IONIZING IRRADIATION QUARANTINE TREATMENT AGAINST SWEETPOTATO WEEVIL (COLEOPTERA: CURCULIONIDAE).

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ABSTRACT

An ionizing irradiation quarantine treatment of 165 Gy was approved by the California Department of Agriculture against sweetpotato weevil, *Cylas formicarius elegantulus* (Summers), infesting sweetpotatoes from Florida. The first commercial shipment was made in May, 2000. At ≥400 Gy, 'Picadito' white-fleshed sweetpotatoes sometimes showed noticeable discoloration of cooked flesh. Therefore, there is not a large margin between the minimum absorbed dose required for quarantine security (165 Gy) and the minimum dose which might cause objectionable loss to commodity quality (about 400 Gy); it can be expected that the absorbed dose range absorbed by sweetpotatoes irradiated on a full pallet when the minimum target dose is 165 Gy will be 165-500 Gy. To be safe, sweetpotatoes should be irradiated in smaller units than pallet loads, which could result in higher processing costs compared with irradiation on standard pallets. This is the first instance of an irradiation quarantine treatment being approved and used against a non-fruit fly where live adults can be found by inspectors and indicates a significant advance in the transfer of this promising quarantine treatment technology.
Sweetpotato weevil adults irradiated with a target absorbed dose of 150 Gy (maximum absorbed dose was 165 Gy) lived for 32 days, while at 32 days unirradiated weevils had suffered 57% mortality.

Key Words: *Cylas formicarius elegantulus*, boniato, disinfestation, gamma

RESUMEN

Un tratamiento cuarentena de irradiación ionizante de 165 Gy fue aprobado por el Departamento de Agricultura de California contra el picudo de batata, *Cylas formicarius elegantulus* (Summers), infestando batatas de Florida. El primer envío comercial fue hecho en mayo del 2000. A ≥400 Gy, batatas con carne blanca 'Picadito' a veces demostraron decoloración evidente de carne cocida. Por lo tanto, no hay un margen amplio entre la dosis mínima absorbida requerida para seguridad de cuarentena (165 Gy) y la mínima dosis que pueda causar perdida objecionable a la calidad del producto (alrededor de 400 Gy); es de esperarse que la gama de dosis absorbida por las batatas irradiadas en una paleta cuando la dosis objetivo mínima debe ser 165 Gy será 165-500 Gy. Para estar seguros, las batatas deberían ser irradiadas en unidades más pequeñas que en cargas de paleta, lo cual puede resultar en costos de procesamiento mayores comparado con irradiación en paletas estándar. Esta es la primera instancia que un tratamiento cuarentena de irradiación es aprobado y usado contra una mosca no frutal donde adultos vivos pueden ser encontrados por inspectores e indica un avance significativo en la transferencia de esta prometedora tecnología de tratamiento cuarentena.
Adultos del picudo de batata irradiados con una dosis objetivo de absorber 150 Gy (dosis máxima absorbida fue 165 Gy) vivieron por 32 días, mientras que en el día 32 picudos sin irradiar sufrieron una mortalidad de 57%.

The sweetpotato weevil, *Cylas formicarius elegantulus* (Summers), is considered the most serious pest of both orange-fleshed and white-fleshed (boniato) sweetpotatoes, *Ipomea batatas* (L.) Lam., in much of the crop's growing range (tropics and subtropics) including the southeastern United States, Hawaii, and Puerto Rico. It was first noted in the United States in Louisiana in 1875. Female weevils oviposit in sweetpotatoes by chewing a small cavity in the root or stem, depositing an egg, and sealing the hole with frass. In the field they tend to oviposit near the juncture of the stem and tuber. In storage sweetpotato weevils infest all over the roots until they are completely destroyed. The complete life cycle requires about 35 days in the warm sweetpotato-growing regions of the world. Larvae usually pupate in the roots, and the female has about a 7 day preoviposition period. Sweetpotato-growing areas which do not have the weevil, such as the southwestern United States and the Mediterranean region, prohibit the importation of sweetpotatoes without a treatment that ensures that all weevil stages present are dead. Killing the weevils without harming the roots is difficult (Hallman & Chalot 1993); a feasible treatment has not been available.

