MULTI-FACETED APPROACH TO CONTROLLING LIPID OXIDATION IN COOKED PORK

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INTRODUCTION

Lipid oxidation is one of the principal causes of deterioration in the quality of cooked meats during storage (Gray and Pearson, 1987). The products of lipid oxidation are responsible for off-flavours and off-odours in cooked meats and limit the shelf-life of these products.

Cooking accelerates lipid oxidation in meat and meat products for a number of reasons. Muscle cell compartmentalisation is destroyed by heating and this results in the exposure of membranal phospholipids to oxygen and pro-catalysts of lipid oxidation (Mottram, 1987). In addition, antioxidant enzymes are heat-denatured during cooking and their protective effect on lipid components is lost (Lee et al., 1996).

The susceptibility of cooked meat products to lipid oxidation is influenced by the intrinsic characteristics of the meat itself, including the unsaturated fatty acid content, the level of prooxidants present and the level of antioxidants present. Intrinsic factors may be influenced by production factors such as diet. In the case of pigs, supplementation of the diet with vitamin E tocopherol acetate has been shown to increase both the level of α-tocopherol and oxidative stability in muscle (Asghar et al., 1991; Cannon et al., 1995) Extrinsic factors such as the addition of antioxidants during processing, altering cooking procedure and packaging system can also be manipulated to increase the oxidative stability of cooked meats (Chastain et al., 1982; Ang and Huang, 1993; Mielche, 1995).

The objective of the present study was to investigate the effectiveness of a multi-faceted approach to inhibiting lipid oxidation as a means increasing the oxidative stability of cooked pork. The individual and combined effects of (i) muscle vitamin E level, (ii) cooking procedure and (iii) packaging method were investigated for their effects on the oxidative stability of cooked pork during refrigerated storage.

MATERIALS AND METHODS

Experimental design. Three factors were investigated for their effect on lipid oxidation in cooked pork: (i) muscle vitamin E level; (ii) cooking procedure and (iii) method of packaging following cooking. Cooking procedure was further sub-divided into cooking end-point temperature, duration of cooking at end-point temperature and rate of cooking to end-point temperature. Thus, three 3-factor experiments were undertaken in the study (Table 1).

Muscle vitamin E level. *M. biceps femoris* samples were obtained at 24 h *post mortem* from Landrace X Large White pigs fed either a control diet (10 mg α- acetate/kg diet) or a vitamin E-supplemented diet (500 mg α-tocopherol acetate/kg diet) for 7 weeks prior to slaughter. The muscle samples were vacuum packaged and stored at -20°C prior to analysis. The α-tocopherol content of the muscle samples was determined by HPLC.

Cooking procedures. Minced *M. biceps femoris* samples (100 g) were placed in retortable bags and cooked according to one of three procedures: (a) samples were cooked by immersion in water baths at 73 ± 1°C or 83 ± 1°C to internal temperatures of 72°C or 82°C, respectively, and removed immediately on reaching the internal temperature (end-point temperature effect); (b) samples were cooked to an internal temperature of 72°C by immersion in a water bath at 73 ± 1°C and removed immediately on reaching 72°C or held at 72°C for 30 min (cooking duration effect); (c) samples were cooked to an internal temperature of 72°C by immersion in water at 25°C and heating slowly (0.3°C/min) or quickly (2.0°C/min) to 72°C and removed from the water bath on reaching 72°C (cooking rate effect). All cooked samples were cooled on ice to 4°C and packaged.

Packaging method. Cooked pork samples (33 g) were packaged for aerobic storage by placing in open bags or for vacuum storage by placing in vacuum pack bags drawing a vacuum and sealing using a Webomatic vacuum packaging system. All samples were held at 4°C and analysed for lipid oxidation immediately (day 0) and after packaging and storage at 4°C for 1 and 2 days.

Measurement of lipid oxidation. Lipid oxidation in the meat samples was assessed by the 2-thiobarbituric acid method of Tarladgis et al. (1964). The thiobarbituric acid reactive substances (TBARS) numbers were expressed as mg malondialdehyde (MDA)/kg meat. Statistical computations were run on the SAS® programme (SAS Institute, 1985).

RESULTS AND DISCUSSION

Vitamin E levels. The mean α-tocopherol level of muscle from pigs fed the vitamin E-supplemented diet was ~4-fold higher than that of pigs fed the control diet. For cooking and packaging, the muscle samples were classified as either low (0.97 μg α-tocopherol/g) or high (4.24 μg α -tocopherol/g) vitamin E samples.

