Reducing waste in the beef and lamb supply chains

The problem

Considerable amounts of fresh beef and lamb meat are discarded before sale and in the home because of discolouration rather than product exceeding 'sell by' dates. In the Waste and Resources Action Programme (WRAP) Food Waste Report v2, 'The Food We Waste, July 2008', it was estimated that 161,000 tonnes of meat and fish was wasted in the home, and that there are 5.2 million tonnes of food related packaging waste.

The WRAP report also estimated that retailer 'back of store' waste was 1.6 million tonnes of food per annum and that each tonne of waste was equivalent to 4.5 tonnes of carbon. There are no comparable figures for in-store meat waste but contacts with retailers suggest this is considerable, of the order of 7,000 tonnes per annum, equating to about 245,000 tonnes of carbon. The key to waste reduction is better control of supply chain processes, from production to consumer, optimising key elements both for the meat itself, and associated packaging.

Why was work needed?

High oxygen modified atmosphere packing (MAP) accounts for 80% of red meat sold through UK retailers. High oxygen MAP promotes the formation of oxymyoglobin and extends the colour shelf life beyond that of simple overwraps with an atmosphere of air (20% oxygen), allowing the efficiency of central packing of meat and producing the seven days shelf life required by retailers. However, not all packs achieve seven days shelf life, mainly due to differences in stability of different muscle fibre types and concentrations of natural antioxidants (redder muscles having a shorter shelf life). High oxygen MAP can also induce more lipid oxidation, leading to rancidity and the generation of free radicals. Recent studies have suggested that these free radicals can also oxidise proteins leading to tougher meat, either through the inhibition of tenderisation or the induction of toughening.

Solutions to the problem of meat discolouration include changes in packaging technology and targeted use of natural antioxidants in diets. Vitamin E is an important antioxidant, present at high levels when cattle and sheep consume fresh grass before slaughter, and its impact on reducing colour and lipid oxidation are well known. Its prevention of protein oxidation is less well established. In the winter months low antioxidant levels produce more rapid discolouration, but Vitamin E supplementation is effective.

There is a need for a better understanding of how key components in production, post-slaughter processing and distribution, including the use of alternative packaging methods, can be used to reduce meat discolouration and hence the retail waste of beef and lamb. Longer shelf life will also lead to less waste in the home.

What has been achieved?

The project addressed five key questions:

1. *What is the optimum gas to meat volume for MAPs in terms of colour shelf life, lipid and protein oxidation?*
2. *How do gas mixtures with lower concentrations of oxygen affect shelf life and product quality?*
3. *What are the alternatives to MAP packs for beef and lamb cuts?*
4. *What are the effects of processing variables such as muscle pH/temperature and ageing time on colour, lipid and protein oxidation?*
5. *What are the effects of processing variables such as muscle pH/temperature and ageing time on colour, lipid and protein oxidation?*

The results

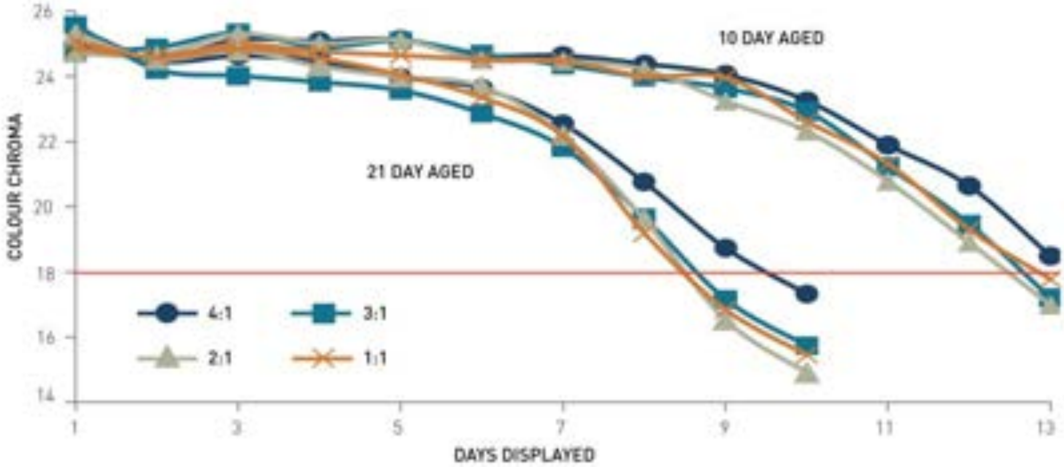
1. What is the optimum gas to meat volume for MAPs in terms of colour shelf life, lipid and protein oxidation?

