An Improved Method for Storing Yam (*Dioscorea alata*)[1]

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INTRODUCTION

A *Dioscorea alata* yam variety known locally as "Florido," is a highly regarded tuber in Puerto Rico. It is harvested only once a year during October to February as it has a 4-month dormancy period. Because of its seasonal nature and the practical impossibility of storing the tuber beyond the dormancy period, farmers produce it in limited quantities. If produced in large quantities, losses from each crop would be great because the tubers are no longer marketable after the 4-month dormancy period as they start to sprout and lose considerable weight. If the dormancy period of the tuber could be prolonged, however, production could be increased because the product could be marketed over a longer period of time.

Studies have been conducted to find ways of increasing the dormancy period in fruits and vegetables by storing them at low temperatures (3). Low storage temperatures reduce the natural metabolic process in these products, retard maturity, sprouting, etc.

D. rotundata yam tubers were stored in 1937 for 10 days at a temperature of 1.1° C. (1), under experimental conditions. At that temperature level the tubers showed a complete physiological breakdown. D. G. Coursey (7) in 1967 experimented with yam tubers by subjecting them to below freezing temperatures in cold ship stores. Working with samples of *D. alata* kept at a temperature of 12.5° C, Coursey (6) found in 1968 that the tubers showed no sign of spoilage after an 8 week storage period, although they registered a great weight loss compared with control tubers stored at ambient temperature. Young (20) found the optimum temperature range for storing *D. alata* yam tubers to be between 12° and 16° C.

The dormancy period of fruits and vegetables has been successfully prolonged by using gamma radiation (2,4,8,12,17,18,19). Gamma radiation acts on microorganisms, enzymes, and food constituents by producing a preservative effect. One of the preservative effects in tubers is sprout inhibition.

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Studies conducted at the Food Technology Laboratory of the Agricultural Experiment Station (11) indicated that cured Florido yam tubers stored in a well-ventilated room at 16° C ± 1° and a relative humidity of 70 percent have their dormant period lengthened by 4 additional months without affecting palatability or physical characteristics. Weight losses were about 17 percent.

These results were very satisfactory up to this point but when the tubers are taken out of their controlled environment they immediately begin to sprout and degenerate. This paper presents information obtained from additional studies carried out in this respect.

MATERIALS AND METHODS

The experimental work was conducted with tubers from 1971 and 1972 crops purchased from a small commercial plantation located in the central region of Puerto Rico. Selected freshly harvested tubers were placed in laminated wood crates 19 by 12 by 12 inches, each full crate weighing 40 pounds. The crates were placed for 8 days in Forma Scientific environmental rooms 5 feet 2 inches wide, 6 feet 6 inches deep, and 7 feet 1 inch high, at a temperature ranging from 29.4° to 32.2° C and a relative humidity of 90 to 95 percent. Under the conditions described all wounded tissue suberized. This curing treatment considerably reduces losses from the physiological breakdown of the tubers (11).

After the curing treatment the tubers were divided into three lots in the environmental rooms. The temperature for one was set at 16° C ± 1° and the relative humidity at 70 percent and 80 percent for another. The third lot of tubers was taken out of the environmental rooms to be used as a control sample, and stored in a screened, well-ventilated, wooden storage house under prevailing ambient conditions at a temperature ranging from 21° to 32° C and a relative humidity of 60 to 95 percent. After 7 months in storage, some of the tubers which had been kept under controlled conditions were taken out of the environmental rooms and treated with isopropyl-N-(3-chlorophenyl) carbamate (CIPC) in aerosol form, at concentrations of 1, 10, 25 and 50 percent, and in Dinafog form. The Dinafog application was performed in a screened, well-ventilated wooden storage house 7 feet 6 inches long, 7 feet 6 inches wide, and 10 feet high. Four ounces of CIPC were applied to 10 crates of tubers. The house was completely sealed and two inside fans were used to recirculate the fog. The house was unsealed (11) after 24 hours. Residue analyses were performed on the tubers after this application using the Diazotization Dye-coupling Spectrophotometric method which employs direct alkaline hydrolysis (10). The tubers, as well as the control samples, were stored at prevailing ambient conditions. Sensory evaluation analyses were not performed on any of the tubers subjected to this treatment as no toxicity tests have been conducted on yam treated with this chemical. Some of the tubers that had been kept under controlled conditions were exposed to 5, 7.5 or 10 Krad doses of gamma radiation from a Cobalt-60 source at the Puerto Rico Nuclear Center in Río Piedras (17). After irradiation the tubers were stored for 60 days under conditions similar to those employed for the previous control samples (prevailing ambient conditions). They were checked and weighed weekly and records kept for weight losses and sprouting. Some of the samples previously stored under controlled conditions were used as a nonirradiated control and stored under the same conditions used for the irradiated samples.

