INTRODUCTION:

It is impossible at the present time to draw more than some very general conclusions regarding the acceptability of foods treated with ionizing radiations. This is unfortunate, because so much costly effort has already been spent in studying the possible causes of the flavor changes which occur in foods during irradiation and possible means of preventing them, and still there is no clear-cut definition of the flavor involved. More regrettable is the fact that there is no precise measure of the degree to which the imparted radiation flavor makes the food unacceptable.

One factor which contributes to our inability to draw more than a few general conclusions is the lack of published information relating to the extent to which consumers will eat or refuse to eat irradiated foods when they are served to them in a customary manner of food service. There are no reports available to indicate to what extent people will purchase irradiated foods offered for sale in stores, which is usually an excellent way to determine acceptance.

In spite of the difficulties, it is intended in this paper to review some of the results of studies in various laboratories and to attempt to draw some inferences which will at least tell us where we stand at the moment in our evaluation of the extent to which irradiated foods, especially meat, may or may not be acceptable.

EFFECT OF RADIATION DOSAGE:

The three major areas for which the use of ionizing radiations might be considered for foods are: (1) for preservation by total sterilization utilizing relatively large dosages; (2) for "pasteurizing treatment" whereby the microbial population is reduced so that storage periods can be extended using sub-sterilizing dosages; and (3) for destroying parasites in food products using relatively small dosages.

There is no question that the changes which occur in foods as a result of subjecting them to ionizing radiations are more pronounced as the dosages are increased. Therefore, one is immediately attracted to the idea that the ionizing radiations might be very useful in the last two areas above, if total sterilization with large dosage were found to be impractical. However, since most studies have dealt with dosages at or near those required for total sterilization, this paper
will concern itself principally with such dosages and their affect upon acceptability of foods.

COLOR CHANGES DUE TO IRRADIATION:

Meats which have been treated with ionizing radiations and for which the degree of effect on color has been recorded by certain workers are listed in Table 1.

<table>
<thead>
<tr>
<th>Food</th>
<th>Dosage (Megarep)</th>
<th>Color</th>
<th>Texture</th>
<th>Flavor</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacon</td>
<td>2.0</td>
<td>Unchanged</td>
<td>Unchanged</td>
<td>Unchanged</td>
<td>(10)</td>
</tr>
<tr>
<td>Beefsteak</td>
<td>3.5</td>
<td>Light color</td>
<td>Softening</td>
<td>Off-flavor</td>
<td>(10)</td>
</tr>
<tr>
<td>Ground Beef</td>
<td>2.0</td>
<td>Unchanged</td>
<td>Crumbly</td>
<td>Off-flavor</td>
<td>(6)</td>
</tr>
<tr>
<td>Ham</td>
<td>1.9</td>
<td>Unchanged</td>
<td>Unchanged</td>
<td>Slight change</td>
<td>(10)</td>
</tr>
<tr>
<td>Pork Sausage</td>
<td>2.0</td>
<td>---</td>
<td>---</td>
<td>Unchanged</td>
<td>(5)</td>
</tr>
</tbody>
</table>

It may be understood that in some instances a change of color, per se, may not have an influence on the acceptability of the food, especially if the color change is slight, or if the usual preparation for eating disguises the change. In the case of fresh meat, a slight browning may not have any great effect on acceptability because cooking causes a severe browning.

The effect of ionizing radiations on the color of meat and meat products has been reported to be anywhere from very slight to pronounced (3). The authors' experiences with ground beef and pork, bologna, ham, bacon, beef steak, beef and pork roasts and pork chops, are that the color, in general, is very slightly browned on the outer surfaces when the meat is in the raw state, but when cooked there is no discernible effect.

TEXTURE CHANGES DUE TO IRRADIATION:

Consumers expect foods, as they eat them, to have certain usual textures, therefore, texture can have a profound effect on the acceptability of a food.

