Survey of Food Irradiation Studies in Mexico

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Recent work undertaken in Mexico on the effects of radiation on food and on the application of radiation to food preservation is discussed.

The institutions in Mexico which have been doing research in food preservation by irradiation are the Universidad Nacional Autônoma de Mêxico (UNAM), Instituto Nacional de Energia Nuclear (INEN), Escuela Nacional de Agricultura de Chapingo (ENA.Ch.), and as coparticipants, the Joint International Atomic Energy Agency, the Organization of Food and Agrilculture (AIEA/FAO), and the Almacenes Nacionales de Depôsito Sociedad Anômina (ANDSA).

At the Universidad National Autônoma de Mêxico, the Centro de Estudios Nucleares (CEN) and the Instituto de Fisica (IFUNAM), in collaboration with INEN, have carried out research with fruits and vegetables of national interest, harvested in the main production zones for consumers of the Distrito Federal, the capital city of the country. Irradiation is carried out in either a "Gammacell-200" (3600 Ci) or a "Gammabeam-650" (50 000 Ci), both cobalt-60 sources.

Preliminary tests with a large range of doses were made to find the appropriate dose levels of γ radiation for each product, compared with nonirradiated controls (Table I), to extend their shelf life when stored at atmospheric conditions or close to atmospheric conditions (17–19 °C and 50–60% RH). In order to assess the radiation effects in each product the following parameters were analyzed periodically: (a) chemical: total acidity, pH, ascorbic acid, total reducing sugar and carotene; (b) physical: maturity by color of the skin and loss of weight; (c) biochemical: enzyme activity; (d) microbiological: the main fungi were identified.

The following were the results of these tests: (a) The statistical results of analyses of the chemical constituents are shown in Table II. In 61% of the cases there were no significant effects (10% level, "F" test), as shown marked with a "O" in Table II, compared with nonirradiated control products.

Nevertheless, there were some cases (13%) where the radiation treatment was significant (5% level, marked with an asterisk in Table II). The changes produced were not so great that the nutritional value of the fruits and vegetables was changed because it was found that a normal composition was attained on ripening.

(b) Statistical data obtained about the physical characteristics are shown in Table III. In 33% of the cases there were no significant effects (marked with a "O" in Table III), in 13% the effect was significant (marked with an asterisk), and in 54% the effect was highly significant (double asterisk).

(c) In 90% of the cases, the activity of the enzymes decreased as shown in Table IV.

(d) The microorganisms identified are shown in Table V. The most frequent were *Aspergillus niger*, *Penicillium digitatum*, and *Rhizopus stolonifer* (Azamar et al., 1974, 1975; Cabrera et al., 1973a,b; Carrasco et al., 1974).

In other work at the Instituto de Fisica in collaboration with the INEN or with ANDSA, irradiation of the following products was studied.

Orange Juice (*Valencia* variety). Commerical samples were irradiated with electrons in a Van de Graff accelerator with doses from 1.0 to 16.0 Mrad incubated to 37 °C for 24 to 72 h and with γ radiation from a cobalt-60 source between 0.2 and 2.5 Mrad, from 0 to 11 °C and at ambient temperature. Studies were also made of combined thermal shock–irradiation, using doses from 100 to 900 krad and temperatures at 60 °C and 0 °C, at 2–5-min intervals (Table VI, A, B, C) on samples incubated from 24 to 72 h at 37 °C in polyethylene bags.

With doses of electron radiation up to 24 krad, an increase in the number of microorganisms was observed in the irradiated samples. With doses higher than 24 krad up to the sterilization dose (2500 krad), the infestation was reduced or disappeared. The pH and refractive index did not change with the 300-krad dose. With doses higher than 2500 krad, unusual tastes and flavors in irradiated juice were noticed.

In samples irradiated with γ rays, the sterilization dose was greater than 1000 krad. At this dose infestation was not found. A decrease in the vitamin content was observed as follows: 22% less vitamin C, 11% less carotene, 29% less vitamin A, and 47% less niacin.

When the combined treatment was used (thermal shock–irradiation), pH and refractive indices did not change, but darkening of the orange juice was observed after 4 weeks. There was no production of gas in irradiated samples, while in control samples there was a very high gas production. It was concluded that irradiation of orange juice with 125 krad followed by a warming to 60 °C produced no unusual tastes and flavors. The vitamin C content decreased 13%, carotene 10%, vitamin A 11%, and niacine 20%. The changes commonly found in methods of preservation point out that irradiation could be practical (Adem, 1970).

