Meat Science 80 (2008) 1116–1121

Contents lists available at ScienceDirect

Meat Science

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

Effects on growth performance, carcass characteristics, and the fat and meat fatty acid profile of rabbits fed diets with chia (*Salvia hispanica* L.) seed supplements

P.G. Peiretti [a,*], G. Meineri [b]

[a] Istituto di Scienze delle Produzioni Alimentari, National Research Council, Via Leonardo da Vinci 44, 10095 Grugliasco, Torino, Italy
[b] Dipartimento di Produzioni Animali, Epidemiologia ed Ecologia, University of Torino, Via L. da Vinci 44, 10095 Grugliasco, Torino, Italy

ARTICLE INFO

Article history:
Received 28 September 2007
Received in revised form 5 May 2008
Accepted 6 May 2008

Keywords:
Rabbit
Meat quality
Salvia hispanica
Fatty acid

ABSTRACT

The effects of three levels (0%, 10%, or 15%) of chia (*Salvia hispanica* L.) seed (SHS) included in the diet on the growth performance, some carcass characteristics and fatty acid profile of rabbit meat and perirenal fat was studied. At the end of the experiment, there were no significant differences among the groups in live weight, live weight gain, feed consumption, feed efficiency, carcass yield or the percentages of edible organs. The percentage values of hind legs, fore legs, loin and abdominal wall, breast and ribs, skin and limbs, and head were not affected by the inclusion level of SHS. The polyunsaturated fatty acid (PUFA) concentration in the *longissimus dorsi* muscle and perirenal fat was significantly increased with increasing SHS inclusion, while the saturated fatty acid (SFA) decreased. The $n-6/n-3$ PUFA ratio of the rabbit meat decreased from 4.55 in the control group, to 1.03 in the 15% SHS group.

1. Introduction

Chia (*Salvia hispanica* L.) is a member of the *Labiatae* family and is native to southern Mexico and northern Guatemala. The revival of interest in chia seed (SHS) is due to their oil content, which is about 25–39% oil by weight (Ayerza, 1995; Ting, Brown, Naqvi, Kumamoto, & Matsumura, 1990). This oil is a rich source of the following polyunsaturated fatty acids (PUFA): linoleic (C18:2n6; 17–26%) and α-linolenic acid (C18:3n3; 50–57%). The seeds have crude protein and fibre contents that range from 17% to 24% and from 18% to 22%, respectively (Ayerza & Coates, 2000; Bushway, Belya, & Bushway, 1981). These variations are probably due to environmental conditions (Ayerza & Coates, 2004). The nutritional and chemical evaluation of chia seeds was reported by Weber, Gentry, Kohlhepp, and McCrohan (1991), while Meineri and Peiretti (2007) determined the apparent digestibility of mixed feeds with increasing levels of chia seeds in rabbit diets. Furthermore, Castro-Martinez, Pratt, and Miller (1986) asserted that SHS oil contains a number of compounds with potent antioxidant activities: myricetin, quercetin, kaemperol, and caffeic acid and this makes the oil quite stable in spite of its high PUFA content (Taga, Miller, & Pratt, 1984). Recent research shows that it is possible to use SHS oil, or its by-products, for animal nutrition with the aim of obtaining PUFA enriched animal products. Ayerza and Coates (1999) used chia seed in laying hen diets to produce eggs with a high $n-3$ PUFA content, a reduced SFA content, and a lower $n-6/n-3$ ratio without imparting off-flavours. A more comprehensive trial was undertaken by Ayerza and Coates (2000), who reported the compositional analysis of the eggs and showed that $n-3$ PUFA content increased, while cholesterol and saturated fatty acid contents decreased, with increasing levels of chia in the diets. Ayerza and Coates (2002) showed that up to 280 g/kg of chia seed can be fed to brown laying hens with no adverse effects on egg production, and with increased egg weights. White hens were superior in terms of egg production with the 70 g/kg chia diet; however, they tended to have a lower egg production when fed on diets containing more than 140 g/kg of chia. A subsequent trial (Ayerza, Coates, & Lauria, 2002) was conducted to determine the effects that feeding chia to broilers would have on white and dark meat cholesterol, fat content, and fatty acid composition, as well as on broiler weight gain and mortality. The most significant findings in this trial were the effects that chia had on palmitic acid, SFA, $n-3$ PUFA, and the $n-6/n-3$ fatty acid ratio of broiler white and dark meats. Enriched $n-3$ PUFA poultry meat brought about by feeding chia could be useful to help consumers meet health recommendations. Recent recommendations for human diets suggest increasing $n-3$ PUFA consumption and decreasing the $n-6/n-3$ ratio to 5/1 (Lunn & Theobald, 2006).

