ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN
ANN ARBOR

Progress Report

GAMMA-RAY SPROUT INHIBITION OF POTATOES

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CONTRACT NO. DA19-129-qm-349
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CONTRACT RESEARCH PROGRESS REPORT

QUARTERMASTER FOOD AND CONTAINER INSTITUTE
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Title of Contract: Gamma-Ray Sprout Inhibition of Potatoes

SUMMARY

One ton of Idaho seed potatoes of the 1954 crop was obtained in May 1955, divided into experimental lots, given varying dosages of gamma radiation and allocated as follows:

1. Potatoes given doses of 0 and 10,000 rep were placed in storage at the following temperatures: 0°, 35°, 40°, 45°, 50°, 55°, 60°, and 70°F in the constant temperature rooms of the Food Service Building, University of Michigan.

2. Potatoes given gamma radiation doses of 0, 5,000, 10,000, 15,000, 50,000, 100,000, and 200,000 rep were placed in storage at 0 and 45°F.

3. Cartons of potatoes (about 50 lb each) receiving radiation doses of 0, 5,000, 10,000, 15,000, 100,000, and 200,000 rep were sent to Lt Col Belmont, Quartermaster Food and Container Institute, for acceptance testing.

4. Cartons of potatoes (about 30 lb each) receiving the same exposures as in item 3 were sent to Professor D. Islieb of the Department of Farm Crops, Michigan State University, East Lansing, Michigan, to be stored under varying degrees of humidity.

5. About 1 lb of potatoes from each exposure given in item 3 was sent to Professor C. D. LaRue, Botany Department, University of Michigan, to study for differences in plant physiology and metabolism.

Plantings of Russet Rural, Sebago, and Katahdin potatoes were made by the Michigan State University Experiment Station to provide potatoes of known history from the 1955 crop for this experiment.

Early results after storage for 1 month at 60°F indicate no visible signs of deterioration in potatoes receiving an irradiation dose of 10,000 rep, whereas the controls have sprouted badly with concomitant weight loss and shrinkage. Potatoes stored at lower temperatures have shown less difference between the irradiated and control specimens.

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I. TECHNICAL OBJECTIVES

Low-dosage gamma irradiation of potatoes has been found to be very successful in preventing sprouting and spoilage of potatoes under storage without the development of undesirable changes. Certain types of potatoes, such as Idaho-grown russet variety, are preferred for baking, French fries, etc. These potatoes are available only 8 or 9 months of the year. Because of sprouting followed by rapid deterioration, it usually is not possible to keep potatoes under storage for longer periods. In studies conducted in the Fission Products Laboratory, University of Michigan, irradiated Idaho russets of the 1953 crop were stored successfully at 50°F for a year and a half. It is believed that desirable types of potatoes can, by irradiation, be made available the year around. This treatment might be particularly useful in increasing the storage life of any type of potato shipped overseas for the armed services.

More specifically, the general technical objective is described below:

A. A study will be made on the effect of low dosages of gamma radiation (approximately 5,000 to 20,000 rep) on at least one white-skinned and one russet-variety potato with the object of determining the dosage needed to inhibit sprouting when stored at 35°, 40°, 50°, and 70°F with 50% relative humidity. Samples of these potatoes will be made available for acceptance testing by the QMF and CI.

B. An investigation will be made using doses of gamma radiation as high as 200,000 rep on the same types of potatoes as studies in (A) above to determine the effect of overdose. Evaluation will include sprout inhibition, general appearance, keeping quality at 40° to 50°F, and sugar and starch content during intervals of storage.

C. A study will be made of the effect of two different relative humidities and two different temperatures during storage on a white-skinned and russet-variety potato.

D. An evaluation will be made at no less than four regularly scheduled intervals during the storage of the irradiated potatoes that have been stored. The said evaluation shall include:

1. total starch and reducing sugar content,
2. sprouting and its inhibition,
3. general appearance and texture,
4. interior fleshy region of peeled and sliced potatoes for decay, black heart, blackening, and other manifestations of enzyme and/or microbial action, and
5. loss in weight, to be determined and subdivided into combined respiration and transpiration loss and loss due to sprouts.

