USE OF GAMMA RADIATION, CHEMICALS, AND PACKAGING FILMS TO
CONTROL POST HARVEST DISEASES AND TO EXTEND REFRIGERATED
LIFE OF STRAWBERRIES AND CHERRIES

by

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Gerald M. Cooper
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INTRODUCTION

In recent years there has been a considerable amount of work done on developing chemicals that would inhibit mold growth when applied to fresh fruit, and at the same time, be acceptable to man when taken orally. This would save many thousands of tons of fresh produce that are lost each year by spoilage before it ever reaches the consumer. Along with the development of new chemicals to inhibit mold growth there is a substantial amount of research being done on developing a packaging film that will prevent recontamination of the produce, at the same time allowing the passage of gasses into and out of the package to allow respiration of the fruit. During the present century much emphasis has been placed on growing certain varieties of fruit for our specific needs. It has been found that particular varieties are better for canning and that other varieties are better for freezing.

With the release of atomic energy for peaceful use in 1933 by the United States Congress, a new era of food preservation was introduced. Men in the scientific fields believe it is possible to extend the shelf-life of fresh fruits without altering their physical condition to great extent. Many institutions have been awarded grants and contracts to work on various phases of food preservation.
with atomic energy. Utah State University was awarded a contract by the United States Army Quartermaster Corp to study the use of gamma radiation for extending the shelf-life of fresh produce.

It was with this idea in mind that work for this thesis was conducted to study the effects of gamma radiation, fungicides, and packaging film on the microbial growth on certain varieties of strawberries and cherries. In addition, experiments were conducted using fungicides and packaging films in order to lower the dose of radiation necessary to prevent mold growth. In order for this method of preserving fresh fruit to become successful, new and more economical methods and techniques in handling the materials will have to be developed.
According to DiMarco (14) relatively few fungi and none of the bacteria that are important in post-harvest decay are capable of penetrating the uninjured skin of fruit. Each year there are 2.8 billion dollars or about 7 percent of the potential production of all farms and forest growth in the United States that is lost (2). Minute injuries such as broken hairs, skin checks, and sand scarring are common avenues for entrance on apparently sound produce. Likewise, there are visible injuries and blemishes such as blossom scars, growth cracks, and mechanical injuries that often allow entry. Most of the fruit rot results from entry of fungi and bacteria present on the fruit at the time of harvest into one of these two groups. These saprophytic organisms are world-wide in distribution.

Chemicals

People have been using chemicals to control diseases of plants since before Christ. Democritus in 470 B.C. recommended sprinkling pure amaca of olives on plants to control blight, but there were practically no successful producers in general use before 1600 (44). Probably the first organic fungicide to gain wide acceptance was
formaldehyde (20). In the past, this compound has been used for the surface sterilization of grain and potato tubers but at present, formaldehyde is used but very little. Various dyes are fungistatic compounds. Malachite green and crystal violet are used to control various skin diseases.

Anderson and Michener (1) report that with the use of subtilllin it will be possible to reduce the heat requirement, shorten cooking time, and eliminate the need for pressure heating equipment, and give promise of higher food quality. McClure (26) found that a combination treatment of hydrocooling peaches in a 0.1 percent solution of Dowicide A and storage at 40° F. for five days reduced brown rot 91 percent and Rhizopus rot 47 percent. Norman (30) working with 140 inorganic and organic compounds found that strawberries treated with mercury-containing compounds had less rot caused by Botrytis cinerea than those treated with any other compound. Captan showed substantially less effect than the mercury compounds; however, Captan-treated berries were less than 45 percent rotten as compared to the inoculated controls, which were nearly 100 percent rotten.

Winter, Landon, and Alderman (42) extended the length of storage time for red raspberries and strawberries by treating the fruits with carbon dioxide at temperatures of 55 to 60° F. and with a relative humidity of 80 to 90 percent.
Inhibition of the more important fungi-causing rot in strawberry fruits, *Botrytis* and *Rhizopus*, was made when 0.025 percent sorbic acid was put in the strawberry puree (5). Nury, Miller, and Brekke (31) using 2, 5, and 10 percent concentrations of potassium sorbate showed control of mold and yeast on dried prunes (35 percent flesh moisture after sixty days storage at 78°F and 80 percent relative humidity).

Other chemicals used to control fruit-rot microorganisms that have shown some promise are: Mycostatin, DHA-S, Candicidin, Myprozine, and Amphotericin (14, 40).

**Packaging**

When selecting the proper packaging material one must consider the character of the food as well as the storage condition after treatment. Above all, the packaging material must protect the product against reinestation after irradiation far in excess of the maximum expected storage period before consumption. The mechanical construction must be such that it can withstand the additional storage and handling of the product made possible by the radiation treatment. In addition, none of the essential properties of the package such as composition, tensile strength, and vapor-moisture permeability must be changed due to the fact that the package and its contents have been irradiated. Lastly, one cannot overlook the fact that fresh fruits, for example, must be packaged in such a way that gaseous exchanges
both in and out of the package is not impaired (13). Robinson (37) declares that packages used in heat sterilization must be able to withstand high temperatures and pressures.

Ayres and Denisen (3) found plastic containers were better (less spoilage) for strawberries and raspberries than wooden boxes, especially if the wooden boxes had been used previously. They also found cellulose acetate to be the best film for wrapping berries. Other films did not allow sufficient water vapor transmission. Studies using inner containers within sealed cans during radiation of strawberries showed that the use of vacuum was detrimental; Mylar was slightly better than polyethylene, but it was questionable that the inner container was of any value (34). Salunkhe, et al. (39) report the mean flavor of Lindalicious strawberries scored by the Hedonic Scale (33) was higher when Mylar film was used rather than polyethylene.

In tests wherein cranberries were stored for thirty days or longer, firmness and color were better if the fruit was packaged in Mylar, Saran, or polyethylene rather than the more permeable films (3).

Radiation

Cold sterilization or radiation sterilization of foods is considered to be the first new basic method of food preservation since Appert's discovery of canning (24).
In the process of canning there is a breakdown of the tissue upon heating. With radiation sterilization, this would be eliminated as the dosage necessary for complete sterilization of a product produces a temperature rise usually not over 10°F. (37).

One of the aims in processing foods by ionizing radiation is the killing of fungal spores and mycelium and inactivation of enzymes of both the food and the organism. Ryer (38) gives five prerequisites that the radiation processing of food must satisfy:

1. The treatment must, in fact, kill the bacteria, parasites, insects, and other contaminating entities present in food.
2. The irradiated food must not be toxic to man.
3. The treatment must not adversely affect the taste, odor, texture, and appearance of foods.
4. Foods so processed must be stable in storage.
5. The process must be economically practicable.

All ionizing radiations are capable of the same biological effect (16). Some types of irradiation are more effective than others in the sense that a smaller absorbed dose of these radiations is required to produce a given degree of effect. Alpha particles produce more marked effects than electrons because they are more densely ionized.

There has not been as much work done on the effect of ionizing irradiation on enzymes as there has been on
its effects on fungi and other food-spoiling organisms (37). However, the limited research that has been done shows that a great deal more energy is required to in-active enzymes completely than to destroy food-spoilage organisms. Some enzymes are resistant to doses as high as 10,000,000 rep\(^1\) which is a reasonable sterilization dose (38). Investigations have shown that foods treated with irradiation are more susceptible to breakdown by enzymes than non-irradiated foods and are more susceptible to entry of food-spoilage microorganisms. McArdle and Nehemias (25) have shown that in both apples and carrots there is a breakdown of protopectin to pectates and soluble pectin. Since protopectin is the main material which maintains cellular adhesion in plant tissues, the destruction of this substance by ionizing radiations appears to be the cause of radiation-induced softening of fruits and vegetables.

It was mentioned previously that most of the work that has been done to date with ionization, pasteurization, and sterilization has been on food-spoilage microorganisms. Beraha, et al. (8) have shown that the shelf-life of lemons inoculated with *Penicillium italicum* was extended to fifteen

\(^1\)rep (roentgen equivalent physical) is that amount of nuclear radiation which dissipates 93 ergs (some workers use 83 ergs) of energy per gram of tissue producing 1.61 x 10\(^{12}\) ion pairs in the process. It is approximately equal to the amount of energy that would be dissipated by a one roentgen X-ray beam in a gram of tissue.
days at 75° F. and seventeen days at 55° F. after a dose of 15,000 rep without injury, while non-irradiated controls showed some decay within three days.

Beraha et al. (7), using gamma rays, irradiated grapes inoculated with *Botrytis cinerea* and found that the fungistatic effect was inversely proportional to the dose in the range of $5 \times 10^4$ to $3 \times 10^5$ rep. In grapes irradiated at $5 \times 10^5$ and $1 \times 10^6$ rep no rot developed in any of the replicates for a period of ten days at room temperature while non-irradiated controls were completely rotted within four days (6).

