Available online at www.sciencedirect.com
SCIENCE DIRECT®
Meat Science 72 (2006) 303–311
MEAT SCIENCE
www.elsevier.com/locate/meatsci

Flavour perception of oxidation in beef

M.M. Campo *, G.R. Nute, S.I. Hughes, M. Enser, J.D. Wood, R.I. Richardson

Division of Farm Animal Science, University of Bristol, Langford, Bristol BS40 5DU, UK

Received 28 February 2005; received in revised form 10 July 2005; accepted 21 July 2005

Abstract

Lipid oxidation is a major factor in meat quality. In order to relate human perceptions of lipid oxidation, as determined by a trained taste panel, to a chemical measurement of oxidation, we studied meat from animals with a wide range of potential oxidation through differences in their PUFA composition and by displaying the meat in high oxygen modified atmosphere packs for varying lengths of time. Meat was obtained from 73 Angus- and Charolais-cross steers from different trials that had been raised on 10 different diets: grass silage (high in C18:3, *n*-3), cereal concentrate (high in C18:2, *n*-6), three diets with 3% added fat consisting of three levels of protected lipid supplement (high in C18:2, *n*-6 and C18:3, *n*-3, ratio 1:1), a control with Megalac® (relatively saturated), three diets with three levels of inclusion of protected fish oil (high in C20:5 *n*-3 and C22:6 *n*-3) plus a constant amount of unprotected fish oil and a final diet with an unprotected fish oil control. The longissimus dorsi muscle was excised from the left carcass side, aged vacuum packaged for 10–13 days depending on the projects and frozen for less than eight months. TBARS and sensory analyses were performed on steaks displayed for 0, 4 or 9 days under simulated retail conditions, exposed to light in modified atmosphere packaging (CO_2:O_2; 25:75). Meat oxidation increased throughout display for each of the diets, as shown by a rise in TBARS values. This increase was not linear, differences between 0 and 4 days of display were smaller than between 4 and 9 days of display. The lowest TBARS and lowest increment occurred in the two control diets and the grass-fed animals, probably due to the more saturated fat of meat from animals fed the control diets and the higher content of vitamin E. Sensory attributes were also influenced by time of display. Positive attributes, such as beef flavour or overall liking, decreased throughout display, whereas negative attributes, such as abnormal and rancid flavours, increased.

The correlations between sensory and analytical attributes were high. TBARS were a good predictor of the perception of rancidity (Spearman's rho = 0.84). Panellist preferences were related to the presence of beef flavour (rho = 0.93) and to the absence of abnormal (rho = −0.88) and rancid flavours (rho = −0.83). Under the experimental conditions used, a TBARS value of around 2 could be considered the limiting threshold for the acceptability of oxidised beef.

Keywords: Beef; Oxidation; Flavour; MAP

1. Introduction

Lipid oxidation is a major cause of deterioration in meat quality (Gray & Pearson, 1987; Gray, Gomaa, & Buckley, 1996). It limits the storage or shelf life of meat exposed to oxygen under conditions where microbial spoilage is prevented or reduced such as refrigeration or freezing. The products of fatty acid oxidation produce off-flavours and odours usually described as rancid (Gray & Pearson, 1994). Lipid oxidation in muscle systems is initiated at the membrane level in the phospholipid fractions as a free-radical autocatalytic chain mechanism (Labuza, 1971) in which prooxidants interact with unsaturated fatty acids resulting in the generation of free radicals and propagation of the oxidative chain (Ashgar, Gray, Buckley, Pearson, & Booren, 1988).

The relationship of rancidity to flavour is unclear. As rancid flavours develop there is a loss of desirable flavour notes. However, most studies of rancidity rely on chemical assay methods that determine the fatty acid breakdown

* Corresponding author. Present address: Department of Animal Production and Food Technology, University of Zaragoza, C/Miguel Servet 177, 50013-Zaragoza, Spain. Tel.: +34 976 761600; fax: +34 976 761590.

E-mail address: marimar@unizar.es (M.M. Campo).

0309-1740/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.meatsci.2005.07.015

products, mainly because they are objective, cheap and rapid compared with organoleptic assessment. The disadvantage of such methods is that they measure one amongst many contributors to the rancid flavour, such as hexanal, or secondary breakdown products that do not contribute to flavour, such as the widely used determination of malondialdehyde by the thiobarbituric acid reaction (TBARS) (Tarladgis, Watts, Younathan, & Dugan, 1960). Several attempts have been made to determine the threshold in sensory perception of oxidation in relation to that assessed chemically. Tarladgis et al. (1960) suggested that oxidation was perceived at TBARS in the range of 0.5–1.0 in pork. Greene and Cumuze (1981) found that oxidized flavour in beef was detected over a broad range of TBARS from 0.6 tp 2.0 indicating a big variation in the threshold of the panellists. The latter were inexperienced, resembling ordinary consumers, and the correlations between TBARS and consumers taste were low. Furthermore, as the authors acknowledged, threshold does not indicate acceptability.

