IRRADIATION OF NORTHWEST AGRICULTURAL PRODUCTS

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ABSTRACT

Irradiation of food for disinfestation and preservation is increasing in importance because of increasing restrictions on various chemical treatments. Irradiation treatment is of particular interest in the Northwest because of a growing supply of agricultural products and the need to develop new export markets. Several products have, or could potentially have, significant export markets if stringent insect control procedures are developed and followed. Due to the recognized potential benefits of irradiation, Pacific Northwest Laboratory (PNL) is conducting this program to evaluate the benefits of using irradiation on Northwest agricultural products under the U.S. Department of Energy (DOE) Defense Byproducts Production and Utilization Program. Commodities currently included in the program are cherries, apples, asparagus, spices, hay, and hides.

INTRODUCTION

The Pacific Northwest produces a wide variety of food and agricultural products. Although many of these products currently have significant export markets, additional markets could be developed if stringent insect control procedures were used. For example, cherries destined for Japanese markets are fumigated with methyl bromide to control insects (primarily the codling moth and the cherry fruit fly). A satisfactory technique for fumigating apples has not been developed yet; therefore, a Japanese export market does not exist for apples. Even for cherries, the fumigation process results in poorer quality cherries being prepared for export (as compared with nonfumigated cherries). In addition, the fumigant leaves a residue that may be questioned with respect to carcinogenicity and teratogenicity as a result of adverse findings for ethylene dibromide (a common fumigant used for citrus fruit). Thus, apples and cherries could both benefit from the use of the alternative insect control method offered by irradiation. Other regional products of interest that could benefit from irradiation include asparagus, spices, hay, and hides.

Because of the potential benefits to be derived, PNL is conducting the Northwest Food and Agricultural Products Irradiation Program. This cooperative program involves other organizations that have provided services including supplying commodity samples for irradiation, measuring results, and being involved in program planning. In general, these organizations have provided their support. Organizations that have participated in the program include:

- U.S. Department of Agriculture (USDA) Agricultural Research Service Laboratories, Yakima and Wenatchee, Washington
- Oregon State University Experiment Station, Hood River, Oregon
- Washington State Fruit Commission
- Washington State Apple Commission
- Iowa Beef Processors, Inc., Pasco, Washington, and Dakota City, Nebraska
- Sensory Science Laboratory, Oregon State University, Corvallis, Oregon
- Crescent Manufacturing Company, Seattle, Washington
- USDA Animal Biomaterials Laboratory, Philadelphia, Pennsylvania
- Washington State University/Irrigated Agriculture Research and Extension Center, Prosser, Washington.

OBJECTIVE

The long-term objective of this program is to evaluate the need for a demonstration irradiator in the Pacific Northwest that would demonstrate the effectiveness of irradiation of agricultural products in sufficient quantities to establish the market potential and stimulate public acceptance. The Northwest Food and Agricultural Products Irradiation Program focuses on evaluating the efficacy of irradiation processing of certain commodities of special interest to the region. The commodities to be evaluated in this program are expected to include, but are not limited to, cherries, apples, asparagus, spices, hay, and hides. Specific tests need to be conducted in the Pacific Northwest on these commodities to establish dose levels required to meet quarantine regulations and evaluate product quality. The industry is more likely to commercialize irradiation if the background information has been developed regionally and if they have had a role in developing it.

APPROACH

The approach to achieving this objective has been organized into the following activities for FY 1985:

- product irradiation testing
- transportable cesium irradiator (TPCI) scheduling, dosimetry testing, and support
- public acceptance testing
- information dissemination.

A brief description of each of these activities is given in the following paragraphs.

Product Irradiation Testing

Considerable irradiation data are available on many food and other agricultural products. However, this activity will clearly define the irradiation requirements for the specific products to be irradiated. Work conducted on cherries and apples as part of this program has generally defined the dose levels required for disinfestation and limits as related to product quality. Additional testing is required to determine the effect of various dose rates and other environmental factors such as temperature and atmosphere under which the irradiation is conducted. These factors will be important design parameters to be considered in irradiator design. All of these tests will be conducted in the cobalt-60 facility at PNL. These studies will be conducted jointly with the USDA laboratories and other organizations in the Northwest. PNL will perform the apple and cherry irradiations and the USDA laboratories will conduct testing on the effectiveness of the irradiation as well as the impact on product quality. Irradiation testing has also been conducted on hides and spices, and tests on asparagus and hay are planned in FY 1985.