Observations in our laboratories lead us to believe that the protein in fresh meat may be denatured. Ground fresh beef subjected to dosages of $4 \times 10^8$ rep or above appeared coarse and dry and was difficult to mold into patties or to "hold together" during broiling. However, this
did not seem to have any great influence on the texture of the meat as experienced during eating. The results with ground pork were similar, although the magnitude of the changes was much smaller than in beef. No difficulty was experienced in making patties and cooking ground pork which had been subjected to $2 \times 10^6$ rep.

When roasts, steaks, and chops irradiated at 2 and $3 \times 10^6$ rep have been served to large taste test panels in our laboratories, typical comments on the taste test ballots lead us to believe that the samples irradiated to $5 \times 10^6$ rep are more tender than the non-irradiated sample. There were no differences in cooking losses between non-irradiated beef and pork roasts and those irradiated to $3 \times 10^6$ rep.

**FLAVOR CHANGES RESULTING FROM IONIZING RADIATIONS:**

There is no question that the flavor of many foods is affected by subjecting them to ionizing radiations. Certain cured meat products such as frankfurters (6, 7) have become examples of producers of undesirable flavors when irradiated.

Based upon an adjudged promise as to their likely acceptability, foods which have been irradiated have been classified by Siu (7). The meats and meat products in his classification are given in Table 2.

**Table 2**

**PRESENT ESTIMATES OF PROMISE--STORAGE OF PERISHABLES WITHOUT REFRIGERATION**

(Dose: 2,000,000 reps)

<table>
<thead>
<tr>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacon</td>
<td>Beefsteak</td>
<td>Frankfurters</td>
</tr>
<tr>
<td>Beef liver</td>
<td>Ham</td>
<td></td>
</tr>
<tr>
<td>Pork</td>
<td>Hamburger</td>
<td></td>
</tr>
<tr>
<td>Pork sausage</td>
<td>Lamp chops</td>
<td></td>
</tr>
</tbody>
</table>

Since it appears that the above judgment of promise was influenced greatly and probably largely by the extent to which radiation flavor is induced in the foods, it seems appropriate to examine critically the results of flavor evaluations of irradiated meats to determine to what extent acceptability has been affected.

From results which already have been reported elsewhere (6) by our laboratories, we have concluded that there are definite differences between the flavors of irradiated and non-irradiated meat samples, but we have not, heretofore, interpreted these differences in terms of probable consumer acceptance. We are now asking these questions: "How great is this difference?" and "Is the difference one of such magnitude
or of such character that consumers will not accept the irradiated food as well as they have accepted certain other processed foods?"

Results of Small vs. Large Panels

The use of the small panel of 10 to 15 people is confined, in our laboratories, to determining the differences in the amount of irradiated flavor existing in samples of irradiated meat. The panel members are instructed to taste only for irradiated flavor and to disregard other flavors. This was done because our main purpose has been to find methods whereby the irradiated flavor might be reduced. We are not certain that other laboratories have or have not conducted taste panels similarly.

The ballot used consists of a simple line five inches long with "no irradiation flavor" at one end and "extreme irradiation flavor" at the other.

In all instances, except that of ground pork, we have shown (6) that the tasters could detect a difference between the control and irradiated meat products. In all instances, the average score given to the non-irradiated sample was higher than that of the irradiated by approximately one unit on a five-point scale. This means that the tasters could always detect a difference in the meats with respect to the irradiated flavor. Even though the ballot did not specify preference, with respect to flavor, it is easy to draw an incorrect inference that the irradiated sample was less preferred than the non-irradiated meat because it scored lower. Actually the lower score should be interpreted to mean only that there was more irradiated flavor.