E. A limited study will be made on the effects of wound healing with special emphasis on formation of special cork cambium, and a limited study will also be conducted on chlorophyll formation in stored potatoes.

F. A quantitative respiration study will be conducted on at least a white-skinned variety and a selected russet variety of potatoes. As time permits, this study may be extended to differentiate between the tuber respiration and microbial respiration.

G. The effect of gamma radiation on the activity of specific enzymes involved in potato respiration will be investigated. This will be aimed at understanding the inhibition of enzyme activity as reflected by changes in starch content, total and reducing sugar content, and color change allowing for extended storage life of the potato.

H. A study will be undertaken to determine whether gamma-ray induced inhibition of potato sprouting is caused directly by destruction of germinal cells or indirectly by interfering with the nutrition of these cells.

I. A study will be conducted to determine the susceptibility of irradiated potatoes to common storage rot. This will include innoculation storage studies utilizing common potato-rotting bacteria and fungi.

J. As time allows, limited studies will be undertaken to determine the effects of radiation on the internal structure of the potato. This will include studies on cell growth, cell size, nuclear condition, condition of plastids, starch, cell turgor, penetrometer tests, etc.

II. SOURCE OF POTATOES

Because of the late date of activation of this research contract relative to the potato season, uniform potatoes of good quality and known history which were suitable for experimental studies were difficult to obtain. Twenty bags, 100 lb each, of Idaho certified seed potatoes of known history were obtained in May, 1955, irradiated as soon as possible according to the schedule plan in Table I, and placed in storage.

TABLE I

WEIGHT (IN POUNDS) AND DISPOSITION
OF EXPERIMENTAL IDAHO SEED POTATOES

Dose, rep	QM	MSU	U of M Storage Temperature, °F							
			0	35	40	45	50	55	60	70
0	50	30	20	25	25	80	25	25	25	10
5,000	50	30	20			80				
10,000	50	30	20	100	100	130	100	100	100	50
15,000	50	30	20			80				
50,000	50	30	20			80				
100,000	50	30	20			80				
200,000	50	30	20			80				

The seed for these potatoes was planted about May 15, 1954. The potatoes were harvested shortly after October 5, 1954, and stored in a below-the-ground storage with a temperature range of between 34° and 38°F. They were grown on an irrigated farm with a very light, sandy loam soil, in rows about 36 inches wide and the plants about 12 inches apart. These potatoes were sorted in February, 1955, to take out the larger potatoes for commercial stock and then were graded for seed in late March. The ground, according to the farmer, was not rotated too well between crops, but nevertheless, the history is as follows: 1950, potatoes; 1951, wheat; 1952, peas; 1953, wheat; and 1954, potatoes.

III. IRRADIATION AND ALLOCATION OF POTATOES

The irradiations were performed in quart cardboard containers in the radiation cave of the Fission Products Laboratory. The use of these small containers permitted more precise evaluation of the radiation dosage delivered, although somewhat more handling time was required to complete the task. Figure 1 shows a typical arrangement of these cartons, full of potatoes, in place around the outside of the source position. After the irradiation has been half completed, all cartons are rotated 180 degrees, and the upper and lower rows are interchanged. In the background, other irradiation experiments (animal food for feeding studies) may be seen in progress.

