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Avocado waste for finishing pigs: Impact on muscle composition and oxidative stability during chilled storage

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ABSTRACT

The utilization of agricultural waste materials for pig feeding may be an interesting option for reducing production costs and contributing to sustainability and environmental welfare. In the present study, a mixed diet enriched with avocado waste (TREATED) is used for finishing industrial genotype pigs. The muscle longissimus thoracis et lomborum (LTL) from TREATED pigs was analyzed for composition and oxidative and color stability and compared with muscles obtained from pigs fed a CONTROL diet. Dietary avocado had significant impact on the content and composition of intramuscular fat (IMF), reducing the lipid content in LTL muscles and increasing the degree of unsaturation. This did not increase the oxidative instability of samples. On the contrary, muscles from TREATED pigs had significantly lower lipid and protein oxidation rates during chilled storage. The color of the muscles from TREATED pigs was also preserved from oxidation.

1. Introduction

The feeding background of pigs has a capital influence on the animal production rates, carcass conformation and meat quality (Lebret, 2008). Additionally, feeding consists of about 70% of the total cost in raising pigs (National Research Centre on Pig, 2011). The utilization of waste materials from agricultural production has been proposed as a feasible means to reduce production costs and additionally, guarantee production sustainability and environmental welfare (Kumar, Roy, Lakhani, & Jain, 2014; Westendorf, Zirkel, & Gordon, 1996). Previous studies have tested a variety of food and agricultural by-products for pig feeding including bread waste (Kumar et al., 2014), spent coffee grounds (Sikka & Chawla, 1986), cane molasses (Garg, Pathak, Anjaneyulu, & Lakshmanan, 1986), dairy by-products (Kjos, Øverland, Arnkværn, & Sørheim, 2000) and assorted dehydrated restaurant food waste materials (Myer, Brendemuh, & Johnson, 1999). However, most of these studies focus on the toxicological and nutritional properties of the feeds and overlook the potential impact of such feeding on animal performance and in particular, meat quality.

While recycling food wastes for livestock feeding is an attractive waste disposal alternative, certain US states have banned such practice for health and safety reasons (Myer et al., 1999; Westendorf et al., 1996). In EU, meat wastes are forbidden for animal feeding and hence, this practice is restricted to fruit and fish by-products (Esteban, García, Ramos, & Márquez, 2007). Avocado (*Persea americana* Mill.) is a tropical and subtropical fruit, native to southern Mexico and currently grown in distant countries from four continents (FAOSTAT, 2008). The massive production of avocado in México allows fulfilling the internal demand, exporting to third countries (mostly EU) and still leads to considerable excess of this crop. Avocados may be used for animal feeding and this is particularly applicable for fruits dismissed for human consumption due to lack of adherence to commercial standards. Regarding its potential nutritional value, avocado is known for being an excellent source of unsaturated fatty acids, tocopherols and other phytochemicals with alleged positive biological effects (Wang, Terrell, & Liwei, 2010). In previous studies, avocado oil and phenolic-rich extracts from the peel and the seed have been included in processed porcine patties leading to beneficial effects on their nutritional value and oxidative stability (Rodríguez-Carpena, Morcuende, Andrade, Kylli, & Estevéz, 2011; Rodríguez-Carpena, Morcuende, & Estévez, 2011; Rodríguez-Carpena, Morcuende, & Estévez, 2012; Utrera, Rodríguez-Carpena, Morcuende, & Estévez, 2012). In particular, the significant increase of monounsaturated fatty acids (MUFA), tocopherols, flavonoids and chlorophylls in porcine patties treated with avocado by-products were identified as responsible for the protection of meat lipids and proteins during storage and processing (Rodríguez-Carpena et al., 2011; Rodríguez-Carpena et al., 2011; Rodríguez-Carpena et al., 2012; Utrera et al., 2012). The application of avocado in animal feeding, however, is scarcely documented

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as just one single article has reported data on the effect of dietary avocado on nitrogen and energy balances in pigs (Grageola et al., 2010). As a result, the impact of this feeding regime on the quality of pork, is ignored. On this line, the composition of meat in terms of intramuscular fat (IMF) and fatty acid composition is paramount as these parameters have a direct influence on particular sensory traits such as juiciness and flavor (Wood et al., 2004). Conversely, the discoloration of meat as well as the onset of lipid and protein oxidation during retail display affects the shelf life and the sensory and nutritional value of pork (Lund, Heinonen, Baron, & Estévez, 2011; Soladoye, Juárez, Aalhus, Shand, & Estévez, 2015).

