4:5

IRRADIATION OF VACUUM-PACKAGED SHEEP CARCASSES TO EXTEND CHILLED STORAGE LIFE

Beilken, S.L., Bill, B., Grau, F.H., Griffiths, I., Macfarlane, J.J., and Vanderlinde, P.

CSIRO Division of Food Research, Meat Research Laboratory, Cannon Hill, Queensland, Australia

and Wills, P.A.

Australian Atomic Energy Commission, Lucas Heights, N.S.W., Australia.

SUMMARY

The odour produced as a result of the gamma irradiation of vacuum-packaged carcasses detracted from the acceptability of the raw meat assessed at the time carcasses were taken from their packages. However, off-odours as a result of microbial spoilage were a greater detraction in control samples after some weeks' storage. Irradiation increased weep that accumulated during storage.

Microbial numbers on the control carcasses increased to approximately 10^7 organisms/cm^2 over 4 weeks, after which they increased little, if at all. In contrast, microbial numbers on the irradiated carcasses increased throughout storage, but by 16 weeks numbered only about 10^5 organisms/cm^2. The organoleptic acceptability of irradiated meat as assessed by a taste-panel changed little over the duration of the experiment. Ratings for the control samples initially were more favourable than for the irradiated samples, but by 11 weeks' storage became less favourable.

In considering the commercial application of the treatment, gains in storage life need to be balanced against losses in some quality attributes.

INTRODUCTION

The technique of vacuum-packaging, using plastic packaging films of low oxygen permeability, is now widely employed to extend the chilled storage life of meat. Using this technique, a storage life of about 10 weeks can be obtained for vacuum-packaged portions of sheep carcasses, provided the temperature of storage is near 0°C. However, when entire sheep carcasses are vacuum-packaged, storage life is considerably shorter than for the portions. This shortened storage life is not always sufficient to enable vacuum-packaged sheep carcasses to reach distant markets without a substantial risk of microbial spoilage. Therefore, ways to extend the storage life of vacuum-packaged sheep carcasses have been sought. Although a procedure involving treating carcasses with dilute acetic acid shows promise of achieving an adequate extension of storage life, other possible methods are being investigated. Here we report a study into the use of gamma radiation for this purpose.

The bacterial effects of ionizing radiations such as gamma rays from cobalt-60 have been known for many decades, as has the potential of these radiations to extend the storage life of meat. However, it is only recently that wide approval by Health Authorities of the treatment up to specified dose levels appears likely. This is thought so in view of the recommendation, in 1980, by a Joint FAO/IAEA/WHO Expert Committee for the clearance, for conservation purposes, of all foods up to a dose of 10 kGy (Anon 1981).

In an investigation in which samples of vacuum-packaged longissimus dorsi muscle from sheep carcasses were irradiated (Macfarlane et al. 1983) it was found that after a dose of 4 kGy total bacterial counts remained low over the whole storage period of 57 days at 0-1°C. However, a laboratory taste-panel could detect an effect of irradiation at this level on some organoleptic attributes of the cooked meat. In a small trial in which vacuum-packaged sheep carcasses were irradiated to a mean dose of 2.4 kGy, less than 1/100 of original bacterial numbers was achieved. Accordingly, it was decided to use this radiation dose for the larger trial reported here.

MATERIALS AND METHODS

Meat source

Sixty three lambs were slaughtered, dressed and placed in a chiller at a commercial abattoir. Approximately 6 hours after slaughter, the carcasses were temporarily removed from the chiller and individually vacuum-packaged in plastic bags (Barrier Bag, T gauge; W.R. Grace; nominal oxygen transmission rate: about 35 ml/m^2 per 24 hr per 101 kPa measured at 25°C and 75% relative humidity). Care was taken to ensure that all packs were well evacuated before they were sealed. Retention of a tight-fitting package during storage was used as an indication of maintenance of the integrity of packaging. Packages showing any indication of failure were discarded. One day after slaughter, 21 of the carcasses were taken from their packages and the hind legs and loins removed. These portions were individually vacuum-packaged, frozen, and transported to the Meat Research Laboratory where they were kept in frozen storage until needed for use as 'frozen controls' in taste-panel tests. The remaining 42 intact, vacuum-packaged carcasses were despatched by refrigerated transport to the Australian Atomic Energy Commission. There they were stored in a chiller controlled at 0-2°C.