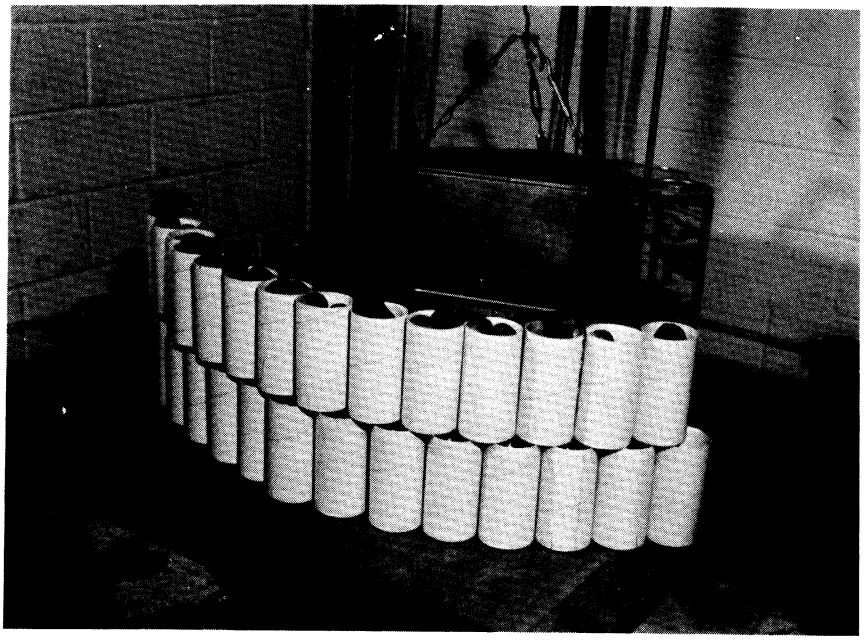

Fig. 1. Potatoes in cardboard containers in position to be irradiated.

The potato irradiation schedule, given in Table 1, may be divided into several different categories:

1. About 50 lb from each of seven different irradiation exposures (0, 5,000, 10,000, 15,000, 50,000, 100,000, and 200,000 rep) were sent to Lt Col Belmont for acceptance testing.

2. About 30 lb from each of the same irradiation exposures were sent to Professor D. Islieb for studies on weight loss and changes in appearance as a function of relative humidity during storage. These studies are discussed in detail in another section.

3. About 20 lb from each of the same irradiation exposures were placed in deep freeze to halt enzyme action for future studies of the effects of irradiation on enzyme systems. The samples were divided into lots which were kept at room temperature for the following times after irradiation before freezing: 0, 1, 2, 4, 6, 12, 24, and 48 hours.

4. About 30 lb from each of the above exposures were placed in storage at 45°F. Visual observation, routine weighing, and biochemical analyses will provide information about the effect of irradiation dosage on the potato under constant, fairly typical storage conditions.

5. About 1 lb from each of the nineteen storage samples mentioned in the previous two paragraphs were sent to Professor Carl D. LaRue for observation to detect differences in plant physiology and metabolism.

6. The remainder of the 2,000 lb of potatoes was treated and placed in storage at 35°, 40°, 45°, 50°, 55°, 60°, and 70°F, as shown in Table 1. All irradiation exposures for this experiment were of 10,000 rep, which is considered sufficient to inhibit sprouting. The same data mentioned in the previous paragraph will provide information about the effect of storage temperature on the keeping qualities of irradiated potatoes.

IV. THE EFFECT OF RELATIVE HUMIDITY ON STORAGE QUALITIES

Cooperative studies on problems of potato sprout inhibition between the University of Michigan and Michigan State University were begun in January, 1955, prior to the approval of this contract. At that time it was difficult to incorporate additional storage studies into those begun at Michigan State in the fall of 1954, but some comparisons between different methods of sprout inhibition were possible, using control tubers from a maleic hydrazide trial for gamma and beta irradiation. Beta irradiation was performed by the Agricultural Engineering Department of Michigan State University but dosages were changed by error in communica-

tion. Gamma irradiations were performed in the Fission Products Laboratory at the University of Michigan. Analysis of the reducing sugar in samples stored at 40° to 44°F for 2 months after treatment and then stored at room temperature for 3 months indicated only slightly more reducing sugar after irradiation in one of the two varieties tested. These data are listed in Table II.

TABLE II

REDUCING SUGAR ANALYSIS OF POTATOES
AFTER TREATMENT FOR SPROUT INHIBITION

	Percent Reducing Sugar	
	Russet Rural	Sebago
Control	0	0
Gamma radiation, 10,000 rep	0	0.36
Maleic hydrazide	0	0

Alcohol color tests of the same tubers did not indicate an increase in after-cooking darkening associated with sprout inhibition treatments. These data are listed in Table III. A rating of 8 indicates no discoloration with progressively lower numbers corresponding to increasing darkening.