In response to this lack of knowledge, the present study was designed to evaluate the carcass conformation, and quality and oxidative stability of *M. longissimus thoracis et lumborum* (LTL) from pigs fed with avocado.

2. Material and methods

2.1. Animals and sampling

This study was carried out with sixteen male hybrids of commercial genotype pigs (50% York–50% Landrace) with an initial live average weight of 53.77 kg. Pigs were randomly divided into two groups according to the type of feeding during the fattening period: Control group (CONTROL, n = 8) and Treated group (TREATED, n = 8). The composition of the CONTROL diet was as follows (percentage in dry matter): sorghum meal 83.7, soybean meal 12.9, $CaHPO_4H{\cdot}2H_2O$ 1.0, $CaCO_3$ 1.2, NaCl 0.2, vitamins and trace elements 1.0. The TREATED diet contained (percentage in dry matter): sorghum meal 53.7, soybean meal 12.9, avocado paste 30.0, $CaHPO_4H{\cdot}2H_2O$ 1.0, $CaCO_3$ 1.2, NaCl 0.2, vitamins and trace elements 1.0. The share of avocado paste in the TREATED diet (30%) was optimized in a previous trial following digestibility and productivity criteria (unpublished data). The avocado paste was made with avocado waste from packing company. When avocado reached its consumption ripeness, determined objectively by firmness with 23.63 ± 4.0 N of force values (Stable Micro Systems Model TA. XT2, Texture Technologies Corp., Scarsdale, NT), the entire avocado fruit was ground in a screenless hammer mill to obtain a homogeneous paste and then was mixed with the other ingredients. Pigs were in individual pens. Mixed diets and water were supplied to pigs ad libitum. Both mixed diets were isoproteic and provided 14% of crude protein. Additional information about the composition of the mixed diet is provided in Table 1. Digestibility was calculated though the analysis of fecal material according to the procedure described by Paiva-Martinsa, Barbosa, Pinheiro, Mourãoc, and Outor-Monteiro (2009).

At the end of the fattening period at a live weight of 100 kg, pigs were electrically stunned and subsequently slaughtered. *Muscles longissimus thoracis et lomborum* (LTL) were removed hot from the carcasses, immediately freed from visible fat, and kept at 4 °C for its analysis within the hour following slaughter. Five slices of each LTL muscle were cut, dispensed in polystyrene trays, wrapped in oxygen-permeable film (14 μm thickness and 10,445 mL/m^2/24 h of oxygen permeability) and stored in the dark at 4 °C for 12 days. Samplings were made at days 0, 3, 6, 9 and 12 days of storage.

Table 1
Analysis of CONTROL and TREATED experimental diets.

	CONTROL		TREATED	
	Mean	SD	Mean	SD
Moisture (g/100 g feed)	12.64	0.36	30.54	1.44
Crude Protein (g/100 g feed)	13.40	1.64	12.24	1.74
Ether extract (g/100 g feed)	0.31	0.09	3.22	0.13
Ash (g/100 g feed)	3.91	0.10	3.84	0.16
Tocopherol (mg/kg feed)	164.62	18.77	273.03	16.24
Digestibility (% dry matter)	87.33	1.81	86.25	1.85
Gross energy (kJ/g feed dry matter)	17.84	–	25.58	–

SD: standard deviation.