Irradiation

Three days after slaughter 21 of the carcasses, selected at random, were irradiated up to 6 at a time in two refrigerated irradiation chambers, each of which could hold 3 carcasses. The radiation source was cobalt-60. The mean dose received by the carcasses was 2.43 ± 0.1 kGy at a dose rate of 1 kGy/h approximately. The dose variation throughout the carcasses ranged from 2.07 kGy minimum to 2.94 kGy maximum. Carcasses were returned to the chiller immediately after they were irradiated. After completion of irradiation treatment, the carcasses were returned using chilled transport to the Meat Research Laboratory where they were placed in a chiller at 0°C until removed as required for assessment.

Assessments

(i) The appearance of the carcasses while still in the vacuum package was assessed by an eight member panel.

(ii) The odour of the carcasses was assessed immediately after packages were opened.

(iii) The fluid (weep) in the packages at the time they were opened was collected, its volume measured and weep per kg carcass weight calculated.

(iv) Immediately after carcasses were removed from storage their microbial status was estimated from samples, each 25 mm in diameter, excised from the following six locations: brisket, mid-back, rump, inside hind leg, inside flap, renal area. Samples from each carcass were pooled for microbiological assessment.

(v) Taste panel assessments were carried out on the hind leg and loin portions of carcasses. After completion of the microbiological sampling of carcasses, a hind leg portion and a loin portion from each of the carcasses were individually vacuum-packaged then stored frozen at -20°C until required, along with the 'frozen control' samples, for taste panel assessment.

Upon removal of legs from frozen storage, they were thawed at 1°C then boned out, the fat being separated from muscle. Except for the semimembranosus muscle which was needed for other purposes not reported here, the meat was minced and samples for taste panel assessment were prepared by mixing 500g of lean mince with 50g of fat and 500 ml water. This mixture was brought to the boil and allowed to simmer for 20 min, then samples were served hot to a laboratory taste panel. Panellists assessed the minces for meat aroma, other aroma, meat flavour, other flavour and acceptability.

Loins were thawed at 5°C. The eye muscle was then removed and roasted in a forced fan-convection oven at 230°C for 25 min. Portions were assessed by a laboratory taste panel for the same attributes assessed for minces.

Analysis of variance was used to analyse the taste panel data.

RESULTS

Appearance

Although there was considerable variation between panellists in their rating of the appearance of the carcasses in the unopened vacuum package, on balance, the panellists preferred the appearance of the irradiated carcasses. The fat of the irradiated carcasses had a slight pink colouration, which along with a slight bleaching of the usual yellowish colouration of the fat, was generally thought to improve appearance. However, after carcasses were removed from their packages and hung for approximately 1 hour to allow them to 'bloom', the appearance scores for the irradiated and the control carcasses were about the same.

Odour

For control samples 'off' (or foreign) odour assessed immediately after the package was opened was found to be negligible at the commencement of storage. The odour rating then increased progressively with duration of storage until by 14 weeks it approached an extreme degree. In contrast off (or foreign) odour for the irradiated samples initially was rated about 'slight', but then did not increase greatly over the entire 16 weeks' duration of the experiment. The odour in the irradiated samples, at least at the early stages of storage, was from radiolytic changes and not microbial action. By 4 weeks' storage the scores for the irradiated and control samples were comparable, and at the later sampling times the irradiated samples were rated as having a more acceptable odour.

Fluid (weep) at the time of opening of vacuum package

From Fig.1 it can be seen that when sampled at week 1 the amount of weep present in the irradiated and control treatments was small. However, the amount released during subsequent storage was markedly greater for the irradiated treatment.

Microbiological assessments

Fig.2 shows the development of the micro-flora on the surface tissues of both the irradiated and control lamb carcasses during storage at 0° to 0.5°C.

