Reports

Radiation Flavor—Fact or Fancy

Abstract. Experimental results indicate that sensory evaluations in different laboratories give equivalent results if standardized procedures and a standard sample are used. Conflicting results concerning the flavor of irradiated foods are due largely to different methods of evaluation and to incorrect interpretation of results. Unusual flavor due to irradiation should be considered different, not necessarily objectionable.

It is estimated that the sterilization of food by ionizing radiation at a dose of 4.5 megarad breaks about 0.0075 percent of the chemical bonds (*1*). That this small absolute change is quite apparent to man's olfactory and gustatory senses, which have a sensitivity of parts per billion, has been amply documented in the literature. Unfortunately, a critical appraisal of the literature also indicates that various laboratories have frequently disagreed as to the extent and importance of the sensory changes produced. As a result, objective evaluation of the potential of ionizing radiation to preserve foods has been difficult for scientists and nonscientists alike.

An attempt to resolve some of the diversity of research results in this field occurred in 1957 when investigators in the Quartermaster Corps Radiation Preservation of Foods Project formulated a controlled, cooperative experiment in which a standard homogeneous sample of meat was used. It had been suggested that the diversity of results might be due to the difference in the experimental materials used, to unrecognized variations in treatment and testing procedures, or to nonuniformity in the interpretation of results. It was hoped that through a controlled experiment with a standard sample of meat, the data and results reported by different investigators could be compared and correlated, and some explanation could be obtained for the nonagreement of earlier data.

Such a study was subsequently carried out with 17 cooperating investigators. Unfortunately, the results did not give the hoped-for correlations between flavor and chemical evaluations. This was partly because of technological difficulties in preparing, handling, and shipping the meat, and partly because of an obviously great variation in laboratory procedures and expressions of results. The success of this first study lay primarily in its focusing of attention on the problems involved in designing and executing such an experiment.

Plans for a second cooperative study were formulated in early 1958. In this study it was decided to concentrate upon sensory evaluation, since it was felt that the greatest amount of variability in methods and interpretations arose in that area. Moreover, it was obvious that until reliable sensory evaluation could be achieved, a correlation of chemical evaluation with flavor would not be possible.

Accordingly, a test plan was formulated which attempted to standardize, in so far as possible, the methods of preparation and evaluation, so that any differences found would be attributable to factors other than methods (*2*). Two sensory testing methods were used. One required rating of the intensity of "irradiation flavor"; the other was the hedonic-scale preference method (*3*). The chief difference in the methods was the use of "experts" for rating intensity of irradiation flavor and "consumer-type" subjects in the preference tests.

The average intensity and hedonic-scale ratings are shown in Table 1. The intensity of irradiation flavor is shown to be a direct (though not linear) function of dose. The agreement among laboratories for this method is excellent, the mean correlation coefficient r (by Fisher's z method) being 0.94.

In the preference tests, no differences were found between the nonirradiated samples and the samples irradiated with 1.25 and 2.5 megarad, respectively, and only the sample irradiated with 5 megarad was significantly less preferred ($.01 > p > .001$). While the mean correlation coefficient r for this method was only 0.55, the absence of a definite trend among the four samples gives some clue to the reason for the low correlations.

The results clearly indicate that the purpose of the test had been accomplished—that is, it had been demonstrated that sensory evaluations carried out by a number of different laboratories give equivalent results if standardized procedures and a standard material are used.

The results also suggest that the nonagreement of research results reported in the literature is due, to a large degree, to differences in interpretation of the results. The value of a panel of experts lies in the ability of its members to evaluate a particular component of the total flavor according to the instructions given, but no correlation of this evaluation with a preference rating of the sample should be assumed.

Although an evaluation of the relationship of irradiation flavor and preference was not an objective of the cooperative study, the results suggested that investigations of such a relationship were in order. It must be assumed that the preference-test subjects could detect the irradiation flavor, even though their preferences were not affected by it except at the highest level of irradiation.