Proctor et al. (36) treated spinach with higher levels of cathode ray irradiation than was possible with asparagus or green beans without developing undesirable flavors.

Strawberries have thin skin, soft flesh, high rate of metabolism and are among the most susceptible to fruit decay. Shasta strawberries irradiated in single layers showed no injury at $2 \times 10^5$ rep their interiors had a water-soaked appearance as well as a cooked odor and an off-flavor. At $8 \times 10^5$ rep the berries exuded juice (29). Nelson, Maxie, and Eukel (29) also said that by doubling the dose (from $1 \times 10^5$ to $2 \times 10^5$ rep etc.) the period for fungistatic effect was nearly doubled. Either with or without refrigeration, $2 \times 10^5$ rep markedly prolonged the storage life of non-inoculated strawberries by delaying development of both *Rhizopus nigricans* and *Botrytis cinerea*,
two of the most serious rot-causing organisms of harvested strawberries, without visible radiation damage (7). Beraha and Ramsey (6) noted that following a forty-eight hour storage at room temperature and an additional ninety-six hour period at $41^\circ$ F., no rot had developed at any of the dosages employed ($1 \times 10^5$, $3 \times 10^5$, $5 \times 10^5$, $7.5 \times 10^5$, and $1 \times 10^6$ rep) while the non-irradiated controls were completely rotten. Even to extend the shelf-life of strawberries for one day would be very desirable since they have such a short storage life.

Apples and carrots when irradiated to a dose range of $16.2 \times 10^3$ rep to $2210 \times 10^3$ rep for apples and $100 \times 10^3$ rep to $2070 \times 10^3$ rep for carrots showed a linear relationship between the percentage change in crushing load (pounds required to crush the cylinders) and the logarithm of the gamma radiation dosage within these ranges (10). McArdle and Nehemias (25) found in both carrots and apples a breakdown of protopectin to pectates and soluble pectin occurred when irradiated. Since insoluble pectin materials maintain cellular adhesion in plant tissues, the destruction of protopectin by ionizing radiation appears to be the cause of radiation induced softening of fruits and vegetables.

Peach brown rot caused by Monilinia fructicola (Wint.). Honey and Rhizopus rot caused by Rhizopus nigricans (Ehr. ex. Fr.) are the primary decay organisms of harvested peaches (14). Both are ripe-rot organisms. Peaches
inoculated with *M. fructicola* and irradiated at $2 \times 10^5$ to $3 \times 10^5$ rep controlled *R. nigricans* without radiation injury (7).

When green beans were irradiated, destruction of carotene and xanthophyll ranged from 5 to 95 percent depending on the conditions (17). The greatest loss was found in beans packed dry in air and irradiated frozen. Lukton and Mackinney (21) found the loss of carotenoids in irradiated whole tomatoes small even at dosages of several million rep, but the internal structure of the tomato was destroyed. The problem, therefore, being one of pectin and carbohydrate instability. When apple sauce was irradiated, an orange discoloration appeared in the samples (27). The intensity of discoloration increased with increased irradiation dose.

There are many factors associated with the sterility of food products by ionizing radiation. These include cost of sterilization, color loss, and nutrition, but probably the main factor is taste. Pratt and Ecklund (35) in an experiment with meats and vegetables showed off-flavor in each. In every case important changes in appearance or flavor developed on storage. Some of these changes, but not all, might be attributed to enzymatic action. Huber, Brasch, and Waly (17) found that changes in taste, odor, color, or texture are drastically reduced or eliminated when foods have been thoroughly freed of oxygen prior to irradiation.
It is fortunate that the federal government is financing the initial work being done on ionization sterilization because most private organizations could not afford to promote such a program under present conditions. The military objectives of the Quartermaster Food and Container Institute program are space and weight saving, extended storage life, and increased acceptability of some ration items. Clifcorn (12) states three items of importance concerning the military with irradiated foods: 1. cost of transportation, 2. be able to ship perishable foods to remote places where refrigerated storage is not available or feasible, 3. because radiation will extend the life of foods, it will be possible to stay out at sea and go on longer trips without stopping for supplies.

Mason and Taimuty (23) predict that irradiated food products will not be on the open market for another ten years. However, one should not get too concerned that food irradiation is not progressing at a faster rate. History is just repeating itself. Frozen food took fifteen years to become accepted by the public (23). The military has a great influence on developing and accepting new types of foods. Thus, they may influence schools, hospitals, prisons, and orphanages who in turn will influence the public. Chester (11) states that young families are eager for convenience and are less prejudiced about irradiated foods. This tendency is demonstrated by the
fact that younger people are the best customers for frozen foods.
METHODS AND MATERIALS

Gamma Radiation Technique

Sweet cherries (Prunus Avium L., varieties Bing, Napoleon, Windsor, and Lambert), and strawberries (Fragaria sp. L., varieties Kasuga, Lindalicious, Marshall, Robinson, Shasta, and Sparkle) were irradiated at the Material Testing Reactor Station near Arco, Idaho.

The sources of gamma rays used were spent-fuel elements from the Materials Test Reactor Station near Arco, Idaho. These elements had approximately 25 percent of their original U235 burned out by fissioning and were no longer useful in the reactor. They were placed around a twenty foot vertical aluminum tube at the bottom of a canal filled with eighteen feet of demineralized water to provide the necessary shielding. This tube is referred to as the U.I.A.¹ column (Figure 1). The rate of radiation was determined by dosimeter measurements, and from this the time required for the particular dose was calculated (13). The rate at which the fruit was irradiated was arranged by placing the fuel elements at varying distances from the aluminum tube. A container known as

¹Named after the University of Idaho at Aberdeen.
Figure 1. Entire radiation apparatus showing airation device, U.I.A. Column, and fuel elements
an aeration chamber (Figure 2) was used to lower the food into the U.I.A. column for radiation. Two No. 10 cans were placed in the aeration chamber and lowered inside the U.I.A. column to the level of the fuel elements and irradiated for half the calculated time required for the dose. To insure equal dosage for both cans in the aeration chamber, at the end of half the calculated time the chamber was brought to the surface and the two cans rearranged, putting the bottom can on top and visa versa and returned for the remainder of the dose. Subsequent to irradiation, the cans were returned to storage at 40° F. from which they had been taken prior to irradiation. At predetermined time intervals, the cans were opened and evaluation of the fruit was made.

**Physical and Microbial Changes in Gamma Irradiated Cherries and Strawberries**

Five experiments were conducted to study the physical quality and microbial growth of irradiated strawberries. They were as follows: 1. to determine procedures and methods to be used later on fruits locally grown; 2. to evaluate the effect of dose of irradiation on the physical quality and microbial growth of six strawberry varieties; 3. to determine if partially green strawberries are more suitable for irradiation than commercially ripe strawberries; 4. to study the combination effect of radiation with fungus-inhibiting chemicals; and 5. to test the control of microorganisms with a combination of post-harvest chemical dips and packaging films.
Figure 2. Airation device used at the National Reactor Testing Station near Arco, Idaho
All strawberries treated with radiation were irradiated to 0 (control), 1, 2, and $3 \times 10^5$ rads$^{-1}$ dose. After irradiation, the samples were stored at 40$^\circ$ F. and evaluated at predetermined time intervals for mold count and percentage survival. Streak plates were made using Czapek's nutrient agar as a culture medium, and classification (4) of the mold was determined after three or four days incubation at room temperature.

In the first experiment, Shasta strawberries grown in Salinas Valley, California, were shipped to Logan, Utah, and were irradiated within three days of harvest. These berries were in good condition. They were procured for use in exploratory work to determine procedures and methods to be used later on fruits locally grown.

Six varieties of locally grown strawberries - Kasuga, Lindalicious, Marshall, Robinson, Shasta, and Sparkle - were used in the subsequent experiment. The Kasuga and Lindalicious were at the stage of excellent commercial ripeness; the Marshall, Robinson, and Shasta were fair-to-good commercial ripeness, slightly on the over-ripe side;

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1 Rad is equal to the unit of absorbed dose and is 100 ergs per gram. In comparing the relative biological effectiveness of the radiation it is now considered best to do this on the basis of the total energy absorbed in the tissue rather than the amount of ionization taking place. (As recommended by the Sixth International Congress of Radiology in 1950, the dose is expressed as follows: "For the correlation of the dose of an ionizing radiation with its biological or related effects the International Commission of Radiology Units recommends that the dose be expressed in terms of quantity of energy absorbed per unit mass (ergs per gram) of irradiated material." For this reason the radiation dose is expressed in rads rather than reps or r in this thesis.)
while the Sparkle was slightly dry due to low-irrigation treatment before harvest.

Shasta strawberries were picked when they were partially green, for the next experiment, to determine if partially green strawberries would be better for irradiation than commercially ripe strawberries.