It is immediately apparent that throughout 16 weeks of storage there were considerably fewer micro-organisms on the irradiated carcasses than on the control, vacuum-packaged carcasses.

Lactic-acid bacteria were virtually absent from irradiated carcasses. On these carcasses there were less than 10^2 (log 2) lactic-acid bacteria per cm^2 or per ml of weep. In contrast, on the control carcasses, these organisms were the dominant flora in the weep and a considerable proportion of the total flora on carcass tissue. The lack of lactic-acid bacteria on the irradiated carcasses was unexpected in view of the relative radiation resistance of these organisms (Ingram and Roberts, 1980) and their presence on lamb carcasses irradiated to 4 kGy in the study by Rhodes and Shepherd (1966). Their absence may be a consequence of their low numbers initially. Although *Brochothrix thermosphacta* was present on the irradiated carcasses the growth of this group of organisms was severely retarded both on surface tissue and in the weep. The reason for this is not clear.

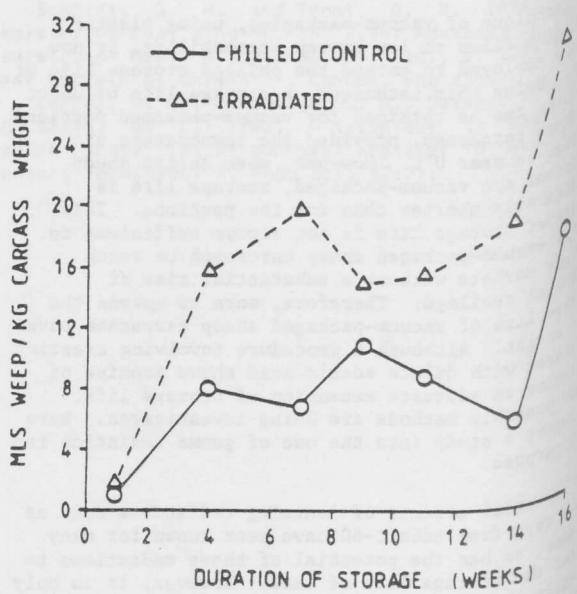

Figure 1: Volume of weep per kg carcass weight, present in package when opened after removal from storage.

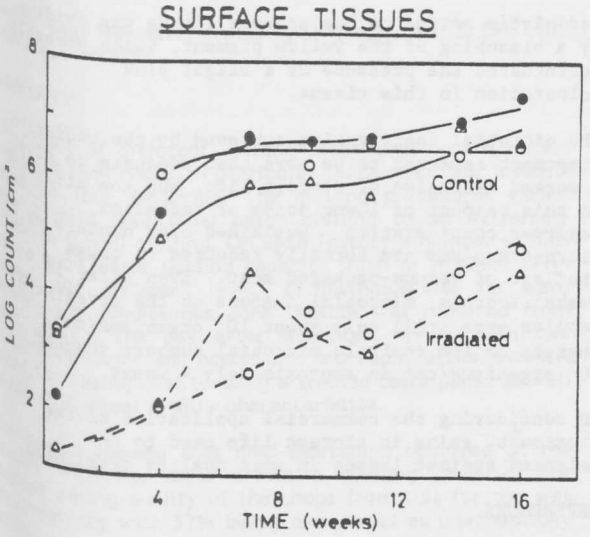

Figure 2: Development of micro-flora on the surface tissues of vacuum-packaged lamb carcasses with duration of storage.

○ B.thermosphacta ● Lactobacilli △ Gram negative

The numbers of gram-negative bacteria on irradiated, stored carcasses were also markedly lower than on the control carcasses. In addition, there were significant differences in the composition of this flora. The only gram-negative organisms detected were moraxellas. The presence of these organisms is consistent with their known relative radiation resistance. On the other hand, the gram-negative flora of the control carcasses was a mixture of enterobacteriaceae, aeromonads, alteromonads, pseudomonads and moraxellas. For most of the storage time of the control carcasses, there were approximately equal numbers of oxidative and fermentative types of gram-negative organisms. Only at 14 and 16 weeks did the fermentative types predominate.

