Meat Science 119 (2016) 185–192

Contents lists available at ScienceDirect

Meat Science

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

Sensory quality and chemical composition of meat from lambs fed diets enriched with fish and rapeseed oils, carnosic acid and seleno-compounds

Danuta Jaworska [a,*], Marian Czauderna [b], Wiesław Przybylski [a], Agnieszka J. Rozbicka-Wieczorek [b]

[a] Warsaw University of Life Sciences, Faculty of Human Nutrition and Consumer Sciences, 02-776 Warszawa, Poland
[b] The Kielanowski Institute of Animal Physiology and Nutrition, Polish Academy of Sciences, 05-110 Jabłonna, Poland

ARTICLE INFO

Article history:
Received 15 December 2015
Received in revised form 4 May 2016
Accepted 5 May 2016
Available online 6 May 2016

Keywords:
Diet supplementation
Lambs
Longissimus muscle
Sensory quality
Fatty acids

ABSTRACT

The aim of the study was to evaluate *longissimus* muscle quality in lambs fed diets including fish oil (FO), rapeseed oil (RO), carnosic acid (CA) and seleno-compounds. Lambs were fed one of diets: Group I — the basal diet (BD) with 3% RO; Group II — BD with 2% RO and 1% FO; Group III — BD with 2% RO, 1% FO and 0.1% CA; Group IV — BD with 2% RO, 1% FO, 0.1% CA and 0.35 ppm Se as selenized-yeast; Group V — BD with 2% RO, 1% FO, 0.1% CA and 0.35 ppm Se as selenate. The addition of FO and FO, CA and selenium in the inorganic form was characterized by lowest tenderness and juiciness ($P < 0.05$). The lowest concentration of fatty acids (ΣFAs), atherogenic-FAs (A^{SFA}) and thrombogenic-FAs (T^{SFA}) in the muscle was found for Group V ($P < 0.05$). Experimental diets decreased indexes of A^{SFA} and T^{SFA} in muscle. The lowest ratio ($P < 0.05$) of n-6polyunsaturated-FAs to n-3polyunsaturated-FAs was obtained for Group III.

1. Introduction

To increase lamb consumption a number of specific actions should be undertaken in order to make consumers more interested in buying this type of meat. Consumers' choices made during the purchase process are determined by the quality of food, in particular by sensory quality. This factor is of crucial importance (Grunert, 2006; Grunert, Bredahl, & Brunso, 2004). As far as consumers' perception of meat is concerned, sensory studies have provided evidence that sensory quality components such as flavour and tenderness are most important (Font i Furnols et al., 2009; Oltra et al., 2015; Thompson et al., 2005). Besides sensory quality, other features like price, health benefits and safety have also significant influence on customers' decisions. Products meeting these requirements are likely to maintain the appropriate position in the market. To obtain a high meat quality producers could implement an appropriate feed supplementation strategy. This method seems to be more profitable and easier in comparison to genetic modification of animals. However, there are contradictions with the intensification of lamb meat production and consumers preferences. The dietary nutrition of animals can have an impact on meat quality by optimizing the intrinsic and extrinsic characteristics of muscles (Font i Furnols et al., 2009; Lefaucheur, 2010). The nutritional characteristics of diets (such as protein, fatty acids, energy, vitamins and minerals) can influence value-adding properties of meat and consequently its quality. Studies on the role of dietary factors in the development of human diseases focus on the possibility of increasing the share of n-3 polyunsaturated fatty acids (PUFAs) in meat and thereby reducing the adverse ratio of n-6PUFAs to n-3PUFAs (n-6/n-3), which in the human diet should ideally be 4:1 (Patterson, Wall, Fitzgerald, Ross, & Stanton, 2012; Simopoulos, 2002). The adequate supply of n-3 long-chain PUFAs (n-3LPUFAs) in the diet provides a balance in the physiological system and prevents the development of a number of human diseases (Gebauer, Psota, Harris, & Kris-Etherton, 2006).

Many authors have analyzed the levels of additives in animal feed that would not negatively affect the quality of meat; too much additive can adversely affect the meat flavour, worsen fat texture (excessive softness), and have a bad impact on the meat stability (Haak, De Smet, Fremaut, Van Walleghem, & Raes, 2008; Hallenstvedt, Kjos, Rehnberg, Overland, & Thomassen, 2010; Wood et al., 2008). Increasing the share of PUFAs to n-3PUFAs in the diet of animals requires adequate protection against oxidation processes. Currently special attention has also been paid to supplementation with phenolic compounds, some of which (e.g. carnosic acid) have the ability to modify ruminal microbiota and hence fatty acid metabolism in the rumen (Morán et al., 2013). In fact, dietary carnosic acid (CA) modifies the profile composition of fatty acids (FAs) in the rumen and has a significant influence on the biosynthesis of volatile compounds and the composition of FAs (especially PUFAs) in the body of ruminants. Moreover, dietary CA is used as an antioxidant to prolong the shelf life of meat (Morán et al.,