For the fourth experiment, Shasta strawberries were treated with a 2000 ppm concentration of either Captan or potassium sorbate before being irradiated. One-half of the berries were treated with Captan and one-half with potassium sorbate. The purpose of this experiment was to determine if a combination treatment of irradiation with fungus-inhibiting chemicals would prove more effective than irradiation alone.

For the last experiment with strawberries, four chemicals - Captan (N-(Trichloromethylthio)-4-cyclohexene-1,2-dicarboxamide) 1000 ppm, Dowicide A-M 254 (sodium O-phenylphenate) 1000 ppm, Mycostatin (an antibiotic) 100 ppm, and potassium sorbate 2500 ppm - were used in combination with two packaging films - Mylar (Type C, 0.0005 inches thick) and polyethylene (0.0015 inches thick) - to determine the feasibility of using post-harvest dips and sealing the fruit in packaging film to extend their shelf-life.

The fruit was sorted and only top-quality was used. Subsequently, they were immersed in their designated chemical solutions, drained, placed in wooden berry cups, and sealed in one or the other packaging films.
Three more experiments were conducted using sweet cherries: 1. studies were made on the effect of radiation on the physical quality and microbial growth of four cherry varieties; 2. two sweet cherry varieties with five fungus-inhibiting chemicals and two packaging films; and 3. one sweet cherry variety in combination with four chemical dips and two packaging films.

The irradiated cherries were treated to a dose of 0 (control), 2, 3, and \(4 \times 10^5\) rads. Subsequent to irradiation, the cherries were treated in a similar manner as the strawberries mentioned above.

Four varieties of sweet cherries - Bing, Lambert, Napoleon, and Windsor - were used for this experiment. Napoleon and Windsor were at the firm ripe stage, Lambert was slightly under-ripe, while Bing was slightly over-ripe. The cherries were sorted and only top-quality fruit with pedicels attached was used.

In this next experiment, 1000 ppm concentration of five different fungus-inhibiting chemicals - Captan, D.H.A-s (Dehydroacetic Acid, sodium salt), Dowicide A, Mycostatin, and potassium sorbate - were used in conjunction with radiation. Two varieties of cherries - Bing and Lambert - were used. The fruits were dipped in the chemical solutions prior to irradiation. After dipping, the cherries were air dried and placed in two types of packaging film. Bing cherries were placed in Mylar bags, while Lambert were placed in polyethylene film prior to sealing in No. 10 tin cans for radiation.
For the last experiment, locally grown Lambert cherries were picked with pedicels attached. They were taken to the processing laboratory where they were sorted for injured fruit. Following the sorting they were dipped into specified concentrations of anti-fungal chemicals and placed in two different types of packaging films - polyethylene and Ful-look. The anti-fungal chemicals used in this experiment were; Captan, Dowicide A, Mycostatin, and potassium sorbate.

A statistical analysis (32) of the experiments was made whenever it was feasible.
RESULTS

Experiment I: Effect of Radiation Dose on the Physical Quality and Microbial Growth of Shasta Strawberries

The strawberries were irradiated to 0 (control), 1, 2, and $3 \times 10^5$ rads prior to storage at 40°F.

During the extended storage period of eighteen days there was a wide variation in the physical characteristics of the berries. After two days of storage, the berries were similar at all levels of radiation—firm and bright red. As seen from Table 1, there was an increase in mold growth with increased time, but a decrease with advanced dose. Table 2 shows the percentage of edible fruit was greater at the higher ($2$ and $3 \times 10^5$ rads) doses of radiation, but decreased with lapse of time.

Ten days after treatment the color of the berries remained good at the high dose. The physical quality of the berries decreased during the ten day storage period, but decreased more at the lower $1 \times 10^5$ rads) level of radiation. Most of the mold growing on the surface of the berries was a species of Botrytis. It was present in essentially all of the treatments (Table 3). Hormodendrum was equally as prevalent, but due to the fast and profuse growth of Botrytis, it was not as evident. Alternaria,
Table 1. Effect of radiation dose on mold growth* on Shasta strawberries stored at 40° F. for various time intervals

<table>
<thead>
<tr>
<th>Days in storage</th>
<th>Control</th>
<th>1</th>
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*+ No mold; ++ Slight mold; +++ Moderate mold; ++++ Much mold; +++++ Profuse mold.
Table 2. Effect of radiation dose on keeping qualities of Shasta strawberries stored at 40°F. for various time intervals

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<th>Percent edible fruits</th>
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Table 3. Effect of radiation dose on type of mold growth on Shasta strawberries stored at 40° F. for various time intervals

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</table>
Penicillium, and Rhizopus were not as prevalent as the above-mentioned molds.

**Experiment II: Effect of Radiation Dose on the Physical Quality and Microbial Growth of Six Strawberry Varieties**

Six varieties of strawberries - Kasuga, Lindalicious, Marshall, Robinson, Shasta, and Sparkle - were irradiated to 0 (control), 1, 2, and 3 x 10^5 rads and stored at 40°F.

After irradiation, the control strawberries of all varieties were the firmest. Soft spots and softer berries appeared with increased irradiation. As the number of days of storage increased, strawberries became somewhat dry and progressively darker in color, with an increasing number of soft berries until at twenty-three and twenty-eight days of storage. Controls of all varieties became unacceptable, and the 1 x 10^5 rads group became mostly unacceptable because of mold (Figure 3). Increase in radiation from 2 x 10^5 to 3 x 10^5 rads showed an increase in number of soft berries and a number of soft spots in the berries. A peculiar spongy, soft texture was observed in all varieties at 3 x 10^5 rads. As the storage period was lengthened, the number of spongy berries became more apparent. The varieties - Kasuga, Lindalicious, and Sparkle - were fairly firm with a few soft berries at 2 x 10^5 rads.

With the exception of Kasuga and Sparkle, all varieties exhibited varying degrees of bleaching at 2 and 3 x 10^5 rads.
Figure 3. Effect of radiation dose on the physical quality and microbial growth of Shasta strawberries (photographed 22 days after irradiation). Left to right: A=control, B=$1 \times 10^5$ rads, C=$2 \times 10^5$ rads, D=$3 \times 10^5$ rads
throughout the experiment. The physical quality of Kasuga, Lindalicious, and Sparkle did not decline as fast as that of Marshall, Robinson, and Shasta. Hence, it is apparent that Kasuga, Lindalicious, and Sparkle varieties have better keeping qualities than the others. Perhaps it may be due to the inherent firmness of these varieties.

In all probability, the low number of marketable fruit in Marshall was due to the fact that the berry bruises easily and is, therefore, a poor shipping variety. Of all strawberries tested, this variety was in the poorest physical condition. In general, Kasuga and Sparkle were more suitable for radiation preservation because these varieties were more firm and less susceptible to bleaching and softening.

Fruits used as controls contained little mold growth at the end of seventeen days storage (Table 4). But at that time, moderate-to-much mold growth was observed. There was no survival after twenty-three days storage. Prior to the seventeen and twenty-eight days of storage, there was only a slight amount of mold growth observed at 1 and 2 x 10^5 rads, respectively. Moderate-to-much mold growth was observed at that time. Much mold was common in the 1 x 10^5 rads level after twenty-three days storage. Generally speaking, the percentage survival decreased progressively with length of storage period and decreased radiation dosage (Table 5). There was very little mold growth during the first three storage periods.
Table 4. Effect of radiation dose on mold growth* on strawberry varieties stored at 40° F. for various time intervals

<table>
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<th>Days in storage</th>
<th>Dose x 10^5 rads</th>
<th>Kasuga</th>
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* + No mold; ++ Slight mold; +++ Moderate mold; ++++ Much mold; ++++ Profuse mold.
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<th>Days in storage</th>
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* Marketable refers to edible fruit.
Of the types of mold causing rot in strawberries, *Hormodendrum* was the most common (Table 6). It appeared in about 60 percent of the cans and was observed in all treatments. Although *Botrytis* was found only in 25 percent of the treatments, the author feels that where it was present, it caused more spoilage than any other type of mold because of its profuse-growth habit. *Penicillium* appeared only in the control fruits. Other types of mold—*Alternaria, Aspergillus, Rhizopus, and Stemphylium*—found growing on the fruits were of minor importance since they were erratic in occurrence.

**Experiment III: Effect of Radiation Dose on the Physical Quality and Microbial Growth of Partially Green Strawberries**

Partially green Shasta strawberries were irradiated to 0 (control), 1, 2, and $3 \times 10^5$ rads prior to storage at $40^\circ$ F.