Samples of non-irradiated and irradiated unseasoned ground pork and ground beef have been submitted to a panel of 112 tasters, none of whom had experienced the flavor of irradiated meat. The ballot used contained nine designations: Like extremely, like very much, like moderately, like slightly, neither like nor dislike, dislike slightly, dislike moderately, dislike very much, dislike extremely. For each taste test, a taster was given three coded samples: A sample of irradiated (2x10^6 rep) beef or pork; two identical samples of non-irradiated beef or pork, one of which was designated "reference". Tasters were instructed to score as "neither like nor dislike" the reference, which, like the other samples, was unknown to them as far as treatment was concerned. Further, they were instructed to score the other two samples in relation to the reference. For statistical purposes, values of 9, 8, 7, 6, 5, 4, 3, 2, and 1 were assigned to "like extremely", "like very much", etc., respectively.

The difference in average numerical scores for irradiated beef and pork were found to be 0.57 and 1.3, respectively.

The use of the 9 point hedonic scale in the manner of centering judgments around the mid-point ("neither like nor dislike," score of 5) by the use of the reference sample in the above manner is open to question in that it does not permit the tasters to exercise free judgment. Whether or not holding preference judgments around some pre-selected point is valid is not the question of this discussion. Our main point is that by doing so, a dislike was registered for ground pork and beef. The reason
being that because of the location of the reference at the point of "neither like nor dislike", if less degree of preference was registered, it could only be in the direction of dislike.

To further illustrate this point, in other preference type panels of 125 tasters and using the nine-point hedonic scale, wherein the tasters were allowed to exercise free judgment, we have also obtained significantly lower preference scores for the irradiated meats. However, the mean scores for such meats occur in the "like" side of the hedonic scale and vary by degrees of "like". These results are recorded in Table 3.

Table 3

<table>
<thead>
<tr>
<th></th>
<th>Irradiated</th>
<th>Non-Irradiated</th>
<th>2x10^6 rep</th>
<th>3x10^6 rep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacon</td>
<td>6.96*</td>
<td>6.96</td>
<td>5.97</td>
<td>5.07</td>
</tr>
<tr>
<td>Pork Chops</td>
<td>7.15</td>
<td>7.08</td>
<td>6.08</td>
<td>5.53</td>
</tr>
<tr>
<td>Pork Roasts</td>
<td>7.17</td>
<td>7.17</td>
<td>6.66</td>
<td>5.72</td>
</tr>
<tr>
<td>T-Bone Steak</td>
<td>6.77</td>
<td>6.77</td>
<td>5.32</td>
<td>5.61</td>
</tr>
<tr>
<td>Beef Roast</td>
<td>6.71</td>
<td>6.71</td>
<td>5.80</td>
<td>6.23</td>
</tr>
</tbody>
</table>

*Score of 5 means "neither like nor dislike".

It may be seen that the differences in mean scores between the irradiated (2x10^6 rep) and non-irradiated meat is approximately one unit. This difference is approximately the same as that experienced with ground beef and pork although the position of the scores on the hedonic scale of the latter were lower because of the inclusion of a reference scored at "neither like nor dislike", score 5. There appears to be no reason to believe that if tasters were to be allowed full expression of their likes or dislikes with irradiated ground beef or pork, that the mean scores would lie on the "like" side of the ballot.

The fact that the scores of the irradiated (2x10^6 rep) and non-irradiated meats are different does not show the relative numbers of judgments registered at each of the categories on the hedonic scale. Such data are developed in the form of bar graphs shown in Figures 1, 2, and 3.
Figure 1  Percent Response by Categories of the Hedonic Scale for Irradiated and Non-Irradiated Bacon from 125 Tasters.
Figure 2  Percent Response by Categories of the Hedonic Scale for Irradiated and Non-Irradiated Meat Products from 125 Tasters.
Figure 3  Summation of the Percent Response by Categories of the Hedonic Scale for Irradiated and Non-Irradiated Meat Products.
These graphs show for practically every product that the tasters scored the samples irradiated at $2 \times 10^6$ rep as somewhat less preferred and that the curve became somewhat flattened as the dosage was increased to $3 \times 10^5$ rep. The percentages recording the numbers of judgments in the four categories on the "dislike" side of the scale indicate that less than one-third of the judgments are on this side of the preference scale, as shown in Table 4.

