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Radiation-Induced Changes in Bread Flavor[a,b]

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Ionizing radiations, although capable of sterilizing, pasteurizing, or deinfesting various food products, produce concomitant flavor, textural, nutritional, and other changes *(10)*. In particular, ionizing radiations have been shown to destroy certain grain-infesting insects *(1, 6, 9)*. These grain-insect studies and other studies *(3, 8)* have also revealed some of the undesirable changes in the finished flour product that are attributable to the radiation treatment. This paper describes work undertaken to establish a treatment level threshold at which flavor change could be detected in bread made from both milled irradiated wheat and irradiated flour. No attempt was made to mitigate, by chemical or physical means, the associated flavor change. One physical property, loaf volume, was measured.

EXPERIMENTAL

Approximately 100 lb. of hard red spring wheat and 70 lb. of an all-purpose flour of comparable protein content were irradiated with a 1,000,000-volt, resonant-transformer, electron beam generator *(7)*. Dose measurements were based on ionization chamber dosimetry.

All bread used in the tests was made by the recipe given in Table 1. The actual amounts of ingredients used yielded a 1½ pound loaf. The tests were conducted over a 4-month period with limits of 3 tasting days a week and 2 judgments a day. All bread was tasted within a few hours after baking; loaf weights and volumes were measured one hour after baking. The bread samples, ½ x 3 x 1 inches, were presented to the 7 male panel members (not all of whom were present each tasting day) according to randomly selected triangle arrangements of the irradiated and non-irradiated (control) bread samples.

The panel members were instructed to use the warm coffee and water rinses as they wished and to wait 5 minutes before the second group of samples for the day. The tests were conducted in two consecutive series; first, bread made from flour and, second, bread made from flour milled from irradiated wheat. During the first series the panel members were informed of the correctness of their judgments; however, this practice was abandoned during the second series. Since the 100 lb. of wheat used in the second series was all irradiated on the same day, and since the bread was tasted over a period of several weeks, the 2 treatment levels tested on any particular day were chosen by random numbers to avoid the introduction of any systematic error in the results due to a possible change in irradiation-induced flavor with time. To lessen any possible flavor carry-over, the lower treatment level was tasted first on each tasting day. Shortly after the first series was started, the panel was asked to not only identify the odd sample, but to tell whether it was irradiated or not and to state a preference.

TABLE 1

Bread recipe

Ingredient	Relative weight
Flour	100
Yeast	1.58
Sugar	2.95
Salt	1.47
Non-fat dry milk solids	4.84
Hydrogenated shortening	5.05
Potassium bromate[1]	0.0005
Water	63.2

[1] Added only to the non-commercial flour.

The threshold is that defined by Bierman, Proctor, and Goldblith *(2)*, the dose at which 50% of the judgments (above chance) are correct. Since the responses at each particular dose are quantal in nature, i.e., the judge is right or wrong, the per cent of correct judgments will be binomially distributed. The logarithm of the dose was chosen in the expectation that it would be a normalizing transformation of the distribution function. The final analysis was made, using the probit of the per cent of correct judgments adjusted by Abbott's formula and the logarithm of the dose *(5)*. The weighting coefficients used were those required by the fact that one-third of the judgments will be correct on a purely chance basis; this modification avoids the introduction of any spurious precision in the threshold limits. The loaf volumes between treatments were analyzed by co-variance to correct for the daily variation in the control loaf volumes. The loaf volume means were compared using Studentized multiple ranges *(4)*.

RESULTS AND DISCUSSION

The probit lines coresponding to judgments made on irradiated wheat and irradiated flour are given in Figure 1. Each plotted point represents 17 or more judgments. The extension of the probit line for flour beyond the plotted points is justified by the existence of a point at 500,000 rep at which all of 10 judgments were correct. This point can not be plotted because its probit is infinite. These lines and the corresponding thresholds are based on the judgments of four of the panel members (the same four in both cases). These judges were selected to represent the data on the basis of their discriminatory ability as evidenced in preliminary tests, and on the basis of attendance at the tasting sessions. The judgments of all the panel members are given in Tables 2 and 3 in which