Fresh Shrimp. Several tests were made with commercial fresh shrimps (Roston, 1970) (Table VI). They were irradiated with a cobalt-60 source from 700 to 3500 krad and from 1000 to 5000 krad. A minimum sterilization dose of 350 krad was found for 27% of the samples. A minimum total sterilization dose for all samples was 3000 krad, but hardening, discoloration, and an odor loss were noted at this dose.

Corn. Several studies of corn were made. Two sources of corn, *Blanco Ancho* variety, were selected by ANDSA, one in transit and the other in storage. Samples were irradiated with a cobalt-60 source with doses from 10 to 3000 krad and compared with controls (Table VI) stored at ambient temperature and humidity in glass flasks with a wire screen cover.

Samples of corn from a public storage, infested with several insect species at different stages, were irradiated with γ rays at doses from 1.0 to 50.0 krad and compared

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0021-8561/78/1426-0007$01.00/0

Table I. Dose Levels Used for Food Irradiation at Centro de Estudios Nucleares, UNAM

Product	Variety	Dose, krad
Peaches	Amarillo	0, 250, 275, 300, 325, 350
Strawberries	Solana	0, 360, 400, 440
Strawberries	Tioga	0, 360, 400, 440
Red tomatoes	Bola	0, 350, 400, 450, 500
Mangoes	Manila	0, 10, 25, 50, 100, 200
Mangoes	Nativo	0, 10, 25, 50, 100
Apples	Delicia	0, 10, 50, 100, 200
Melons	Chino	0, 0.5, 1.0, 2.5, 5, 10
Oranges	Tangerine	0, 0.25, 0.50, 1.0, 2.5, 5
Oranges	Valencia	0, 25, 50, 100, 200
Papaya	Amarilla	0, 10, 20, 40, 50
Pineapples	Cayena	0, 30, 60, 90, 120
Banana	Dominico	0, 1, 5, 10, 25, 50
Beans	Negro	0, 25, 250, 1220
Beans	Pinto	0, 25, 250, 1220
Beans	Rosado	0, 25, 250, 1220
Wheat	Hard, soft-mixed	0, 10, 20, 30, 40, 50
Flour	Oats, quaker	0, 10, 20, 50, 100, 150, 200, 250
Flour	Wheat, Covadonga	0, 1, 5, 10, 15, 20, 50, 100
Flour	Soya, commercial	0, 20, 50, 100

Table II. Statistical Results of the Radiation Effect on Chemical Constituents of Various Fruits[a]

Fruit	Total acidity	pH		Ascorbic acid		Total reducing sugars	Carotene
Peaches	*±	**±			–	*–	+
Strawberries S.	O–	*+	**		–	**+	
Strawberries T.	*+	**+	O		±	*+	
Tomatoes	O±	*+	O		–	O+	** –
Mangoes M.	O±	O–	O		+	O–	O–
Mangoes N.	**±					**±	
Apples	O±					O±	**–
Melon	O–	O+	**		–	O–	O±
Orange T.	O–	O+		±		O–	–
Orange V.	–			–		=	=
Papaya	O±	O±	O+			O±	O±
Pineapple	**–	O+	**–			**–	O–
Banana	O–	O±	O±			O+	

[a] (O) 10% level, not significant; (*) 5% level, significant; (**)1% level, highly significant; (+) increase; (–) decrease.

Table III. Statistical Results of the Radiation Effect on Physical Qualities of Various Fruits[a]

Fruit	Maturity	Loss of weight	Texture
Peaches	+	** +	+
Strawberries S.		–	–
Strawberries T.		–	–
Tomatoes	** –	+	
Mangoes M.	* –	–	
Mangoes N.	** –		** –
Apples	+	+	+
Melons		** –	
Orange T.	** –	** –	0 ±
Papayas	+	** +	+
Pineapples	0 ±	** +	
Bananas	** +	** +	

[a] See Table II for definition of symbols.

Table IV. Activity of Enzymes in Irradiated Fruits[a]

Fruit	Days	P.M.E.
Peaches	20	–
Mangoes M.	15	–
Apples	70	±
Melons	8	–
Oranges T.	24	–
Papayas	15	–
Pineapple	19	–
Bananas	22	–

[a] (+) increase; (–) decrease.

with controls (Table VI) stored under conditions similar to the *Blanco Ancho* variety.

Control samples from the storage lot lost their nutritive characteristics after 18 weeks. Samples irradiated with 10 krad had no infestation after the same length of time. Both irradiated and nonirradiated control samples from the source in transit had no infestation after 20 weeks.

When tests of color and flavor were made in "tortillas" prepared with 25 krad irradiated corn and controls, there were no differences observed. The effect of germination and sprout size was studied in samples irradiated between 10 and 500 krad. No effect was observed in controls and samples irradiated with 10 and 15 krad, but germination and sprout size decreased at 20 krad and above. Ability to germinate did not vary in 10 Mrad irradiated samples.

