# DETECTION OF OXYGEN IN COMMERCIALLY PACKAGED BEEF SYSTEMS USING OXYGEN SENSORS: IMPACT OF DETECTED OXYGEN ON DIETARY α-TOCOPHERYL ACETATE SUPPLEMENTED AND CONTROL BEEF

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**Background**

Packaging under vacuum and in modified atmospheres are widely used for packaging of foods, the residual oxygen being an important determinant of food quality and shelf life for such products (Tewary *et al.* 1999). Knowledge of the actual levels of oxygen in each pack provides important information about the integrity of packages, the efficiency of the packaging machine and an indication of quality changes in the product (Fitzgerald *et al.* 1999). The determination of oxygen in food packages has been difficult and expensive, usually requiring destruction of the package (Johnson, 1997).

Recently, research has lead to the development of optical oxygen sensors, which work by the effect of luminescence quenching by molecular oxygen (Bacon and Demas, 1987). The active component of the sensor normally consists of a long-decay fluorescent or phosphorescent dye polymer matrix. The dye-polymer material is applied as a thin film coating onto a suitable solid support. Molecular oxygen penetrates the sensitive coating through simple diffusion and quenches luminescence of the dye by a dynamic i.e. collisional mechanism. This allows oxygen to be quantified by measuring changes in luminescent parameters from the oxygen sensing element in contact with the gas or liquid sample, using a predetermined calibration. Papkovsky *et al.* (1992) showed the effectiveness of phosphorescent dyes, mainly platinum (II) and palladium (II) complexes of porphyrins and some related structures, for practical oxygen sensing, due to their long lifetimes and suitable spectral characteristics. Papkovsky *et al.* (1995) designed the phosphorescent complexes of porphyrin-ketones for use as oxygen probes. Some of their favourable properties include high stability, water insolubility, high melting points (non-volatile), biogenic origin and low toxicity. Advantages of optical oxygen sensing include; non-invasive technique for measuring oxygen through translucent material, the solid-state sensor is inert and does not consume oxygen or participate in other chemical reactions. When observing oxygen levels in packaged foods these advantages are especially important. When the sensor is packaged with the food or attached to the inside of the package it provides a means of non-destructive measurement of the oxygen in the package. Potential applications are varied and include non-destructive quality control testing of pre-packaged foods, optimisation, observing oxygen levels in packaged foods during storage and comparing oxygen levels with food quality (Papovsky *et al.* 2000).

Vacuum packaging involves an almost total exclusion of oxygen allowing a longer shelf life to be obtained.

Removal of oxygen is particularly important for cooked modified atmosphere packaged (MAP) beef. MAP involves holding perishable foods in an environment which has been changed to inhibit the spoilage agents, thereby maintaining a higher quality during it's natural life and/or extending the shelf life (Church and Parsons, 1995). Cooking promotes lipid oxidation, partly due to the release of iron, which acts as a pro-oxidant. The presence of small amounts of oxygen accelerates oxidation of cooked MAP beef even further.

Supplementing the diets of cattle with α-tocopheryl acetate results in higher concentrations of this antioxidant in the meat tissue, resulting in greater lipid stability (Faustman *et al.* 1989).

The objectives of this study were to determine if oxygen could be detected by the oxygen sensor in fresh vacuum packaged beef and cooked MAP beef over various display periods and by so doing, determine the impact that oxygen and dietary α-tocopheryl acetate supplementation might have on lipid.

**Materials and Methods**

Fitzgerald *et al.* (1999) discussed the preparation and calibration of the sensors.

The fibre-optic phosphorescence phase detector was described in detail by ( Papkovsky *et al.* 1995).

Cattle (n = 6) were fed basal (20mg) or supplemented (3000mg) α-tocopheryl acetate/head/day for 50 days prior to slaughter.

Carcass sides were chilled (4°C x 24hrs), the *gluteo biceps* muscles removed, vacuum packed and frozen @ -20°C for 6 months.

Slices (4mm thickness) were cut from each muscle and half were oven cooked @ 180°C for 4 minutes. Raw samples were vacuum packed and cooked samples were held under MAP (60:40, $N_2$:$CO_2$). Oxygen sensors were placed between the meat and the package for vacuum packaged samples and attached to the inside of the package for MAP samples. Packaged slices were displayed in a refrigerated cabinet (4°C and 616 lux fluorescent lighting) for 2 weeks (MAP samples) or 5 weeks (vacuum packed samples). Low oxygen permeable (8-12$cm^3/m^2$/24hrs) polystyrene/EVOH/polyethylene and (45$cm^3/m^2$/24hrs) polyamide/polyethylene films were used for vacuum packaging and MAP, respectively. TBARS values were measured using the method of Ke *et al.* (1977).