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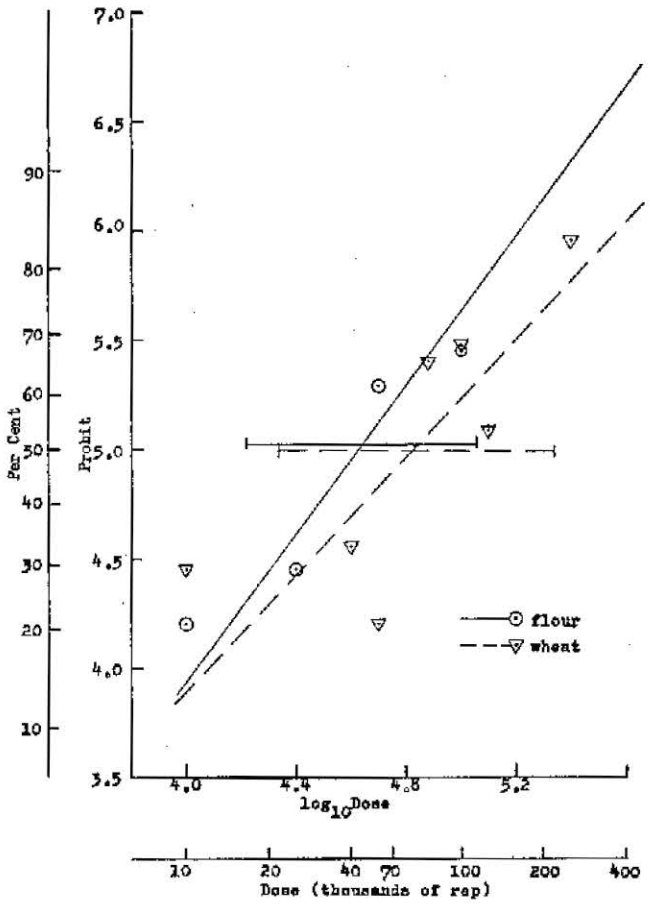

Figure 1. Probit lines for bread made from irradiated flour and irradiated wheat.

are included the additional results with respect to ability to tell whether the odd sample was irradiated.

TABLE 2

Taste panel results (all judges)
Irradiated flour

Dose (rep)	Correct selection of odd sample	Correct identification of odd sample treatment
1.0×10^4	15/29*	8/17
2.5×10^4	23/46*	18/46**
5.0×10^4	25/44**	12/34*
1.0×10^5	27/38**	11/28**
5.0×10^5	17/20**	12/15**

*Significant at the 5% level.
**Significant at the 1% level.

TABLE 3

Taste panel results (all judges)
Irradiated wheat

Dose (rep)	Correct selection of odd sample	Correct identification of odd sample treatment
1.0×10^4	12/25	7/25
4.0×10^4	12/28	11/28**
5.0×10^4	14/26*	8/26
7.5×10^4	16/30**	12/20**
1.0×10^5	18/35**	18/25**
1.25×10^5	14/22**	12/22**
2.5×10^5	20/22**	17/22**

*Significant at the 5% level.
**Significant at the 1% level.

The levels of significance were determined from published tables *(11, 12)*.

In the case of bread made from irradiated flour, two doses were given that were not included in the probit analysis. Figure 2 shows control 500,000, 1,000,000 and 10,000,000-rep loaves. These latter 2 loaves were those excluded from the final analysis. One taste test was conducted with the 1,000,000-rep loaf; the samples were placed under red lamps to avoid a choice being made on the basis of the obvious color difference. The 6 judgments were all correct; therefore, this dose was eliminated from further trial.

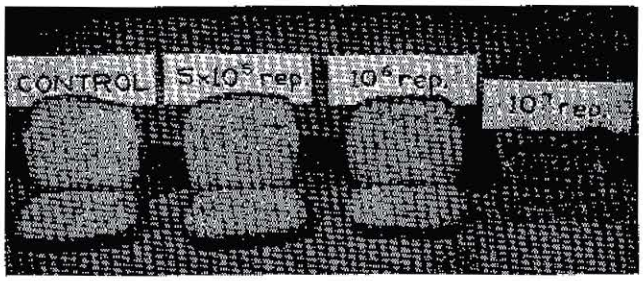

Figure 2. Bread made from irradiated flour.

The 10,000,000-rep loaf had such a disagreeable odor and taste, to say nothing of the appearance, that it was not tested at all. Such high doses, well above those necessary to kill insects, were employed to ensure exceeding the threshold dose.

The group threshold established by the probit analysis lies at about 50,000 rep in the case of both breads. The 95% confidence limits are rather wide in both instances; nevertheless, the analysis has served to establish a threshold and its limits. Since this group threshold lies in the neighborhood of the treatment levels required to disinfest grain, some additional treatment may be required to reduce the off-flavors. The general tendency of the judges is toward being able to tell which sample is irradiated and then not to prefer it; of the 85 correct identifications of the odd sample in series two, 84 preferences were for the non-irradiated sample. There is no way to evalnate to what extent a knowledge that a particular sample has been irradiated prejudices preference. Loaf volumes were not significantly different among treatments up to 500,000 rep in the case of bread made from irradiated flour; but in the case of bread made from the milled irradiated wheat, dose

TABLE 4

Adjusted loaf volume means (cc.)
Irradiated wheat

Dose (rep)	No. of loaves	Volume
1.0×10^4	5	2831
4.0×10^4	5	2866[1]
5.0×10^4	6	2890[2]
7.5×10^4	5	2815
1.0×10^5	5	2746
1.25×10^5	5	2821
2.5×10^5	5	2704

[1] Significantly higher than the 250,000-rep loaf at the 5% level.
[2] Significantly higher than the 100,000-rep and 250,000-rep loaves at the 5% level.

levels in the mid-range (50,000 rep) gave significantly higher volumes than at 250,000 rep (Table 4). No analysis of variance is required to note the significant volume decrease at the 10,000,000-rep level.

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