Livestock Science 178 (2015) 140–149

Contents lists available at ScienceDirect

Livestock Science

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

Animal performance, carcass characteristics and beef fatty acid profile of grazing steers supplemented with corn grain and increasing amounts of flaxseed at two animal weights during finishing

L. Pouzo [a,b,c], N. Fanego [c,d], F.J Santini [c,e], A. Descalzo [f], E. Pavan [e,*]

[a] Consejo Nacional de Investigaciones Científicas y Técnicas, Av. Rivadavia 1917, C1033AAJ Ciudad Autónoma de Buenos Aires, Argentina
[b] Facultad de Ciencias Exactas, Universidad Nacional de La Plata, Calle 115 y 47, 1900 La Plata, Buenos Aires, Argentina
[c] Facultad de Ciencias Agrarias, Universidad Nacional de Mar del Plata, Ruta Nac. 226 km. 73.5, 7620 Balcarce, Argentina
[d] Comisión de Investigaciones Científicas de la Provincia de Buenos Aires, Calle 526 entre 10 y 11, 1900 La Plata, Argentina
[e] Estación Experimental Agropecuaria Balcarce, Instituto Nacional de Tecnología Agropecuaria, Ruta Nac. 226 km. 73.5, 7620 Balcarce, Argentina
[f] Instituto Tecnología de Alimentos, Instituto Nacional de Tecnología Agropecuaria, Nicolas Repetto y de los Reseros, 1686 Hurlingham, Argentina

ARTICLE INFO

Article history:
Received 5 March 2014
Received in revised form
18 May 2015
Accepted 19 May 2015

Keywords:
Forage
Plant oil
Intake
Digestibility
Polyunsaturated fatty acid
Conjugated linolenic acid

ABSTRACT

The objective of this study was to determine (1) the effects of increasing flaxseed addition to the corn grain supplemented at finishing to grazing steers on animal performance, carcass characteristics and *longissimus* muscle (LM) fatty acid profile, and (2) whether dietary treatments effects are affected by animal body weight (BW) at supplementation. Forty eight steers were assigned to eight treatment combinations defined by four dietary treatments (CNTRL, no supplement; FLAX-0, 0.7% BW of cracked corn grain; FLAX-1 and FLAX-2, FLAX-0 plus 0.125% and 0.250% BW of unprocessed flaxseed, respectively) and by two animal BW treatments generated by supplementing steer in early spring (EARLY) or late spring (LATE). Steers assigned to EARLY received their dietary treatment when reaching 366 ± 27.3 kg BW (August, 3rd) and those assigned to LATE when reaching 458 ± 42.8 kg (October, 10th). After 70 d on trial, carcass data and LM samples (12th rib region) were collected for fatty acid (FA) analysis. Total DMI was greater in supplemented treatments (FLAX-0, FLAX-1 and FLAX-2) than in CNTRL, with no flaxseed level effect. Dietary treatment effects on performance and carcass characteristics were not affected by BW treatments. Increasing flaxseed supplementation linearly increased subcutaneous fat thickness; whereas increasing BW at initiation of supplementation decreased average daily again, but increase final BW, hot carcass weight, and LM total fatty acid content. Animal BW at initiation of supplementation affected dietary treatments effects on LM n-6/n-3 ratio; ratio was highest in FLAX-0 and lowest in CNTRL and FLAX-2 in both BW treatments; did not differ between BW treatments in CNTRL and in FLAX-2, but was greater in EARLY than in LATE in FLAX-0 and FLAX-1. *Trans*-vaccenic acid proportion was greater in CNTRL than in supplemented treatments, but was not affected by flaxseed level; similar trend was observed for CLA *cis*-9, *trans*-11 proportion. Linolenic acid proportion did not differ between CNTRL and supplemented treatments, but was linearly increased with flaxseed level. Fatty acids changes with increasing animal BW at supplementation were associated with the increased in total muscle fatty acid content; total and individual polyunsaturated fatty acids were lower in LATE than in EARLY, whereas *trans*-vaccenic acid and CLA *cis*-9, *trans*-11 were greater. Adding flaxseed to the corn grain supplemented increase subcutaneous fat thickness of grazing steers without negatively affecting fatty acid profile, except for a reduction in trans-vaccenic acid proportion. Therefore, adding flaxseed to the corn supplemented to grazing steers increases carcass fatness while reducing the negative effect of corn supplementation on LM n-6/n-3 ratio but not on *trans*-vaccenic acid. Increasing BW at supplementation reduces supplementation effects on LM n-6/n-3 ratio.

