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THE EFFECT OF IONISING RADIATION ON THE COLOUR OF PORCINE MUSCLE

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INTRODUCTION

The use of ionizing radiation to increase the shelf-life of foodstuffs has been well-documented and various beneficial effects have been recognised. Other less desirable side-effects, however, such as the discolouration of meat and meat products have also been reported.

The visual appearance of foodstuffs is known to be a very important factor in terms of consumer acceptability and so an understanding of the pigment changes occurring during irradiation would be advantageous to the meat industry. Irradiated meat and poultry products have been shown to exhibit a red/pink discolouration following irradiation (Tappel, 1956; Taub *et al.*, 1979) and to elucidate the nature of these changes research has been carried out both on meat and in solutions of myoglobin. It has been proposed that the discolouration is due to oxymyoglobin (OxyMb) regeneration from metmyoglobin (MetMb) via an intermediate step dependent on the formation of quadrivalent iron produced due to hydroxyl radical formation during irradiation (Tappel, 1956; Bernofsky, 1959). Other reaction mechanisms have been proposed by Satterlee et al. (1972), Giddings and Markakis (1972), Kamarei *et al.* (1979) and Whitburn *et al.* (1981 but there is still some doubt as to the precise nature of the irradiated meat pigment.

MATERIALS AND METHODS

Thirteen porcine *m.longissimus dorsi* (L.D.) sections (12cm long) were obtained from a local abattoir 24 hours post-mortem. The sections were stored for a further 24 hours at 4°C after which they were bisected, placed in trays with the freshly cut surface uppermost and overwrapped in oxygen permeable film. One of each matched pair was irradiated at 5kGy (4°C) using a Cobalt 60 source (Nordion International Inc. Kanata, Canada) while the remainder were stored at 4°C. After seven days the surface colour was measured using a Monolight systems 6800 spectrophotometer with a 6101 monochromator. An integrating sphere with 0°/diffuse viewing geometry was used. A 1mc slice was then removed from each of the samples in turn and the colour of the freshly cut surface measured immediately. Two samples from each treatment were then stored at 4°C and the colour measured 45 minutes, 75 minutes, 3 hours and 18 hours after cutting to assess the ability of the meat to re -oxygenate.

RESULTS AND DISCUSSION

After seven days storage the CIE LAB values (Table 1) for the pork L.D.`s showed that irradiation resulted in a significant ($P<0.001$) increase in the a* values for the meat thus giving a more red appearance. The exterior surface of the L.D.'s had significantly ($P<0.01$) higher a* and b* values corresponding to a more red/yellow appearance than the interior of the L.D. The very highly significant ($P<0.001$) interaction between irradiation dose and surface for a* values was due to the fact that these values for the exterior surface significantly decreased from 5.32 to 3.96 following irradiation while those for the interior increased from 1.83 to 5.90.

The absorption spectral data was also notable showing that the peak at 630nm indicating the presence of MetMb on the exterior surface of the control samples (Figure 1a) was absent in the irradiated samples. The spectra of the freshly cut controls (Figure 1b) consisted mainly of reduced myoglobin (RedMb) with some OxyMb while the irradiated freshly cut surface had a spectra which differed markedly from this. In both cases exposure to air for 18 hours (Figure 1c) gave spectra which were typical of OxyMb thus indicating that the haem structure still had the capacity for oxygenation.

On the basis of the results presented here the production of OxyMb due to irradiation would seem unlikely and a more plausible explanation may be the formation of carboxymyoglobin (COMb) as it is already known that carbon monoxide is produced in irradiated meat following irradiation (Futura *et al.*, 1992). OxyMb and COMb have similar spectra and both appear red thereby making it difficult to discriminate between them. The same difficulties also arise with haemoglobin compounds which undergo similar reactions to those of myoglobin. It is known, however, that at low concentrations oxyhaemoglobin appears yellow while carboxyhaemoglobin appears pink (Lemberg and Legge, 1949). It follows therefore that in meat with a low level of myoglobin for example pork and poultry, OxyMb may be expected to be brown as opposed to bright red while COMb would be pink. This phenomenon may then account for the high a* values in the interior of the irradiated meat which in a low myoglobin meat such as pork would be more likely to be due to COMb than OxyMb. Indeed visual examination would suggest that the pink colour is too vivid to be attributable to OxyMb when compared to the normal pale red/brown colour of bloomed (oxygenated) pork.
The absorption spectrum of OxyMb should show a peak at 544nm which is slightly smaller than the peak at 582nm. The spectra from the freshly cut irradiated meat surface shows two peaks but with the peak at 543nm being larger than the peak at 575nm and therefore it is unlikely that pure OxyMb is the cause of this spectral shape. COMb and nitrosomyoglobin (NOMb) also have absorption spectra where the peak is higher than the peak and of the two, the spectra presented here seem more in character with COMb in which the peaks occur at 542nm and 579nm. These wavelengths correspond better to those of the irradiated pigment than the corresponding peaks of NOMb at 549nm and 578nm. On the basis of the spectra in Figure 1b it would be difficult to suggest that irradiation caused the appearance of a peak at 610nm as reported by Clarke and Richards (1971) but there is a shift in the Soret peak (418nm) compared to that of pure COMb (424nm) which would indicate that sulphmyoglobin may be present.