The study used simulated retail display rooms to assess the optimum gas:meat ratio in beef striploin. The loins were vacuum packed and stored at 1°C for 10 or 21 day ageing. Steaks were then prepared and packed in MAP with gas:meat ratios of 4:1, 3:1, 2:1 and 1:1 for a two week period representing retail shelf life. Colour was measured throughout and lipid oxidation measurements were made after 7 and 10 days of simulated retail display. It is generally agreed that a colour (chroma) value of 18 is indicative of the end of acceptable colour shelf life.

Figure 1 shows that meat previously aged for 10 days had a shelf life of 13-14 days whilst that aged for 21 days had a shelf life of 9-10 days. There was no statistically significant effect of meat to gas ratio on colour shelf life, although the ratio 4:1 appears to have given one day extra shelf life.

Figure 1

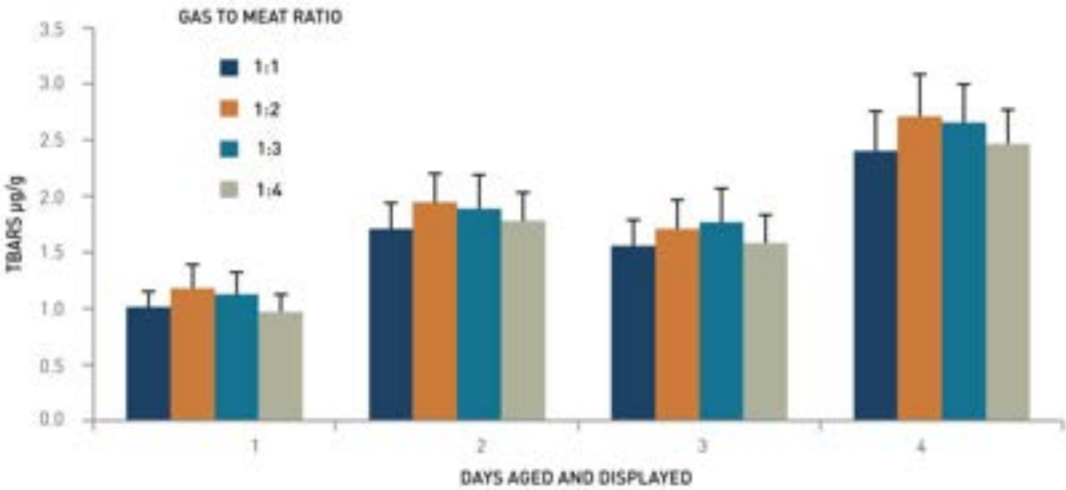
The effect of ageing time and gas to meat ratio in MA packs on the change in colour chroma of sirloin steaks during simulated retail display. The solid red line indicates chroma 18, the colour associated with the end of acceptable colour shelf life.



Lipid oxidation in meat can be assessed by the thiobarbituric acid reactive substances (TBARS) assay and high levels – above 2 – are seen as the cut off point at which consumers would regard the product as rancid. The results (Figure 2) showed that the gas:meat ratio did not appear to have any effect on lipid oxidation at any ageing/display time. The results also showed that values for lipid oxidation were higher at 10 day display time than at seven day display time and that for each display time values for lipid oxidation were higher if the meat had been aged for 21 days.

Figure 2

The effect of ageing time and gas to meat ratio in MA packs on lipid oxidation (TBARS) of sirloin steaks during simulated retail display.



These results showed that ageing meat from 10 days to 21 days reduced its colour shelf life and made it more prone to lipid oxidation, and that the gas:meat ratio is not important. So pack sizes can be reduced with the saving of gas, plastic and space during transport and retail display. However, it should be noted, that if reducing pack size, the

meat must not touch the pack surface otherwise discolouration will occur where the meat is in contact with the non-permeable pack material.

