EFFECT OF IONISING RADIATION ON THE COLOUR AND OXIDATIVE RANCIDITY OF STORED MEAT PUREES CONTAINING ANTIOXIDANTS

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Introduction
Irradiation of meat has been shown to result in a number of colour changes, with chicken breast meat becoming 'pinker' (Miller *et al.*, 1995) and beef becoming 'browner' (Millar *et al.*, 2000). A number of pigment forms have been proposed to account for these observed changes in appearance following irradiation. Moss *et al.* (2000) suggested that the differences in spectra of irradiated and unirradiated pork could be due the formation of carboxymyglobin. The production of free radicals during irradiation results in degradation of a number of chemicals and increased oxidation of fatty acids leading to rancidity and off-odours (Nam *et al.*, 2003). One way of overcoming this problem is to include antioxidants in the foodstuff and given consumer concerns about food additives, the use of natural antioxidants such as flavonoids could be an option. The following study was undertaken to study the effect of inclusion of natural antioxidants on the free radical induced oxidation in meat following irradiation with the effects of their addition of the colour also being examined.

Materials and Methods
Fresh minced beef (8% lipid) was purchased locally in Belfast and mixed to provide a homogenous bulk sample. A total of 100 patties (50 g weight) were prepared. The antioxidants α-tocopherol, epicatechin, quercetin and resveratrol were included at concentrations of 25, 50, 100, 250, 500 and 700 µmol/kg whilst other patties were prepared with no antioxidant included. The samples were packed in plastic containers, double wrapped with cling film and treated with an irradiation dose of 2.5 kGy or left unirradiated. They were then stored for 1 or 14 days at 4 ± 1°C. Samples were analysed for oxidative rancidity by measuring their thiobarbituric acid number (TBA) according to the method of Pikul *et al.* (1989) but using trichloroacetic acid in place of perchloric acid. The reflectance spectra of the patties were measured immediately after opening using a Monolight spectrophotometer and CIELAB values calculated (Moss *et al.*, 2000). The experiment was repeated on three separate occasions.

Results and Discussion
Irradiation at 2.5 kGy resulted in significantly higher a* values and significantly lower a* and b* values (Table1) than control samples. Storage for 14 days in overwrap packs resulted in significantly lower a* and b* values compared to fresh samples. There was no statistically significant effect of either type of antioxidant added or its level on any of the colour parameters studied (Table 1). There was a statistically significant interaction between Irradiation and storage time which showed that a* and b* values decreased less with storage for irradiated samples than unirradiated samples.

TBA values were significantly higher ($p<0.001$) after irradiation at 2.5 kGy and storage for 14 days (Table 1). Inclusion of antioxidants in the patties significantly reduced ($p<0.001$) oxidative rancidity. Resveratrol proved to be the most effective antioxidant with TBA values being half those of the control samples. Quercetin and epicatechin produced similar effects with oxidation levels being significantly lower than those of the controls but higher than samples containing resveratrol. α-Tocopherol was the least effective antioxidant. Antioxidant concentration had a significant effect ($p<0.05$) on the TBA values. The decrease in TBA values with increasing concentration of resveratrol did not appear to be significant as similar values were obtained at each concentration. Thus, it would appear that inclusion levels of as low as 25 µmol/kg would effectively reduce oxidation in meat purees containing resveratrol as an antioxidant. There were statistically significant interactions fro TBA values between; irradiation and type of antioxidant; irradiation and storage; and storage with type of antioxidant (Table1).

Conclusions
Resveratrol is a highly effective antioxidant for reducing oxidation in meat puree samples, with quercetin and epicatechin also proving to be effective although to a lesser extent. Although, α-tocopherol did reduce oxidation of the meat it was significantly less effective than the other three antioxidants employed. Irradiation of beef purees resulted in samples which were less red and less yellow, however the colour of irradiated samples showed less change during storage.

Table 1: Effect of ionising radiation and storage on the colour (CIELAB values) and TBA values (mg malonaldehyde/kg muscle) of overwrapped meat purees containing antioxidants.

	L*	a*	b*	TBA
Effect of irradiation (kGy)				
0	46.03	18.32	17.09	0.261
2.5	47.35	17.39	15.85	0.386
Significance of effect	**	*	***	***
SEM (n = 150)	0.317	0.259	0.161	0.0110
Effect of storage (days at <3°C)				
1	47.01	21.66	17.13	0.211
14	46.36	14.06	15.80	0.436
Significance of effect	n.s.	***	***	***
SEM (n = 150)	0.317	0.259	0.161	0.0110
Effect of antioxidant (AO)				
Control (n = 12)	42.97	17.88	15.92	0.480
α-Tocopherol (n = 72)	46.77	17.53	16.23	0.410
Epicatechin (n = 72)	46.97	17.57	16.38	0.311
Quercetin (n = 72)	46.93	17.81	16.56	0.306
Resveratrol (n = 72)	46.70	18.51	16.79	0.242
Significance of effect	n.s.	n.s.	n.s.	***
SEM (max)	0.457	0.374	0.233	0.0159
(min)	1.120	0.915	0.570	0.0389
Effect of AO concentration				
0 (n = 12)	42.97	17.88	15.92	0.480
25 (n = 48)	46.09	17.52	16.22	0.361
50 (n = 48)	46.38	17.94	16.41	0.345
100 (n = 48)	47.12	18.04	16.43	0.320
250 (n = 48)	46.66	18.23	16.67	0.295
500 (n = 48)	47.41	17.64	16.49	0.290
700 (n = 48)	47.39	17.77	16.73	0.294
Significance of effect	n.s.	n.s.	n.s.	*
SEM (max)	0.560	0.457	0.285	0.0195
(min)	1.120	0.915	0.570	0.0389
Significance of interaction				
A x C	n.s.	n.s.	n.s.	n.s.
I x A	n.s.	n.s.	n.s.	***
I x C	n.s.	n.s.	n.s.	n.s.
I x S	***	***	**	**
S x A	n.s.	n.s.	n.s.	***
S x C	n.s.	n.s.	n.s.	n.s.

where: I = irradiation treatment; S = storage; A = antioxidant; C = antioxidant concentration; SEM = standard error the mean; ***=p<0.001; **=p<0.01; *=p<0.05; n.s.=p>0.05 (not significant)

References

Millar, S.J., Moss, B.W., McDougall, D.B. and Stevenson, M.H. (1995). The effect of ionising radiation on CIELAB colour coordinates of chicken breast as measured by different instruments. International Journal of Fo Science and Technology, 30, 663-674.

Millar, S.J., Moss, B.W. and Stevenson, M.H. (2000). The effect of ionising radiation on the colour of beef, pork a lamb. Meat Science, 55, 349-360.

Moss, B.W., Millar, S.J. and Kilpatrick, D.J. (2000). The use of discriminant analysis for the interpretation of reflectance spectra of irradiated porcine *M. longissimus dorsi*. Meat Science, 55, 337-348.

Nam, K.C., Min, B.R., Yan, H., Lee, E.J., Mendonca, A., Wesley, I. and Ahn, D.U. (2003). Effect of dietary vitamin and irradiation on lipid oxidation, color, and volatiles of fresh and previously frozen turkey breast patties. M Science, 65, 513-521.

Pikul, J., Leszczynski, D.E. and Kummerow, F.A. (1998). Evaluation of three modified TBA methods for measur lipid oxidation in chicken meat. Journal of Agricultural and Food Chemistry, 37, 1309-1313.