TPCI Scheduling, Dosimetry Testing, and Support

The TPCI will be available for studies in the Northwest in FY 1985. The purpose of this activity is to provide for scheduling, dosimetry testing, and support of the TPCI unit while it is in the region. A "Demonstration/Test Plan" for the TPCI has been developed. The planning committee included members from PNL, the USDA Yakima and Wenatchee laboratories, Washington State University, and Balcom & Moe, Inc. (a potato-packing company). Products included in the plan are cherries, apples, pears, potatoes, onions, fish/seafood, hay, peaches, nectarines, and apricots. Sites included are: Yakima, Wenatchee, Tri-Cities, Prosser, Spokane, and Seattle, Washington; Hermiston and Salem or Portland, Oregon; and Boise, Idaho. The demonstration/test is scheduled to run from the second week of July until the second week of November.

Public Acceptance Testing

During the course of these studies, considerable attention will be paid to public perception; this activity will assess public acceptance of irradiated agricultural products. In addition, licensing requirements will be established and necessary actions taken to meet all such requirements. This activity will necessarily address public acceptance and licensing requirements on an international scale because the major function of irradiation for some of the products is to make them acceptable to foreign markets.

Information Dissemination

This task will fully inform members of the public, government, and industry of the potential for commercialization of the agricultural products irradiation technology. Two major activities are planned as part of this task: 1) organization, preparation, and conduct of a public seminar; and 2) preparation and distribution of a summary report on program results. Information requested by interested parties will be supplied, and public relations related to the TPCI unit and other elements of the program will be provided. In addition, public presentations and seminars will be given to various commodity associations, civic groups, and other organizations.

COMMODITIES INCLUDED IN PROGRAM

The commodities currently included in this program are cherries, apples, asparagus, spices, Timothy hay, and hides. Additional commodities could be added as warranted by regional needs and desires.

Cherries destined for the Japanese market are fumigated with methyl bromide to meet quarantine requirements (primarily for the codling moth). The fumigation process results in poorer quality cherries being prepared for export (as compared with nonfumigated cherries). In addition, the fumigant leaves a residue that may be subject to adverse findings on health effects similar to those for ethylene dibromide (a common fumigant used for citrus fruit).

No satisfactory technique for fumigating apples to control the codling moth has been developed; therefore, a Japanese export market does not exist for apples. Apples could benefit from the utilization of the alternative insect control method offered by irradiation.

Asparagus from Washington State is quarantined for a one-month period at the beginning of the season from entering California for the fresh market due to asparagus aphid infestation. At the present time, no effective chemical control exists, although efforts are being made to register the fumigant methyl bromide. In addition to the disinfestation problem, it would be very beneficial to extend the shelf life to lengthen the marketing period for fresh asparagus.

Spices are a highly contaminated commodity and are currently treated with ethylene oxide (ETO) to kill microorganisms. Irradiation may be a viable alternative to ETO because of the more stringent handling requirements for this chemical.

Timothy hay destined for Japan is currently fumigated to control the Hessian fly. Irradiation could benefit the export in two specific ways: 1) enable the treatment and shipment of condensed bales with a density double those currently fumigated and 2) extend the shipping season, which is currently limited to April to November because of the temperature requirements for fumigation.

Cattle hides are currently soaked in salt brine before export in shipping containers. The salt solution is corrosive to the containers, shipping docks, trailers, barges, and handling equipment, which results in considerable added shipping expense. Salt removal from hides prior to tanning also adds to costs. Therefore, irradiation may be an alternative method to prevent microbial deterioration.

The quantity and value of the commodities (excluding spices) that could be irradiated in the near term have been projected to be over 60,000 tons per year valued at over $40 million. The distribution of these products is listed in Table I.

This analysis does not include projected potential increases in export markets for these commodities. For example, about 2,100 tons of cherries are exported to Japan every year from the State of Washington. Market analysts have predicted that this amount could increase by a factor of five through

TABLE I

Quantity and Value of Potential Irradiated Products

Commodity	Tons/Year	Value ($ Million)
Timothy hay	25,000	2.5
Asparagus	1,250	1.0
Cherries	2,100	3.6
Apples	20,000	10.7
Hides	14,400	24.0
Total	62,750	41.8

improved marketing. The analysis also does not include other high volume commodities such as potatoes or wheat. Therefore, the total potential for irradiated products from the Pacific Northwest may have a value of several hundred million dollars per year.