Tubers from both experimental and control samples were cooked and submitted to a taste panel for sensory evaluation. The panelists rated the samples on the basis of a five-point hedonic scale, where +2 stands for "very acceptable" and −2 for "not acceptable."

Tubers from both the experimental and the control samples were also subjected to chemical evaluation. Moisture content was determined by the vacuum oven method (14); total and reducing sugars by the Holgate Method (16), using invertase for the total sugar determination; and starch determinations by the Carter and Neubert method (5), but instead of using 6 N $HClO_4$ for the digestion of samples, a 7.8 N concentration was employed. The density of the samples was determined by measuring the volume of water displaced by a known weight of the peeled tuber and the results expressed as g/cc; the analysis for ascorbic acid (vitamin C) by the 2,4-dinitrophenylhydrazine method (15); and texture determinations by a Food Technology Corporation electrical recording and indicating texture instrument with a 3,000-pound proving ring, with the range set at 1,500 pounds. The plunger was adjusted to a 1-minute stroke, a time force curve was recorded, the maximum force applied was read directly from the chart, and the area under the curve was determined using a planimeter. A standard shear cell packed full was used for each determination. The sample was placed in the cell with the fibers perpendicular to the path of the knives.

RESULTS AND DISCUSSION

Figure 1 shows the effect on weight loss during storage at 16° C and at two different relative humidities. It was found that the tubers stored at a relative humidity of 80 and 70 percent had weight losses of only 15.52 and 17.95 percent, respectively after 200 days, while the control samples had a weight loss of 39.85 percent. The graph shows that after 120 days in storage, the control samples start to lose weight more rapidly than tubers stored under controlled conditions. The reason for this change is that after 120 days these samples sprout much more rapidly. After 200 days of stor-