1. Introduction

The link between nutrition and health is a hot topic. According the guidelines provided by the World Health Organization (WHO,

* Correspondence to: EEA Balcarce-INTA, C.C. 276, 7620 Balcarce, Argentina. Fax: +54 2266 439101.
E-mail address: pavan.enrique@inta.gob.ar (E. Pavan).

http://dx.doi.org/10.1016/j.livsci.2015.05.034
1871-1413/

2003) to reduce the risk of cardiovascular disease (CVD) and considering the potential anti-carcinogenic and anti-atherogenic effects of the isomer *cis*-9, *trans*-11 from the conjugated linoleic acid (Bhattacharya et al., 2006; Kelley et al., 2007), grass-fed beef could be perceived by consumers as a beef product with enhanced fatty acid profile (Daley et al., 2010). Furthermore, McAfee et al. (2011) reported that subjects that consumed red meat from grass-fed cattle had not only greater n-3 poliunsaturated fatty acids (PUFA) dietary intake, but also plasma and platelet long-chain (LC) n-3 PUFA concentration than subject that consumed red meat from concentrate-fed cattle; suggesting that meat from grass-fed cattle may be considered as a potential dietary source of LC n-3 PUFA in populations where red meat is regularly consumed.

This potential opportunity to add value through marketing grass-fed beef as an alternative product with enhanced fatty acid profile is being threatened by the loss of competitiveness of these productions systems. Low productivity of grass-fed systems, in conjunction with increasing land cost and agricultural commodities value, force these beef production systems to increase their productivity through intensification. One tool used to intensify grazing systems is through strategic supplementation during periods of nutrient deficiency at backgrounding, finishing or both fattening phases. However, this strategy could alter the characteristic grass-fed beef fatty acid profile. Increases on beef n-6/n3 ratio and decreases on CLA *cis*-9, *trans*-11 proportion had been reported when 1% BW or less of corn grain was supplemented to grazing cattle for relatively long periods ($>$ 100 d) (Duckett et al., 2007; Garcia et al., 2008; Latimori et al., 2008) or when higher levels were supplemented for shorter periods (60 d) at finishing (Chicatún et al., 2006a). However, results from other studies (Kronberg et al., 2006; Nassu et al., 2011; He et al., 2012; Mapiye et al., 2013) suggest that these negative impacts of grain supplementation could be reverted by vegetable oil supplementation, especially when using flaxseed oil which is high in linolenic acid. In addition, despite negative effects of oil supplementation to grazing steers on forage intake, increases in live weight gain and subcutaneous fat thickness were observed (Pavan et al., 2007; Pavan and Duckett, 2008).

On the other side it has been reported that increasing slaughter weight/age increases intramuscular fat content and with this muscle fatty acid profile is altered (Duckett et al., 1993; De La Torre et al., 2006; Moreno et al., 2008; Barton et al., 2011); another factor that could alter the intramuscular fat content and fatty acid profile on muscle is the season of year in which animals are slaughtered (Alfaia et al., 2007), this effect is mainly due to differences in the quality of pastures consumed.

Increasing intramuscular fat reduces muscle polyunsaturated fatty acids proportion and increases saturated and monounsaturated fatty acids proportions by changing the relative proportion of polar and neutral lipids in the muscle. Since, as oppose to saturated and monounsaturated fatty acids, polyunsaturated fatty acids are preferentially accreted in the polar than in the neutral lipids, the effect of supplementation with polyunsaturated fatty acids on fatty acid profile could be affected by the muscle fat content. In addition, it has been observed that *trans*-11 vaccenic acid and CLA *cis*-9, *trans*-11 are preferentially accreted in the neutral lipid fraction (Santora et al., 2000) and that fatty acid profile could also be altered through changes in desaturase gene expression with changes in animal weight/age (Smith et al., 2006).