Ionizing irradiation has proven to be a viable quarantine treatment against fruit flies (Diptera: Tephritidae) because much research with these insects has been conducted and doses required to control fruit flies are relatively low (Hallman 1999). The only commercial uses of irradiation as a quarantine treatment have been against fruit flies. An unfavorable property of irradiation quarantine treatments which sets it apart from all other treatments that have been commercially implemented is the fact that irradiation does not provide acute mortality at the doses used on fresh commodities. Inspectors may find live insects and be unable to distinguish them from unirradiated insects. The measure of efficacy of irradiation quarantine treatments against fruit flies is prevention of adult emergence from irradiated eggs and larvae. Thus, inspectors will find no adult fruit flies in imported fruits. Even though live larvae may be found, a treatment which prevents the presence of adults is easier to accept than one which allows for the presence of live adults in properly treated produce. All stages of the sweetpotato weevil may be found in marketed roots. The adult is invariably the stage of insects which requires the highest radiation dose to control (Hallman 2000). This has been substantiated for sweetpotato weevil by Dawes et al. (1987), who observed little reproduction after 30 pairs of 7 day-old adults were irradiated with 100 Gy. At 150 Gy, no reproduction occurred (n = 30).

Materials and Methods

After obtaining permission from the U.S. Dept. Agric., Animal and Plant Health Inspection Service, Plant Protection and Quarantine and the Texas Dept. Agric., sweetpotato weevils were collected from a 'boniato' sweetpotato field near Homestead, Florida in the spring of 1999. They were shipped to our laboratory and reared on orange-fleshed sweetpotato roots purchased from the local market and 'boniato' (larger, white-fleshed) sweetpotato roots shipped from Homestead. Rearing conditions were about 25°C, 75%RH, and a photoperiod of 16:8 (L:D).

Gamma radiation was applied with a ^{137}Cs self-contained, dry-storage irradiator (Husman Model 521A, Isomedix, Inc., Whippany, NJ) which was delivering a centerline absorbed dose rate of about 40 $Gy \cdot min^{-1}$ during the time of this research. Reference standard dosimetry was done in 1997 using the Fricke system. Routine dosimetry during our research was done with radiochromic film (Gafchromic MD-55, ISP Technologies, Inc., Wayne, NJ), and absorbance at the 510 nm wavelength was read with a spectrophotometer (Milton Roy Spectronic 401, Ivyland, PA) using the Fricke centerline determination as the standard.

Adult sweetpotato weevils up to 3 weeks old were placed with pieces of sweetpotato root in clear plastic cylinders (29 cm × 4 cm diameter) in the center of perforated stainless steel mesh cylinders (11.4 cm inside diameter, 50 cm long) which were placed in the irradiator for sufficient time to achieve the target dose of 125 Gy. Routine dosimetry readings yielded the absorbed dose range. Irradiated weevils and unirradiated controls were placed with sweetpotato roots, which were changed every 3-4 days, until all irradiated weevils were dead. Data recorded were death of weevils and the number of new insects found in sweetpotato roots exposed to both irradiated and unirradiated weevils. Eight replicates of 200-600 weevils (sex ratio of about 1:1) with a total of 3,250 weevils were irradiated with 125 Gy. All irradiated insects within each replicate were held together to maximize the probability that fertile adults would mate. Subsequently 14 replicates with 1,000-3,950 adult weevils per replicate (total 30,655) were treated with a target dose of 150 Gy and counts of mortality and reproduction were made as before.

To be viable a quarantine treatment must not only ensure near 100% efficacy but it must also not lessen fruit quality excessively. McGuire & Sharp (1995) found darkening of cooked sweetpotato tubers at 400 Gy but not at 200 Gy; there were no other negative consequences (concerning appearance, rot, shelf life, weight, or organoleptic qualities) from irradiation up to 1 kGy. Therefore, sweetpotato quality research was only focused on color of cooked roots; organoleptic preference tests were conducted because color can influence an organoleptic rating. 'Boniato' (cv Picadito) tubers grown in Homestead, Florida and shipped to Weslaco, Texas were irradiated with 0 (control), 200, 300, 400, and 500 Gy, held at about 24°C, and cooked 4 days after irradiation using the following recipe: Roots were washed, peeled, cut into slices about 2.5 cm thick, and placed in about 2 liters of about 24°C water with about 2 ml of lemon juice for about 10 minutes while the cooking pot was prepared. In the cooking pot the root chunks were placed in about 2 liters of 100°C water with about 4 g of salt and kept in the boiling water until they were tender upon which they were removed from the water and kept in a covered dish. Qualitative observations on color of cooked roots were made and an informal panel was assembled from laboratory personnel (7-10 persons) and asked to rate organoleptic qualities of sweetpotato pieces by marking on a 9 cm-long line with 'extremely dislike' written on the left end and 'extremely like' written on the right end of the line. Data were recorded as distance (cm) from the left end of the line to the mark. There were 4 replicates done on different dates. These data were not analyzed statistically because they are qualitative and may not be normally distributed, but are reported as mean and SEM of the 4 replicates.