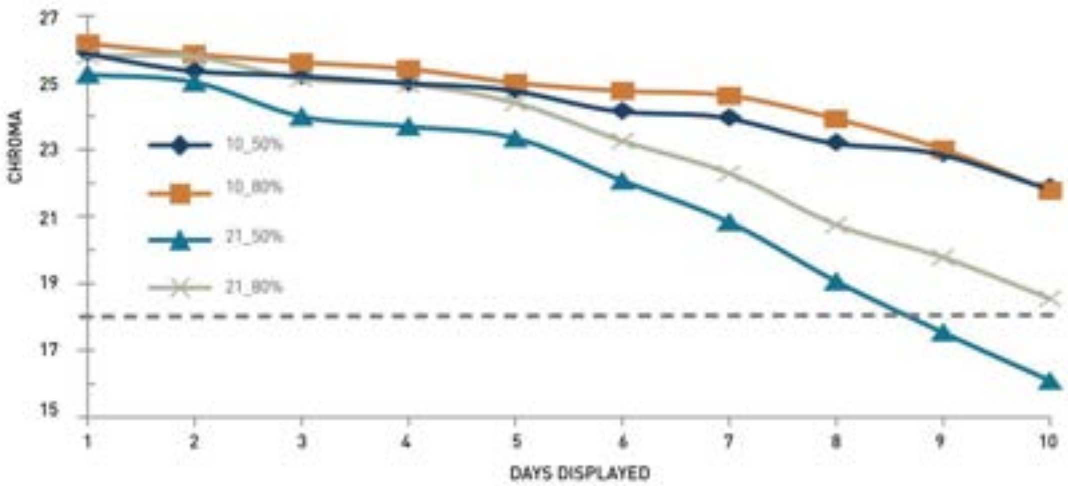
2. How do gas mixtures with lower concentrations of oxygen affect shelf life and product quality?

To assess the effect of different levels of oxygen in MAP, beef striploins aged for 10 or 21 days respectively, steaks were cut and either vacuum packed or packed in MAP with 80 or 50% oxygen, 20% carbon dioxide and for the 50% oxygen, a balance of 30% nitrogen. Colour was measured daily for the oxygen containing packs and lipid oxidation measures were made in all samples after seven days display.

As before the results confirmed that extended ageing time reduces the subsequent retail colour display life of the meat in an MA pack (Figure 3). Reducing the oxygen concentration from 80% to 50% appeared not to affect the colour shelf life of 10 day aged meat but reduced that of 21 day aged meat by at least one day.

Figure 3

The effect of ageing time and oxygen concentration upon colour shelf life of beef sirloin steaks. The grey broken line indicates chroma 18 the colour associated with the end of acceptable colour shelf life.



Lipid oxidation was not affected by oxygen concentration after either 10 or 21 day ageing but was much higher in high oxygen MAP than zero time or aged and seven day vacuum packed samples (Figure 4). Ageing for 21 days made the meat more prone to lipid oxidation than 10 day aged meat with values approaching 2, the cut-off point at which a consumer might declare the meat sample rancid.

Figure 4

The effect of ageing time and oxygen concentration upon lipid oxidation (TBARS) of beef sirloin steaks. [a,b,A,B] Values with different superscripts within and between columns are statistically significantly different $p<0.05$.

