produced by a decrease in overall metabolic activity. This decrease of metabolic activity is the consequence of a "biochemical shock" produced by the large doses of thiol compounds which initiate a sequence of intracellular changes which alter the radioresistance of cells[11–15].

We thank L'Agence Internationale de l'Energie Atomique and the Fonds de la Recherche Scientifique Fondamentale Collective for support.

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Received August 8; revised October 17, 1967.

[1] Leblond, C. P., and Stevens, C. E., *Anatom. Record*, **100**, 357 (1948).
[2] Leblond, C. P., and Carricie, R., *Endocrinol.*, **56**, 261 (1955).
[3] Hooper, C. S., and Blair, M., *Exp. Cell Res.*, **14**, 175 (1958).
[4] Sherman, F. G., and Quastler, H., *Exp. Cell Res.*, **19**, 343 (1960).
[5] Loran, M. R., and Althousen, T. L., *J. Biophys. Biochem. Cytol.*, 7, 667 (1960).
[6] Lesher, S., Fry, R. J. M., and Kohn, H. I., *Labor. Invest.*, **10**, 291 (1961).
[7] Abrams, G. D., Bauer, H., and Sprinz, H., *Labor. Invest.*, **12**, 355 (1963).
[8] Quastler, H., and Sherman, F. G., *Exp. Cell Res.*, **17**, 420 (1959).
[9] Lesher, S., Walburg, jun., H. E., and Sacher, jun., G. A., *Nature*, **202**, 884 (1964).
[10] Loran, M. R., and Crocker, T. T., *J. Cell Biol.*, **19**, 285 (1963).
[11] Bacq, Z. M., *Chemical Protection against Ionizing Radiation* (Charles Thomas, Springfield, Illinois, 1965).
[12] Bacq, Z. M., and Alexander, P., *Nature*, **203**, 162 (1964).
[13] Hugon, J., Maisin, J. R., and Borgers, M., *C.R. Soc. Biol.*, **158**, 201 (1964).
[14] Hugon, J., Maisin, J. R., and Borgers, M., *Experientia*, **22**, 235 (1966).
[15] Maisin, J. R., Leonard, A., and Hugon, J., *J. Nat. Cancer Inst.*, **35**, 103 (1965).

Cytotoxic Effects of Extracts from γ-irradiated Pineapples

γ-IRRADIATION of foods shows increasing promise for the improvement of storage life, the inhibition of sprouting, and the disinfestation, sterilization and pasteurization of selected commodities. Treatments with gamma irradiation under 50 kr. have been shown to disinfest as well as improve the storage life of fresh pineapples without producing undesirable changes in the fruit colour, flavour and sweetness[1].

Substances with cytotoxic or mutagenic properties have been reported from tissues and culture media treated with ionizing radiations[2–9], although no evidence of their toxicity to ingesting animals has been obtained. Our investigations were initiated to assess the significance of cytotoxins induced in the pineapple by small doses of γ-irradiation, and the ability of intact fruits to catabolize the cytotoxins produced.

Pineapple fruits were γ-irradiated at 0, 30, 50, 100 and 500 kr. (4·5 kr./min) in the Hawaii Research Irradiator. Half the fruits in each treatment were stored for 8 days at 65° F. Juice was extracted immediately after irradiation from the edible flesh of the remaining fruits. Onion roots were treated for 2 and 4 h with pineapple juices adjusted to a *p*H of 7·0 with phosphate buffer and to a total sugar content of 7 per cent. Frequencies of mitotic and chromosome aberrations in onion root cells were scored as measures of cytotoxicity.

Mitotic frequencies were depressed markedly by the juices from irradiated fruits after treatment for both 2 and 4 h. The effect was positively correlated with dose in 4 h treatments, depressing mitotic frequencies by 0·84 per cent for each 100 kr. increase in dose (control frequency = 4·02 per cent). In contrast to juices extracted immediately after irradiation, those extracted from fruits stored for 8 days did not depress mitotic frequency significantly except in the case of 100 and 500 kr. treatments. The juices from stored fruits which had been irradiated with 30 and 50 kr. seemed to stimulate mitotic frequencies. With large doses of radiation, however, the cytotoxic effects did not change during storage.

