. Sales of tomatoes in molded pulp trays with cellophane overwrap were four times as great as the other two combined (molded plastic tray and open bottom cushioned tube).
3. Increased sales of the open bottom tube and the molded plastic tray, near the end of the test, indicated a growing acceptance of these types of containers by the consumer.

DISCUSSION

The fact that the temperature of prepackaged tomatoes did not rise above room temperature is due to their relatively low respiration rate. Red ripe tomatoes were used in determining the hot spot because of their higher respiration rate. In a study by Wright, et al., (39) a table listing the heat evolved due to respiration at different temperatures gives an indication of what to expect.

This study shows the need for ventilation of prepackaged tomatoes and agrees with the results of other workers (8) (33) (20). Even at the lower temperature range (55 to 60° F.) tomatoes develop off flavors, mold, and ripening is retarded.

The results of the gas analysis agrees with work done by Allen and Allen (8) and Scott and Tewfik (33). The high concentration of carbon dioxide and low concentration of oxygen developed faster at higher temperatures (70° F.). Low temperatures (55 to 60° F.) slowed the above changes in the internal atmosphere of the packages but could not be relied upon to keep atmospheric changes in non-ventilated packages from eventually affecting the quality of the tomatoes. On the basis of this study it would be advisable to provide ventilation even for cellulose acetate film which has a high gas permeability. Low temperature cannot be relied upon in marketing to prevent these undesirable changes from taking place.

Lower temperatures (55 to 60° F.) kept red ripe tomatoes in excellent condition for five days. Refrigeration would be necessary if red ripe tomatoes are to be kept salable for any length of time. Room temperature (70° F.) for five days will produce tomatoes that are soft and over-ripe. At 55 to 60° F. mature green tomatoes take too long to ripen (31 days) and result in off flavored fruit. Low temperature is advisable only to retard ripening and therefore normal temperatures (70° F.) should be used for the final stages of ripening.

Cellulose acetate film was considered superior to 300 LSAD and 300 MSAD cellophane under most conditions. Particularly under refrigeration the dimensional stability of cellulose acetate made itself evident. The higher permeability of cellulose acetate greatly reduced the problem of fogging and wrinkling.

The variety of packages available for marketing tomatoes is nothing new. Many workers (29) (10) have been concerned about it. Perhaps the greatest variation in sizes and shapes is found in paperboard tubes.

Overwrap tubes (four tomato) are not satisfactory for the use of local growers. The equipment involved would make the cost of such an operation prohibitive. Such an operation is much too slow if it is done by hand.

Some of the larger overwrap trays holding two pounds of tomatoes could be used without an overwrap. Colored

adhesive tapes could be used to keep the tomatoes in the containers. It would also meet the need for larger units which are in demand in the summer when the prices are lower. Serious drawbacks are poor visibility and the time required to tape the package.

The molded plastic tray seemed to have the greatest possibility for use of nearby growers. A stapler would be the only equipment necessary to seal these containers. The packaging methods involved with the molded plastic tray were efficient, lent themselves to inexpensive equipment, and demanded a minimum amount of skill.

A much broader consumer test running for a longer period of time would be very desirable. The molded paper-board store tray was used all year by the store to market a high quality product. The factor of consumer confidence in this package cannot be overlooked.

SUMMARY

This study was designed to assist local growers with their prepackaging problems regarding types of containers, films, temperature and ventilation as they relate to the quality and shelf-life of tomatoes. In this work, five types of containers and three types of film were used, three stages of maturity were utilized and two different temperatures were maintained. Gas analyses were made on firm, red ripe tomatoes and a consumer survey was conducted at a local "super-market."

The molded plastic tray was found to be one of the most promising containers for use by local growers. Its complete visibility and adaptability to small operations make it an ideal container.

Ventilation was found to be necessary to prevent the development of off flavors. Even tomatoes overwrapped with cellulose acetate benefited from ventilation. Ripening was retarded in non-ventilated packages.

At low temperatures (55 to 60° F.) ripening is retarded and mature green tomatoes developed an off flavor. Red ripe tomatoes remained in excellent condition after being held for five days at low temperatures (55 to 60° F.).

Low concentrations of oxygen and high concentrations of carbon dioxide resulted in retarded ripening and the pro-

duction of off flavors. Ventilated packages had normal concentrations of carbon dioxide and oxygen.

Cellulose acetate film proved to be superior to 300 LSAD and 300 MSAD cellophane at both temperatures (55 to 60 and 70° F.). At low temperatures 300 LSAD and 300 MSAD were subject to considerable wrinkling and fogging.

The consumer survey was very limited but increased sales near the end of the test may indicate increased consumer confidence in the new molded plastic tray.

The success of prepackaging tomatoes locally is governed by the consideration of such factors as ventilation, type of package, type of film, temperature, internal atmosphere, and consumer preference.

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PLATE I

Mature green tomatoes overwrapped with MSAD film, in a ventilated and non-ventilated package, held at room temperature (70° F.) for fourteen days.

PLATE II

Mature green tomatoes overwrapped with MSAD film, in a ventilated and non-ventilated package held under refrigeration (55 to 60° F.) for thirty-one days.



PLATE I



PLATE II

PLATE III

Turning or "breaker" tomatoes overwrapped with MSAD film, in a ventilated and non-ventilated package, held at room temperature (70° F.) for five days.

PLATE IV

Turning or "breaker" tomatoes overwrapped with MSAD film, in a ventilated and non-ventilated package, held under refrigeration (55 to 60° F.) for seventeen days.



PLATE III



PLATE IV

PLATE V

Turning or "breaker" tomatoes in a molded plastic tray and a control held at room temperature (70° F.) for five days.



PLATE V

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