Table 1. Data on cooperative flavor evaluation of a standard beef sample (*2*). Method *A*, intensity of irradiation flavor (1–none to 9–extreme), at eight laboratories; method *B*, hedonic-scale preference tests, at ten laboratories; *r*, mean correlation coefficient. The slope over the four ratings under method *A* is highly significant ($p > .001$).

Irradiation levels (Mrad)	Av. rating	
	Method A (r = 0.94)	Method B (r = 0.55)
0	2.1	6.1
1.25	3.7	6.0
2.5	4.5	6.0
5	5.2	5.4*

* Significantly different from the other three values ($.01 > p > .001$).

Table 2. Mean preference ratings of irradiated beef samples by the same individuals at successive intervals.

Day	Judgments (No.)	Av. ratings (hedonic scale)	
		(0 Mrad)	(4 Mrad)
1	80	7.3	6.3*
2	68	7.5	6.2*
3	74	7.4	6.3*
4	72	7.3	6.1*
16†	54	7.3	6.5
23†	60	6.8	6.4

* Significantly less preferred ($p > 0.001$). † Data not tested for significance.

Instructions for preparing reports. Begin the report with an abstract of from 45 to 55 words. The abstract should *not* repeat phrases employed in the title. It should work with the title to give the reader a summary of the results presented in the report proper.

Type manuscripts double-spaced and submit one ribbon copy and one carbon copy.

Limit the report proper to the equivalent of 1200 words. This space includes that occupied by illustrative material as well as by the references and notes.

Limit illustrative material to *one* 2-column figure (that is, a figure whose width equals two columns of text) or to *one* 2-column table or to *two* 1-column illustrations, which may consist of two figures or two tables or one of each.

For further details see "Suggestions to Contributors" [*Science* **125**, 16 (1957)].

The question then arises as to whether a consumer will learn to recognize, and to like or dislike, the flavor upon further or repeated consumption of irradiated beef products. To test this potential of recognition, a panel of 40 consumer-type subjects was requested to rate nonirradiated and irradiated ground beef on 4 successive days and again on the 16th and the 23rd days from the start of the test. In each test session each subject rated two nonirradiated samples and two samples irradiated at a level of 4.0 megarad; all samples were identified only as "ground beef."

The mean preference ratings obtained are shown in Table 2; for statistical analyses, only the data from the 28 subjects who participated on each of the first 4 days were included. Again, a high level of irradiation is shown to decrease consumer preference to a significant extent. There was no significant difference between the ratings given either the nonirradiated or the irradiated samples on any single day, however, and no change was evident in people's preferences in regard to irradiated beef with repeated exposure to the product. Although too few subjects ($N = 18$) participated in all of the sessions for an analysis of variance for the 16th and 23rd days to be conclusive, the data suggest that there was less difference in the preferences between nonirradiated and irradiated samples at the end of the test than at the beginning.

The results in the experiments discussed here suggest that the view that irradiated foods have objectionable flavors is not wholly justified. It seems probable that an attitude of suspicion toward anything connected with irradiation, coupled with the noticeable change in flavor, accounts for the opinion. An analogous evaluation situation would be the attempt to obtain a meaningful flavor evaluation for a canned orange juice with a panel of judges who traditionally drink fresh orange juice and interpretation of their evaluations by the staff of a manufacturer of frozen orange juice.

While it is true that the responses of a representative tasting panel may foretell the influence of attitude upon consumer acceptance, it should be remembered that attitudes change and that it will be several years before irradiated foods are offered to the public. It seems more meaningful at this time, therefore, to recognize that irradiation produces changes in flavor but that such changes are not necessarily objectionable (*4*).

MAURICE P. DRAKE
BEVERLEY J. KROLL
FRANCIS J. PILGRIM
Quartermaster Research and Engineering Command, Quartermaster Food and Container Institute, Chicago, Illinois

References and Notes

1. B. H. Morgan and R. G. H. Siu, *Radiation Preservation of Food* (U.S. Army Quartermaster Corps, Washington, D.C., 1957), chap. 17.
2. "A cooperative sensory evaluation using a standard homogeneous beef sample," *Quartermaster Food and Container Inst. Rept. No. 9–59* (1959).
3. D. R. Peryam and F. J. Pilgrim, *Food Technol.* 11, suppl., 9 (1957).
4. The assistance of participating scientists and laboratories in carrying out the cooperative study is gratefully acknowledged. This report is paper No. 2054 in a series approved for publication. The views and conclusions are ours.