There have been additional studies of corn deinfestation using electrons with energies from 0.5 to 1.5 MeV and a beam of variable current from 10 to 100 μA and pulse intervals from 1 to 50 Hz (Adem et al., 1972).

The Instituto Nacional de Energía Nuclear in coordination with the Escuela Nacional de Agricultura has performed research in food irradiation to study the effects on preservation of fruits, grain disinfestation, and genetic characteristics.

Strawberries, mangoes, and red tomatoes were studied for the purpose of preservation and to learn the effects of variable dose levels of γ radiation from a cobalt-60 source. Even though doses were different (Table VII) from those

Table V. Microorganisms Identified in the Fruits[a]

Fruit	*Aspergillus*	*Botritis*	*Pencillium* *digitatum*	*Pencillium* *italicum*	*Rhizopus* *niger*	*Rhizopus* *Stolonifer*
Peaches	+		+	+		+
Strawberries S.		+				+
Strawberries T.		+				+
Tomatoes	+		+		+	
Mangoes M.	+		+		+	
Apples		+	+			+
Melons	+		+			+
Oranges T.	+		+	+		+
Bananas	+		+		+	

[a] (+) indicates presence.

Table VI. Dose Levels Employed for Food Preservation at IFUNAM

Product	Sample	Radiation	krad	Mrad
Orange juice	A	Electrons		0, 16
	B	Gamma	Low temperature (9, 11 °C)	0, 0.2, 2.5
	C	Gamma	Thermal shock (60, 0 °C)	0, 0.1, 0.9
Fresh shrimp	D	Gamma		0, 0.7, 3.5
	E	Gamma		0, 1, 2, 3, 4, 5
White wide corn	F	Gamma	0, 10, 15, 20, 50, 100 200, 300	2.0, 2.5, 3.0
	G	Gamma	1, 3, 5, 7, 10, 15, 17, 20, 22, 25, 30, 50	
Corn in grain	H	Electrons	0, 10, 300	

Table VII. Dose Levels Employed for Food Preservation Studies at INEN/ENA

Product	Variety	Dose, krad
Strawberries	Solana	0, 200, 400, 600
Strawberries	Tioga	0, 200, 400, 600, etc.
Mangoes	Manila	0, 10, 20, 40, 60
Tomatoes	Bola	0, 8, 50, 200
Tomatoes	Bola	0, 5, 25, 75, 100
Corn	Dented	0, 1, 3, 5, 7
Corn	Semihard	0, 5, 10, 20
Rice	Whole grain	0, 1, 3, 5, 7

used in the studies at CEN (see above), the results are quite similar for most of the variables analyzed.

Other studies were made on rice. Cultures of rice weevil (*Sitophilus oryzae*) at differing ages were prepared as follows: (a) eggs, (b) larvae, (c) adults, aged from 0 to 5 days, from second to fourth stage, and from 30 to 50 days, respectively. All were irradiated in a cobalt-60 source to dose levels from 1 to 7 krad. They were stored, together with a control, in a breeding chamber at 28 ± 0.5 °C and 50% RH for 40 days.

Statistical analysis of the results showed that a 1.0-krad dose affects 75% of the eggs. The DL_{50} is 1.5 krad. One-hundred percent mortality is not reached with the maximum dose (7 krad) applied. The DL_{50} is 2.75 krad. Doses between 3 and 7 krad affect reproduction and survival. The DL_{50} is 5 krad and the DL_{100} is 7 krad (Romero et al., 1968b).

The infestation of corn was studied in a similar manner to rice. Cultures of weevil eggs and adults at different ages were prepared and irradiated. Development of eggs was inhibited from 5 to 7 krad. DL_{50} is 1.2 krad. Doses between 3 and 7 krad affect reproduction and survival. DL_{50} is 3.0 krad and DL_{100} is 7.0 krad. Other highly infested corn samples with different weevils (*S.* oryzae, *Tribolium SSP*, *Laemophloeus SSP*, *Liposcelis*, *Lepidoptera*, and Acaros) at different ages were mixed with noninfested white corn, stored in a breeding chamber, and observed periodically over a period of 40 days. The deinfestation doses for *S. oryzae* was around 5 krad, for *Tribolium* 20 krad, *Laemophloeus* between 5 and 10 krad, and for *Liposcelis* more than 20 krad (Romero et al., 1968a,b).

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Received for review February 28, 1977. Accepted September 13, 1977. Presented at the Symposium on Current Studies on the Chemistry of Food Irradiation, First Chemical Congress of the North American Continent, American Chemical Society, Mexico City, Dec 1975.