Therefore, with the aim of increasing productivity of grass-fed beef systems without altering the characteristic fatty acid profile of the product, the present study evaluates the effect of adding increasing levels of unprocessed flaxseed to the corn grain supplement offered to grazing steers during last 70 d of finishing at two different animal weights/age (reached in early or late spring) on animal performance, carcass characteristics and on fatty acid profile.

2. Materials and methods

2.1. Animals, treatments and general management

Forty eight Angus steers (approximately 23 month of age) from the same herd and backgrounded on a rotational grazing system without supplementation were assigned to eight treatments combinations defined four dietary treatments (no-supplement, **CNTRL**; supplemented: 0.7% LW of cracked corn grain plus no flaxseed, **FLAX-0**, plus 0.125% LW of whole flaxseed, **FLAX-1**, or plus 0.250% LW of whole-flaxseed, **FLAX-2**), and by two animal BW treatments generated by supplementing steer in early spring (**EARLY**) or late spring (**LATE**). Steers assigned to EARLY received their dietary treatment when reaching 366 ± 27.3 kg BW (August, 3rd) and those assigned to LATE when reaching 458 ± 42.8 kg (October, 10th). As a consequence to dietary treatment given, fatty acids supplementation increased from 0.00% BW in CNTRL to 0.03% in FLAX-0, to 0.06% in FLAX-1, and to 0.10% in FLAX-2.

Fourteen days before starting the study, steers assigned to EARLY were trained to use gates for individual access to the supplement using wheat brans and in the last 5 d steers were adapted to the assigned supplements. During adaptation steers were allow to graze the same pasture that was then used for the trial. After adaptation, steers received their supplement treatment on a daily basis for 70 d at 10:00 am plus 0.5 kg (as feed) of wheat-middling. During supplementation steers rotationally grazed annual ryegrass (*Lolium multiflorum* cv Billy Max and cv Jack). Animals were removed from grazed paddocks when pasture height was decreased to approximately 5 cm (visually estimated by trained personnel). Every third paddock, pre- and post-grazing forage availabilities were estimated by harvesting 10 random five samples (0.10-m^2 frame) at 1-cm height. Samples from each cutting time were weighed, dried at 60 °C for 48 h to estimate dry matter (DM) content and then pooled for later crude protein (CP), neutral and acid detergent fiber analysis (NDF and ADF, respectively). Crude protein concentration was determined by the combustion method using a Leco FP-2000N analyzer (Leco Corp., St. Joseph, MI). Neutral detergent fiber and ADF were sequentially determined using an Ankom 200 fiber extractor (Ankom Technologies, Fairport, NY) according to the method of Van Soest et al. (1991).

Initial and final animal body weights (BW) were recorded at 0800 after overnight feed withdrawal (16 h) at the beginning (d 0) and finishing (70 d) of the supplementation period. Individual BW was determined every 21 d at 0830, adjusting the level of supplement to be offered using the average treatment BW.

Steers assigned to LATE were kept on an adjacent annual ryegrass pasture and weighed every 21 d until the group average reached their targeted weight for initiation of supplementation (450 kg). At that time the same protocol as EARLY was followed.

2.2. Forage intake and diet in vivo digestibility determinations

Forage DM intake and in vivo apparent total DM digestibility were estimated using chromium sesquioxide as an external marker and indigestible NDF (**INDF**) as an internal marker of the digesta (Lippke et al., 1986). From d 30 till d 49 of the supplementation period, steers were individually supplemented with 0.5 kg per day of pelleted wheat middling containing chromium sesquioxide (50 g Cr_2O_3/kg as feed). Fecal samples were collected from each steer at 0600 and 1600 for the last 9 d of chromium sesquioxide supplementation. Fecal samples (25 g of wet weight) were pooled for each animal and frozen at -20 °C for subsequent analyses. Supplement refusals were recorded daily, and samples