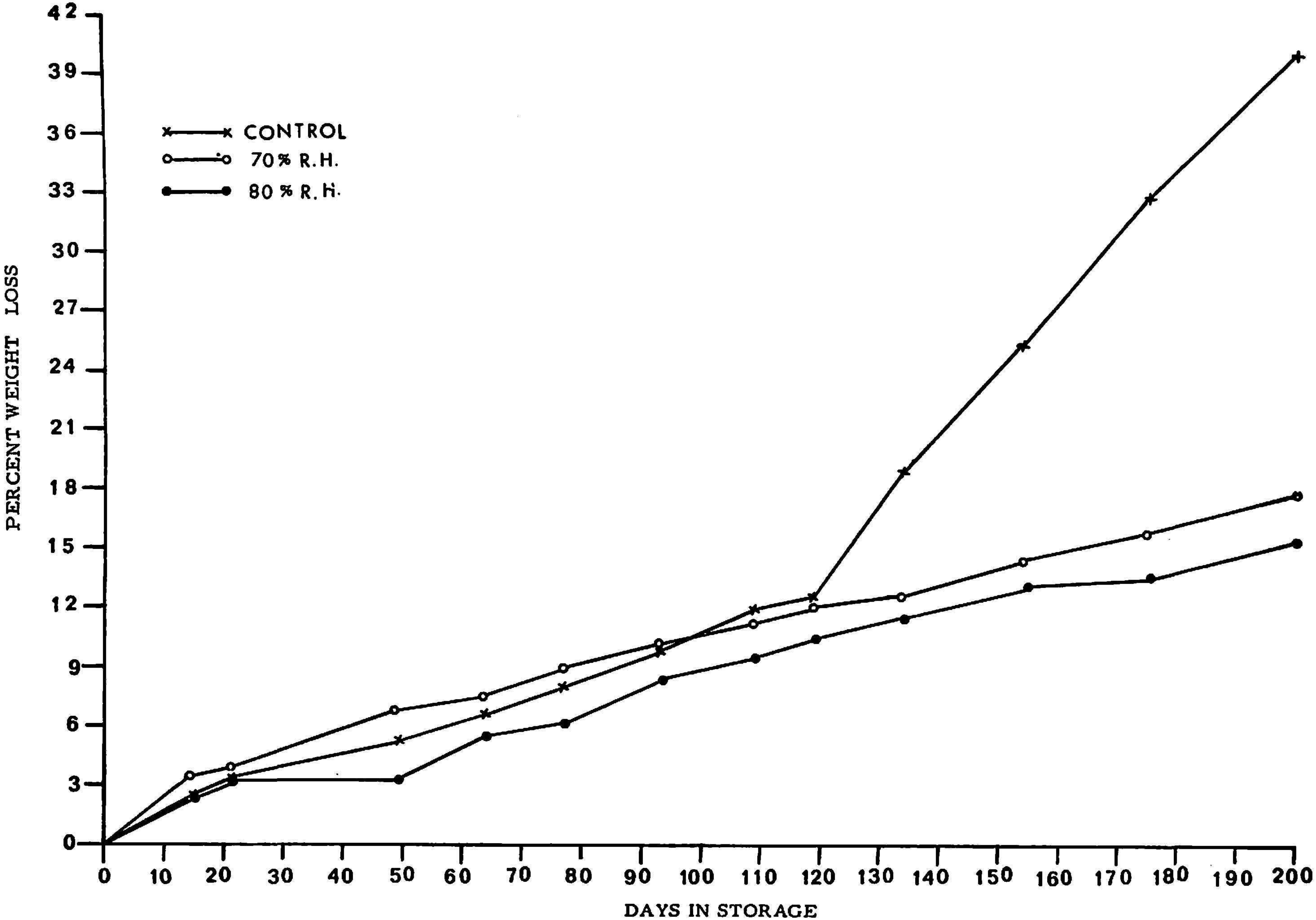

Fig. 1.—Weight loss in yam tubers stored under controlled conditions (70 and 80 percent relative humidity and a temperature of 16° C).

age, the samples stored at 70 percent relative humidity began to show signs of sprouting with the appearance of small buds, while the samples stored at 80 percent relative humidity showed no signs of sprouting.

Table 1 shows the sensory evaluation of the tuber, first when freshly harvested, after curing, then after 70 and finally after 200 days in storage at the various temperature and diverse relative humidity conditions. The statistical analysis of the sensory evaluation data showed no significant differences among the indexes of the controls stored for 70 days and of the tubers stored at 70 and 80 percent relative humidity for 70 or 200 days. The control samples stored for 200 days were spoiled, dried up and gummy, and were thus not sensory evaluated.

Table 2 shows the chemical analyses performed on the tubers first when harvested, then after curing, and finally after 70 days and after 200 days in storage.

The data show, in general, slight decreases in moisture and ascorbic

TABLE 1.—*Sensory evaluation performed on* **D. alata** *yam tubers*

Treatment	Fresh	After curing	70 days in storage	200 days in storage
Control[1]	1.0	1.0	0.71	−2.00[2]
70% R.H.	1.0	1.0	.82	.81
80% R.H.	1.0	1.0	.84	.77

[1] Control—samples stored at prevailing ambient conditions.
[2] Tubers spoiled, no sensory evaluation made.

acid content, a slight increase in density, and an increase in the texture index with time of storage. There were no appreciable changes in starch or sugar content, nor were there any appreciable differences between the corresponding values of the tubers stored at different relative humidities with regard to the various characteristics studied.

The CIPC treatment in aerosol form proved to be inadequate; tubers subjected to it acquired an unpleasant appearance: they shrank, turned dark and became greasy looking.

The CIPC treatment in Dinafog form did not alter the surface appearance of the tubers. These tubers began to sprout 20 days after the treatment while in storage at ambient prevailing conditions, while control samples began to sprout 4 days after the treatment. Residue analyses performed on the tubers after the treatment with CIPC showed 23.51 p/m. Sensory evaluation tests were not performed on any of the tubers subjected to these two treatments. The CIPC treatment is not recommended at present, since its use has not been authorized. The results obtained indicate that this chemical could be used as a good and economical method to control sprouting during the in-transit period in yam tubers that have been stored under controlled conditions for 7 months. However, further studies should be initiated to determine the toxicity in yam tubers so treated, in order to obtain its clearance as a sprout inhibitor in yam, since it is already accepted for potatoes.

