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The Influence of conditions of irradiation and storage on organoleptic changes in meat

M. Ingram and B. Coleby

Radiation preservation of foods has been widely discussed since the initial papers of Brasch and Huber in 1948. A large amount of interest has arisen because of the fundamental novelty of the process. Basically the action of the ionizing radiations is to kill the micro-organisms present in food with the ultimate prospect of producing sterile foodstuffs. The principal advantages are: only negligible temperature rises occur, considerable depth of material can be treated (including penetration of containers), and the process is well suited to continuous operation. Among the disadvantages which may be mentioned:- enzymes are only partially inactivated, chemical changes may occur during and after irradiation, the economics of the process are difficult to assess and the problem of possible toxicity of irradiated foods needs careful consideration.

Ionising radiations can be obtained from radioactive sources or electrical machines. γ-rays have considerable penetration, and the treatment of cuts of meat of 25-30 cms. in depth is quite feasible. β-rays have very low penetration (1-2 mms.) and would only be useful for surface treatment - it is difficult to see how this is practical. Cathode rays from machines are flexible in use, but penetration is limited - two sided irradiation by cathode rays (of the energy usually envisaged for use with foods) is not usually much better than say 7-10 cms,

The basic problem is microbiological: how much radiation is needed to achieve the bacterial kill necessary for a desired increase in storage life? The next immediate problem is to study the effects on quality of such amounts of radiation. The total amount of chemical change is small (less than 1% of the chemical bonds in the material are broken with a dose necessary for complete sterility) but even so adverse changes are commonly reported, and the problem is accentuated by after-effects.

In the early days, 2 M rads (1 rad is equivalent to the absorption of 100 ergs/g. of the material) was usually considered a "sterilising dose"; but Hannan, for example, pointed out that "commercial sterility" particularly with regard to <u>Cl. botulinum</u> implies a dose of 5 M rads. The U.S. Quartermaster Corps recently adopted 4.8 M rads as a sterilising dose. With such doses, the quality changes observed in most foods tend to make then unacceptable, and one is forced to consider the use of lower amounts of radiation in conjunction with other methods of processing, to minimise the damage. Several such methods have been suggested, e.g. irradiation in the absence of oxygen or in the frozen condition, the use of additives (free radical acceptors) to minimise chemical damage, or prolonged storage at room temperature. Our observations on some of these variables are now to be presented.

Qualitative changes.

The colour of fresh meats is usually changed to some extent by radiation, but these changes are not always unattractive. In the absence of oxygen, the red colour of the muscular tissue is often enhanced (formation of oxymyoglobin?), and an increased transparency is apparent; when oxygen is present, there is a tendency to form brown metmyoglobin. The fat of meat is often bleached by irradiation, but on storage in the presence of oxygen, may later acquire unattractive brown discolourations. We ourselves have not made any attempt to characterise colour changes, but there is an increasing amount of work in U.S.A. on the constitution of the various pigments.

Changes in the odour and flavour appear, to us, to be the most serious limiting factor in the radiation processing of meats. The odour is detectable at lower dose levels, but tends to disappear partially during cooking. Flavour changes, which can vary considerably from one meat to another, are pronounced with sterilising doses in most cases. With beef they are particularly obnoxious; with pork and chicken they are not quite so unpalatable.

Our examination of irradiated meats has been mainly based upon a taste panel technique in which the members of the panel usually numbering between 5 and 10 were presented with a small number of randomly coded samples. At any one sitting only samples which had received reasonably similar treatments were presented to avoid poisoning the palate. The tasters were asked to rank the samples in order of preference and, usually, also to give a score using the nine-point hedonic rating (Slides 1 and 2).

We have made a study of flavour and odour changes with canned minced chicken over a range of doses, and these illustrate the discrimination observed. It is apparent that irradiation odour can be detected at 50,000 rads (Slide 3); and after light cooking, irradiation flavours at 250,000 rads (Slide 4). The keeping quality of irradiated minced chicken meat at refrigerator temperatures is not greatly improved by doses of less than 200,000 rads; with 250,000 rads, however, a very useful prolongation is obtained (Slide 5). Flavour changes at this dose level, while noticeable, were not unpleasant. Doses in excess of 2,000,000 rads, however, produced off-flavours which the panel members considered unacceptable and unpleasant.

The method of cooking the meat was found to influence the sensitivity of discrimination considerably (Slide 6). This is an important point, which is not often mentioned in the literature. The method we commonly use is in fact that which makes discrimination easiest. The point may be illustrated by our experiences in the irradiation of whole chicken carcases with a dose of 600,000 rads: after the chicken had been roasted, the irradiation flavour produced was so slight as to be scarcely distinguishable, for the browning during cooking masked the flavour changes; whereas, if the chicken was cooked by light steaming, the flavours could be easily detected (Slide 7).