**Results**

Very low levels of oxygen (< 0.4%) were observed, as expected for vacuum packaged samples and there was no significant difference between the percentage oxygen observed for supplemented and basal groups over time. A higher level of oxygen (5-8%) was observed in MAP samples and cooked, treated meat had a lower level of oxygen than the corresponding control meat ($p < 0.05$).

Levels of vitamin E recorded for beef samples were 1.9 and 3.7 μg/g for basal and supplemented meat respectively. α-Tocopheryl acetate supplemented meat had significantly ($p < 0.05$) lower TBARS values than basal beef for both raw and cooked samples throughout the studies. Although, TBARS increased in all samples over time, oxidation in cooked samples was much greater throughout. Cooked meat and/or the greater level of oxygen present in the MAP packages may have been responsible for the greater oxidation observed. Cooking causes release of free iron, which acts as a pro-oxidant. The packages with higher oxygen contents as

measured by the oxygen sensors had a correspondingly higher level of lipid oxidation. This indicates the ability of the sensor to accurately assess the oxygen content and hence predict the meat quality.

**Conclusions**

Sensors were capable of measuring the oxygen content in all packs. Greater levels of oxygen were observed in MAP packs compared to vacuum packs and the levels of oxygen detected corresponded with the lipid oxidation of the samples indicating the accuracy of the sensor measurements.

Dietary supplementation of cattle with α-tocopheryl acetate resulted in significant ($p < 0.05$) decreases in lipid oxidation in raw and cooked samples compared to basal samples. Cooked samples had a significantly ($p < 0.05$) greater degree of lipid oxidation compared to raw samples irrespective of treatment with α-tocopheryl acetate. The difference in the levels of oxygen between treated and control samples is apparent when samples are cooked.

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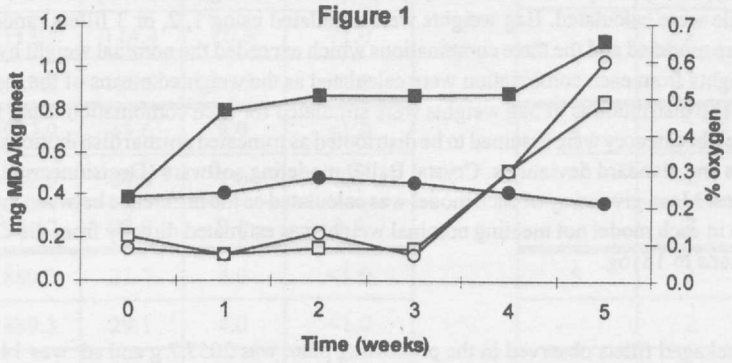


Figure 1. Lipid oxidation (mg MDA/kg meat) of raw vacuum packed beef compared to the level of oxygen present.

Lipid oxidation: (■) basal (20 mg α-tocopheryl acetate/head/day) (●) supplemented (3000mg α-tocopheryl acetate/head/day.

Oxygen: (□) basal (20 mg α-tocopheryl acetate/head/day) (○) supplemented (3000mg α-tocopheryl acetate/head/day).

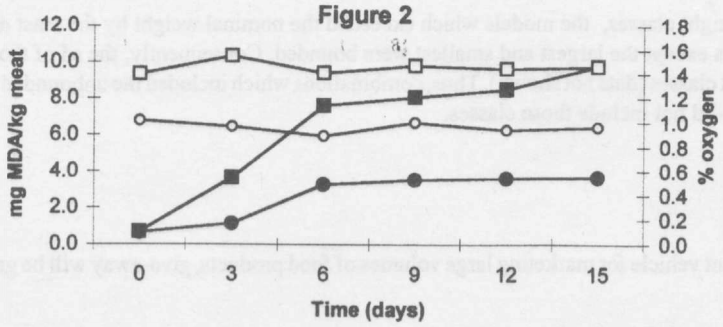


Figure 2. Lipid oxidation of cooked MAP beef compared to the level of oxygen present.