Figure 2 shows the percent of sprouting in tubers irradiated with 5, 7.5 or 10 Krad doses of gamma radiation after being in storage for 200 days at 80 percent relative humidity and 16° C. It was found that the control

TABLE 2.—*Chemical analyses of* **D. alata** *yam tubers stored under different storage conditions*

Treatment	Date of analysis	Moisture	Starch	Texture	Total sugar	Ascorbic acid	Density
		Percent	*Percent**	*In²/g***	*mg/25 ml*	*mg/100 g pulp*	*g/cc*
Control	Fresh	78	23	8.80	0.90	***	1.10
70% R.H.		78	23	8.80	.90		1.10
80% R.H.		78	23	8.80	.90		1.10
Control	After cured	68	26	9.50	.90	11.00	1.10
70% R.H.		68	26	9.50	.90	11.00	1.10
80% R.H.		68	26	9.50	.90	11.00	1.10
Control	70 days in	64	27	11.02	.91	10.13	1.11
70% R.H.	storage	69	26	9.40	.89	9.98	1.15
80% R.H.		70	25	8.15	.90	10.00	1.12
Control	200 days in	60	28	12.33	.90	9.53	1.26
70% R.H.	storage	62	26	12.97	.98	9.25	1.20
80% R.H.		66	24	14.94	.91	9.75	1.22

* Expressed on a dry-weight basis.

** Values obtained by multiplying the results of the ratio area under the curve/weight of sample times 10^{-3} to present the factor as an integral.

*** This analysis was not performed on the fresh yams.

samples (non-irradiated) began to sprout after 3 days under prevailing ambient conditions, and at the end of 60 days 83 percent of the tubers showed sprouts. The samples irradiated with 5 Krad doses began to sprout after 10 days and at the end of 60 days 15 percent had sprouts. The samples irradiated with 7.5 Krad doses began to sprout after 30 days and at the end of 60 days 3 percent had sprouts. The samples irradiated with 10 Krad doses did not sprout at all.

Figure 3 shows the percent of sprouting in tubers irradiated with 5, 7.5 or 10 Krad doses of gamma radiation after being stored for 200 days at 70 percent relative humidity and 16° C. It was found that the control (non-irradiated) samples began to sprout rapidly, and after 20 days all the tubers had sprouts. The samples irradiated with 5 Krad doses began to sprout 10 days after storage, and at the end of 60 days 25 percent had sprouts. The samples irradiated with 7.5 Krad doses started to sprout after 20 days, and at the end of 60 days 5 percent had sprouts. The samples irradiated with 10 Krad doses did not sprout during the 60 days of the experiment.

In comparing figures 2 and 3 it is found that the samples stored at a relative humidity of 80 percent started to sprout later than those stored

