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Meat physicochemical properties, fatty acid profile, lipid oxidation and sensory characteristics from three North African lamb breeds, as influenced by concentrate or pasture finishing diets

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ABSTRACT

This study investigated the meat quality of lambs from three North African breeds (Barbarine, BB; Queue Fine de l'Ouest, QFO; and Noire de Thibar, NT) reared on concentrate (S) or on pasture (P). A total of 18 P and 18 S lambs (20 kg initial body weight) were used, with 6 P and 6 S lambs for each breed. After 67 days, all lambs were slaughtered at 26 kg final body weight and meat quality was studied. The pH of S lambs 1 h post-mortem was lower than that of P lambs ($p = 0.001$). Water cooking loss, colour and sensory quality were not affected by both factors. The pasture and the concentrate meats had the same proportions of lipids and proteins; however QFO and BB breeds had more intramuscular fat than NT breed. The saturated fatty acid proportion was higher for S than P groups (50.63 *vs.* 44.48%, respectively) and for QFO compared to other breeds. C18:1 was higher for S groups, while C18:2, C18:3 and CLA were higher for P groups. The S group had higher lipid oxidation, while the QFO breed had the highest TBARS. P lambs may have healthier meat than S lambs and the NT breed had the leanest meat with higher concentration of desirable FAs.

1. Introduction

Food is no longer seen as a way to only alleviate hunger, but rather provide good health and welfare for humans; consumers are becoming more health-conscious and tend to search nutritious foods with health-promoting functions (Milner, 1999). Recently, special attention is increasingly given to the fatty acid (FA) profile and its partition into saturated fatty acids (SFA) and polyunsaturated fatty acids (PUFA), especially *n*–3 PUFA at the expense of *n*–6 PUFA. Also some biologically-active substances like conjugated linoleic acid (CLA), a product of biohydrogenation of linoleic acid, have particular interest (Pariza et al., 2001). It is believed that meat of sheep and beef produced on pasture has a superior nutritional quality and better taste (Atti and Abdouli, 2001; Ådnøy et al., 2005; Serrano et al., 2007). The nutritional value of *n*–3 PUFAs is well recognized, and increased consumption of these FAs has been recommended.

Ruminant fats are among the richest natural sources of CLA, in particular the *cis*-9, *trans*-11 isomer, which arises from microbial hydrogenation of dietary linoleic acid in the rumen (Ha et al., 1990). Previous research has shown that including grass in the diet increased CLA concentration in milk and intramuscular fat of ruminants (Atti et al., 2006; French et al., 2000). Although an increase in the *n*–3 PUFAs concentration is desirable from a human health perspective, oxidative stability of meat is reduced. Lipid and muscle pigment oxidation are the major problems causing quality deterioration in meat. Meat oxidation can be reduced by the presence of anti-oxidants which are naturally present at elevated levels in green forage (López-Bote et al., 2001; Wood et al., 2004). Products of auto-oxidation processes can adversely affect texture, colour, flavour, nutritive value and safety of meat products (Buckley et al., 1995). Some studies have reported negative effects of forage-feeding on meat colour, toughness and sensory attributes compared with that from concentrate-fed animals (Larick and Turner, 1989, 1998; Priolo et al., 2002), while other studies

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reported no differences (French et al., 2001). Greater fat content is generally found in muscle from animals raised on concentrate compared with animals allowed to graze herbage at pasture (Aurousseau et al., 2004; Atti et al., 2013; Hajji et al., 2014).

Although the dietary effect on different meat quality aspects has been widely studied, information on the differences between sheep breeds in most meat characteristics, particularly lipid oxidation is, to our knowledge, scarce or absent. Furthermore, information about African sheep meat quality and FA profile is very scarce (Van Heerden et al., 2007). The purpose of this work was to characterize meat quality, FA profile and lipid oxidation of lambs from three different North African breeds, reared on concentrate and pasture.

2. Material and methods

The experiment was carried out at the experimental farm Lafereg of the Crop Center of Beja, in the sub-humid region of Tunisia; the annual rainfall was 650 mm, mean temperature and humidity were about 17.5 °C and 65%, respectively, during the trial. The animals were handled by specialized personnel who ensured their welfare. Furthermore, all procedures employed in this study (transport and slaughtering) meet ethical guidelines and adhere to Tunisian legal requirements (The Livestock Law No. 2005-95 of 18 October 2005, Chapter II; Section 1 and Section 2 relative to the slaughter of animals).