After fifteen days of storage, the berries were in good physical condition with only a slight amount of mold growth in the control and $1 \times 10^5$ rads treatment (Table 7). There was wide variation in color. Control ranged from medium dark red to yellow red. Some brown, spoiled spots were present; as dosage increased, berries were more immature and under-ripe. Also, soft spots decreased with increase in radiation, except at $3 \times 10^5$ rads where 25 percent of the berries, which had a grayish cast, were soft and spongy.
Table 6. Effect of radiation dose on the type of mold growth on strawberry varieties stored at 40° F. for various time intervals

<table>
<thead>
<tr>
<th>Days in storage</th>
<th>Dose x 10^5 rads</th>
<th>Kasuga</th>
<th>Lindalicious</th>
<th>Marshall</th>
<th>Robinson</th>
<th>Shasta</th>
<th>Sparkle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
<td>Penicillium Hormodendrum Stemphyllum</td>
<td>Penicillium</td>
<td>None</td>
<td>None</td>
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</tr>
<tr>
<td>1</td>
<td></td>
<td>Botrytis</td>
<td>Botrytis Hormodendrum</td>
<td>None</td>
<td>Botrytis</td>
<td>None</td>
<td>None</td>
</tr>
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<td>2</td>
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<td>None</td>
<td>None</td>
<td>Botrytis</td>
<td>None</td>
<td>None</td>
</tr>
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<td>None</td>
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<td>None</td>
</tr>
<tr>
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<td>1</td>
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<td>---</td>
<td>---</td>
<td></td>
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</tr>
<tr>
<td>None</td>
<td>None</td>
<td>None</td>
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</tr>
<tr>
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<td>None</td>
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</tr>
<tr>
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<td>None</td>
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<td>Hormodendrum</td>
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<td>None</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>None</td>
<td>None</td>
<td>Rhizopus</td>
<td>Aspergilli</td>
<td>Hormodendrum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Hormodendrum</td>
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Table 6 Continued

<table>
<thead>
<tr>
<th>Days in storage</th>
<th>Dose x 10⁵</th>
<th>Kasuga</th>
<th>Lindalicious</th>
<th>Marshall</th>
<th>Robinson</th>
<th>Shasta</th>
<th>Sparkle</th>
</tr>
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<tbody>
<tr>
<td>8</td>
<td></td>
<td></td>
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</tbody>
</table>

None None None Botrytis

None None Hormodendrum Penicillium Stemphylium

None None Hormodendrum Hormodendrum

None None None None

None None Rhizopus Aspergilli Hormodendrum

None None None Hormodendrum
<table>
<thead>
<tr>
<th>Days in Dose</th>
<th>Botrytis</th>
<th>Botrytis</th>
<th>Hormodendrum</th>
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<tbody>
<tr>
<td>Control</td>
<td>Stemphylium</td>
<td>Hormodendrum</td>
<td></td>
</tr>
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<td>Hormodendrum</td>
<td>Rhizopus</td>
<td>Botrytis Penicillium Hormodendrum</td>
</tr>
<tr>
<td>1</td>
<td>Hormodendrum</td>
<td>Alternaria</td>
<td>Hormodendrum</td>
</tr>
<tr>
<td>13</td>
<td>Hormodendrum</td>
<td>Botrytis Stemphylium</td>
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<td>Hormodendrum</td>
<td>Hormodendrum</td>
<td>Botrytis Hormodendrum</td>
</tr>
<tr>
<td></td>
<td>Hormodendrum</td>
<td>Hormodendrum</td>
<td>Hormodendrum</td>
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Table 6. Continued
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<th>Days in storage</th>
<th>Dose (x 10^5)</th>
<th>Days in storage</th>
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<tbody>
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<td>17</td>
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<table>
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<tr>
<th>Control</th>
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<th>None</th>
</tr>
</thead>
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<tr>
<td>Alternaria Botrytis Hormodendrum</td>
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<td>None</td>
</tr>
<tr>
<td>Alternaria Botrytis Hormodendrum</td>
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<td>None</td>
</tr>
<tr>
<td>Botrytis Hormodendrum</td>
<td>Botrytis</td>
<td>None</td>
</tr>
<tr>
<td>Hormodendrum Botrytis Hormodendrum</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Botrytis Alternaria Hormodendrum</td>
<td>Botrytis Penicillium Hormodendrum</td>
<td>None</td>
</tr>
<tr>
<td>Botrytis Hormodendrum</td>
<td>Botrytis Hormodendrum</td>
<td>Hormodendrum</td>
</tr>
<tr>
<td></td>
<td>Botrytis Hormodendrum</td>
<td>Botrytis Penicillium</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Hormodendrum</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hormodendrum</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Storage: Kauai, Lindal, S. Marsh, Robinson, Shasta, Sparke

Dose in: Days x 10^6

Table 6. Continued
<table>
<thead>
<tr>
<th>Botrytis</th>
<th>Hormodendrum</th>
<th>None</th>
<th>Hormodendrum</th>
<th>Botrytis</th>
<th>Alternaria</th>
<th>Hormodendrum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hormodendrum</td>
<td>Botrytis</td>
<td>Hormodendrum</td>
<td>Botrytis</td>
<td>Alternaria</td>
<td>Hormodendrum</td>
<td>Botrytis</td>
</tr>
<tr>
<td>Botrytis</td>
<td>Alternaria</td>
<td>Hormodendrum</td>
<td>Botrytis</td>
<td>Alternaria</td>
<td>Hormodendrum</td>
<td>Botrytis</td>
</tr>
</tbody>
</table>

**Table 6. Continued**
<table>
<thead>
<tr>
<th>Botrytis</th>
<th>Hormodendrum</th>
<th>Botrytis</th>
<th>Hormodendrum</th>
<th>Botrytis</th>
<th>Hormodendrum</th>
<th>Botrytis</th>
<th>Hormodendrum</th>
<th>Botrytis</th>
<th>Hormodendrum</th>
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<tbody>
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<td></td>
</tr>
</tbody>
</table>

**Table 6. Continued**
<table>
<thead>
<tr>
<th>Days in storage</th>
<th>Dose x $10^5$ rads</th>
<th>Kasuga</th>
<th>Lindalicious</th>
<th>Marshall</th>
<th>Robinson</th>
<th>Shasta</th>
<th>Sparkle</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Botrytis Hormodendrum</td>
<td>Alternaria</td>
<td>Botrytis Hormodendrum</td>
<td>Hormodendrum</td>
<td>Botrytis</td>
<td>Hormodendrum</td>
<td></td>
</tr>
</tbody>
</table>
Table 7. Effect of radiation dose on mold growth* and percentage of marketable** strawberries picked green and stored at 40° F.

<table>
<thead>
<tr>
<th>Dose x 10^5 rads</th>
<th>Evaluation 15 days after irradiation</th>
<th>Evaluation 49 days after irradiation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mold Growth</td>
<td>Percent Survival</td>
</tr>
<tr>
<td>Control</td>
<td>++</td>
<td>94</td>
</tr>
<tr>
<td>1</td>
<td>++</td>
<td>98</td>
</tr>
<tr>
<td>2</td>
<td>+</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>+</td>
<td>100</td>
</tr>
</tbody>
</table>

* ++ No mold; ++ Slight mold; +++ Moderate mold; ++++ Much mold; +++++ Profuse mold.
** Marketable refers to edible fruit.
As evidenced in Figure 4, only the treatments in the highest (2 and $3 \times 10^5$ rads) doses of radiation showed any sign of marketable fruit after forty-nine days storage. All of the berries in the control were brown and decayed but there was an increase in color retention with increased dose of radiation. However, the berries in the $3 \times 10^5$ rads treatment were still on the green side.

From Table 8 one can see that Botrytis and Hormodendrum were essentially present in all treatments showing evidence of mold growth, as per usual. Botrytis with its profuse-growth habit, seemed to mask all other molds present. However, Alternaria, Stemphylium, and Penicillium were present when isolation classification was made on streak plates.

**Experiment IV: Effect of Radiation Dose and Pre-irradiation Chemical Dip on the Physical Quality and Microbial Growth of Strawberries**

Shasta strawberries were treated with 2000 ppm concentrations of either Captan or potassium sorbate prior to irradiation to 0 (control), 1, 2, and $3 \times 10^5$ rads and storage at $40^\circ$ F.

The degree of mold growth present on the berries at both the thirty day and the forty-nine day storage periods was substantially less in those treated with Captan (Table 9). Although Figure 5 may indicate that there was less mold growth in the potassium sorbate treatment after
Figure 4. Effect of radiation dose on the physical quality and microbial growth of partially green strawberries (photographed 49 days after irradiation). Left to right: A= control, B=1 x 10^5 rads, C= 2 x 10^5 rads, D=3 x 10^5 rads
Table 8. Effect of radiation dose on type of mold growth on Shasta strawberries picked green and stored at 40°F.