It is also clear that the meat pigment formed due to irradiation is unstable in air because the exterior goes brown while the interior stays pink. COMb would be expected to behave similarly in this respect given that carbon monoxide has a greater affinity than oxygen for binding to the haem of RedMb but can also be displaced by oxygen in excess. This change to OxyMb is clearly what happens when the freshly cut surface of the irradiated L.D. (Figure 1c) is exposed to air for a period of time.

From the experimental work presented here it is not possible to ascertain the exact mechanism for the production of COMb. While the formation of the compound may be due to a simple combination of carbon monoxide with the haem in the meat, other workers (Whitburn *et al.*, 1981) have found that quadrivalent iron is present on irradiation. Further research is warranted in order to elucidate the manner in which the COMb is formed.

CONCLUSION

Treatment of pork L.D.'s with low dose ionizing radiation causes the production of a pink pigment, unstable in air, which shows colouring and spectral properties indicative of COMb. It is proposed that carbon monoxide formed on irradiation reacts with the myoglobin in the meat producing a pink colour which persists in the meat interior.

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REFERENCES

BERNOFSKY, C., FOX, J.B., and SCHWEIGERT, B.S. 1959. Biochemistry of Myoglobin. VI. The Effects of Low Dosage Gamma Irradiation on Beef Myoglobin. *Archives of Biochemistry and Biophysics.* 80(9).

CLARKE, R., and RICHARDS, J.F. 1971. Effect of g-Irradiation on Beef Myoglobin. *J. Agri. Food Chem.* 19(1):170-174.

FUTURA, M., DOHMARU, T., KATAYAMA, T., TORATANI, H., and TAKEDA, A. 1992. Detection of Irradiated Frozen Meat and Poultry Using Carbon Monoxide Gas as a Probe. *J. Agri. Food Chem.* 40(7):1099-1100.

GIDDINGS, G.G., and MARKAKIS, P. 1972. Characterization of the Red Pigments Produced from Ferrimyoglobin by Ionizing Radiation. *J. Food Sci.* 37(3):361-364.

KAMAREI, A.R., KAREL, M., and WIERBICKI, E. 1979. Spectral Studies on the Role of Ionizing Radiation in Colour Changes of Radappertized Beef. *J. Food Sci.* 44(1):25-32.

LEMBERG, R., and LEGGE, J.W. 1949. *Hematin Compounds and Bile Pigments: Their Constitution, Metabolism and Function.* Interscience Publishers, Inc., New York. pp.214-215.

SATTERLEE, L.D., BROWN, W.D., and LYCOMETROS, C. 1972. Stability and Characteristics of the Pigment Produced by Gamma Irradiation of Metmyoglobin. *J. Food Sci.* 37(2):213-217.

TAPPEL, A.L. 1956. Regeneration and Stability of Oxymyoglobin in some Gamma Irradiated Meats. *Food Res.* 21:650-655.

TAUB, I.A, ROBBINS, F.M., SIMIC, M.G., WALKER, J.E., and WIERBICKI, E. 1979. Effect of Irradiation on Meat Proteins. *Food Tech.* 33(5):184-193.

WHITBURN, K.D., HOFFMAN, M.Z., and TAUB, I.A. 1981. A Re-evaluation of the Products of Gamma Irradiation of Beef Ferrimyoglobin. *J. Food Sci.* 46:1814-1816.

Table 1. Effect of irradiation on the expose surface and internal colour of pork m.longissimus dorsi.

CIELAB VALUES IRRADITION DOSE (kGy)	L*	a*	b*
0	63.01	3.57	12.04
5	62.58	4.93	12.39
SEM	0.35	0.156	0.195
SIG.	NS	***	NS
SURFACE			
Exterior	63.10	4.64	13.41
Interior[a]	62.48	3.87	11.02
SEM	0.372	0.176	0.209
SIG.	NS	**	***
Statistical effect of irraditional surface interaction			
SEM	0.511	0.235	0.286
IRRADITION SURFACE	NS	***	NS

All figures are means of 26 values measured from the 13 samples in each treatment.
[a] Where interior is a freshly cut surface.
NS not significant
*** $P<0.001$; ** $P<0.01$
SEM standard error of the mean
SIG significance