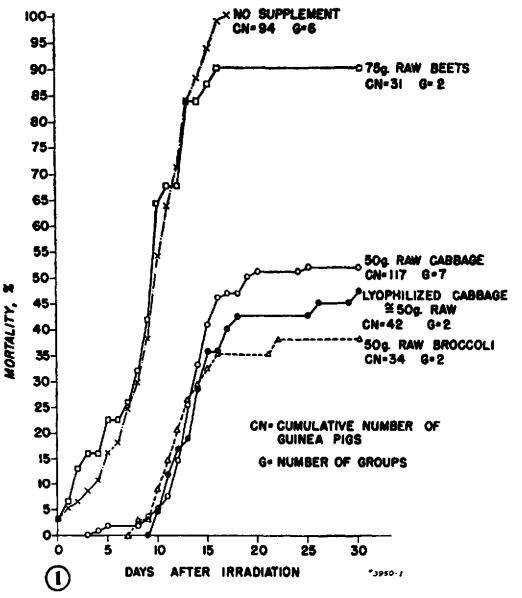
Reduction of X-Radiation Mortality by Cabbage and Broccoli.* (24643)

HARRY SPECTOR AND DORIS HOWES CALLOWAY
U. S. Army QM Food and Container Inst. for Armed Forces, QMR & E Command, Chicago

In studying composition of diet as one of the factors contributing to large variation in resistance of guinea pigs to whole body X-radiation, Lourau and Lartigue(1) reported significantly higher mortality and incidence of hemorrhages in animals receiving supplement of beets, than in those receiving supplement of cabbage. (An unsupplemented control group was not available.) They considered 2 possible explanations: cabbage is protective and diminishes incidence of hemorrhages because of high content of Vit. P and C; or, beets contain a substance perfectly tolerated by normal animal, but which becomes toxic to an irradiated animal. They adopted the latter explanation. This observation led us to perform experiments to test these reported effects of cabbage and beets and to investigate ability of other foods to increase or decrease mortality due to radiation exposure.

Materials and methods. Young male albino guinea pigs, weighing 250 to 325 g, were maintained on basal diet of equal parts of whole field oats and wheat bran, *ad lib.* Supplements of beets (75 g), cabbage (50 g) or broccoli (50 g) were given to at least 2 groups of animals. Raw vegetables were diced and given in separate cups.† Lyophilized cabbage was wetted with twice its weight of distilled water. After 2 weeks of pre-feeding, all animals were exposed to 400 r of whole-body X-radiation. Irradiation was carried out at Argonne National Laboratory‡ using a General Electric Maximar X-ray machine. Radiation factors were 180 KV, 15 ma, no filtration



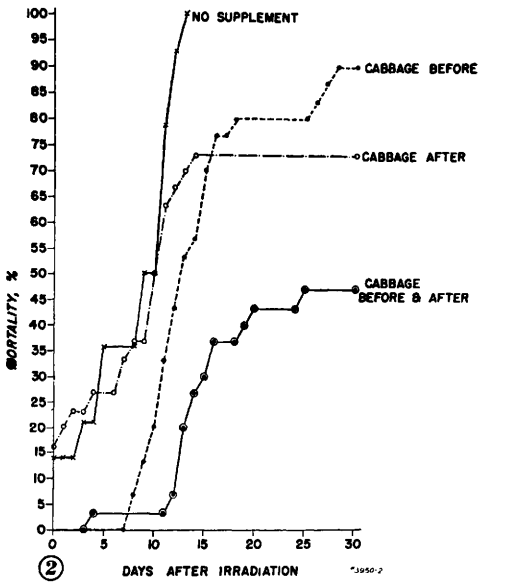


FIG. 1. Effect of supplementation with beets, cabbage, and broccoli on mortality of 224 guinea pigs exposed to 400 r of whole-body X-radiation.

FIG. 2. Influence of time of cabbage supplementation, before or after irradiation, on mortality of 90 guinea pigs exposed to 400 r of whole-body X-radiation.

* This paper has been assigned No. 907 approved for publication. Views or conclusions are those of the authors. They are not to be construed as necessarily reflecting the views or indorsement of the Dept. of Defense.

† Beet tops, cabbage core and tough portion of broccoli stalk were discarded.

‡ We wish to thank Dr. D. E. Smith, Joseph Trier and Emil Johnson of Argonne National Lab. for irradiation of guinea pigs.

TABLE I. Body Weight before and after Irradiation in a Typical Experiment.

Supplement	No. of guinea pigs	Avg body wt (g) on days before and after irradiation							
		−1	0	+3	+7	+10	+14	+21	+31
					Survivors				
None	0								
Cabbage, 50 g	8	304	319	310	310	309	290	286	321
Broccoli, "	13	310	334	330	340	339	339	366	400
					Decedents				
None	20	276	279	258	260(19)*	264(14)	236(10)		
Cabbage, 50 g	12	301	320	303	311	292	277 (7)		
Broccoli, "	7	305	323	311	305	288 (6)	216 (2)		

* Numbers in parentheses are for this time period, as death intervened.

added, 21-22 r/minute, 41 inches target distance. Six animals were irradiated simultaneously in horizontal beam and each exposure included representatives from each group. Half of the dose was applied to each side of animals.

Results. One hundred percent of 94 guinea pigs fed only the basal diet died within 10 to 15 days after irradiation (Fig. 1). Supplementation with beets did not affect mortality rate of irradiated guinea pigs during the 30-day test. Feeding raw cabbage significantly reduced mortality in all 7 trials to average of 52% (range, 20 to 64%)§ Lyophilized cabbage was fed at level equivalent to 50 g of raw cabbage, and retained ability to reduce radiation mortality. Another member of the *Brassicaceae* family, *i.e.*, broccoli, was found in 2 trials to be even more effective than cabbage in reducing radiation mortality. Analysis of variance of proportions of animals killed during the 30-day test (using arc sine transformation) showed that the difference in mortality due to feeding of cabbage or broccoli, was highly significnt ($p < .001$)(2).