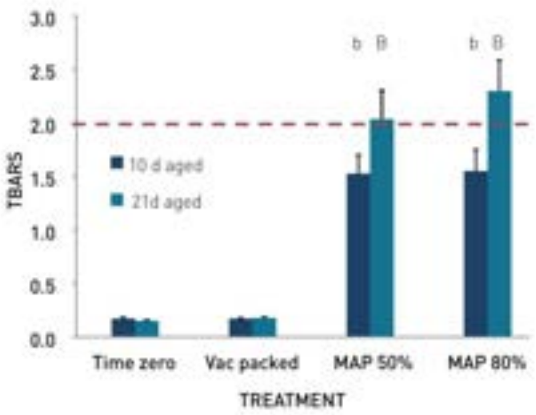
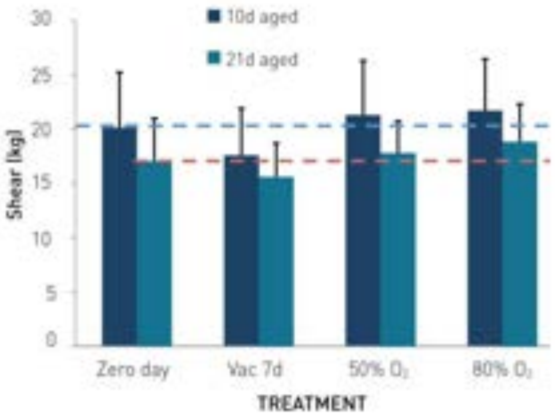


Figure 5

The effect of ageing time and oxygen concentration upon texture of beef sirloin steaks.



Shear force can be used as measure of texture (tenderness) and reducing levels are indicative of increasing tenderness. The results showed that shear force was reduced (tenderness increased) by ageing loins as a steak for seven days over and above that achieved by 10 or 21 day ageing in vacuum as a whole striploin, more so between 10 and 17 days than 21 and 28 days (Figure 5).

However, steaks displayed in high oxygen MAP for seven days were significantly tougher than steaks displayed in vacuum for the same period and fractionally tougher than the zero day samples after both 10 and 21 day ageing.

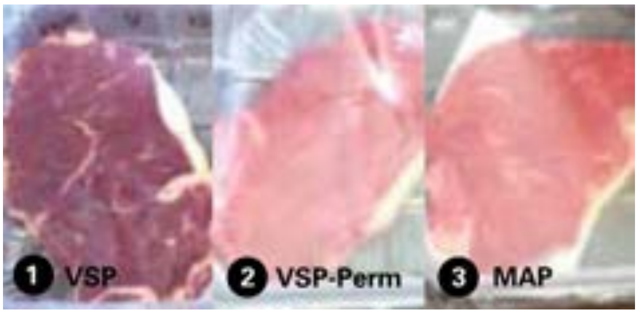
The results showed that high oxygen MAP potentially prevented tenderisation and caused toughening. Reducing the concentration of oxygen will not be beneficial since it does not reduce lipid oxidation and may reduce colour shelf life especially when many suppliers age meat beyond 10 days.

3. What are the alternatives to MA packs for beef and lamb cuts?

Twenty beef striploins were aged to 10 or 21 days from slaughter as before. Steaks were cut and packed in MAP (80% oxygen, 20 % carbon dioxide) vacuum skin packs (VSP) in a non-permeable film, or vacuum skin packed into the bottom of an MAP tray, with a semi-permeable film, and then MA packed with 80% oxygen, 20% carbon dioxide (VSP-Perm).

Because the colour of the VSP-Perm could not be measured through the top web and the VSP sample would change very little with the myoglobin in the un-oxygenated state, the packs were held for 10 days and then opened and allowed to bloom for one hour and then measured. A further set of steaks were taken to 21 day display only for the VSP treatment.

Although VSP could potentially produce a 21 day shelf life as opposed to 8-10 days with MAP, there is a current concern that the consumer will not keep VSP stored below 7°C and, in the absence of oxygen, this will allow the growth of Cl. *botulinum*. Hence, shelf life for VSP is currently restricted to 10 days. (FSA 2008, Food Standards Agency guidance on the safety and shelf-life of vacuum and modified atmosphere packed chilled foods with respect to non-proteolytic *Clostridium botulinum*).