2.1. Animals, diets, slaughtering and meat sampling

The experiment started in April 2012 with a total of 36 male lambs from 3 breeds, fat-tail Barbarine (BB, $n = 12$), Queue Fine de l'Ouest (QFO, $n = 12$) and Noire de Thibar (NT, $n = 12$). Lambs were 4 months old and weighed 20.3 ± 1.9 kg at the beginning of the experiment. Lambs from each breed were randomly allocated on the basis of body weight (BW) to one of two groups, pasture-feeding (P, $n = 18$) or stall-feeding (S, $n = 18$). The three S lamb groups were raised in individual boxes in a sheep fold close to the land grazed by the P group and fed *ad libitum* concentrate (72% barley, 25% faba bean and 3% mineral-vitamin supplement (10.0% Ca, 3.5% P, 8.0% Na, 4.4% Mg, 0.4% S, 0.4% Zn, 0.2 Mn, 0.2%Fe)) plus 500 g/d/lamb of oat hay. The three P lamb groups were reared together on natural pasture and grazed for 6 h daily (from 10 h to 16 h) on a plot of 2500 m^2. The biomass was estimated according to Tothill et al. (1992). The grazed flora was composed of 45% grass, 14% legumes and 41% other species (mainly thistle 30%). The most consumed varieties were grass and legumes. Indoors they received only oat hay, in similar quantity to the S lambs. The chemical composition of different ingredients of the diets is presented in Table 1. At the end of the experiment (67 days), all lambs were transported to a slaughterhouse located 120 km from the experimental site and were slaughtered after 12 h of fasting with access to water. They were weighed before slaughter to determine the slaughter weight (averagely 26 kg). The carcasses were stored at 4 °C for 24 h after which each carcass was split along the midline and *longissimus dorsi* (LD) muscle was removed from the left side and conserved at −20 °C for 3 months for subsequent analysis. Raw meat samples were trimmed of external fat and divided into 5 slices. Two slices were immediately used for pH, colour parameters and cooking loss determination. One sample was dried by lyophilisation (DM), ground (1 mm screen) and stored for subsequent chemical analysis (ash, CP and fat). The last two samples were frozen at −20 °C for sensorial evaluation and individual fatty acids (FA) determination.

Table 1
Chemical compositions of diets (concentrate, oat hay and pasture).

	Pasture	Oat hay	Concentrate
Dry matter (g/kg)	89.60	89.67	90.93
Ash (g/kg DM)	17.63	11.51	4.90
Crude protein (g/kg DM)	13.63	6.94	15.02
NDF (g/kg DM)	44.56	69.77	41.34
ADF (g/kg DM)	27.60	43.16	12.93
ADL (g/kg DM)	6.04	7.21	1.31

2.2. Laboratory analysis

2.2.1. Physical and chemical analyses

The pH was measured 1 h (pH1) and 24 h *post mortem* (pH 2), in the *longissimus lumborum* muscle before carcass slice, with a penetrating electrode connected to a portable pH-meter (Hanna instruments HI 99163) after calibration with two buffers (7.01 and 4.01). For cooking loss determination, meat samples of LD muscle were weighed (initial weight, W_i), held in plastic bags then immersed in a water-bath at 75 °C and heated for 30 min until the internal temperature reached 75 °C which was monitored with a thermocouple. Then the bags were cooled under running tap water for 30 min and blotted dry with paper towels. The cooked meat was weighed again (final weight, W_f) and cooking loss (g/kg) was calculated as $1000 \times (W_i - W_f)/W_i$.

For meat colour parameters, a Minolta CM-2006d spectrophotometer (Konica Minolta Holdings, Inc., Osaka, Japan) was used to measure colour directly on the muscle surface; the measured area diameter was 8 mm. Lightness (L^*), redness (a^*) and yellowness (b^*) parameters were recorded (CIE, 1986). Hue angle (H^*) and chroma (C^*) indices were calculated as $H^* = \tan^{-1}(b^*/a^*) \times 57.29$, expressed in degrees and $C^* = (a^{*2} + b^{*2})^{1/2}$. H^* is the attribute of a colour perception denoted by blue, green, yellow, red, purple, etc.; C^* is related to the quantity of pigments; high values represent a more vivid colour and denote lack of greyness.

The ash content was determined as the residue after combustion at 600 °C for 8 h. Total nitrogen was determined by Kjeldahl method using Büchi Digestion Automat K-438 and Büchi Distillation Unit B-324 (Büchi Laboratory Equipment, Flawil, Switzerland). The CP was calculated as N × 6.25. Intramuscular fat (IMF) was extracted using an automated Soxhlet apparatus with hexane as solvent (AOAC, 1999).

2.2.2. Lipid extraction and methylation and fatty acid analyses

Intramuscular fat extraction was carried out according to Bligh and Dyer (1959) method with the following modifications: 2.5 g of lyophilized minced samples of muscle were mixed with 5 mL of chloroform and 10 mL of methanol and vortexed for 2 min. Five millilitres of chloroform and 10 mL of KCl 0.88% were added, vortexed for 15 min and centrifuged at 4000 rpm for 10 min at 4 °C. The lower phase (FA and chloroform) was extracted and deposited in a glass tube with 10 μL BHT. A rotary evaporator was used to dry the fat extracts under vacuum and the extracts were dried in a vacuum oven at 50 °C. The extracted fat was stored at −80 °C in a glass vial with push-in top until further analyses

Meat FA composition was determined by capillary gas chromatography of the fatty acid methyl esters (FAMEs). These FAMEs were prepared by base-catalysed methanolysis of the glycerides with KOH according to the UNE-EN ISO 5509:2000 methods. FAMEs were separated and determined using gas chromatography with flame ionization detector (GC-FID Bruker 436 gas chromatograph) equipped with a capillary column of biscyanopropyl polysiloxane (100 m × 0.25 mm; 0.20 μm film thickness; Bruker Nederland B.V., Leiderdorp, the Netherlands) The carrier gas was helium and the flow rate was 1 mL/min. The temperature of the inlet and detector was maintained at 250 and 275 °C respectively. The injection volume was 1.0 μL and the split