<table>
<thead>
<tr>
<th>Dose x $10^5$ rads</th>
<th>Evaluation 15 days after irradiation</th>
<th>Evaluation 49 days after irradiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Botrytis</td>
<td>Botrytis</td>
</tr>
<tr>
<td></td>
<td>Alternaria</td>
<td>Hormodendrum</td>
</tr>
<tr>
<td></td>
<td>Hormodendrum</td>
<td>Stemphylium</td>
</tr>
<tr>
<td>1</td>
<td>Botrytis</td>
<td>Botrytis</td>
</tr>
<tr>
<td></td>
<td>Hormodendrum</td>
<td>Hormodendrum</td>
</tr>
<tr>
<td></td>
<td>Stemphylium</td>
<td>Stemphylium</td>
</tr>
<tr>
<td>2</td>
<td>None</td>
<td>Botrytis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hormodendrum</td>
</tr>
<tr>
<td>3</td>
<td>None</td>
<td>Hormodendrum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alternaria</td>
</tr>
</tbody>
</table>
Table 9. Effect of radiation dose on mold growth* on Shasta strawberries chemically treated before irradiation and stored at 40°F.

<table>
<thead>
<tr>
<th>Dose x 10^5 rads</th>
<th>Evaluation 30 days after irradiation</th>
<th>Evaluation 49 days after irradiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>+++</td>
<td>++++</td>
</tr>
<tr>
<td>1</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>2</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>3</td>
<td>+</td>
<td>++</td>
</tr>
</tbody>
</table>

*+++ No mold; ++ Slight mold; +++ Moderate mold; ++++ Much mold; ++++++ Profuse mold.
Figure 5. Effect of radiation dose and pre-irradiation chemical dip on the physical quality and microbial growth of Shasta strawberries (photographed 49 days after irradiation). Left to right: A=control, B=1 x 10^5 rads, C=2 x 10^5 rads, D=3 x 10^5 rads. Top-treated with Captan. Bottom-treated with potassium sorbate.
forty-nine days storage, we see from Table 10 that this is not so. Those berries treated with Captan had a markedly greater percentage of edible fruit in both the thirty and forty-nine day storage period.

Botrytis was prevalent throughout the experiment (Table 11), as was the case in essentially all of the experimental treatments. Captan seems to have some inhibitory effect on Hormodendrum since it was not as prevalent in Captan-treated fruits. Occasionally Penicillium and Stemphylium occurred but were not considered to be very important.

Experiment V: Effect of Post-harvest Chemical Dips in Combination With Packaging Films on the Physical Quality and Microbial Growth of Strawberries

Shasta strawberries were treated with four chemicals - Captan (1000 ppm), Dowicide A (1000 ppm), Mycostatin (100 ppm), and potassium sorbate (2500 ppm) - prior to being placed in two packaging films - Mylar and polyethylene - and subsequently placed in storage at 40°F.

The berries were placed in packaging film after being treated with the chemicals in order to prevent any additional infection of the fruit, and to retain their normal moisture content. At this time, the berries were not thoroughly dry and this may have had an effect on the storage. However, we see from Table 12 that there was little mold growth in berries treated with any of the three chemicals - Captan,
Table 10. Effect of radiation dose on percentage of marketable* Shasta strawberries chemically treated before irradiation and stored at 40° F.

<table>
<thead>
<tr>
<th>Dose x 10^5 rads</th>
<th>Percentage marketable 30 days after irradiation</th>
<th>Percentage marketable 49 days after irradiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
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<td>0</td>
</tr>
<tr>
<td>1</td>
<td>23</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>65</td>
<td>28</td>
</tr>
<tr>
<td>3</td>
<td>100</td>
<td>43</td>
</tr>
</tbody>
</table>

*Marketable refers to edible fruit.
Table 11. Effect of radiation dose on type of mold growth on Shasta strawberries chemically treated before irradiation and stored at 40° F.

<table>
<thead>
<tr>
<th>Dose x $10^5$ rads</th>
<th>Evaluation 30 days after irradiation</th>
<th>Evaluation 49 days after irradiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Botrytis</td>
<td>Botrytis</td>
</tr>
<tr>
<td></td>
<td>Penicillium</td>
<td>Hormodendrum</td>
</tr>
<tr>
<td>1</td>
<td>Botrytis</td>
<td>Botrytis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hormodendrum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stemphylium</td>
</tr>
<tr>
<td>2</td>
<td>Botrytis</td>
<td>Botrytis</td>
</tr>
<tr>
<td></td>
<td>Hormodendrum</td>
<td>Hormodendrum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stemphylium</td>
</tr>
<tr>
<td>3</td>
<td>None</td>
<td>Botrytis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hormodendrum</td>
</tr>
</tbody>
</table>
Table 12. Effect of chemical dips and packaging film on mold growth* on Shasta strawberries stored at 40° F. for various time intervals.

<table>
<thead>
<tr>
<th>Days in storage</th>
<th>Chemicals</th>
<th>Concentration ppm</th>
<th>Packaging films</th>
<th>Polyethylene 50-Mylar-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Control</td>
<td></td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Captan</td>
<td>1000</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Dowicide A</td>
<td>1000</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Mycostatin</td>
<td>100</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Potassium sorbate</td>
<td>2500</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>20</td>
<td>Control</td>
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<td>+++</td>
</tr>
<tr>
<td></td>
<td>Captan</td>
<td>1000</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Dowicide A</td>
<td>1000</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Mycostatin</td>
<td>100</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Potassium sorbate</td>
<td>2500</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>30</td>
<td>Control</td>
<td></td>
<td>++++</td>
<td>++++</td>
</tr>
<tr>
<td></td>
<td>Captan</td>
<td>1000</td>
<td>++++</td>
<td>++++</td>
</tr>
<tr>
<td></td>
<td>Dowicide A</td>
<td>1000</td>
<td>++++</td>
<td>++++</td>
</tr>
<tr>
<td></td>
<td>Mycostatin</td>
<td>100</td>
<td>++++</td>
<td>++++</td>
</tr>
<tr>
<td></td>
<td>Potassium sorbate</td>
<td>2500</td>
<td>++++</td>
<td>++++</td>
</tr>
</tbody>
</table>

*+ No mold; ++ Slight mold; +++ Moderate mold; ++++ Much mold; ++++ Profuse mold.
Dowicide A, and Mycostatin — until after thirty-days storage at which time all treatments were infected by a considerable amount of mold growth.

The percent of edible fruit (Table 13) was not reduced very much from the ten day to the twenty day storage period, but there was a considerable reduction from the twenty day to the thirty day storage period. Captan and Mycostatin show the most significant control of mold growth. They maintained the largest percentage of edible fruit throughout the experiment. Potassium sorbate was not any better than control, but Dowicide A showed some control.

Of the two packaging films used, polyethylene was somewhat better than Mylar in maintaining good quality fruit. However, there was not a great deal of difference between the two films.

There is no definite control of any one microorganism with a particular fungicide (Table 14). There is only a temporary delay in the growth of the fungi. Alternaria, Botrytis, Hormodendrum, and Penicillium are the most common organisms causing spoilage of the fruit. These fungi were observed in essentially all of the treatments used. Rhizopus, Aspergillus, and Stemphylium were observed but seemed to be insignificant.
Table 13. Effect of chemical dips and packaging film on percentage of marketable* Shasta strawberries stored at 40° F. for various time intervals**

<table>
<thead>
<tr>
<th>Days in storage</th>
<th>Chemical</th>
<th>Concentration ppm</th>
<th>Packaging films</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Polyethylene</td>
</tr>
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<td>10</td>
<td>Control</td>
<td>1000</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td>Captan</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Dowicide A</td>
<td>1000</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Mycostatin</td>
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<td>100</td>
</tr>
<tr>
<td></td>
<td>Potassium sorbate</td>
<td>2500</td>
<td>95</td>
</tr>
<tr>
<td>20</td>
<td>Control</td>
<td>1000</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>Captan</td>
<td>100</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td>Dowicide A</td>
<td>1000</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>Mycostatin</td>
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<td>99</td>
</tr>
<tr>
<td></td>
<td>Potassium sorbate</td>
<td>2500</td>
<td>85</td>
</tr>
<tr>
<td>30</td>
<td>Control</td>
<td>1000</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Captan</td>
<td>100</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Dowicide A</td>
<td>1000</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Mycostatin</td>
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<td>19</td>
</tr>
<tr>
<td></td>
<td>Potassium sorbate</td>
<td>2500</td>
<td>0</td>
</tr>
</tbody>
</table>

* Marketable refers to edible fruit.

** The detailed analysis of variance is presented in Appendix Table 1.
Table 14. Effect of chemical dips and packaging films on the type of mold growth on Shasta strawberries stored at 40° F. for various time intervals

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Experiment VI: Effects of Radiation Dose on the Physical Quality and Microbial Growth of Four Sweet Cherry Varieties

Four varieties of sweet cherries - Bing, Lambert, Napoleon, and Windsor - were irradiated to 0 (control), 2, 3, and $4 \times 10^5$ rads and subsequently stored at $40^\circ$ F.