TABLE III

ALCOHOL COLOR RATINGS OF POTATOES
AFTER TREATMENT FOR SPROUT INHIBITION

	Russet Rural	Sebago
Control	5.6	6.2
Gamma radiation, 10,000 rep	6.4	7.0
Maleic hydrazide	6.8	6.2

Further information (sugar analysis, darkening, sprout weight, and weight loss data) will be obtained from these samples.

A second set of samples (Idaho-grown Russet Burbank variety) was supplied to Michigan State University in May, 1955, for storage at varying relative humidities and uniform temperature of 50°F. Weight loss data after 1-1/2 months storage are given in Table IV. Weight loss apparently decreases with increasing relative humidity, as would be expected, and also with increasing dose rate. Further data on weight loss, darkening, sprout inhibition and reducing sugar accumulation will be obtained on these samples.

TABLE IV

WEIGHT LOSS OF POTATOES IRRADIATED FOR SPROUT INHIBITION AND STORED AT 50°F AND THREE RELATIVE HUMIDITIES

Dose Rate, rep	Relative Humidity 70%	80%	90%
Control	2.3	1.9	1.2
5,000	2.2	1.4	0.8
10,000	1.1	1.3	0.7
15,000	1.4	1.2	0.8
50,000	1.2	1.8	0.4
100,000	1.1	0.8	0.5
200,000	1.3	0.9	0.5

Further cooperative efforts will be directed toward supplying suitable potatoes of known field history for these studies. Three half-acre plots are being grown at the Lake City Experiment Station of Michigan State University as a supply of Russet Rural, Sebago, and Katahdin potatoes. In addition, yields from a number of small plots, including fertility comparisons, variety trials, planting and harvesting dates, and chemical applications for weed control, sprout inhibition and prevention of after-cooking darkening will be available for radiation studies. Storage facilities at Michigan State University will be available, if required, and additional studies will be undertaken if advisable.

V. THE EFFECTS OF IRRADIATION DOSE AND STORAGE TEMPERATURE ON PLANT PHYSIOLOGY AND METABOLISM

Following are investigations now under way:

1. Study of unwounded cork covering. Samples have been taken for imbedding and sectioning to determine whether different dosages have affected cork formation. Radiation is not expected to reduce the amount of cork present, but it may stimulate cork formation beyond that found in the controls. The samples are in the process of being made into microscopic slides for study.

2. Study of buds in order to determine whether any evidence of injuries to growing points can be found. Specimens have been fixed and are in the process of being imbedded, cut, and stained.

3. Buds put in culture on agar to see whether any growth will occur. Buds have already been put on agar. This agar contained sugar, 20% coconut milk, and .5 mg per liter of 2-4-D. This nutrient solution has been used for potato culture by Steward and Kaplan. The samples were sterilized.

4. Pieces of potato in culture without eyes to test for bud regeneration. Two-centimeter cubes with buds were cut from each irradiated sample and sterilized. The buds were then cut out to see whether any pieces will regenerate buds.

5. The fungus flora of irradiated potatoes. Potatoes used were control and irradiated potatoes. Eight samples were taken from each potato after the surface had been sterilized. Four samples included skin and four were from the interior of the potato; all were put on sterile potato dextrose agar. Inspections will be made frequently to note the number of infections and the nature thereof. This should give a preliminary idea of the killing of fungi and bacteria by the various dosages and of the effect such parasitic organisms may have on the storage qualities of potatoes.

6. Potential of bud development in sphagnum. One quarter was cut from each potato in each sample at the end with the greatest number of buds. These pieces are being put in moist sphagnum and a count kept of all buds which develop.

7. Regeneration of buds in sphagnum. Another quarter of each potato from each sample is to be put in moist sphagnum with all eyes removed. Formation of new buds is to be observed.

8. Wound healing in normal and irradiated tubers. Tubers are to be wounded to keep in moist sphagnum under the conditions which Artschwager, in his work, found most conducive to wound healing. Samples will be taken at intervals, fixed, and imbedded. Their study should indicate whether the various dosages stimulate or inhibit wound healing. The more rapid healing of wounds and the more thorough sealing of the wound, presumably improve storage qualities of the potatoes.