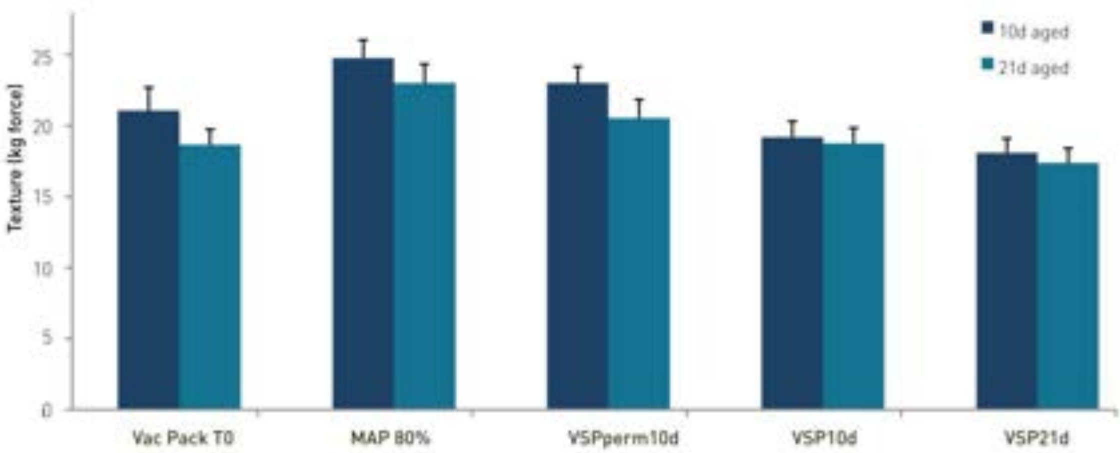


With regard to colour there were small differences between the samples, but all samples were still above the value of 18, below which consumers would describe the colour as brown and unacceptable.

With regard to texture (Figure 6) and sensory assessment, both mechanical and human assessments confirmed that samples displayed in MAP were tougher than those in VSP.

Figure 6

The effect of packaging on the texture of steaks as assessed mechanically. (Average values with sem, n=19).



These results would suggest that displaying meat without exposure to oxygen will allow the product to continue tenderising, whilst oxygen will cause products to toughen, more obviously so in 10 day than 21 day aged meat. Whilst consumers currently do not appreciate the colour of VSP meat, it would allow a longer shelf life and hence reduce wastage.

4. What are the effects of processing variables such as muscle pH/temperature and ageing time on colour, lipid and protein oxidation?

Beef rumps were selected from carcases in which the striploin pH had gone below 6.00 before the temperature had dropped below 35°C. These samples were denoted as 'damaged'. Such muscles will potentially have heat-shortened and it was expected that this would damage the colour pigment proteins and antioxidant enzyme activity thus making the colour less stable in retail display. These rumps were compared with rumps from carcases which had undergone ideal post-mortem pH/temperature decline, which were processed either side of the 'damaged' rumps in the abattoir and had come from the same farm and hence production system as those heat shortened. These samples were denoted as 'normal'. The pH, temperature and Vitamin E results confirmed that suitable rumps had been selected (Table 1).

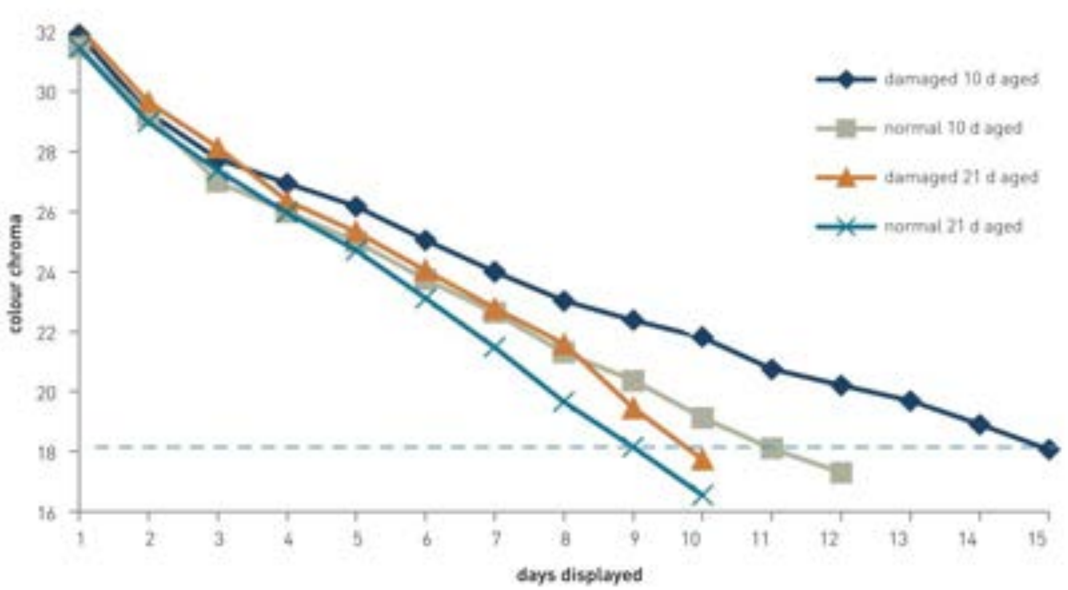
Table 1: The effect of rapid pH fall whilst carcase temperature is still high on colour shelf life parameters (* difference between 'damaged' and 'undamaged' is statistically significant).