Generally speaking, fruits of Bing, Lambert, and Windsor varieties showed an increase in shelf-life with increase in radiation. Cherries of the Napoleon variety developed a darker and more unacceptable color with increase in radiation. They were also slightly softer in texture and were subject to bruising during the first five storage periods. As the storage period increased, non-irradiated cherries became progressively riper, but those irradiated to 2, 3, and $4 \times 10^5$ rads levels exhibited less ripening.

During the first two storage periods, Bing, Lambert, and Windsor varieties at all doses were firm and maintained their characteristic natural color. As the storage period increased through the twenty-ninth day, Lambert and Bing cherries became somewhat softer in texture with increased radiation, while Windsor cherries became firmer. However, as the storage period increased beyond the twenty-ninth day, all cherries at controls became slightly softer than those irradiated to 2, 3, and $4 \times 10^5$ rads levels. As the storage period extended from the forty-third day to the end of the experiment, there was very little change
in the Napoleon variety at the control. They were characterized by firm texture, good color, some surface brownness, and a few bruises. At the forty-third day, a brown discoloration became apparent on the cherries irradiated to 2, 3, and $4 \times 10^5$ rads levels. Apparently, this discoloration was due to a physical change caused by radiation rather than from bruising. As the length of the storage period increased, the greater was the discoloration which progressed until the seventy-first day of storage when most of the cherries irradiated to 2, 3, and $4 \times 10^5$ rads were unacceptable because of this condition (Table 15).

From the fifty-seventh day of storage until the end of the experiment, only those cherries in Bing, Lambert, and Windsor that were irradiated to 3 and $4 \times 10^5$ rads levels were in good condition, being fairly firm and dark red in color (Figure 6). Bing and Lambert showed a decrease in physical condition during the last two storage periods.

After eight days of storage, there was a slight amount of mold growth on fruits in the control and $1 \times 10^5$ rads level treatments (Table 16). No mold appeared on fruits irradiated to the $3 \times 10^5$ rads level until after fifteen days of storage and in the cherries irradiated to $4 \times 10^5$ rads level until twenty-two days of storage when only a slight amount was observed. Mold growth increased with lengthened time and progressively with decreased
Table 15. Effect of radiation dose on percentage of marketable cherry varieties stored at 40°F for various time intervals

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<th>Windsor</th>
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* Marketable refers to edible fruit.
Figure 6. Effect of radiation dose on the physical quality and microbial growth of Bing sweet cherries (photographed 71 days after irradiation). Left to right: A=control, B=2 x 10^5 rads, C=3 x 10^5 rads, D=4 x 10^5 rads.
Table 16. Effect of radiation dose on mold growth* on sweet cherry varieties stored at 40°F for various time intervals

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* + No mold; ++ Slight mold; +++ Moderate mold; ++++ Much mold; ++++ Profuse mold.
doses of radiation until the last three or four storage periods. At that time, more mold growth was observed in the fruits irradiated to $2 \times 10^5$ rads level of Lambert and Windsor than at any of the other doses.

Bing cherries showed the greatest amount of mold growth throughout the experiment. This probably was due to the ripe condition of this variety at the time of harvest. Napoleon cherries had the least amount of mold, but were affected more by yeasts than any other of the varieties. As a result of yeast rot, Napoleon cherries did not have as high a percentage survival as the other varieties.

There was a constant decrease in the number of edible cherries as the length of storage increased. This was more noticeable at the 0 (control) and $2 \times 10^5$ rads levels (Table 15). The percentage of marketable fruits, influenced by both mold and yeast growth showed a considerable decrease when irradiated to the 2 and $3 \times 10^5$ rads levels in the last three or four storage periods for Lambert, Napoleon, and Windsor cherries.

Alternaria and Hormodendrum were the two most common types of mold causing rot in sweet cherries (Table 17). Both were present in about 80 percent of the samples. About 70 percent of the control fruit was infected by Penicillium, but none was observed in any of the irradiated samples. Stemphylium was present in about one-third of the treatments, and Botrytis was noticed when irradiated to 3 and $4 \times 10^5$ rads.
Table 17. Effect of radiation dose on type of mold growth on sweet cherry varieties stored at 40° F. for various time intervals

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<tr>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td></td>
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<td>Hormodendrum</td>
<td>Botrytis</td>
<td>Hormodendrum</td>
</tr>
<tr>
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<tr>
<td>4</td>
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<td>71</td>
<td>Control</td>
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<td>Alternaria</td>
<td>Botrytis</td>
<td>Alternaria</td>
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<tr>
<td></td>
<td></td>
<td>Penicillium</td>
<td>Penicillium</td>
<td>Alternaria</td>
<td>Penicillium</td>
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<td>Hormodendrum</td>
<td>Stemphylium</td>
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<td></td>
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<td>Alternaria</td>
<td>Alternaria</td>
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<tr>
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<td>Hormodendrum</td>
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<tr>
<td>4</td>
<td></td>
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<td>Alternaria</td>
<td>Alternaria</td>
<td>Alternaria</td>
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<tr>
<td></td>
<td></td>
<td>Hormodendrum</td>
<td>Hormodendrum</td>
<td>Stemphylium</td>
<td>Hormodendrum</td>
</tr>
</tbody>
</table>
Experiment VII: Effect of Radiation Dose, Pre-irradiation Chemical Dip and Packaging Film on the Physical Quality and Microbial Growth of Two Sweet Cherry Varieties

Two packaging films were used in conjunction with 2000 ppm concentrations of five different fungus-inhibiting chemicals - Captan, D.H.A-S, Dowicide A, Mycostatin, and potassium sorbate - and radiation to 0 (control), 2, 3, and $4 \times 10^5$ rads. Following treatment, the cherries were placed in storage at $40^\circ$ F. for eighty days.

There was much less mold growth in the higher (3 and $4 \times 10^5$ rads) doses of radiation than in the lower (0 and $2 \times 10^5$ rads) doses (Table 18). The $3 \times 10^5$ rads treatment appears to be equally as good as the $4 \times 10^5$ rads treatment for controlling mold growth. Not any one chemical dip showed any significant control on the mold growth. However, the percent of edible fruit after eighty days storage was considerably higher in the Mylar bags than in polyethylene bags (Table 19). It was noticed that there was more moisture condensation in the polyethylene bags than in the Mylar bags. Cherries in polyethylene bags emitted a sour, disagreeable odor, had turned a brown color, and were not as firm as those in the Mylar bags. The fruit in the Mylar bags retained its natural color and firmness (Figure 7). It is regrettable that there were no Lambert cherries in Mylar bags nor Bing cherries in polyethylene bags.

Four types of mold - *Alternaria*, *Penicillium*, *Hormodendrum*, and *Stemphylium* - were predominant in this
Table 18. Effect of radiation dose on mold growth* on sweet cherries chemically treated before irradiation using two types of packaging and stored at 40° F. for 80 days

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Variety</th>
<th>Type of container</th>
<th>Control</th>
<th>Dose x 10^5 rads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Captan</td>
<td>Bing</td>
<td>50-Mylar-C</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Lambert</td>
<td>Polyethylene</td>
<td>++++</td>
<td>+++</td>
</tr>
<tr>
<td>D.H.A-S</td>
<td>Bing</td>
<td>50-Mylar-C</td>
<td>++++</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Lambert</td>
<td>Polyethylene</td>
<td>++++</td>
<td>+++</td>
</tr>
<tr>
<td>Dowicide A</td>
<td>Bing</td>
<td>50-Mylar-C</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td></td>
<td>Lambert</td>
<td>Polyethylene</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Mycostatin</td>
<td>Bing</td>
<td>50-Mylar-C</td>
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<td>+</td>
</tr>
<tr>
<td></td>
<td>Lambert</td>
<td>Polyethylene</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Potassium</td>
<td>Bing</td>
<td>50-Mylar-C</td>
<td>++++</td>
<td>+++</td>
</tr>
<tr>
<td>sorbate</td>
<td>Lambert</td>
<td>Polyethylene</td>
<td>+++</td>
<td>+</td>
</tr>
</tbody>
</table>

*++ No mold; ++ Slight mold; +++ Moderate mold; ++++ Much mold; ++++ Profuse mold.
Table 19. Effect of radiation dose on percentage of marketable* sweet cherries chemically treated before irradiation using two types of packaging and stored at 40°F for 80 days