9. Comparison of cell differences in various irradiated samples. Comparisons will be made of cells from comparable regions of the tubers from various samples. It is not likely that important changes in cell structure will take place, but surveys will be made of cell size, shape, wall thickness, cytoplasmic and nuclear structures, plastids, etc.

10. Development of chlorophyll. Control and irradiated samples will be exposed to sunlight to determine the nature and the rate of chlorophyll formation.

11. Resistance to infection. Sample lots of control and irradiated potatoes will be sterilized and put on agar. After an incubation period, all infected samples will be removed. The samples still remaining sterile will be inoculated with a set of common potato diseases and resistance noted. The set of disease inocula has not yet begun, and the planning of the experiment is under way.

VI. THE EFFECTS OF IRRADIATION DOSE AND STORAGE TIME AT ROOM TEMPERATURE ON BIOCHEMICAL SYSTEMS

The potatoes for this study were irradiated at the same time as the others and placed in frozen storage after varying periods of time at room temperature. This procedure makes possible a study of the biochemical behavior of the potato during the period immediately following irradiation, despite the fact that the necessary equipment and supplies for these analyses have not yet been assembled.

These preliminary measurements will be performed during the next quarter. The detailed program of studies on the 1955 crop of new potatoes will be guided by these findings.

VII. THE EFFECTS OF IRRADIATION DOSE ON STORAGE QUALITIES AT 45°F

Figure 2 shows the effect of irradiation dose on the percent dry weight after 2 weeks of storage at 45°F. In that period, none of the stored potatoes had sprouted or shown any indication of spoilage.

These preliminary data seem to indicate a definite effect of radiation dose on the potato. Whether this is due to mechanical, chemical, or physiological effects is not clear from these data, but should be better understood as the various portions of this study continue.

VIII. THE EFFECTS OF STORAGE TEMPERATURE ON STORAGE QUALITIES OF POTATOES RECEIVING 10,000 REP DOSAGE

Table V shows the percent dry weight, percent weight loss, and specific gravity of nonirradiated potatoes compared with those having received 10,000 rep. On the basis of these preliminary data, the effect of irradiation dosage on dry weight mentioned in the previous section is verified. There is no indication, as yet, however, of a function dependence of these factors on storage temperature.

TABLE V

EFFECT OF STORAGE TEMPERATURE ON SOME OF THE PHYSICAL PROPERTIES OF IRRADIATED AND CONTROL POTATOES

Dose, rep		Storage Temperature, °F			
		35	40	45	70
0	Percent dry weight	26.6	25.1	25.3	27.9
	Percent gross weight loss	.56	1.33	.35	8.11
	Specific gravity	1.103	1.090	1.094	1.113
10,000	Percent dry weight	23.9	23.4	25.0	23.7
	Percent gross weight loss	.37	.59	.52	4.36
	Specific gravity	1.097	1.095	1.102	1.098