RESULTS OF IRRADIATION TESTS

Specific irradiation tests have been conducted on cherries, apples, hides, and spices. Tests will also be conducted on hay and asparagus in FY 1985. Results are discussed below.

Cherries

The objective of the cherry irradiation testing task is to determine the radiation dose needed to control fruit flies and codling moths by disrupting maturation of their respective larvae. An additional objective is to determine the effects of irradiation on product quality. From the irradiation tests that have been conducted, a dose of 0.25 to 0.3 kGy appears to be sufficient for insect control and has very little effect on product quality.

During the 1984 crop year, two batches of cherries were irradiated for evaluation of quality. Each batch consisted of cherries from three orchards or packing houses. The cherries were irradiated at about 26°C (78°F) at total doses of 0, 0.2, 0.4, 0.6, 0.8, 1.0, and 2.0 kGy. Samples of cherries from the same sources were also fumigated at low temperature (about 7°C or 45°F). Following irradiation, the cherries were transported to the USDA laboratory in Wenatchee, Washington, for chemical and physical testing. Samples of the cherries were held in cold storage for periods of 0, 7, 14, and 28 days prior to conducting quality testing.

The results of these tests showed some statistically significant differences in color, texture, percent decay, pH, acid, soluble solids, stem color, and stem diameter for individual test periods; but there was no correlation with treatment (dose level or fumigation). Generally, there were no significant differences in initial weights or weight losses during further ripening or in fruit size with respect to treatment. The most notable effect of irradiation was on cherry firmness. Cherry firmness ratings for both batches of cherries immediately following cold storage and after three days of ripening following cold storage are presented in Fig. 1. Cherry firmness declined with increasing dose levels so that those irradiated at 2.0 kGy had a firmness of about 93% of nonirradiated cherries. Other differences between cherries irradiated to 2.0 kGy and the nonirradiated control were generally large enough to be considered statistically significant. The fumigated cherries generally ranked between the 0.2 kGy and 0.4 kGy irradiated cherries with respect to firmness. Although the cherries that were irradiated up to 0.6 kGy received lower firmness ratings, the ratings were not seen as being significantly different from those for nonirradiated cherries. The firmness ratings for cherries that were ripened for three days at room temperature are also shown in Fig. 1. During these tests, the cherry firmness declined following this ripening period.

In addition to the quality tests discussed above, samples irradiated at 0, 0.4, 0.8, and 2.0 kGy from the second batch of cherries were sent to the Sensory Science Laboratory at Oregon State University (Corvallis, Oregon) for sensory evaluation. These cherries were evaluated by a 20-member panel on the basis of appearance, firmness, and flavor after refrigerated storage intervals of approximately 1, 2, 3, and 4 weeks following irradiation. The average scores are presented in Fig. 2 as a function of dose level. The ratings in all three categories declined slightly with increasing dose rate. However, it should be noted that in all sensory tests the cherries were judged to be desirable (above the midpoint of the scale) and, thus, acceptable for market.

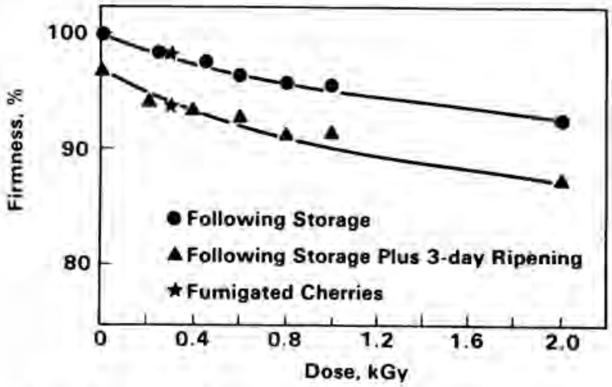

Fig. 1. Cherry Firmness (as percent of firmness of nonirradiated cherries).