In order to investigate further the relationship between flavour and rancidity, assessed chemically and by a taste panel, we have studied beef from a wide range of production systems in order to obtain differences in susceptibility to oxidation. Since the susceptibility to oxidation of a fatty acid is related to the number of double bonds it contains, this was achieved through differences in the muscle content of long chain polyunsaturated fatty acids (PUFA).

In order to limit possible effects of microbial growth on flavour the meat was packed in a modified atmosphere (MAP) of oxygen and carbon dioxide (Gill, 1996). This had two practical aspects: the high oxygen stimulated lipid oxidation (Renerre, 1990) although maintaining the myoglobin in its oxygenated form decreased its activity as a prooxidant (Anton, Gatellier, & Renerre, 1993). Furthermore, MAP is widely used commercially as a way of increasing the shelf life of meat whilst maintaining a desirable bright red colour.

The aim of this work was to assess the limit of rancidity in beef by relating sensory perception by a taste panel to simple chemical measurements, using meat conditioned in MAP from animals fed diets with different fatty acid composition.

2. Material and methods

2.1. Animals

Meat was obtained from 73 Angus- and Charolais-cross steers from different trials that had been raised on 10 different diets: grass silage (high in C18:3, *n*-3), cereal concentrate (high in C18:2, *n*-6), three diets with 3% added fat consisting of three levels of protected lipid supplement (high in C18:2, *n*-6 and C18:3, *n*-3, ratio 1:1) (PLS), a control with Megalac® (relatively saturated) (contPLS), three diets with three levels of inclusion of protected fish oil (high in C20:5, *n*-3 and C22:6, *n*-3) plus a constant amount of unprotected fish oil (PFO) and an unprotected fish oil control (contPFO). The PLS diet was composed of soya beans, linseed and sunflower oils, and the PFO supplement comprised soya beans and tuna oil, together with 350 IU vitamin E/kg concentrate in both supplements. Lipids of PLS and PFO diets were prepared as in Scott, Cook, and Mills (1971), protected from ruminal biohydrogenation by encapsulating them in a matrix of rumen inert protein. Grass and concentrate-fed animals were slaughtered at 19 months (Richardson, Nute, Wood, Scollan, & Warren, 2004), PLS animals at 20 months (Scollan, Enser, Gulati, Richardson, & Wood, 2003) and PFO animals at 24 months (Scollan et al., 2004).

As a result of the fatty acid composition of the different diets we obtained meat with very different fatty acid composition, especially long chain polyunsaturated fatty acids (Table 1).

2.2. Sampling

Forty-eight hours after slaughter, the left side loin of each animal was separated from the carcass, vacuum

Table 1
Fatty acid (FA) composition (% by weight of total fatty acids) of intramuscular fat in the neutral (NL) and phospholipids (PL) fractions in steers fed 10 different diets

	Cont PLS	PLS1	PLS2	PLS3	Cont PFO	PFO1	PFO2	PFO3	Grass	Conc
Saturated FA NL	50.9	48.1	48.3	46.0	49.4	49.4	49.6	48.4	44.8	45.6
Saturated FA PL	36.1	36.1	35.9	35.7	37.3	36.7	36.7	36.7	33.9	32.7
Monounsaturated FANL	43.7	43.3	42.0	43.1	44.8	44.2	43.9	45.3	43.9	44.7
Monounsaturated FA PL	26.9	15.3	12.7	12.4	27.4	25.6	23.8	23.0	22.0	20.0
Polyunsaturated FA NL	2.0	4.9	6.1	7.1	1.7	1.9	2.0	2.0	2.6	3.0
Polyunsaturated FA PL	31.3	43.4	46.4	47.1	28.6	30.1	32.0	32.9	35.6	40.5
n-3 NL	0.5	1.7	2.2	2.7	0.4	0.4	0.5	0.5	0.8	0.2
n-3 PL	9.5	12.2	12.3	12.4	10.9	12.2	12.6	13.5	15.8	2.4
n-6 NL	1.1	2.6	3.3	3.7	0.8	0.9	1.0	1.0	1.2	2.3
n-6 PL	21.5	30.9	33.8	34.5	17.5	17.6	19.2	19.2	19.6	37.9

Cont PLS: control protected lipid supplement; PLS: Protected lipid supplement.
Cont PFO: control protected fish oil; PFO: Protected fish oil.
Conc: concentrate.
1, 2, 3 = three different levels of inclusion of either PLS or PFO in the diet.