While our exploration of flavour changes with other irradiated meats has not been so exhaustive, we consider that all the meats we have examined become unacceptable after a sterilising dose of radiation. Most of our work has therefore been on the use of lower doses of radiation in combination with storage under refrigeration. The dose at which off-flavours become immediately evident depends upon the particular meat: with beef, for example, it is quite low, while with pork it is rather high.

One of the best methods of minimising production of off-flavours by irradiation is to freeze the meat during irradiation. We found however that the extent to which the meat is frozen is most important in determining the degree of protection afforded. This is clearly seen in the results which G. M. Wilson obtained in measuring the destruction of thiamine during irradiation at different temperatures (Slide 8): at -75° the protection afforded to thiamine was virtually complete. Similar results have been obtained in odour and flavour assessments with samples irradiated at different temperatures (Slide 9). Comparison of odour easily enabled us to place samples which had received the same radiation dose in order of increasing temperature. Samples irradiated at -40° could be distinguished from those irradiated at -75° and from those irradiated at -10°. Even at -75° however some flavour change is apparent. Comparison of samples irradiated at room temperature and at -75° at different doses levels (Slide 10) suggests that the protection factor conferred by irradiation at -75° is about 3. This is in agreement with our experience using minced chicken. These results emphasise the need for accuracy in controlling temperature in freezing experiments, a factor not always apparent from a study of the literature.

We have made several studies on the effect of irradiating in the presence or absence of air. Colour changes are usually less attractive in samples irradiated in the presence of air but this is not always the case with regard to odour or flavour. We cannot at present say whether we prefer samples irradiated in air or nitrogen. Some experiments, particularly with regard to odour indicate quite clearly that samples irradiated in air are preferred (Slide 11). On other occasions ambiguous or contradictory results have been obtained (Slides 12, 13). Some of our perplexities in these experiments may be attributable to the difficulty of knowing precisely in what oxidation state the meat may be during and after irradiation. We have tried to eliminate variations in this respect by storing meat for various times before irradiation on the assumption that the amount of oxygen remaining will diminish with the period available for the meat to metabolise it, but the results have given no clear indications so far, and we are hoping that investigations by G. M. Wilson on the oxidation-reduction potential in meats will yield methods enabling us to investigate this matter more precisely.

The presence of air is of clear importance in the development of a rancid flavour in fatty tissue during storage of irradiated meats; this was shown several years ago at American Meat Institute. Here, J. J. Macfarlane has been investigating the use of low doses of radiation to increase the storage life under refrigeration of large cuts of beef. Doses around 200,000 rads produced immediately detectable changes. After a dose of 100,000 rads the flavour changes observed soon after irradiation were negligible and a very useful delay in the development of bacteria was obtained during storage at +1°; but the

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peroxide value of the fatty tissue increased unusually rapidly and rancid flavours were noticeable much sooner than the onset of bacteriological deterioration. The margin of choice between delaying bacterial deterioration and hastening the onset of rancidity is small. Current experiments suggest that a dose of about 50,000 rads may give the most suitable compromise.

It has often been reported that storage of irradiated meat results in an improvement in the flavour of the samples. Some of our experiments with minced beef indicate that this may not always be true. Samples which had been given 5,000,000 rads were stored at 0°, 12° and 25° for periods of up to three months. At each of these temperatures the flavour showed a gradual deterioration on storage (Slide 14), and comparison of samples stored at the different temperatures, for any given period of storage indicated that those samples stored at the lowest temperature were preferred to those stored at higher temperatures. It is moreover interesting to observe, since a sterilising dose had here been applied, that all these samples were disliked after 3 weeks - some of them strongly disliked - as the hedonic ratings indicate. With eviscerated chicken carcases pasteurised by radiation and stored at +1°, the onset of bacterial spoilage can be substantially delayed (Slide 15); we have increased shelflife up to roughly 5-fold with a dose of 825 Kr, which did not cause any obvious flavour change immediately. Here too, however, a readily noticeable deterioration took place (Slide 16) long before there was any significant development of bacteria.

The chief result of the several years work represented here is to show how much we have still to learn about the influence of conditions on flavour changes associated with irradiation. The effects of oxygen, other than in producing rancidity, cannot be predicted or explained; that of freezing is ill-defined; there is disagreement about the benefits of storage. Such disagreement, between different workers or even between replicate experiments, is a common but most undesirable feature of present-day investigations; to eliminate it presumably requires much more precise specification of materials and conditions.

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