Meat Science 97 (2014) 223–230

Contents lists available at ScienceDirect

Meat Science

journal homepage: www.elsevier.com/locate/meatsci

Effect of different cooking methods on lipid oxidation and formation of volatile compounds in foal meat

Rubén Domínguez, María Gómez, Sonia Fonseca, José M. Lorenzo *

Centro Tecnológico de la Carne de Galicia, Rúa Galicia No 4, Parque Tecnológico de Galicia, San Cibrán das Viñas, 32900 Ourense, Spain

ARTICLE INFO

Article history:
Received 24 July 2013
Received in revised form 27 January 2014
Accepted 30 January 2014
Available online 9 February 2014

Keywords:
Foal meat
Thermal treatment
Cooking loss
Lipid oxidation
Volatile compounds

ABSTRACT

The influence of four different cooking methods (roasting, grilling, microwaving and frying) on cooking loss, lipid oxidation and volatile profile of foal meat was studied. Cooking loss were significantly ($P < 0.001$) affected by thermal treatment, being higher (32.5%) after microwaving and lower after grilling (22.5%) and frying (23.8%). As expected, all the cooking methods increased TBARs content, since high temperature during cooking causes increased oxidation in foal steaks, this increase was significantly ($P < 0.001$) higher when foal steaks were microwaved or roasted.

The four different cooking methods led to increased total volatile compounds (between 366.7 and 633.1 AU × 10^6/g dry matter) compared to raw steaks (216.4 AU × 10^6/g dry matter). The roasted steaks showed the highest volatile content, indicating that increased cooking temperature increases the formation of volatile compounds. Aldehydes were the most abundant compounds in cooked samples, with amounts of 217.2, 364.5, 283.5 and 409.1 AU × 10^6/g dry matter in grilled, microwaved, fried and roasted samples, respectively, whereas esters were the most abundant compounds in raw samples, with mean amounts of 98.8 AU × 10^6/g dry matter.

1. Introduction

Meat aroma develops from the interactions of non-volatile precursors, including free amino acids, peptides, reducing sugars, vitamins, nucleotides and unsaturated fatty acids, during cooking. These interactions include the Maillard reaction between amino and carbonyl compounds, the oxidation of lipids, the thermal degradation of thiamine, and interactions between these pathways (Mottram, 1998). Cooking of meat is essential to achieve a palatable and safe product (Tornberg, 2005). In fact, heat treatments applied to meat, improve its hygienic quality by inactivation of pathogenic microorganisms and enhance its flavour and tenderness (Broncano, Petrón, Parra, & Timón, 2009; Rodríguez-Estrada, Penazzi, Caboni, Bertacco, & Lercker, 1997). However, cooking methods as well as cooking conditions, like heating rate, cooking time and temperature or end-point temperature, modify the chemical composition of meat with a consequent change of nutritional value due to nutrient losses (Brugiapaglia & Destefanis, 2012; Clausen & Ovesen, 2005; Kosulwat, Greenfiel, & Buckle, 2003). Another important adverse effect resulting from thermal treatment is lipid oxidation, a major reason for the deterioration of meat, giving undesirable odours, rancidity, texture modification, loss of essential fatty acids or toxic compound production (Alfaia et al., 2010; Broncano et al., 2009). Moreover, lipid oxidation products are implicated in several human pathologies (atherosclerosis, cancer, inflammation or ageing processes) (Broncano et al., 2009).

There are many factors that influence lipid oxidation, including the composition and content of triglycerides (Carrapiso, 2007), and micro-components, such as antioxidants and metal ions (Ma, Ledward, Zamri, Frazier, & Zhou, 2009). However, for the controlled oxidation of any given lipid, the most important parameters are the thermal treatment conditions (temperature and time of cooking) (Byrnea, Brediea, Mottram, & Martens, 2002). Lower temperature of cooking could reduce energy consumption but a final internal temperature of 65–85 °C must to be reached to ensure safety (Tornberg, 2005). When different cooking methods were compared, roasting, which uses high temperatures for a long time, produces an increased lipid oxidation compared to other methods (Hernández, Navarro, & Toldrá, 1999; Rodríguez-Estrada et al., 1997). However, microwave treatment, despite using shorter time and lower temperature also promotes lipid oxidation (Rodríguez-Estrada et al., 1997). Frying is one of the oldest methods of food preparation and improves the sensory quality of food by formation of aroma compounds, attractive colour, crust and texture (Bognar, 1998), but oils or fats can change the fatty acid composition of meat and suffer oxidation (Broncano et al., 2009).