	'damaged'	'normal'
pH at 35°C	5.78	6.33*
Vitamin E	5.48	5.67
Chroma d7 (10d aged)	24.0	22.6*
Chroma d7 (21d aged)	22.8	21.5*
Chroma d10 (10d aged)	21.5	19.1*
Chroma d10 (21d aged)	18.5	17.1*
days to Chroma 18 (10d aged)	13.6	10.0*
days to Chroma 18 (21d aged)	10.4	9.5*
TBARS (10d aged)	1.2	1.7
TBARS (21d aged)	1.7	2.6

As found with sirloin muscle, ageing from 10 to 21 days reduced colour shelf life of rump by 3-5 days (Figure 7). However, contrary to expectations, there was no difference in lipid oxidation (TBARS) between 'damaged' and 'normal' muscles and colour shelf life of 'damaged' muscles was 1 and 4 days better for 21 and 10 day aged meat respectively, as given by the days to Chroma 18 values where Chroma 18 is the cut off value for consumer acceptability (Table 1). Further studies are required to describe the mechanism fully.

Figure 7

The effect of rapid pH fall, whilst the carcase temperature is still high, and meat ageing on the change in colour during simulated retail display in MAP. The broken blue line indicates chroma 18 the colour associated with the end of acceptable colour shelf life.



The results showed that whilst too high a rate of pH fall when the carcase is still hot will lead to muscle damage, a pale colour, excessive drip and toughened meat, it does not appear to have a deleterious effect on colour shelf life when retail displayed in MAP.

The effect of Vitamin E was examined in a further set of rump steaks which had either high or low Vitamin E content.

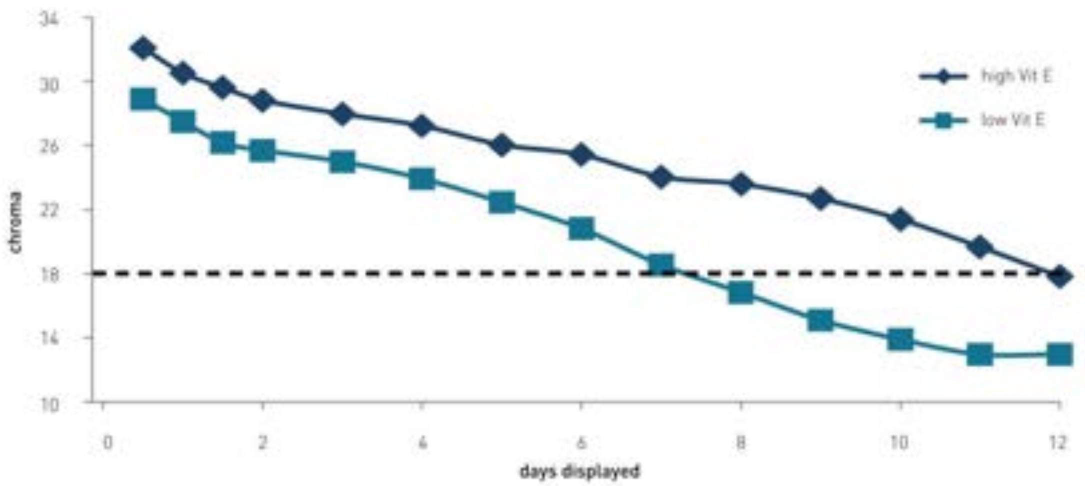
The results showed (Table 2 and Figure 8) that those with a low Vitamin E had a statistically significantly reduced shelf life in terms of both colour (chroma) and lipid oxidation or rancidity (TBARS).