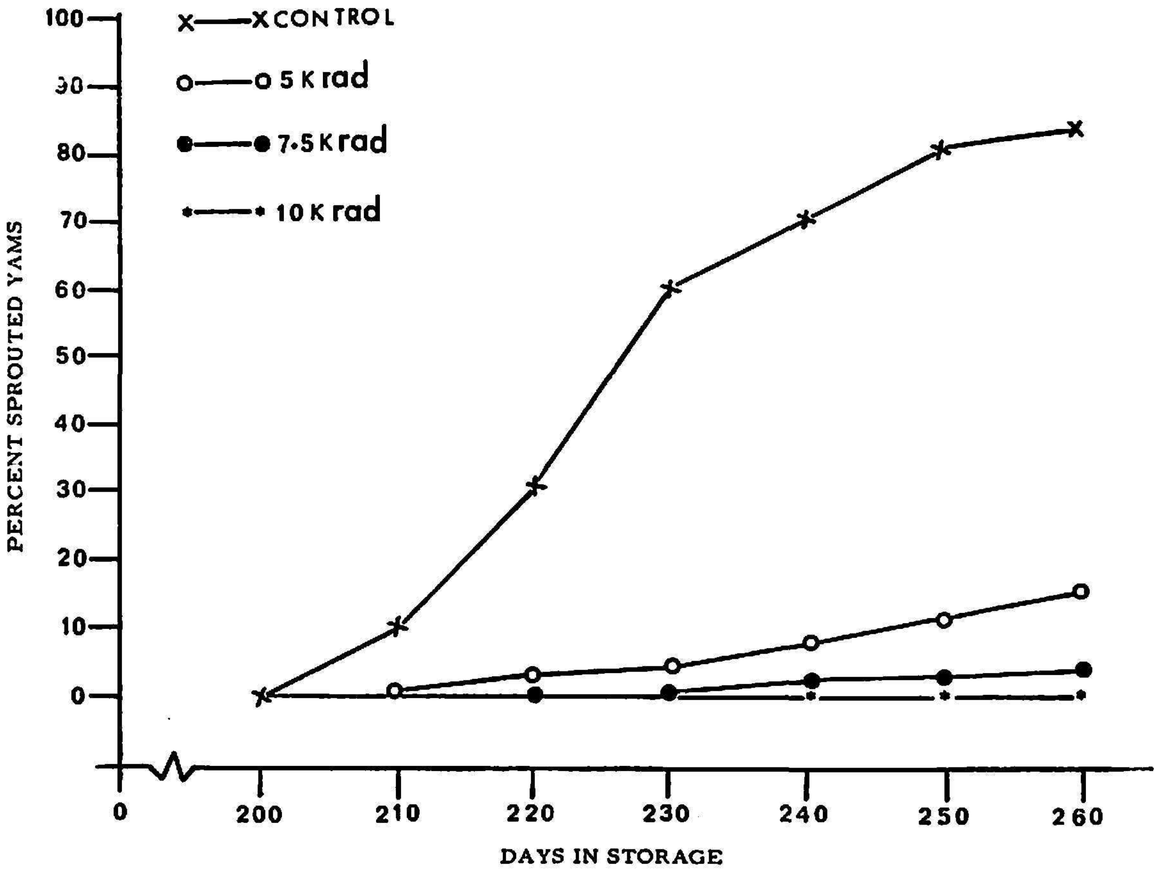

FIG. 2.—Sprouting in yam tubers irradiated after 200 days in storage at a relative humidity of 80 percent and a temperature of 16° C.

at a relative humidity of 70 percent with irradiation doses of 7.5 Krad. Also, at the end of the 60 days 83 percent of the non-irradiated control samples that had been stored previously at a relative humidity of 80 percent had sprouts while, at the end of the 20 days 100 percent of those previously stored at a relative humidity of 70 percent had sprouts. At the end of 60 days the samples treated with irradiation doses of 5 and 7.5 Krad, that had been previously stored at a relative humidity of 80 percent showed a lower percent of sprouting than those previously stored at a relative humidity of 70 percent.