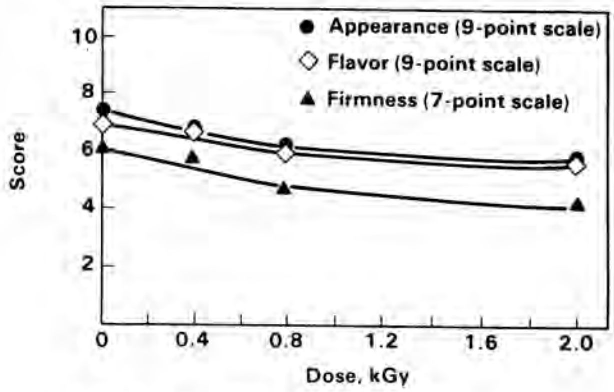

Fig. 2. Sensory Evaluation for Cherries.

During the 1983 cherry irradiation studies, samples of cherries purposely infested with cherry fruit fly larvae were irradiated to nominal doses of 0, 40, 60, 80, 120, and 200 Gy. These tests showed no emergence of adult flies at the lowest dose tested. The doses required to prevent 50% and 95% pupation of larvae were projected to be 27 and 264 Gy, respectively.

During 1984, two batches of cherries infested with fruit fly larvae were irradiated at nominal doses of 0, 3.75, 7.5, 15, 30, 45, 60, and 90 Gy.

The first batch was irradiated on July 5; the second, on July 11, 1984, to determine the level of control achieved at different stages of larvae development. The results of these tests indicated that prevention of pupation is more difficult when irradiating more mature larvae. However, the more important result will be the prevention of adult emergence. These results will be obtained after emergence in the spring of 1985.

Tests conducted to examine control of the codling moth have been evaluated. The irradiation dose required to prevent emergence of adult codling moths was 0.21 kGy for nondiapausing larvae and 0.23 kGy for diapausing larvae. The doses required to prevent emergence of apparently normal adults were 0.14 and 0.15 kGy, respectively.

All biological phases of the insect studies were conducted by the USDA laboratory in Yakima, Washington.

The results of the tests conducted on cherries have led to the following conclusions:

- Irradiation to a dose of 0.25 to 0.3 kGy appears to be sufficient to meet quarantine requirements (based on levels to control the codling moth).
- Irradiation of cherries to doses well above those required for quarantine treatment does not significantly degrade the fruit. Doses of up to 0.6 to 0.8 kGy appear to be acceptable.
- Irradiation reduces the firmness of cherries but has no significant effect on other quality factors.
- Irradiation up to 2.0 kGy at a temperature of about 25°C does not provide measurable shelf-life extension based on sensory evaluations.
- Based on physical quality measurements, there is no apparent advantage of irradiation over low-temperature fumigation. However, there may be other advantages such as improved flavor (no sensory tests were conducted on fumigated cherries) and lack of any chemical residue.

Apples

The objective of the apple irradiation tests was to determine the dose level required to control the codling moth and to determine the effect of radiation on product quality. The results have shown that effective insect control can be achieved at doses of 0.25 to 0.30 kGy and that there is no significant impact on fruit quality at this level.

Apples were obtained from six packing houses and divided into six lots for irradiation after six storage time intervals. Thus, an equal number of apples from each packing house were irradiated at each dose level (0, 0.2, 0.4, 0.6, 0.8, and 1.0 kGy) after each storage time interval. The initial irradiation was done on freshly packed apples (no controlled atmosphere storage). Irradiation tests were then conducted on other batches of apples following 2, 4, 6, 8, and 10 months of controlled atmosphere storage. Following irradiation, the apples were placed in cold storage for two months. After removal from cold storage, quality tests were conducted on 20 apples from each dose level and each packing house. Quality tests were then conducted on five apples following 3, 7, 10, and 14 days ripening time. The quality tests included pH, visual inspection, moisture, and firmness.

In general, irradiation reduced apple firmness at higher doses but did not significantly impact other quality properties. Insect control can be achieved in apples at doses lower than those at which firmness reduction occurs. Irradiation, thus, appears to be a technically feasible technique for meeting insect quarantine requirements.

Hides

The purpose of the hide irradiation tests was to determine the dose required to control microbial deterioration to an acceptable level without resulting in radiation damage. Hide samples were obtained from the Iowa Beef Processors (IBP) plant in Pasco, Washington, for irradiation testing. Each individual sample was approximately 13 cm by 18 cm. Three samples were rolled together and placed in two plastic bags and irradiated to nominal doses of 5, 10, 20, and 50 kGy.