Rabbit meat consumption is important in the Mediterranean area, especially in France, Italy and Spain; in 1995 Italy was the main producer with an estimated production of 300,000 metric tons of rabbit carcass (Colin & Lebas, 1995). Changes in rabbit meat demand over the last 20 years has been less important than observed for meats of other species. Nowadays, rabbit-meat-eating habits are changing (Dalle Zotte, 2002), but an improved fatty acid

* Corresponding author. Tel.: +39 11 6709230; fax: +39 11 6709297.
E-mail address: piergiorgio.peiretti@ispa.cnr.it (P.G. Peiretti).

0309-1740/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.meatsci.2008.05.003

profile may encourage more people to utilise this alternative meat source.

Fat sources influence the fatty acid composition of rabbit body fat, as observed by various authors (Cavani et al., 1996; Cobos, Cambero, Ordóñez, & de la Hoz, 1993; Ouhayoun, Lebas, & Delmas, 1987), and the main physical, chemical, and organoleptic characteristics of rabbit meat (Fernandez & Fraga, 1996).

Rabbit meat could be an alternative to fish and oilseeds as a source of $n-3$ PUFA. Rabbits are able to directly incorporate dietary FA into adipose and muscle tissue lipids, making it possible to modify the FA profile of rabbits through the strategic use of unsaturated dietary fat sources (Dalle Zotte, 2002), for instance supplementing rabbit with fish meal rich in eicosanoic acid and docosahexaenoic acid (Castellini & Dal Bosco, 1997) or other ingredients containing linolenic acid (Bernardini, Dal Bosco, & Castellini, 1999; Castellini, Dal Bosco, & Bernardini, 1999).

Depending on the fat composition, rabbit meat could be a useful food in human diets because it has many positive dietetic characteristics, for example low cholesterol levels (on average 53 mg/100 g fresh meat; Dalle Zotte, 2002), a relatively high content of PUFA (Alasnier & Gandemer, 1998; Ouhayoun, Gidenne, & Demarne, 1985) and a very low $n-6/n-3$ ratio (Dalle Zotte, 2002). Therefore, to decrease this ratio in rabbit would help lower it in the human diet to recommended levels.

The present work was designed to study SHS as a new dietary source of $n-3$ PUFA for the production of healthy rabbit meat and its effect on the growth performance, carcass characteristics, and FA profile of the meat and perirenal fat.

Table 1
Ingredients and composition of the experimental diets

	Chia seed	Chia seed (% of diet)		
		0	10	15
Ingredients (%)				
Corn		15	18	21
Barley		19	24	20
Dehydrated alfalfa meal		46	33	30
Soybean seed meal		12	11	10
Palm oil		4	0	0
Chia seed		0	10	15
Vitamin–mineral premix[a]		2	2	2
Lignosulphite		2	2	2
Chemical composition				
Dry matter, %	94.9	92.3	91.1	91.3
Organic matter, %	95.2	93.4	94.4	94.7
Crude protein, %	23.5	15.9	15.6	15.7
Ether extract, %	31.1	4.9	6.1	5.0
Crude fibre, %	32.9	13.6	11.5	11.9
Crude ash, %	4.8	6.6	5.6	5.3
Nitrogen free extract, %	7.8	59.0	61.2	62.1
Acid detergent fibre, %	34.5	16.1	14.2	14.1
Acid detergent lignin, %	12.6	5.5	4.6	5.2
Gross energy, MJ/kg DM	26.1	15.9	15.6	15.9
Digestible energy[b], MJ/kg DM	8.3	12.9	12.8	12.8
Linoleic acid (% of FA)	18.8	21.9	28.6	27.7
Linolenic acid (% of FA)	64.1	10.5	36.9	39.3

[a] Per kg of diet: vitamin A 200 UI; α-tocopheryl acetate 16 mg; niacine 72 mg; vitamin B_6 16 mg; choline 0.48 mg; DL-methionine 600 mg; Ca 500 mg; P 920 mg; K 500 mg; Na 1 g; Mg 60 mg; Mn 1.7 mg; Cu 0.6 mg.
[b] The digestible energy content of the diets was calculated according to the regression proposed by Fernandez-Carmona, Cervera, and Blas (1996).