Results

Weevils irradiated with 125 and 150 Gy died at a faster rate than unirradiated weevils (Table 1). This

TABLE 1. NUMBER OF ADULT PROGENY AND LONGEVITY OF IRRADIATED AND UNIRRADIATED SWEETPOTATO WEEVILS.

Irradiation dose (Gy)	Mean ± SEM adult progeny/female		Mean ± SEM days until 100%mortality	Mean % ± SEM control still alive
	Irradiated	Control[1]		
125	0.014 ± 0.0078	41.8 ± 7.4	32.6 ± 3.4	53.0 ± 7.3
150	0 -	33.3 ± 5.9	31.5 ± 1.6	57.2 ± 8.3

[1]Control terminated when all irradiated weevils in same replicate died. Therefore, adult progeny/female in control expected to be greater.

is usually, but not always, the case for insects irradiated near the minimum doses that provide sterility (Hallman 2000). Complete mortality of irradiated weevils occurred at a mean of 32.6 days at 125 Gy and 31.5 days at 150 Gy. During the research done at 125 and 150 Gy, respectively, 53 and 57% of unirradiated weevils were still alive the day the last irradiated weevils died. Reproduction, based on the number of F_1 adult weevils found in sweetpotatoes offered to irradiated weevils averaged 0.014 and 0 per female at 125 and 150 Gy, respectively.

The upper range of dosimetry readings when the target dose was set at 150 Gy was 165 Gy; therefore, 165 Gy should be used as the recommended dose for quarantine security of sweetpotato weevil adults.

Even the unirradiated control sweetpotato tubers showed some mottling 10 minutes after the roots were removed from the hot water. However, the roots irradiated with 500 Gy and then cooked showed consistent and dark mottling. Cooked tubers that had been irradiated with 300 Gy were no more discolored than the control. In 2 of the replicates at 400 Gy considerable discoloration, more than in the control, occurred while in the other 2 replicates at 400 Gy the degree of discoloration after cooking was not greater than in the control. The informal organoleptic panel found no differences among the cooked roots, even considering that those exposed to 500 Gy did not look as pleasing as the others. Mean (±SEM) organoleptic values were 5.8 (0.2), 5.7 (0.3), 5.6 (0.3), 5.5 (0.3), and 5.6 (0.2) for 0 (control), 200, 300, 400, and 500 Gy, respectively.

DISCUSSION

The information from this study was submitted via the Florida Department of Plant Industry to the California Department of Agriculture to enable an irradiation quarantine treatment to be applied to Florida sweetpotatoes, including 'boniatos' for shipment to California. It was approved effective April 1, 2000, and the first shipments occurred in late May. Although 30,655 adults were eventually irradiated with a target dose of 150 Gy, authorities in California accepted the treatment after research with only 18,800 of the adults had been completed. California stipulated that sweetpotatoes be packed in cardboard boxes without holes before irradiation to reduce the chance of post-treatment re-infestation.

Because sweetpotatoes irradiated with ≥400 Gy sometimes showed mottling after cooking, there is not a comfortable margin between the minimum dose required for quarantine security (165 Gy) and the maximum which should be allowed to prevent possible detrimental affects to commodity quality. If sweetpotatoes were irradiated in standard pallet-loads, some tubers in the interior of the load would probably receive at least 500 Gy and risk objectionable post-cooking coloration. Sweetpotatoes will probably need to be irradiated in narrower units than the standard pallet, increasing the cost of treatment because of the extra manipulation required to break down and re-stack pallets.

This case is the first acceptance of an ionizing irradiation quarantine treatment involving adult insects and advances the transfer of this promising technology significantly because it sets a precedence for dealing with live adults found in properly irradiated commodities. Acceptance of live, but sterile, adults by inspectors shows a great deal of confidence in irradiation and this research.

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