4 June 1960

Control of Behavior by Presentation of an Imprinted Stimulus

Abstract. When presentation of an imprinted stimulus is contingent upon an arbitrarily chosen response, the rate of emission of this response increases. This control of responding requires a moving imprinted stimulus and does not require a following response by the duck.

Imprinting has been described as "the process by which certain stimuli become capable of eliciting certain 'innate' behavior patterns [during] a critical period of the animal's behavioral development" (*1*). In particular, ducklings have been observed to follow moving objects and to develop a lifelong affinity for the followed object. The experiments reported here (*2*) demonstrate that control of the duckling's behavior by the presentation of the imprinted stimulus is not limited to the elicitation of innate responses. The presentation of the imprinted stimulus will also control the rate of emission of an arbitrarily chosen response.

The experimental space was a rectangular, black plywood box divided by a Plexiglas panel into a runway that contained the duck and an apparatus compartment that contained the imprinting stimulus, a yellow cylinder (Fig. 1). "Presentation" of the stimulus consisted of transilluminating it and lighting the dark apparatus compartment. The imprinting stimulus was moved continuously back and forth along the runway, with a slight swaying and twisting motion, at 1 ft/sec. The response chosen for study was a peck of 8 gm or more on a Plexiglas disk 0.75 in. in diameter. This manipulandum (response key) was mounted on the wall of the runway opposite the dividing panel, at a suitable height (3 to 8 in.). White noise and dim illumination were always present in the runway; neither food nor water was ever present.

Two species of duck, Black *(Anas rubripes tristis)* and Peking *(A. platyrhynchous),* were employed in sessions lasting from 1 to 12 hours; similar results were obtained with the two species. The ducks were housed in individual cages a few hours after hatching and were given continuous access to food and water. Each duck was placed in the runway, and the imprinting stimulus was presented for six 45-minute periods distributed throughout the duck's first and second days of life. All of the ducks were observed to follow the moving stimulus closely by the end of the second day.

When the presentation of the imprinted stimulus is contingent on a selected response, the rate of emission of this response increases. Figure 2 shows the sustained rate of pecking by a 3-day-old duck when the imprinted stimulus was presented for 40 seconds after every eighth response. No appreciable decline in the rate of responding after 12 hours of conditioning and 750 reinforcements is observed (the reduction in the rate of responding in the portion of the record marked *a* was correlated with a temporary equipment failure: the imprinted stimulus did not move when presented).

The performance shown in Fig. 2 was obtained with the following procedure: After the final imprinting session, the peck response was conditioned by making presentation of the imprinted stimulus contingent upon responses that increasingly approximated pecking. The response requirement was then gradually increased over a 75-minute period until every eighth response produced the imprinted stimulus. The imprinted stimulus may properly be called a reinforcer (*3*, p. 731) since it increases the rate of a response which produces it. However, the imprinted stimulus differs from other reinforcers, such as food and water, in its control of pecking in that the rate of responding was not observed to decline after a large number of reinforcements.

The rate of emission of responses that produce the imprinted stimulus was brought under the control of a

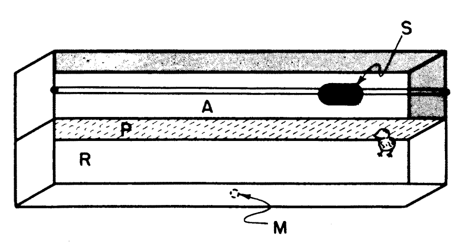

Fig. 1. Experimental space for the control of responding by means of an imprinted stimulus. A plywood box is divided by a Plexiglas panel (*P*) into a runway (*R*) (8 by 1.5 by 1.5 ft) and an apparatus compartment (*A*) (8 by 1 by 1.5 ft). The imprinting stimulus (*S*) is a transilluminated yellow cylinder (4 by 8 in.). The manipulandum (*M*) is a 0.75-in. Plexiglas disk.