Sensory evaluation tests were performed on the irradiated and the non-

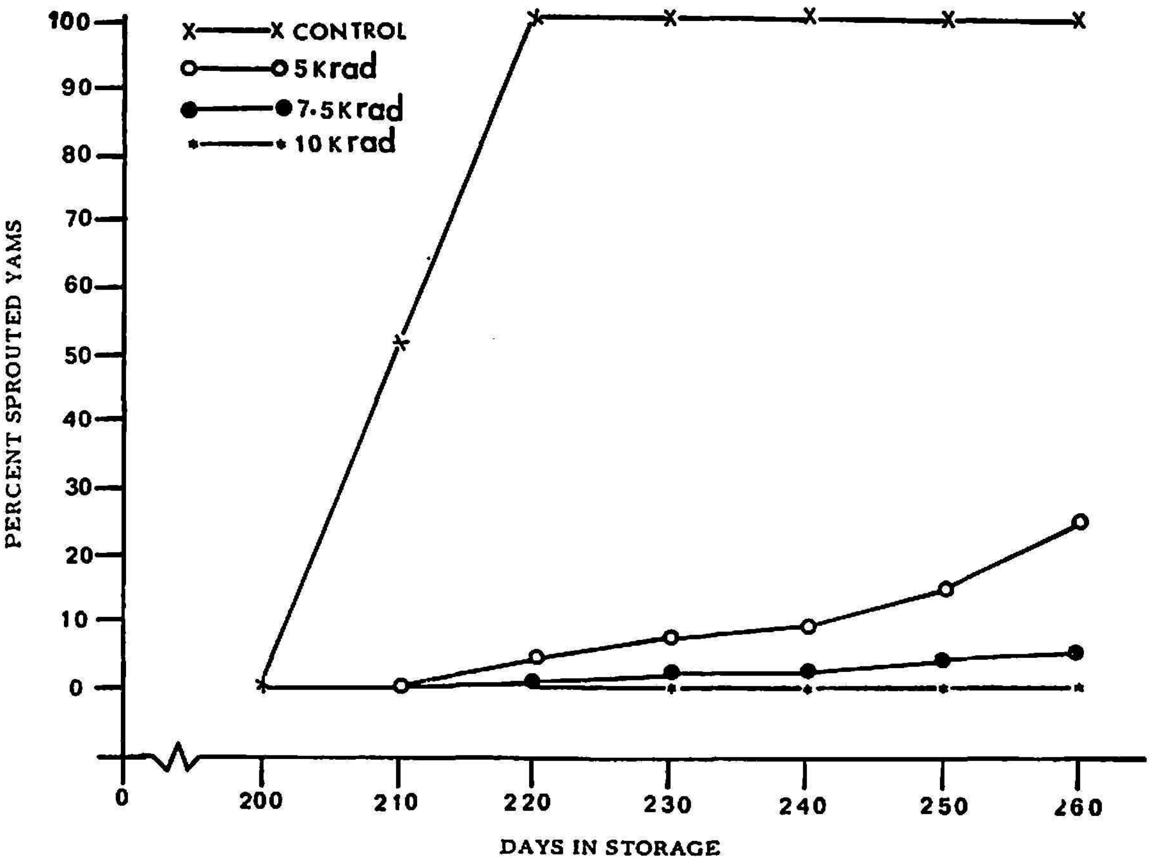

FIG. 3.—Sprouting in yam tubers irradiated after 200 days in storage at a relative humidity of 80 percent and a temperature of 16° C.

TABLE 3.—*Sensory evaluation of irradiated yam tubers after 60 days of storage at ambient conditions*

Treatment	Storage at 80% R.H.	Storage at 70% R.H.
Control[1]	0.57	0.60
5 Krad	.70	.77
7.5 Krad	.83	.83
10 Krad	.83	.80

[1] Control—Non-irradiated samples stored at prevailing ambient conditions.

irradiated yam tubers after 60 days of storage. The results are shown in table 3. There was no significant difference in quality between the control and the irradiated tubers, nor among the latter.

It has been found that the storage of yam tubers at a relative humidity of 80 percent and a temperature of 16° C largely prevents moisture losses and delays sprouting after the tubers are removed from under controlled conditions. No significant difference was revealed by the sensory or chemical evaluation between the samples stored at a relative humidity of 70 and at 80 percent. To control the sprouting process after the tubers have been removed from the temperature and relative humidity controlled storage environment, gamma radiation doses of 10 Krad proved to be the optimum for prolonging the storage time by an additional 40 to 60 days. Nevertheless, doses of 7.5 Krad are recommended for longer storage periods (17).

SUMMARY

By storing cured yam tubers of the variety "Florido" (*D. alata*) at a temperature of 16° C and a relative humidity of 80 percent their dormancy period can be extended 4 additional months. No significant chemical changes are observed during the storage time. Their flavor remains unchanged and they lose very little weight.

When yam tubers stored for 7 months under controlled conditions are treated with the sprout inhibitor CIPC in Dinafog form, their inactivity period is prolonged for 20 additional days. This sprout inhibitor could be used as a good and practical method to increase the transit period of the tubers if and when its use is authorized.

The effects of gamma radiation in yam tubers stored for 7 months under controlled conditions were also studied. Irradiation doses of 7.5 and 10 Krad controlled their sprouting process satisfactorily. No change was observed in flavor. Treatments with 7.5 and 10 Krad doses extend the dormancy period of the tubers kept at prevailing ambient conditions for 60 additional days, thus extending the yam shelf life.

RESUMEN

Los tubérculos del ñame de la variedad Florido (*D. alata*) ya curados pueden almacenarse a una temperature de 16° C y una humedad relativa de 80 por ciento, prolongado así su período de inactividad por 4 meses adicionales. No se observaron cambios químicos significativos durante el tiempo de su almacenamiento. Tampoco se afectó el sabor de los tubérculos, los cuales perdieron muy poco peso.