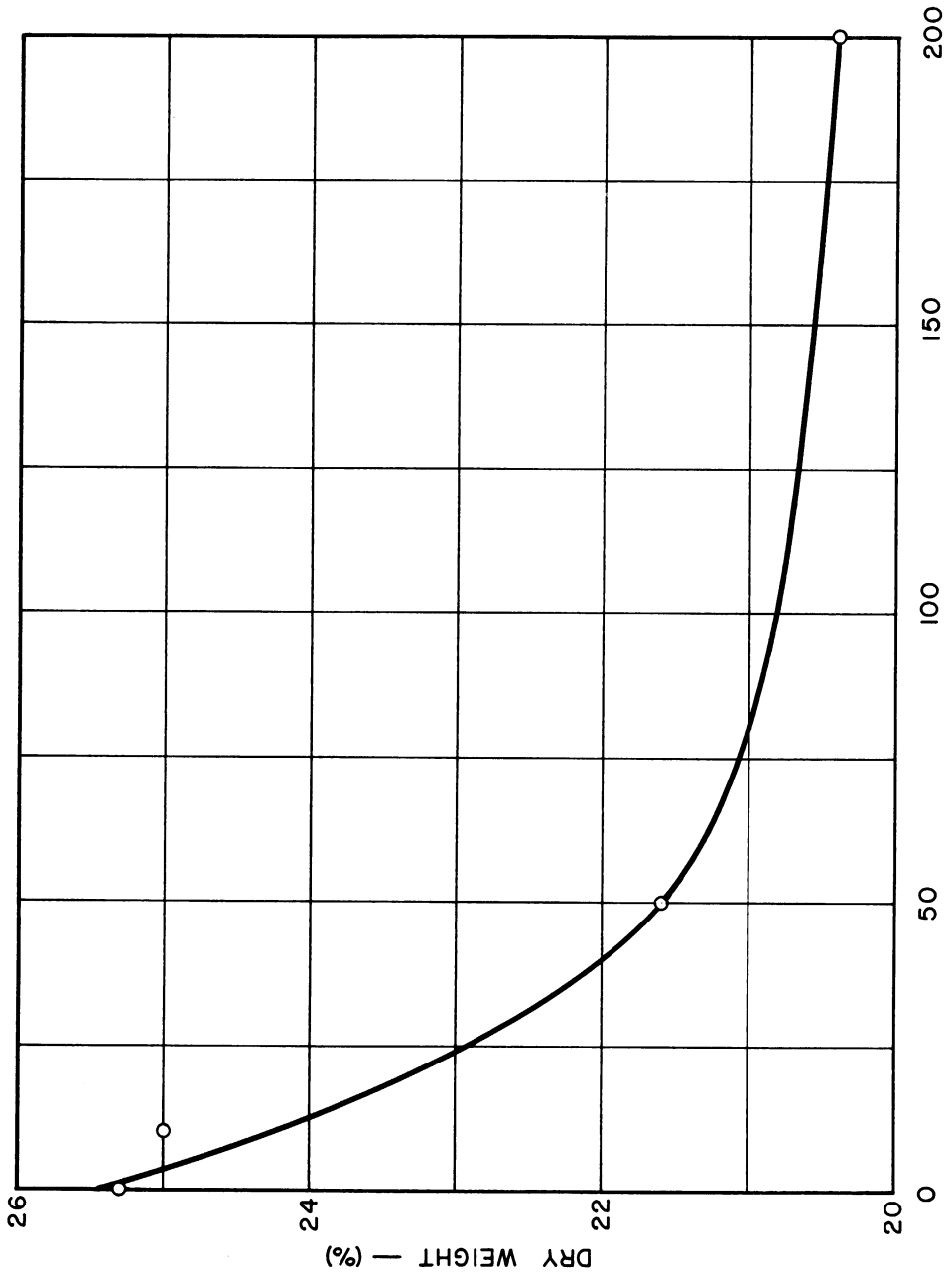

Fig. 2. Effect of radiation dosage on the percent dry weight of potatoes stored for 2 weeks at 45°F.

In the determination of dry weights of potatoes, tubers weighing between 60 and 110 grams were used. The potatoes were weighed and then quartered to facilitate the drying process. The quarters were placed in weighed petri dish halves in an electric dry oven, in which the average temperature was 80°C. A low temperature was used in an effort to avert scorching the sugar and starch of the potato. The petri dishes containing the potatoes were weighed after 4 days and again after 7 days of drying. The results of the weighing after 7 days of drying varied but slightly from the weights obtained after 4 days of drying. This indicated that all the water in the potatoes which could be driven off at this temperature had been removed. The percentages of dry material in the original potatoes were then calculated using these values.

As these dry weight data have been found to correlate very well with specific gravity determinations, future work will emphasize specific gravity measurements.

Figure 3 shows potatoes in the cardboard containers used for storage. The containers were donated for the experiment by the Continental Can Company. The photograph was taken in a room used for food storage at 60°F by the University of Michigan Food Service.

Fig. 3. Potatoes irradiated with 10,000 rep (right) and controls (left) stored in cardboard containers at 60°F for 1 month.

Figure 3 also shows the visible effects of storage at 60°F for 1 month after irradiation. The nonirradiated samples have sprouted badly with concomitant weight loss and shrinkage. The irradiated potatoes (10,000 rep) show no visible signs of deterioration.

IX. THE EFFECTS OF IRRADIATION DOSAGE ON ACCEPTABILITY

No report on the acceptability studies has yet been made available to this laboratory.