The samples were shipped to the USDA Animal Biomaterials Laboratory in Philadelphia and examined for quality. After 36 days of storage at room temperature, the samples were washed in sterilized peptone broth and the bacterial count in the broth was determined on conventional agar plates. The hide samples were then processed into crust leather (the stage just prior to finish application). Prior to washing, it was apparent that most of the samples had deteriorated badly; they had a strong putrid odor and the hair had become extremely loose on all except those irradiated to 50 kGy, which were quite stiff, particularly along the creases where they had been folded. All of the other samples were as flaccid as a fresh hide. The crust leather prepared from each of the samples was examined visually. The grain (top surface) of the leather was intact in the samples that were irradiated at 20 and 50 kGy but was completely destroyed at the two lower doses. Three physical tests were made on each of the samples, comparing their relative strengths. Tensile strength, slit tear, and ball burst values varied from hide to hide as well as within the hide (Table II). The values at 10 kGy appear to be slightly lower than normal. All three values at 50 kGy would be considered low.

TABLE II

Hide Irradiation Results

Sample	Irradiation Dose, kGy	Microbial Count Per Gram	Tensile Strength, psi	Slit Tear, lb/in.	Ball Burst, lb/in.
A	50	0	903	277	522
C	20	5×10^6	1523	666	1315
D	10	10×10^6	1861	614	1712
B	5	0.5×10^6	1455	561	1300

Microbial growth on the hide samples was completely inhibited only at the highest level of irradiation. The sample irradiated at 5 kGy had a low microbial count (0.5×10^6 cells/g) but high microbial damage, indicating that the microbes had essentially completed their life cycle and that the population had died off after having reach some higher level. Physical strength test values were significantly reduced at the 50-kGy treatment level. At 20 kGy, microbial growth was not completely prevented, although little grain damage was observed.

Reduction in the values of the physical tests at 5 kGy is undoubtedly due to microbial damage. It was concluded that an irradiation dose between 20 kGy and 50 kGy may be adequate for preservation with little or no impairment of physical strength properties. Furthermore, lower doses may be adequate for shorter periods.

Spices

The objective of the spice irradiation tests was to determine the level of microbial control achieved when irradiating commercial containers of spices. The results of these tests have shown that a dose level of about 20 kGy is sufficient to provide complete control of all microorganisms in whole black pepper and ground paprika.

Samples of whole black pepper and ground paprika were obtained from Crescent Foods, Seattle, Washington, for irradiation testing. Twelve samples from each of the original spice bags were used to perform the preirradiation microbiological testing. It was not possible to get distinct samples from the outside layer of the bag versus the inside. Six samples from each spice were used for total aerobic bacterial count, coliforms, E. coli, yeast/mold, and coagulase positive Staphylococcus. The other six samples from each spice were used to count Salmonella.

Twelve prebagged samples were placed back into the original spice bags for irradiation treatment. In six samples, a chromic film dosimeter was placed in the center of each spice bag; in six other samples, dosimeters were placed at the surface of the large bag. After the samples were placed back in the large bags, the bags were filled to the top with the spice that was previously removed.

The cardboard shipping containers containing the two spices and prebagged samples were placed vertically next to the cobalt-60 source. The spices were irradiated for 56 hours and then rotated 180° and irradiated for an additional 56 hours. After the samples were rotated, a dosimeter was pulled from the center of each bag and the dose determined; the observed doses for paprika and pepper were 19 kGy and 17 kGy, respectively.

When the irradiation was complete, the 12 samples from each spice bag were tested in the same manner as the preirradiated samples for microbial load and identification. In this case, samples from the surface of the sacks were distinguished from those located at the center.

Microbiological tests showed that total aerobic counts ranged from 10^5 to 10^6 organisms per gram in pepper and from 10^6 to 10^7 in paprika for the preirradiated samples. Postirradiated samples showed 0 counts for all microorganisms for each spice and all samples.

No salmonella was detected in any of the preirradiated samples after incubation in lactose broth. The results clearly show that doses of about 20 kGy are very effective in sterilizing these bulk spices. While these samples were given a single average dose of about 20 kGy, the spice at the edge of the bag received nearly twice the dose of the spice at the center of the bag.

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- D. G. Bailey, USDA Animal Biomaterials Laboratory, Philadelphia, Pennsylvania - evaluation of hide quality.