We then determined separate effects of pre- and post-irradiation feeding of cabbage. Significance of results was evaluated by analysis of variance of cumulative proportions of animals killed at each time period (using arc sine transformation) averaged over 30 days. Prefeeding of guinea pigs with cabbage just prior to radiation exposure, significantly ($p < .001$) delayed onset of death and enabled some animals to survive the test period (Fig. 2). Post-irradiation supplementation with cabbage yielded significantly ($p < .001$) lower total mortality. The greatest number of survivors resulted from feeding of cabbage both before and after radiation exposure.

Average consumption of basal bran and oats diet was 14 g/day by control groups and by guinea pigs fed a vegetable supplement. Irradiation had a relatively small effect on food consumption. Intake of basal diet was about 60% of normal for first 4 days and gradually increased to pre-irradiation level by 21st day. Intake of cabbage dropped 3 to 5 g between 8th and 20th days. Body weight changes followed a typical pattern of initial loss on day 1, followed by gradual recovery until 8th-post-irradiation day, when a second period of weight loss occurred, persisting until 13th day. Representative changes in body weight are shown in Table I. Some mortality occurred at time of initial weight loss, the major incidence of death, however, was simultaneous with second period of weight loss, between 11th and 13th days. Animals which survive this second phase, in general, survive the 30-day test.

Protective effect of cabbage supplementation has also been demonstrated in another species, the rat (unpublished), maintained on standard synthetic ration which is nutritionally adequate in all known nutrients. Studies are in progress to explore these important findings by survey of wide variety of foods, which increase or decrease sensitivity of rats and guinea pigs to radiation injury and to ascertain whether these effects occur in other species of animals.‖

§ In exploratory trials ascorbic had no influence on mortality and was therefore included in drinking water of all animals at level of 75 mg/100 ml.

‖ Acknowledgement is made to the following for assistance in these experiments: Dr. Leonard Sheffner, Lucius Thomas, Gladys Eckfeldt and Robert Potts.

Summary. Exposure to 400 r of whole-body X-radiation resulted in 100% mortality in 10 to 15 days of young male guinea pigs fed a basal diet of bran and oats plus ascorbic acid. Supplementation with cabbage or broccoli for 2 weeks before irradiation and during 30 days after irradiation significantly reduced mortalty. Lyophilized cabbage retained ability to reduce radiation mortality. Pre-feeding of guinea pigs to time of radiation exposure, signficantly delayed onset of death and enabled some animals to survive test period. Post-irradiation supplementation with cabbage also yielded a lower total mortality. Feeding of cabbage both before and after radiation exposure produced greatest amount of protection.

1. Lourau, M., Lartigue, O., *Experientia,* 1950, v6, 25.

2. Fisher-Yates Tables, 1953, Table XII, p66.

Received December 2, 1958. P.S.E.B.M., 1959, v100.

Response of Ciliated Epithelia of Different Histological Origin to Virus Infections *in vitro.* (24644)

GEORGES BARSKI, FRANCINE CORNEFERT AND ROSLYN E. WALLACE*
(Introduced by A. B. Sabin)
Institut Gustave Roussy, Villejuif (Seine) and Centre d'Immunopathologie, Hôpital St.-Antoine, Paris

We recently reported(1) that ciliated epithelia of the respiratory mucosa of man or monkey, exposed *in vitro* to polio- or adenoviruses, can maintain for relatively long periods their morphological and functional integrity. This phenomenon is especially evident in mixed cultures in which histologically organized epithelium is associated with dedifferentiated cells of the same species, such as HeLa or monkey kidney cells. These cells are selectively destroyed, leaving organized ciliated epithelium unharmed, in spite of high virus concentrations. The present experiments were performed to determine whether: (1) the observed phenomenon occurs also in ciliated epithelia of histological location other than respiratory tract, (2) this phenomenon can be demonstrated also with highly epitheliotropic viruses, such as herpes simplex virus, (3) the observed resistance to virus infections can be abolished by chemical or enzymatic treatment of ciliated cells.

Material and methods. Cultures of plasma imbedded rabbit or monkey trachea fragments were prepared and processed in living state or after fixation and staining, according to previously described methods(1). Cultures of rabbit Fallopian tube fragments were cut from upper convoluted oviduct, including its fimbriated extremity. Human ovarian tubes were obtained by total hysterectomy in 5 cases of uterine cancer on patients 40-56 years of age. No histological evidence of malignancy was present in the Fallopian tubes. Only fimbriated extremity of human oviducts was used for explantation. In certain experiments HeLa cells or 2nd and 3rd passage rabbit kidney cells were added to cultures of Fallopian tube fragments as previously described(1). Culture medium contained 0.5% lactalbumin hydrolysate in Earle's solution, supplemented with 0.1% yeast extract, 15% decomplemented horse serum and 3% bovine embryo extract. Poliovirus type 1 Mahoney strain, adenovirus type 1 "Ad 71" strain,† tissue culture adapted strain of Mengo encephalomyelitis virus(2), "5433" strain of herpes simplex virus(3), infectious bovine rhinotracheitis virus (I.B.R.)‡ and a strain of vaccinia virus isolated from commercial calf lymph vaccine, were used. Virus titrations were performed by serial dilutions in tube cultures of trypsinized rabbit kidney cells for herpes simplex virus and HeLa cells for other viruses.

* U. S. Government Fulbright fellow.

† Received from Dr. R. Huebner, N.I.H., Bethesda.

‡ Received from Dr. Cabasso, Lederle Laboratories, Pearl River, N. Y.