In 2011, worldwide horse meat production was over 700 thousand tonnes. The major producers were Asia, with 42% of worldwide production, followed by America (32%) and Europe (19%). The greatest importers (by tonnes) of horse meat were Italy, Russia, Belgium and France, and the most important exporters (by tonnes) were Argentina, Belgium, Canada, Mexico and Poland (FAOSTAT, 2011).

* Corresponding author. Tel.: +34 988 548 277; fax: +34 988 548 276.
E-mail address: jmlorenzo@ceteca.net (J.M. Lorenzo).

0309-1740/$ – see front matter © 2014 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.meatsci.2014.01.023

Horse meat is characterized by low fat, low cholesterol content, and high levels of Fe–heme (Lorenzo & Pateiro, 2013; Lorenzo, Pateiro, & Franco, 2013). From the point of view of fatty acid composition, horse meat is characterized by high levels of unsaturated fatty acids (above 55%); PUFA, predominantly the essential $n-6$ (linoleic acid, 18:2 $n-6$) and $n-3$ (ALA 18:3$n-3$) PUFA and MUFA, primarily oleic acid (18:1$n-9$c) (Lorenzo, 2013). Animal fat plays an important role in the formation of the characteristic flavour of cooked meat. It is well-known that lipid autooxidation can produce off-flavours, rancidity, known as "warmed-over flavour". However, moderate lipid oxidation during the initial cooking of meat contributes to desirable aromas (Song et al., 2011). Unsaturated fatty acids and especially polyunsaturated ones (PUFA) are highly susceptible to oxidation (Alfaia et al., 2010), thus oxidation reactions could be very important during thermal treatment and affect the properties of this type of meat.

To our knowledge, there are no studies describing the effect of cooking on foal meat quality. This study was, therefore, conducted to assess the influence of four different cooking methods (roasting, grilling, microwaving and frying) on cooking loss, lipid oxidation (by TBARs measurement) and volatile profile (using solid phase microextraction coupled to GC–MS) of foal meat.

2. Material and methods

2.1. Animals management

Twelve foals were obtained from "Monte Cabalar" (agricultural cooperative of "Galician Mountain" breed) (A Estrada, Pontevedra, Spain). The majority of the foals were born in April and May of 2010. Animals were reared with their mothers on pasture and were kept suckling and grazing until 6–7 months old. After weaning, foals were fed mainly ryegrass (*Lolium perenne*), gorse (*Ulex europaeus* L.) and bracken (*Pteridium aquilinum* L.), receiving complementary grass silage ad libitum when the grass available was limited, especially in the summer and winter times, but they were never given concentrates. All foals were reared with their mothers in an extensive production system based on wood pasture. The animals were slaughtered at fifteen months old. They were transported to the abattoir the day before slaughter, without mixing foals from different groups, to minimize stress to the animals. The animals were stunned with a captive bolt and slaughtered and dressed according to current European Union regulations (Council Directive of the European Union 95/221EC) in an accredited abattoir. Immediately after slaughter, carcasses were chilled at 4 °C in a cold chamber for 24 h. At this point, *longissimus dorsi* (LD) muscle was extracted from the right side of each carcass, between the fourth and the ninth rib.

2.2. Sample preparation

The LD muscles (n = 12) were sliced into 20 mm thick steaks and divided into five groups according to the cooking methods. A total of 60 samples were obtained (12 muscles × 5 cooking methods). One group was used as control (raw meat), and the other groups were cooked using the following methods: grilled at 130–150 °C during 5 min on each surface, using an electrical griddle (Delonghi, Mod. CG660, Treviso, Italy); microwaved at 1000 W for 1.5 min on each surface, using a microwave oven (Panasonic, Mod. NE-1037, Osaka, Japan); fried using 15 mL refined olive oil, at 170–180 °C during 4 min on each surface; roasted at 200 °C for 12 min using an electrical oven (Rational, Mod. SCC101, Barcelona, Spain). A heating treatment was considered complete when all the samples had reached an internal temperature of 70 °C. After cooking, cooling and calculated cooking loss, the steaks were minced, vacuum-packed and stored at −30 °C for no longer than four weeks until analysis.