Tubérculos de ñame almacenados por 7 meses bajo condiciones controladas se sometieron a un tratamiento con el inhibidor de germinación CIPC aplicado en forma de niebla, prologándose su período de inactividad 20 días adicionales. Este inhibidor de germinación podría constituir un método bueno y práctico para prolongar el período de tránsito del ñame una vez se autorice su uso.

También se estudiaron los efectos de la irradiación con rayos gamma en los tubérculos de ñame almacenados previamente por 7 meses bajo condiciones controladas. Las dosis de irradiación de 7.5 y 10 Krad evitan la germinación satisfactoriamente sin afectar el sabor. Los tratamientos con 7.5 y 10 Krad prolongaron por 60 días adicionales el período de inactividad de los tubérculos que se almacenaron bajo las condiciones ambientales prevalecientes, extendiendo así, el período de mercadeo del ñame.

LITERATURE CITED

1. Anonymous, USDA Annual Report of the Puerto Rico Expt. Sta., 42-9, 1937.
2. Beraha, L., Smith, M. A., and Wright, W. R., Gamma radiation dose-response of some decay pathogens, Phytopathology, 50: 474-76, 1960.

3. Borgsrom, G., Principles of Food Science, The Macmillan Company, New York, N.Y., 1: 148, 1968.
4. Brownell, L. W., Gustafson, F. G., Nemehios, J. V., Isleib, D. R., and Hooker, W. J., Storage properties of gamma irradiated potatoes, Food Technol. 11: 306–12, 1957.
5. Carter, G. H., and Neubert, A. M., Rapid determination of starch in apples, J. Agr. Food Chem. 2(21): 1070–2, 1954.
6. Coursey, D. G., Low temperature injuries in yams, J. Food Tech. 3: 143–50, 1968.
7. ——, Yams, Longmans, Green and Co. Ltd., London W1, England, 188–9, 1967.
8. Cuevas-Ruíz, J., Graham, H. D., and Luse, R. A., Gamma radiation effects on biochemical components of Puerto Rican mangoes, J. Agr. Univ. P.R. 56(1): 26–32, 1972.
9. Czyhrinciw, N., and Jaffe, W., Modificaciones químicas durante la conservación de raíces y tubérculos, Arch. Venez. Nutr. 2(1): 49–67, 1951.
10. Gard, L. N., and Ferguson, C. E., Jr.; CIPC Chap. 7: 49–65, in Analytical Methods for Pesticides, Plant Growth Regulators and Food Additives, Vol. IV, Herbicides, ed. Gunter Zweig, Academic Press, New York and London, 1964.
11. González, M. A., and Collazo de Rivera, A., Storage of fresh yam *Dioscorea alata* under controlled conditions, J. Agr. Univ. P.R. 56(1): 46–56, 1972.
12. Jiravatana, V., Cuevas-Ruíz, J., and Graham, H. D., Extension of storage life of papayas grown in Puerto Rico by gamma radiation treatments, J. Agr. Univ. P.R. 54(2): 314–19, 1970.
13. Kushman, L. J., Inhibition of Sprouting in Sweet Potatoes, Hort. Science, 4(1): 61–33, 1969.
14. Methods of Analysis of the Association of Official Agricultural Chemists, 9th ed, Washington, D.C., p. 272, 1960.
15. Methods of Vitamin Assay, 2nd ed Interscience Publishers, Inc., New York, N.Y., 1951.
16. Moyer, J. C., and Holgate, K. C., Determination of alcohol insoluble solids and sugar content of vegetables, Anal. Chem. 20(5): 472–74, 1948.
17. Rivera, J. R., González, M. A., and Cuevas-Ruíz, J., Sprout inhibition in yams by gamma irradiation, J. Agr. Univ. P.R. 58(3): 330–37, 1974.
18. Salunke, D. K., Gamma radiation effects on fruits and vegetables, Econ. Bot. 15: 28–56, 1961.
19. Talburt, W. F., and Smith, O., Potatoes Processing, The Avi Pub. Co. Inc., Westport, Conn., pp. 160–1, 1967.
20. Young, R. A., Cultivation of the true yams in the gulf region, USDA Bull. No. 1167, 1923.