An investigation was also made of the effects of irradiated pineapples on the frequency and types of chromosome breaks. Almost all the breaks observed occurred at the kinetochore. There was a significant increase in the frequency of breaks in the root tips grown on irradiated pineapple juice with all doses of irradiation immediately after treatment, but there was no correlation with dose (Table 1). Rinehart and Ratty[7], in *Drosophila melanogaster*, reported similar non-correlation between sex-linked recessive lethals and increasing dose of irradiation of fruit fly media.

Table 1. PERCENTAGES OF METAPHASES AND ANAPHASES IN ONION ROOTS SHOWING CHROMOSOME BREAKS AFTER TREATMENTS WITH EXTRACTS FROM IRRADIATED PINEAPPLES

Treatment	Percentage of breaks after treatments for: 2 h	4 h
Distilled water	6·0	5·7
7 per cent sucrose solution	7·0	6·0
A. Extracts obtained immediately after treatment (kr.)		
control	7·0	6·7
30	16·3	21·3
50	12·9	15·3
100	16·8	14·7
500	14·8	23·0
B. Extracts obtained after 8 days storage of fruit (kr.)		
control	7·0	6·7
30	6·3	7·0
50	7·3	6·3
100	18·4	11·0
500	17·3	16·0

Three hundred cells were scored for each treatment

When extracts from fruits stored for 8 days were tested, those resulting from treatments with 30 and 50 kr. induced breakage frequencies similar to the controls, whereas the mutagenicity of extracts of fruits given 100 and 500 kr. remained unchanged during storage (Table 1). The results indicate a high degree of detoxification of cytotoxins during 8 days storage of pineapples irradiated with 30 and 50 kr., but little or no recovery of fruits which received 100 and 500 kr. It seems probable that cytotoxins are destroyed by enzymes during storage after irradiation when irradiation doses have been moderate. Larger dosages may render the fruits unable to recover, through the impairment of certain types of enzyme activity. At present the nature of cytotoxic substances formed in pineapple after irradiation is not known.

Cytotoxic and antimitotic properties revealed by these and previous investigations need not necessarily have any correlation with the use of the respective foodstuffs for human and animal nutrition[7]. As Berry *et al.*[9] have observed, cytotoxicity *in vitro* may not be paralleled by clinical toxicity in the intact animal, caused by dilution in body fluids and possible rapid removal of toxic substance by digestive, humoral or tissue-sited protective mechanisms. Detailed toxicity tests can therefore only be made by adequately exploring the biochemical nature of the irradiation induced cytotoxic substances, and by using them in animal feeding experiments.

This work was supported by research grants from the U.S. National Science Foundation and from the U.S. Atomic Energy Commission.

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Received July 25; revised October 4, 1966.

[1] Upadhya, M. D., and Brewbaker, J. L., *Hawaii Farm Science*, **15**(1), 8 (1966).
[2] Stone, W. S., Wyss, O., and Haas, F., *Proc. U.S. Nat. Acad. Sci.*, **33**, 59 (1947).
[3] Swaminathan, M. S., Chopra, V. L., and Bhaskaran, S., *Radiat. Res.*, **16**, 182 (1962).
[4] Swaminathan, M. S., Nirula, S., Natarajan, A. T., and Sharma, R. D., *Science*, **141**, 637 (1963).
[5] Holsten, R. D., Sugii, M., and Steward, F. C., *Nature*, **208**, 850 (1965).
[6] Pollard, E. C., Ebert, M. J., Miller, C., Kolacz, K., and Barone, T. F., *Science*, **147**, 1045 (1965).
[7] Rinehart, R. R., and Ratty, F. J., *Genetics*, **52**, 1119 (1965).
[8] Cook, A. M., and Berry, R. J., *Nature*, **210**, 324 (1966).
[9] Berry, R. J., Hills, P. R., and Trillwood, W., *Intern. J. Radiat. Biol.*, **9**, 559 (1965).