2. Materials and methods

2.1. Animals and diets

The study was carried out at the CISRA experimental rabbitry at the University of Turin according to the guidelines for applied nutrition experiments in rabbits (Fernández-Carmona et al., 2005).

Thirty weaned crossbred rabbits aged 50 days and weighing, on average, 1433 ± 28 g were randomly assigned to three groups of ten (five male and five female rabbits each). The animals were housed individually under standard conditions at 22 °C ± 2 °C in wire cages at a height of 90 cm from the concrete floor. The animals were assigned three isocaloric and isonitrogenous dietary treatments containing 0%, 10%, and 15% of SHS. The ingredients of the diets are shown in Table 1. The chia seeds were obtained from the Ornitalia Product Service s.a.s. (Colleredo di Monte Albano (UD), Italy). The SHS were premixed with dehydrated alfalfa meal to optimize the inclusion of the seeds in the diets. All the diets were pelleted fresh and stored in darkness to avoid auto-oxidation of the lipid sources. The experimental period lasted 35 days for each diet in each trial. Feed and water were available *ad libitum* to the animals.

2.2. Measured traits

The rabbits were weighed individually at weekly intervals, while the feed consumption was recorded daily and the feed efficiency was estimated as the ratio between consumption and weight gain.

Rabbit mortality was zero during the test. At the end of the experimental period, all rabbits from each group were weighed and slaughtered without fasting. The carcasses were prepared by removing the skin, feet, paws, genital organs, urinary bladder and digestive tract, as recommended by Blasco, Ouhayoun, and Masoero (1993). The carcass was weighed and the weights of the skin and limbs, head, liver, kidneys, heart and lungs recorded and expressed as a percentage of slaughter weight (SW). The forelegs, hindlegs, breast and ribs, loin and abdominal wall were weighed. Their weights were expressed as a percentage of commercial carcass weight (CW).

The *longissimus dorsi* muscle and perirenal fat samples were collected 24 h post mortem from the carcass and immediately frozen at −20 °C until analysed.

2.3. Analytical determinations

The proximate composition of the SHS and diets were determined according to AOAC procedures (AOAC, 1995). The diet samples were analysed to determine dry matter, total N content, ash by ignition to 550 °C and ether extract (EE) using the Soxlet method. The diet samples were also analysed to determine the acid detergent fibre (ADF), as described by Van Soest, Robertson, and Lewis (1991), expressed exclusive of residual ash, acid detergent lignin (ADL) determined by solubilization of cellulose with sulphuric acid, as described by Robertson and Van Soest (1981), and gross energy (GE) by means of an adiabatic bomb calorimeter (IKA C7000, Staufen, Germany).

Lipid extraction was performed on the SHS, the diets and the meat and fat samples according to Hara and Radin (1978), while the transesterification of the FAs was carried out according to Christie (1982), with the modifications described by Chouinard, Corneau, Sæbø, and Bauman (1999).

The FA were analysed as their methyl esters. The analysis was carried out by gas chromatography, using a Dani GC 1000 DPC (Dani Instruments S.P.A., Cologno Monzese, Italy), equipped with a fused silica capillary column – Supelcowax-10 (60 m × 0.32 mm (i.d.), 0.25 μm). The injector and detector ports were set at 245 °C and 270 °C, respectively. The oven temperature program was initially set at 50 °C for the first min, and then increased at 15 °C/min to 200 °C, where it remained for 20 min and then increased at 5 °C/min to 230 °C, where it remained for the last 3 min. The carrier gas was hydrogen. One microlitre was injected