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Variety</th>
<th>Type of container</th>
<th>Control</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Captan</td>
<td>Bing</td>
<td>50-Mylar-C</td>
<td>61</td>
<td>70</td>
<td>95</td>
<td>92</td>
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<tr>
<td></td>
<td>Lambert</td>
<td>Polyethylene</td>
<td>0</td>
<td>12</td>
<td>54</td>
<td>74</td>
</tr>
<tr>
<td>D.H.A-S</td>
<td>Bing</td>
<td>50-Mylar-C</td>
<td>18</td>
<td>40</td>
<td>71</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>Lambert</td>
<td>Polyethylene</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>47</td>
</tr>
<tr>
<td>Dowicide A</td>
<td>Bing</td>
<td>50-Mylar-C</td>
<td>34</td>
<td>58</td>
<td>63</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>Lambert</td>
<td>Polyethylene</td>
<td>44</td>
<td>59</td>
<td>51</td>
<td>50</td>
</tr>
<tr>
<td>Mycostatin</td>
<td>Bing</td>
<td>50-Mylar-C</td>
<td>24</td>
<td>71</td>
<td>93</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>Lambert</td>
<td>Polyethylene</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Potassium sorbate</td>
<td>Bing</td>
<td>50-Mylar-C</td>
<td>0</td>
<td>32</td>
<td>71</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td>Lambert</td>
<td>Polyethylene</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

* Marketable refers to cherries not affected by mold and/or yeast rot.
Figure 7. Effect of radiation dose and packaging film on the physical quality and microbial growth of two sweet cherry varieties (photographed 80 days after irradiation). Left to right: A=control, B=2 x 10^5 rads, C=3 x 10^5 rads, D=4 x 10^5 rads. Bing cherries were packaged in Mylar. Lambert cherries were packaged in polyethylene.
experiment (Table 20). However, as was found in the experiment with radiation alone, Penicillium grew only in the irradiated control treatments. Hence, it appears that the growth of Penicillium mold is inhibited by gamma radiation.

Experiment VIII: Effect of Certain Chemical Dips in Combination With Packaging Films on Inhibiting the Microbial Growth of Cherries

Locally grown Lambert cherries were picked with pedicel attached and treated with four chemicals - Captan (500 and 1000 ppm), Dowicide A (500 and 1000 ppm), Mycostatin (50 and 100 ppm), and potassium sorbate (1250 and 2500 ppm) - prior to being placed in two packaging films - polyethylene and Ful-look - and placed in storage at 40° F.

The main purpose for leaving the pedicel attached to the fruit is to prevent any possible injury when removed. By doing this, it is felt there will be less spoilage by mold that could enter the injured fruit. We see from Table 21 that there was only a slight amount of mold growth after fifteen days storage. The control treatments were slightly more infested than those treated with chemicals. After thirty days of storage there was considerably more mold growth than at fifteen days. Those cherries treated with Captan had somewhat less infestation than any other treatment. Mycostatin at the high rate (100 ppm) of chemical was about like the Captan-treated cherries. In
Table 20. Effect of radiation dose on the type of mold growth on sweet cherries chemically treated before irradiation using two types of packaging and stored at 40°F for 80 days

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Dose x 10^5 rads</th>
<th>Type of container and variety (Lambert)</th>
<th>50-Mylar-C (Bing)</th>
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</thead>
<tbody>
<tr>
<td>Captan</td>
<td>Control</td>
<td>Alternaria</td>
<td>Alternaria</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Penicillium</td>
<td>Penicillium</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stemphylium</td>
<td>Stemphylium</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Alternaria</td>
<td>Alternaria</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hormodendrum</td>
<td>Hormodendrum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stemphylium</td>
<td>Stemphylium</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Hormodendrum</td>
<td>Alternaria</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stemphylium</td>
<td>Hormodendrum</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Hormodendrum</td>
<td>Alternaria</td>
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<tr>
<td></td>
<td></td>
<td>Stemphylium</td>
<td>Stemphylium</td>
</tr>
<tr>
<td>D.H.A-S</td>
<td>Control</td>
<td>Penicillium</td>
<td>Alternaria</td>
</tr>
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<td></td>
<td></td>
<td>Hormodendrum</td>
<td>Penicillium</td>
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<td></td>
<td></td>
<td></td>
<td>Hormodendrum</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Alternaria</td>
<td>Alternaria</td>
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<tr>
<td></td>
<td></td>
<td>Hormodendrum</td>
<td>Stemphylium</td>
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<tr>
<td></td>
<td>3</td>
<td>Hormodendrum</td>
<td>Hormodendrum</td>
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<tr>
<td></td>
<td></td>
<td>Stemphylium</td>
<td>Stemphylium</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Alternaria</td>
<td>Hormodendrum</td>
</tr>
<tr>
<td>Dowicide A</td>
<td>Control</td>
<td>Alternaria</td>
<td>Alternaria</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Penicillium</td>
<td>Penicillium</td>
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<td></td>
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<td>Hormodendrum</td>
<td>Hormodendrum</td>
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<td>2</td>
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<td></td>
<td></td>
<td>Hormodendrum</td>
<td>Hormodendrum</td>
</tr>
<tr>
<td>Chemical</td>
<td>Dose x 10^5 rads</td>
<td>Type of container and variety</td>
<td>Polyethylene (Lambert)</td>
</tr>
<tr>
<td>------------------</td>
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<tr>
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<td>Alternaria</td>
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<tr>
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<td>Hormodendrum</td>
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</tr>
<tr>
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<td>Control</td>
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<td>Penicillium</td>
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<td>Alternaria</td>
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<td></td>
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<td></td>
<td>Hormodendrum</td>
</tr>
<tr>
<td>Potassium sorbate</td>
<td>Control</td>
<td>Alternaria</td>
<td>Alternaria</td>
</tr>
<tr>
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<td>Penicillium</td>
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<td>Alternaria</td>
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<tr>
<td>4</td>
<td></td>
<td>Hormodendrum</td>
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</table>
Table 21. Effects of chemical dips and packaging film on mold growth* on Lambert cherries stored at 40°F for various time intervals

<table>
<thead>
<tr>
<th>Days in storage</th>
<th>Chemicals</th>
<th>Concentration ppm</th>
<th>Packaging film</th>
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<td>Polyethylene</td>
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<td>15</td>
<td>Control</td>
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<td>500</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>1000</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Dowicide A</td>
<td>500</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1000</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Mycostatin</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Potassium sorbate</td>
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<td>++</td>
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<td>2500</td>
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<tr>
<td>30</td>
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<td></td>
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<td>++++</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>Dowicide A</td>
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<td>50</td>
<td>++++</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>++++</td>
</tr>
<tr>
<td></td>
<td>Potassium sorbate</td>
<td>1250</td>
<td>++++</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2500</td>
<td>++++</td>
</tr>
</tbody>
</table>

* + No mold; ++ Slight mold; +++ Moderate mold; ++++ Much mold; +++++ Profuse mold.
both instances the cherries which were placed in Ful-look packaging film had less mold growth than those placed in polyethylene films.

In the first fifteen day storage period there was no significant difference between the two types of packaging film in retaining edible fruit (Table 22). However, after thirty days storage, there was a highly significant difference. The Ful-look film was much better for retaining edible fruit. Captan showed the greatest effect of any chemical dip after thirty days of storage. There was up to 73 percent marketable fruit when they were treated with Captan; however, there is an objectionable residue left on fruit treated with Captan. This would not be very good for public sales.

It was expected that this experiment would run for sixty days. However, at the end of the thirty day storage period, there was such a small percentage of edible fruit that further studies would be pointless, so the experiment was terminated at that time. One possible explanation for this early spoilage is that there was frost during the latter part of July which may have caused some injury to the cell structure, thus causing an early breakdown of the tissue and allowing entry of microorganisms which caused considerable damage. This frost did not occur during the previous year in which cherries for experiment VII were grown.
Table 22. Effect of chemical dips and packaging film on percentage of marketable* Lambert cherries stored at 40°F for various time intervals**

<table>
<thead>
<tr>
<th>Days in storage</th>
<th>Chemicals</th>
<th>Concentration ppm</th>
<th>Packaging film</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Polyethylene</td>
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<tr>
<td>15</td>
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<tr>
<td></td>
<td></td>
<td>100</td>
<td>99</td>
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<tr>
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<td>Potassium sorbate</td>
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<td>88</td>
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<td>91</td>
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<tr>
<td></td>
<td></td>
<td>1000</td>
<td>36</td>
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<tr>
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<td>Dowicide A</td>
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</tr>
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<td></td>
<td></td>
<td>1000</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Mycostatin</td>
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<td>5</td>
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<td></td>
<td>Potassium sorbate</td>
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<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2500</td>
<td>0</td>
</tr>
</tbody>
</table>