Table 2: The effect of Vitamin E concentration on colour and lipid oxidation in MAP beef rump steaks

	High Vitamin E	Low Vitamin E
Vitamin E	5.04	3.15
Chroma d7	24.05	18.85
Chroma d10	21.40	13.91
days to Chroma 18	12.3	8.1
TBARS	0.87	4.85

Figure 8

The effect of Vitamin E concentration upon the colour shelf life of beef rump steaks displayed in MAP. The broken black line indicates chroma 18 the colour associated with the end of acceptable colour shelf life.



5. What are the effects of dietary Vitamin E and selenium on the shelf life characteristics of lamb including colour, lipid oxidation and protein oxidation?

Leg muscles (m. *gluteobiceps* [GB], and the m.*semimembranosus* [SM] Figure 9), from lambs finished commercially on one of three finishing diets, expected to be either low or high in Vitamin E and slaughtered in early March, were used. The diets were as follows: predominantly roots; predominantly concentrates or predominantly grass-based. Three 2 cm steaks were packed in MAP and one steak was packed in VSP. Colour was measured daily on one each of the MAP and VSP packs. TBARS were measured in the GB and SM of the second MA pack after seven days simulated retail display.

Chroma values in SM muscle from concentrate and root-fed lambs fell to below 18 after four days, whereas grass-fed lamb did not fall below 18 until six days of display in MAP. There was a similar two day difference in chroma of GB muscle (not shown) which lasted slightly longer in MAP (seven days for grassfed lamb v. five days for the other two groups, see Figure 10, P.16). Chroma of SM muscle in VSP was unchanged after 11 days display although values were initially lower (around 16) at the start due to the lack of oxygen present. Steaks stored in VSP for 21 days showed a steady decline in chroma value, with the muscles from concentrate-fed animals again showing a more rapid decline than from the grass-fed or rootsfed animals.

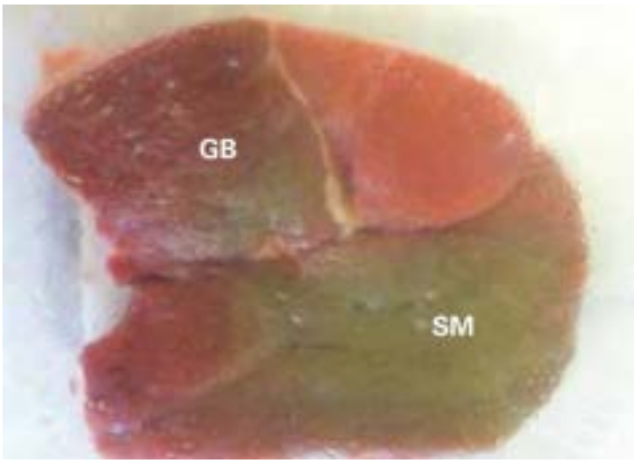


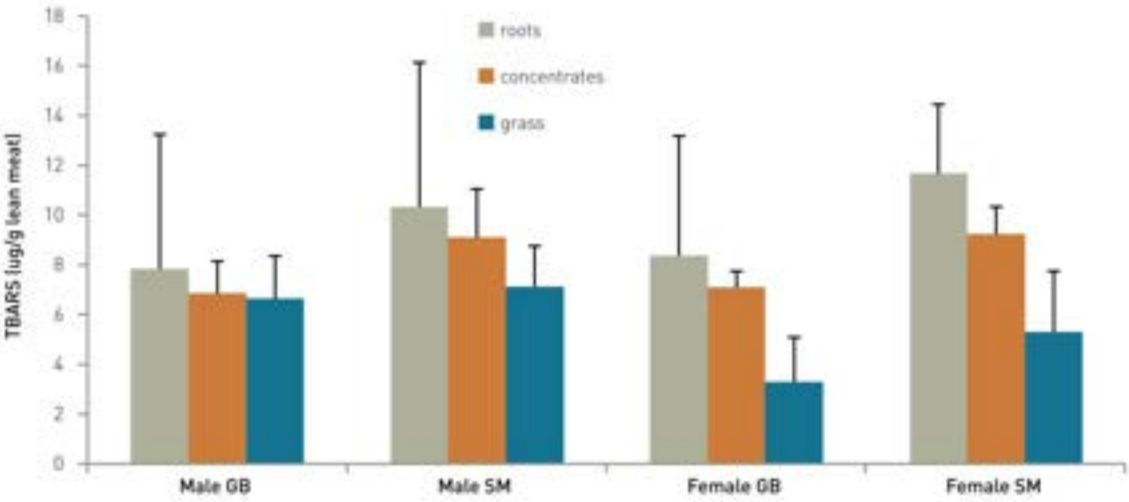
Figure 9
A lamb leg steak showing the two muscles of interest m. gluteobiceps (GB) and m. semimembransous (SM).
The difference in colour is clear.