* Corresponding author.
E-mail address: danuta_jaworska@sggw.pl (D. Jaworska).

http://dx.doi.org/10.1016/j.meatsci.2016.05.003
0309-1740/

2013). In addition, dietary selenized yeast (SeY), selenate (SeVI) and especially CA and fish oil (FO) would decrease the capacity for the biohydrogenation of unsaturated FAs (UFAs) in the rumen (Czauderna, Kowalczyk, & Marounek, 2013; Czauderna, Rozbicka-Wieczorek, Wiesyk, & Krajewska-Bienias, 2015; Miltko, Rozbicka-Wieczorek, Więsyk, & Czauderna, 2016). Consequently, the concentrations of PUFAs, particularly conjugated isomers of linoleic acid (CLA) and their precursors, increased in lamb muscles. Additionally, positive correlations were observed between dietary contents of Se and concentrations of UFAs in the tissues of animals in the study of Ortman, Andersson, and Holst (1999). Taking into account all the facts mentioned above, we hypothesize that dietary FO, CA and Se (as SeY or SeVI) added to a diet could influence sensory quality and increase the concentration of UFAs in lamb meat. The main novelty of this study was to investigate the influence of different chemical forms of Se added to the diet including CA and FO on sensory quality and chemical composition of lamb meat. Thus, the first objective of the study was to investigate effects of FO added to the diet including rapeseed oil (RO) on the *longissimus* muscle quality of lambs as well as the effect of CA and FO added to the diet with RO. The second objective was to investigate the impact of different chemical forms of Se (as SeY or SeVI) added to the diet including RO, FO and CA on the *longissimus* muscle quality of lamb.

2. Material and methods

2.1. Materials

Thirty male Corriedale lambs with an average body weight (BW) of 30.5 ± 2.6 kg at the beginning of the experiment were individually penned and divided into 5 groups consisting of 6 animals each (Tables 1 and 2). The animals were divided into 5 groups, according to the initial liveweight of lambs; so that the average initial body liveweight of lambs between the groups was similar (Table 2). The study was conducted under the authority of the Third Local Commission of Animal Experiment Ethics at the University of Life Sciences, Ciszewskiego 8, 02-786 Warsaw (Poland). During a 3-week preliminary period the animals were given free access to the standard concentrate-hay diet with vitamins and mineral premix (the basal diet; Table 1). The basal diet (BD) consisted of the following components: meadow hay (~36%), a mixture of soybean meal (~36%) barley meal (~16.5%), wheat starch (~9%) and mineral-vitamin mixture (20 g/kg BD). This BD contained: crude protein 12%, crude fibre 1.2%, and 11 MJ metabolizable energy per kg dry matter. The basal diet (BD) was enriched with 3% rapeseed oil (RO) or 2% RO and 1% odourless fish oil (FO) (Table 2).

Table 1
Chemical composition (% in dry matter) of the concentrate-hay diet with vitamins and mineral mixture[a] (the basal diet) and rapeseed oil (RO) and odourless fish oil (FO)[b] fed to lambs.

Item	Meadow hay[d]	Concentrate[c]		
		Barley meal	Soybean meal	Wheat starch
Dry mass (%)	88.4	87.6	89.7	87.3
Crude protein (%)	9.50	9.94	41.8	0.90
Crude fibre (%)	27.3	2.87	4.34	–
Crude fat (%)	3.40	2.50	2.25	0.09
Ash (%)	4.85	1.84	6.16	0.12
Neutral detergent fiber (%)	59.2	18.0	18.8	–
Acid detergent fiber (%)	32.1	4.61	6.44	–
Acid detergent lignin (%)	4.47	1.14	1.49	–

[a] Vitamins and mineral mixture provided by POLFAMIX OK (www.trouwnutrition.pl).
[b] The iodine value of FO: 50–65 g/100 g FO; the acid value of FO: 20 mg KOH/g FO.
[c] The main fatty acids in concentrate (μg/g): C14:0 104, C16:0 3189, C18:0 1425, c9C18:1 774, c9c12C18:2 29163, c9c12c15C18:3 1014; the gross energy (MJ per kg of dry matter (DM)): barley meal: 16.3, soybean meal: 17.8, wheat starch: 16.7.
[d] The gross energy: 17.1 MJ per kg of DM; the mean fatty acid composition of meadow hay (μg/g): C8:0 83, C12:0 142 , C14:0 239, c9C15:1 131, C16:0 4034, c9C16:1 184, C18:0 459, c9C18:1 1266, c12C18:1 72, c9c12C18:2 13100, c9c12c15C18:3 4178, C20:0 58, c11C20:1 74, C22:0 101, C24:0 69, c15C24:1 71.