* Marketable refers to edible fruit.
** The detailed analysis of variance is presented in Appendix, Table 2.
During the first fifteen days storage, Hormodendrum was most prevalent throughout the experiment (Table 23). However, at the thirty day storage period, Alternaria and Stemphylium were considered to be the main spoilage organisms in the experiment. There was a considerable amount of Rhizopus during this storage period and where present it had very profuse growth causing considerable damage to the fruit. Penicillium, due to its abundant spore production, was present in essentially all of the treatments. It also caused considerable damage to the cherries. Hormodendrum was not as noticeable in the second storage period as it was during the first fifteen day storage.
Table 23. Effect of chemical dips and packaging films on the type of mold growth on Lambert cherries stored at 40°F for various time intervals

<table>
<thead>
<tr>
<th>Days in storage</th>
<th>Chemical</th>
<th>Concentration ppm</th>
<th>Packaging films</th>
</tr>
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<td></td>
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<tr>
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</tr>
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<td></td>
<td></td>
<td>1000</td>
<td>Hormodendrum</td>
</tr>
<tr>
<td></td>
<td>Dowicide A</td>
<td>500</td>
<td>Hormodendrum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1000</td>
<td>Hormodendrum</td>
</tr>
<tr>
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<td>Mycostatin</td>
<td>50</td>
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</tr>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Alternaria</td>
</tr>
<tr>
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<td>Potassium sorbate</td>
<td>1250</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>2500</td>
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<td>Concentration ppm</td>
<td>Packaging films</td>
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<td>Stemphylium</td>
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<td>Chemical</td>
<td>Concentration ppm</td>
<td>Packaging films Polyethylene</td>
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<td></td>
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DISCUSSION

The results obtained in the experiments conducted at the Utah State University during 1959-61 seasons showed that there was a difference in sensitivity among microorganisms to gamma radiation. Species of Penicillium were suppressed by gamma radiation, even at the low dose of $1 \times 10^5$ rads. This is in agreement with work done by Beraha et al. (7). Growth of microorganisms was retarded at the higher (3 and $4 \times 10^5$ rads) dose of radiation in both strawberries and cherries. Generally speaking, there was a progressive increase in mold growth with lengthened storage time and with decreased dose of radiation. However, after twenty days storage for cherries, more mold growth was observed in the fruit irradiated to the $2 \times 10^5$ rads level of Lambert and Windsor than with the control or other doses. This agrees with work done by Nehemias, Brownell, and Harlin (28). A possible explanation might be that radiation causes a change in the fruit, either physical or chemical, which enables the mold to grow more readily. At lower doses, this effect apparently stimulates growth rates to more than compensate for the fact that fewer organisms were present initially. At higher radiation doses, the probability of killing completely all mold organisms on a particular sample of fruit increases,
and more samples may be free from mold formation regardless of growth-promoting factors.

The main infestation at these higher doses were the multicellular-spored fungi as Alternaria, and Stemphylium. Fields (16) and Beraha, Smith, and Wright (9) have shown that these multicellular-spored fungi have greater resistance to gamma radiation than the monocellular-spored Penicillium. Even species within the same general show a difference of resistance to gamma radiation.

The results have shown that radiation alone is not adequate to control the microorganisms in fresh fruit. Fungicides were used in combination with gamma radiation and placing the chemically-treated fruit in certain packaging films prior to being irradiated. With this combination of treatments, there was an increase in the length of storage in which fruit maintained good quality. Fruit treated with Mycostatin and Captan showed a much greater degree of freedom from microorganisms than did fruit treated with potassium sorbate. Dimarco (14) and Salunkhe and Norton (40) also found that when fruit was treated with Mycostatin and Captan there was a reduction in mold growth on fresh fruit.

Once the fruit has been freed of the existing microorganisms, some means of protection from recontamination is necessary. There are many new and improved packaging films on the market, but in order for them to be of any value they must allow normal respiration of the product and at the same time prohibit the entry of microorganisms.
Fruit placed in the more permeable Mylar and Ful-look films maintained better color and physical qualities than those placed in polyethylene. Polyethylene apparently did not allow sufficient water vapor transmission to take place since increased decay and water vapor collection, inside the package, seemed to increase. Ayre and Denisen (3) also found this to be true. Aeration, during irradiation of fruits, is also essential for extension of shelf-life as well as for retention of natural flavors of fresh fruit. The supplying of O₂ for normal respiration process at the same time removes CO₂ and other gases given out as a result of increased respiration during radiation.

Softening of many fresh fruits and vegetables by an ionizing radiation process, while extending storage life, is one of the many problems encountered. All varieties of strawberries irradiated to 3 x 10⁵ rads developed a soft, spongy texture and had a water-soaked appearance. Nelson, Maxie, and Eukel (29) found this to be true when Shasta strawberries were irradiated in monolayers at 4 x 10⁵ rep. Tissue firmness is attributed largely to intercellular pectic substances. According to McArdle and Nehemias (25) this is a result of a breakdown of protopectin to pectates to soluble pectin. Alteration of protopectin in the intercellular areas may allow the cells to separate with loss of texture as a result.
Cellulose is degraded at gamma-radiation dosages equal to or lower than those required for softening plant tissues. Therefore, it seems probable that the degradation of this cell wall constituent is a major factor in the radiation-induced softening of plant tissues (18). Immature strawberries and relatively firm cherries showed less softening than the mature strawberries. However, the Napoleon cherries did have a soft texture after being irradiated. Subsequent to gamma irradiation, Windsor cherries seemed to maintain a good physical condition; Kasuga strawberries maintained good physical quality; but the Marshall variety of strawberries became very soft and mushy.

When green strawberries were irradiated, there was little or no color development during storage. Lack of color development in green strawberries is indicative of the slowing down of the normal ripening process by gamma irradiation. There was some loss of color in both the mature strawberries and cherries at the higher (3 and $4 \times 10^5$ rads) radiation dosage. Loss of color in mature strawberries and cherries is one of the problems of ionizing radiation. The red pigment, anthocyanin, is generally sensitive to ionizing radiations and, therefore, its destruction is understandable. Markakis, Livingston, and Fagerson (22) found that 63 percent of the anthocyanin pigment in strawberries is destroyed by $4.65 \times 10^5$ rep of gamma radiation.
SUMMARY AND CONCLUSIONS

Experiments were carried out to study the effects of gamma radiation, chemical dips, and packaging film for the control of post-harvest diseases and extension of the shelf-life of varieties of strawberries and cherries. A brief summary of these observations is listed below.

Strawberries

1. A dose of $2 \times 10^5$ rads was the optimum dose of radiation for preservation. The shelf-life was extended about fifteen days at this dose.

2. At the high $(3 \times 10^5$ rads) dose of radiation there is a breakdown of tissues which caused the berries to have a spongy texture.

3. Partially green berries when irradiated retain good physical quality and have extended storage life but are lacking in flavor.

4. Captan and Mycostatin are better fungicides than Dowicide A and potassium sorbate. Mycostatin was somewhat better than Captan.

5. There was no significant difference between polyethylene and Mylar as packaging films.

6. Hormodendrum and Botrytis were the two most common molds. Penicillum was killed in all irradiated treatments.
Cherries

1. For extending the shelf-life of cherries, a dose of $3 \times 10^5$ rads was most effective.

2. At the $2 \times 10^5$ rads dose there was more spoilage than at control after fifty days storage. This was due to a breakdown of the tissue by a dose of radiation that was not high enough to kill all of the microorganisms.

3. The cherries turned a brown color at the high ($4 \times 10^5$ rads) dose of irradiation.

4. There was better fungus control with Captan than any other fungicide used. Mycostatin was nearly as good as Captan.

5. A significant increase in storage-life of fruit was observed when Ful-look packaging was used in storage. Mylar also showed a favorable increase.

6. Of the different types of mold growth on the cherries, Alternaria was considered to be the most predominant. As in strawberries, Penicillium was not observed in any of the irradiated treatments.


Appendix Table 1. Analysis of variance for the effect of chemical dips and packaging film on percentage survival of Shasta strawberries stored at 40°F for various time intervals.

<table>
<thead>
<tr>
<th>Source</th>
<th>Degrees of Freedom</th>
<th>Evaluated 10 days after treatment</th>
<th>Evaluated 20 days after treatment</th>
<th>Evaluated 30 days after treatment</th>
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</thead>
<tbody>
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<td></td>
<td></td>
<td>Mean Square</td>
<td>F</td>
<td>Mean Square</td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>119.84</td>
<td>0.01</td>
<td>329.97</td>
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<td>656.93</td>
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<tr>
<td>4 vs. 5</td>
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aReference to Table 13
bTreatment: 1=Control, 2=Captan, 3=Dowicide A, 4=Mycostatin, 5=Potassium sorbate
Appendix Table 2. Analysis of variance for the effect of chemical dips and packaging film on percentage survival of Lambert cherries stored at 40°F. for various time intervals\textsuperscript{a}

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<th>Source</th>
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<td>4 vs. 5</td>
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Error 60

aReference to Table 2
bTreatments: 1=Control; 2=Captan; 3=Dowicide A; 4=Mycostatin; 5=Potassium sorbate