Lipid oxidation in cooked pork. Analysis of variance of the data for each of the three experiments revealed significant effects due to each of the individual factors examined (Table 1). Thus, oxidative stability of cooked pork was significantly higher ($P<0.01$) in the high vitamin E pork, following cooking to the lower temperature, for the shorter cooking time, at the fastest cooking rate and following storage in the vacuum packs.

Significant two-way interactions were observed (Table 1). Lipid oxidation increased with increasing cooking temperature, but the low vitamin E pork was influenced more by the increased cooking temperature than the high vitamin E pork (0.413 mg/MDA/kg increase in day 2 TBARS vs 0.233 mg/MDA/kg increase in day 2 TBARS). At the higher cooking temperature and after storage for 2 days at 4°C vacuum packaging was shown to be more effective than aerobic packaging in inhibiting lipid oxidation (0.55 ± 0.08 vs 0.96 ± 0.8 mg MDA/kg), whereas at the lower cooking temperature there was no

significant difference between the packaging types (0.41 ± 0.08 vs 0.44 ± 0.07 mg MDA/kg). At the slower cooking rate vacuum packaged pork had lower TBARS compared to pork stored in air (0.56 ± 0.23 vs 2.02 ± 0.13 mg MDA/kg) but at the higher cooking rate there was no significant difference in lipid oxidation due to packaging methods (0.72 ± 0.22 vs 1.17 ± 0.21 mg MDA/kg).

Significant three-way interactions were observed between muscle vitamin E level, cooking end-point temperature and packaging and between muscle vitamin E level, duration of cooking and packaging method (Table 1). Thus, after 2 days at 4°C, the combination of high vitamin E level, low cooking temperature, and vacuum packaging gave the lowest level of lipid oxidation (0.26 ± 0.08 mg MDA/kg). However, lipid oxidation in high vitamin E meat cooked to 72°C and vacuum packed was not significantly different from high vitamin E meat cooked to 82°C and vacuum packed (0.34 ± 0.08 mg MDA/kg) or cooked to 72°C and aerobically packed (0.31 ± 0.08 mg MDA/kg). The results suggest that if high vitamin E meat is used in combination with a low cooking temperature (72°C), these two parameters are sufficient to protect pork from lipid oxidation despite exposure to oxygen during aerobic storage. Similarly, if high vitamin E meat is used in combination with vacuum packaging these two parameters protect the pork from the accelerating effect of increased cooking temperature (72°C to 82°C) on lipid oxidation.

CONCLUSION

The results demonstrate that a multi-faceted approach to inhibiting lipid oxidation in cooked meats is more likely to be effective than a single strategy approach. Further research should focus on identifying more closely the critical points at which lipid oxidation is accelerated in cooked meats and adopting approaches to minimising oxidation at these points while adhering to food safety regulations.

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Table 1. Significance of F values for individual factors and two- and three-way interactions following ANOVA of lipid oxidation data obtained for cooked, chilled pork from pigs fed two levels of dietary vitamin E, cooked according to two cooking regimes and stored in aerobic or vacuum packs for up two days.

Experiment	Factors examined	F value significance Day 0	Day 1	Day 2
Muscle vitamin E level	Vitamin E level	0.0001	0.0001	0.0001
x cooking end-point temperature	Cooking temperature	0.0001	0.0014	0.0001
x packaging method	Packaging method	NA	0.0459	0.0019
	Vitamin E level * cooking temperature	0.1616	0.8417	0.0072
	Vitamin E level * packaging method	NA	0.3936	0.1163
	Cooking temperature * packaging method	NA	0.3016	0.0030
	Vitamin E level * cooking temperature * packaging method	NA	0.6868	0.0354
Muscle vitamin E	Vitamin E level	0.0753	0.0001	0.0001
x cooking duration	Cooking duration	0.0104	0.0001	0.0001
x packaging method	Packaging method	NA	0.0001	0.0001
	Vitamin E level * cooking duration	0.3581	0.7725	0.5511
	Vitamin E level * packaging method	NA	0.2859	0.1584
	Cooking duration * packaging method	NA	0.3585	0.0712
	Vitamin E level * cooking duration * packaging method	NA	0.0474	0.0570
Muscle vitamin E level	Vitamin E level	0.0002	0.0001	0.0001
x rate of cooking	Cooking rate	0.6304	0.0240	0.0192
x packaging method	Packaging method	NA	0.0001	0.0001
	Vitamin E level * cooking rate	0.3581	0.7725	0.5511
	Vitamin E level * packaging method	NA	0.8146	0.7845
	Cooking rate * packaging method	NA	0.0014	0.0009
	Vitamin E level * cooking rate * packaging method	NA	0.8796	0.4464

NA = not applicable (the meat was analysed before packaging)