2.3. Cooking loss and TBARs measurement

After cooking, the samples were cooled at room temperature for 30 min and the percentage of cooking loss recorded. Cooking loss was calculated as the percent weight difference between fresh and cooked samples relative to the weight of fresh samples:

$$\text{Cooking loss} = \frac{\text{Raw meat weight} - \text{cooked meat weight}}{\text{Raw meat weight}} \times 100.$$

The 2-thiobarbituric acid (TBARs) assay was carried out according to the extraction method described by Vyncke (1975) with a few modifications: the meat sample (2.0 g) was homogenized (Ultra Turrax T-25, Janke & Kunkel IKA-Labortechnik, Staufen, Germany) with 10 mL of a 5% trichloroacetic acid (TCA) for 2 min at 3900 g (Allegra X-22R, Beckman, Fullerton, CA, USA), and the homogenate was centrifuged for 10 min at 2360 *g* (Allegra X-22R, Beckman, Fullerton, CA, USA) and then filtered through 0.45 μm (Filter Lab, Spain). The extract (5.00 mL) was mixed with 0.2 M thiobarbituric acid (5.00 mL) and heated in a 97 °C water bath (JP Selecta, Precisdg, Barcelona, Spain) for 40 min followed by cooling in ice-water for 5 min. The absorbance was measured (Agilent 8453, Waldbronn, Germany) at 532 nm against a blank consisting of 5 mL of the same homogenizing solution plus 5 mL of TBA solution. Thiobarbituric acid reactive substance (TBARs) values were calculated from a standard curve of malonaldehyde (MDA) and expressed as mg MDA/kg sample.

2.4. Volatile compound profile

The extraction of the volatile compounds was performed using solid-phase microextraction (SPME). An SPME device (Supelco, Bellefonte, PA, USA) containing a fused-silica fibre (10 mm length) coated with a 50/30 mm thickness of DVB/CAR/PDMS (divinylbenzene/carboxen/polydimethylsiloxane) was used and analysis was performed as following: For headspace SPME (HS-SPME) extraction, 3 g of each sample was weighed in a 40 mL vial, after being ground using a commercial grinder. The vials were subsequently screw-capped with a laminated Teflon-rubber disc. The fibre, previously conditioned by heating in a gas chromatograph injection port at 270 °C for 60 min, was inserted into the sample vial through the septum and exposed to headspace. The extractions were carried out in an oven at 35 °C for 30 min, after equilibration of the samples for 15 min at the temperature used for extraction, ensuring a homogeneous temperature for sample and headspace. Once sampling was finished, the fibre was withdrawn into the needle and transferred to the injection port of the gas chromatograph–mass spectrometer (GC–MS) system.

A gas chromatograph 6890N (Agilent Technologies, Santa Clara, CA, USA) equipped with a mass selective detector 5973N (Agilent Technologies) was used with a DB-624 capillary column (30 m, 0.25 mm i.d., 1.4 μm film thickness; J&W Scientific, Folsom, CA, USA). The SPME fibre was desorbed and maintained in the injection port at 260 °C during 8 min. The sample was injected in splitless mode. Helium was used as a carrier gas with a linear velocity of 40 cm/s. The temperature programme was isothermal for 10 min at 40 °C, raised to 200 °C at 5 °C/min, and then raised to 250 °C at 20 °C/min, and held for 5 min: total run time 49.5 min. Injector and detector temperatures were both set at 260 °C. The mass spectra were obtained using a mass selective detector working in electronic impact at 70 eV, with a multiplier voltage of 1953 V and collecting data at 6.34 scans/s over the range m/z 40–300. Compounds were identified by comparing their mass spectra with those contained in the NIST05 (National Institute of Standards and Technology, Gaithersburg) library, and/or by comparing their mass spectra and retention time with authentic standards (Supelco, Bellefonte, PA, USA), and/or by calculation of retention index relative to a series