After the preliminary period, the lambs were fed for 35 days on the basal diet enriched with 3% rapeseed oil (RO) (Group I), the second diet enriched with 2% RO and 1% FO (Group II) or the supplemented diets (Groups III–V) with combined addition of additives (2% RO, 1% FO, 0.1% CA or/and 0.35 ppm Se as SeY or SeVI) (Table 2). The control and all experimental diets were formulated to be isoenergetic and isonitrogenous. All diets were adjusted weekly and given as two equal meals at 7.30 a.m. and 4.00 p.m. each day to ensure free access to feed. Animals consumed the whole amount of served meal portions. All lambs were fed the same weight of freshly prepared diets with the appropriate additives (Table 2). The average daily diet intake was 1.08 kg of fresh weight per lamb. Fresh drinking water was always available. The lambs were slaughtered at the end of the 35-day experiment (i.e., at 7.00 a.m. after 12 h of starving, lambs were made unconscious by the intramuscular injection of xylazine (2–4 mg/10 kg BW). Both whole *longissimus* muscles were removed and weighed; 5 g of muscle samples were stored in sealed tubes at −32 °C until analysis of fatty acids by capillary gas-chromatography. For sensory assessment, *longissimus* muscle samples were taken, vacuum packed and aged 7 days at a temperature of 6 °C (samples were never frozen).

2.2. Reagents

Fatty acid standards, 25% BF_3 in methanol and sodium selenate (SeVI) were provided by Sigma (USA); n-hexane (99%; GC) was purchased from Lab-Scan (Ireland). Chloroform, dichloromethane (DCM), methanol, KOH, NaOH, Na_2SO_4 and conc. HCl were purchased from POCh (Poland). All other chemicals were of analytical grade and organic solvents were of HPLC grade. Carnosic acid (CA) was purchased from Hunan Geneham Biomedical Technology Ltd. (689 Changsha Road, Changsha, 410129 Hunan, China). Rapeseed oil (RO) and odourless fish oil (FO) were supplied by Company AGROSOL (28-133 Pacanów, Poland). RO comprised the following main fatty acids (μg/g RO): C14:0 56, C16:0 13091, *c9*C16:1 33, C18:0 5490, *c9*C18:1 85859, *c12*C18:1 786, *c9c12*C18:2 282394, *c9c12c15*C18:3 74, C20:0 194, *c11*C20:1 108, C22:0 430 and *c15*C24:1 61. FO included the following main fatty acids (μg/g): C12:0 82, C14:0 12345, *c9*C14:1 215, C15:0 477, C16:0 56947, *c7*C16:1 318, *c9*C16:1 420, ∑C16:2 15586, C17:0 493, *c9*C17:1 193, C18:0 9452, *c6*C18:1 188, *c7*C18:1 842, *c9*C18:1 290592, *c12*C18:1 15834, *c14*C18:1 159, *c9c12*C18:2 114512, *c9c12c15*C18:3 20968, *c11*C20:1 24206, *c7c9c12c15*C18:4 473, *c11c14*C20:2 2270, *c8c11c14*C20:3 258, *c5c8c11c14*C20:4 304, *c8c11c14c17*C20:4 607, C22:0 139, *c13*C22:1 11036, *c11*C22:1 1704, *c5c8c11c14c17*C20:5 6792, *c13c16*C22:2 95, *c7c10c13c16*C22:4 144, *c15*C24:1 397, *c7c10c13c16c19*C22:5 1560 and *c4c7c10c13c16c19*C22:6 26570.

The vitamin and mineral mixture was purchased from POLFAMIX OK (Grodzisk Mazowiecki, Poland); 1 kg of vitamin and mineral mixture comprised: 285 g calcium, 16 g phosphorus, 56 g sodium, 42 mg cobalt as carbonate, 10 mg iodine as iodate, 1 g iron as sulphate, 6 mg Se as selenite, 0.5 g copper as sulphate, 5.8 g manganese as sulphate, 7.5 g zinc as sulphate; vitamins: A (500,000 IU/kg), D3 (125,000 IU/kg), and E as α-tocopherol (25,000 IU/kg).

The selenized yeast (Se-*Saccharomyces cerevisiae*) was donated by Sel-Plex (Alltech In., USA). About 83% of the Se content of selenized yeast (SeY) represents Se in the form of Se-methionine (Se-Met) incorporated into the proteins of *S. cerevisiae*; the chemical composition of SeY was presented in the previous publication (Czauderna, Kowalczyk, Niedźwiedzka, Leng, & Cobanova, 2009).

2.3. Chemical methods

2.3.1. Meat composition

Meat composition (water, fat, protein and collagen content) was determined using a near-infrared spectrometer NIRFlex N-500 (Büchi,