Taste-panel assessments

In these assessments, panellists evaluated 3 samples, namely (i) a non-irradiated sample that had been stored, vacuum-packaged, at -20°C (frozen control), (ii) a non-irradiated sample that had been stored chilled (chilled control), and (iii) an irradiated sample that had been stored chilled (irradiated). It was assumed that change in the frozen control over the duration of the study would be negligible, and therefore this sample would provide an unchanging reference for the detection of change in the other samples.

The effects of irradiation on the attributes of meat aroma and meat flavour were not pronounced. Changes in the attributes of other flavour and other aroma followed a similar pattern to changes in acceptability, and only the latter results for the minces and the roast loins are presented here.

From the results shown in Fig.3 for assessments of the acceptability of minced leg meat, it can be seen that the ratings for the irradiated samples remained fairly steady over the duration of the trial. However, at all times irradiated samples were rated significantly lower than the frozen controls. At weeks 1 and 4, the chilled control samples were judged to be very similar to the frozen controls, but at week 7, 9 and 11, their ratings approximated those of the irradiated samples. After week 11, the acceptability of the chilled controls decreased sharply.

Experience gained from other studies at our laboratories suggests that assessment of meat as boiled mince is a sensitive method for the detection of change in organoleptic characteristics. This is in accord with the results of the present study, where from Fig.4 it can be seen that the trends evident from the results obtained from roast loins were similar to, but less pronounced than, those for the minces.

DISCUSSION

An important consideration in the irradiation of meats is the susceptibility of animal fats to accelerated development of rancidity if irradiated in the presence of oxygen (Lea et al. 1960). The degree to which oxygen has to be excluded in order to avoid problems with development of rancidity has not been defined. Rhodes and Shepherd (1966) found that sides of lamb packaged in an oxygen impermeable film (Metathene x) but without evacuation, then irradiated to about 4 kGy had a rancid odour when removed from the bag. However, those that were evacuated in their package before sealing and irradiation showed no significant change from the fresh condition.

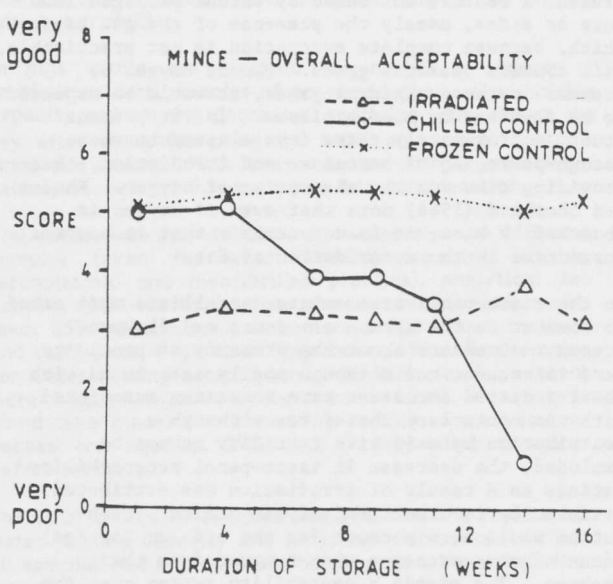

Figure 3: Effect of duration of storage of carcasses on means of panel scores for overall acceptability of minces prepared from hind-leg meat.

Scoring scale: 8 - very good; 6 - good; 4 - moderate; 2 - poor; 0 - very poor.

Least significant difference, p = 0.05: 0.7

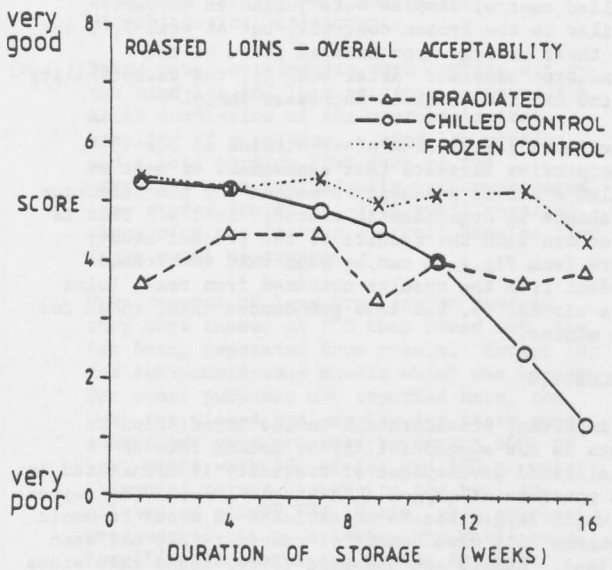

Figure 4: As for Fig.3 except data is for roasted loins in place of minces.