Comparison of Acceptability of Irradiated Meat with Other Foods.

These graphs can be compared to the data of Peryam and Girardot (4) shown graphically in Figure 4. In fact, the response to the irradiated meat lies between Peryam's Food B and Food C which he considers to be of "poor" and "good" acceptability, respectively. Wood and Peryam (9) state that "Good acceptance may be predicted for foods that are disliked by less than 10% of the respondents; conversely, any food disliked by 40% or more of the respondents generally represents an acceptance problem."

Table 4

<table>
<thead>
<tr>
<th></th>
<th>Non-Irradiated</th>
<th>Irradiated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$2 \times 10^6$</td>
</tr>
<tr>
<td>Bacon</td>
<td>7</td>
<td>23</td>
</tr>
<tr>
<td>Pork Chops</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>Pork Roast</td>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>T-Bone Steak</td>
<td>6</td>
<td>22</td>
</tr>
<tr>
<td>Beef Roast</td>
<td>7</td>
<td>19</td>
</tr>
</tbody>
</table>
Figure 4  Percent Response by Categories of the Hedonic Scale and Degree of Acceptability for Four Foods (after Peryam and Girardot)
Referring again to Table 4, it will be noted that in our laboratories, not one of the meats irradiated at $2 \times 10^6$ rep was disliked by more than 23% of the 125 tasters. Not more than 32% disliked the meats irradiated at $3 \times 10^6$ rep.

In further attempts to rationalize our results of flavor tests with irradiated meats, we have examined flavor differences which have been reported obtainable with other foods through modifications of raw materials, processing, or storage. A few examples may help to understand the practical significance of the degree of flavor change which results in meats from irradiation.

It is known that canned single-strength orange juice stored at room temperature undergoes a loss in flavor. Guyer and Boyd (1) reported that after 6 months storage at room temperature the flavor score on a 7-point hedonic scale was 1.9 units lower. Using the same type of scale, Sterling and Boggs (6) report differences of 1.3 as the result of variations in blanch time, and 1.0 as the result of variation in blanch temperature of frozen lima beans. Leonard, Luh, Hinreiner, and Simone (2) have shown that ripe Bartlett pears varying only slightly according to pressure tests can produce canned pears having differences of as much as 2.1 points on a 7-point hedonic flavor scale.

Since the above variations in flavor were produced by variables well within the range of commercial practices, and since the variations are as great or greater than the differences we found between irradiated and non-irradiated meats, it appears that irradiation of meat may cause no greater degree of flavor change than can be experienced in other food processes today.

SUMMARY AND CONCLUSIONS:

There are few if any studies which have been specifically designed to provide a scientific basis for determining the degree to which acceptability of meats is changed by irradiation.

Taking the evidence at hand, it appears reasonable to believe that the changes in color and texture resulting from irradiation of meats may not be serious obstacles to consumer acceptance.

An attempt has been made to relate the degree of flavor preference for irradiated meats to flavor preference ratings or acceptability scores obtained with other foods. In doing this, the changes in flavor due to sterilizing dosages of ionizing radiations do not appear to be alarmingly great, since they seem to fall in the range of flavor differences experienced with foods in usual commercial procedures.

This analysis of acceptability emphasizes the great need for large-scale acceptability studies with irradiated foods. It should also serve to caution those who are inclined to draw hasty conclusions regarding the acceptability of irradiated foods that present evidence neither proves nor disproves the acceptability of foods sterilized by this new method.
References


7. Siu, Ralph G. H., in the Hearing before the Subcommittee on Research and Development of the Joint Committee on Atomic Energy. May 1955.


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CHAIRMAN PEARSON: We would like to thank Dr. Schultz for his paper.

I would like to ask Bob Henrickson, who is chairman of this committee, to come forward and sit at the speakers' table.

The next paper we are to have deals with the chemical changes in irradiated meats, and this paper will be presented by Dr. B. S. Schweigert of the American Meat Institute Foundation.