Figure 10
The two packs at the left of the tray have leg steaks from animals which had grazed grass whilst the others were from animals which had been fed concentrates.

Lipid oxidation was lower in muscles from grass-fed lambs (Figure 11). Levels were significantly lower in SM muscle of lambs fed grass compared with those given concentrate or roots. Variation in values for rootfed lambs (particularly males) was considerable. GB muscle showed a similar trend but the results were not significant probably due to this variation.

Figure 11

Effect of animal gender and diet on TBARS in lamb GB and SM muscle aged for 10d and displayed in MAP for 7d.



The study showed that lambs fed concentrates had significantly less Vitamin E in their muscle than those which had grazed roots which in turn had significantly less than that in the muscle of those grazed on grass, although grass and roots were not significantly different from one another (Table 3). This explains the difference in colour and lipid stability of these dietary groups.

Table 3 Effect of diet on Vitamin E concentration in the muscle.

Levels (µg/g)	Roots	Concentrates	Grass
Vitamin E	3.7^{a}	2.1^{a}	5.6^{b}
sed	0.63	0.62	0.73
TBARS SM	10.0^{a}	9.1^{a}	5.8^{b}
sed	4.4	1.5	2.2
TBARS GB	7.9^{a}	6.9^{a}	4.3^{b}
sed	4.2	1.0	2.4
SM colour d6	14.5^{a}	14.35^{a}	18.6^{b}
sed	2.39	3.11	1.33
GB colour d6	16.6^{a}	17.1^{a}	19.7^{b}
sed	1.86	2.53	1.60

abValues with different superscripts within rows are statistically significantly different $p<0.05$

It is suggested that the limit for optimum meat stability for beef is to have greater than 3-3.5 ug/g muscle, but this may be higher for lamb. Hence, the grass-fed group had the highest Vitamin E concentration and a significantly better colour and lipid stability, while the roots-fed animals had the least lipid stable muscle despite having more Vitamin E than those fed concentrates.

The results suggested that the poor shelf life of carcases from some over-wintered lambs could be explained by the Vitamin E content of the diet, especially if supplemented with concentrates or grazed on turnips. However, late in the season grass Vitamin E content can also be low and should only be relied upon if actively growing.

The benefits of this work for producers and processors are a clear demonstration that:

1. **ageing (conditioning) meat shortens the subsequent retail colour shelf life, which can be four days or more, depending upon other factors in the meat.**
2. **Vitamin E has a substantial effect on the colour shelf life of both beef and lamb and that wintering systems can reduce optimum levels of Vitamin E in the muscle and lead to reduced shelf life.**
3. **MA pack sizes can be reduced relative to their contents, thus reducing gas to meat ratio, provided that the product does not touch the pack lid.**
4. **vacuum skin packaging will give a longer retail shelf life than MAP, whilst acknowledging that many consumers have not yet accepted the colour of meat in this system.**
5. **meat in high oxygen MAP is toughened during retail display whilst it can continue to tenderise in VSP.**
6. **optimising production, processing and packaging of beef and lamb will increase retail shelf life, reduce waste and improve quality.**

With thanks to Dr Ian Richardson and Prof Charlotte Maltin for compiling this report.