Least significant difference, p = 0.05: 0.9.

However, vacuum-packaged entire lamb carcasses present a feature not shown by vacuum-packaged lamb cuts or sides, namely the presence of the gut cavity which, because complete evacuation is not practicable, will contain residual gases. Should oxygen be present in these residual gases, it would be expected to be absorbed by muscle tissue. In the present study, approximately three days elapsed between vacuum-packaging of carcasses and irradiation, thus providing time for the absorption of oxygen. Rhodes and Shepherd (1966) note that even if oxygen is absorbed by meat, it is not certain that it becomes unreactive in the autoxidation of fat.

In the taste-panel assessments, panellists were asked to comment on the nature of odours and flavours present. Comments about the presence of rancidity were infrequent and although mostly associated with the irradiated carcasses were sometimes associated with the controls. Therefore, although a contribution by oxidative rancidity cannot be excluded, the decrease in taste-panel acceptability ratings as a result of irradiation was attributed principally to direct radiolytic action. Such action would also account for the off (or foreign) odour of raw carcasses when removed from their package. The steady acceptability rating over the storage period of the irradiated carcasses indicates that the packaging material presented a sufficient barrier to oxygen to prevent noticeable development of rancidity.

Every endeavour was made to subject control carcasses to the same amount of handling as the irradiated treatments, so that the increased amount of weep in the packs of the irradiated carcasses probably reflects slight radiation-induced disruption of muscle structure, and an increased release of weep.

Unless a suitable absorbent material capable of retaining the weep is included in the package, the presence of weep will lead to severe discolouration of the surfaces of carcasses.

Radiolytic action on the adipose tissue was evident by a bleaching of the yellow pigment, which probably accentuated the presence of a slight pink colouration in this tissue.

The microbial inactivation achieved by the radiation treatment appeared to be more than adequate to give a marked extension of storage life, and the utility in this respect of lower doses of radiation deserves consideration. Sustained high numbers of micro-organisms are normally required to cause spoilage of vacuum-packaged meat. Even after 16 weeks' storage, microbial numbers on the irradiated samples were still only about 10^5 organisms/cm^2, whereas on the controls microbial numbers reached 10^7 organisms/cm^2 in approximately 4 weeks.

In considering the commercial application of the treatment, gains in storage life need to be balanced against losses in some quality attributes.

REFERENCES

Anon., 1981. Food Irradiation Information, Number 11, p.4.

Ingram, M., and Roberts, T.A. 1980. Ionizing irradiation. In: Microbial Ecology of Foods, by The International Commission on Microbiological Specifications for Foods, Academic Press, London, p.46.

Lea, C.H., Macfarlane, J.J., and Parr, L.J., 1960. Treatment of meats with ionizing radiations. V. - Radiation pasteurisation of beef for chilled storage. J. Sci. Fd. Agric., 11, 690.

Macfarlane, J.J., Eustace, I.J., and Grau, F.G. (1983). Ionizing energy treatment of meat and meat products. Proc. National Symposium on the Ionizing Energy Treatment of Foods, Sydney, 5-6 Oct. 1983, p.39.

Rhodes, D.N., and Shepherd, H.J., 1966. The treatment of meats with ionizing radiations. XIII. - Pasteurisation of beef and lamb. J. Sci. Fd. Agric. 17, 287.

ACKNOWLEDGEMENT

This investigation was funded by the Advisory Committee to the Australian Meat and Livestock Corporation for the Market Development and Promotion of Sheepmeat.