2.2. Analytical methods

2.2.1. Chemical composition of feeds and muscles, intramuscular fat isolation and fatty acid profiles

Moisture, protein, ether extractives, nitrogen free extractives (NFE) and ash were determined in feeds and muscles using official methods (AOAC, 2000). Intramuscular total lipids were extracted from muscles using the Folch method (Folch, Lees, & Sloane-Stanley, 1957). For the analysis of the fatty acid profiles of the LTL muscle, fatty acid methyl esters (FAMEs) were prepared by methylation with cold methanolic solution of potassium hydroxide (Cert, Moreda, & Pérez-Camino, 2000). FAMEs were analyzed by gas chromatography (GC) using a Hewlett–Packard HP-5890A gas chromatograph, equipped with an on-column injector and a flame ionization detector, using a polyethyleneglycol capillary column (Supelcowax-10, Supelco, Bellefonte, Pa., U.S.A.) (60 m × 0.32 mm i.d. × 0.25 μm film thickness). Oven temperature ramp was 180 °C to 250 °C. Injector and detector temperatures were 250 °C. Carrier gas was Helio with a constant pressure flow of 22 psi. Individual FAME peaks were identified by comparison of their retention times with those of standards (Sigma, St. Louis, Mo., U.S.A.). Results were expressed as percentage of the total fatty acids analyzed.

2.2.2. Tocopherol quantification

Prior to analysis, IMF and ether extractives from feeds were dissolved in isopropanol (1:10, v/v). Tocopherol determination was performed on a Shimadzu "Prominence" HPLC (Shimadzu Corporation, Kyoto, Japan) equipped with a quaternary solvent delivery system (LC-20AD), DGU-20AS on-line degasser, SIL-20A auto-sampler, RF-10A XL fluorescence detector, and CBM-20A system controller. Separation was made on a reversed-phase C18 column (150 mm length × 4.6 mm i.d., 5 μm particle diameter) manufactured by Phenomenex (USA) with the mobile phase being methanol:water (97:3 v/v) at a flow rate of 1.5 mL min^{-1}, and peaks were registered at 285 and 335 nm as excitation and emission wavelength, respectively. The mobile phases were filtered by a Millipore vacuum filtration system equipped with a 0.45 μm pore size filter. Samples were injected (2 μL) by the aid of the auto-sampler. Identification and quantification of the peaks were done by comparison with α-tocopherol and γ-tocopherol standards (0.2–14 μg/mL). Results were expressed as μg of α- or γ-tocopherol/g fresh matter.

2.2.3. Objective color measurement

Surface color measurements of loin slices at days 0, 3, 6, 9 and 12 days of storage were performed using a Minolta Chromameter CR-400 (Minolta Camera Corp., Meter Division, Ramsey, N.J., U.S.A.), which consisted of a measuring head (CR-400), with an 10 mm diameter measuring area and a data processor. Before each measuring session the chromameter was calibrated on the CIE color space (CIE, 1978) system using a white tile. One measurement consisted of three consecutive flashes of illumination to obtain a mean value. Color measurements were made at room temperature (approximately 22 °C) with illuminant D65 and a 0° angle observer. The L*a*b* values were recorded from the average across each loin slice surface. The L*, a* and b* values (CIE L*a*b* color system) were assessed as a measure of respectively lightness, redness and yellowness; through them Chroma and Hue values were calculated. Numerical total color differences (E) were calculated to assess the total color change undergone by slice loin as a result of feeding type of pigs (ΔE_{C-T}) and the days of storage of slice loins (ΔE_{0-3}), (ΔE_{3-6}), (ΔE_{6-9}), and (ΔE_{9-12}). Therefore, ΔE_{C-T} was calculated between samples from the C group (C) and T group (T), ΔE_{0-3} was calculated between 0 (0) and 3 (3) days of storage, ΔE_{3-6} was calculated between 3 (3) and 6 (6) days of storage, ΔE_{6-9} was calculated between 6 (6) and 9 (9) days of storage and ΔE_{9-12} was calculated between 9 (9) and 12 (12) days of storage as follows: