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Feeding of Extruded Flaxseed (*Linum usitatissimum* L.) and Pasture in Podolica Young Bulls: Effects on Growth Traits, Meat Quality and Fatty Acid Composition

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Abstract.-The present trial aimed to evaluate the effect of feeding extruded flaxseed (*Linum usitatissimum* L.) in concentrate feed and pasture on Podolica young bulls performance and meat characteristics. Eighteen male bulls were randomly divided in three homogeneous groups and fed for 180 days two isocaloric and isonitrogenous concentrates as: (1) diet containing 350 g/kg DM of extruded flaxseed (EFS); (2) diet containing 350 g/kg DM of extruded flaxseed for the first 90 days, then bulls had also 10 h/days grazing on a natural pasture (EFSP); and (3) a control diet containing 600 g/kg of dry matter (DM) of soybean (SB) seeds. Results from growth trial of bulls showed that none of the parameters studied were influenced by the dietary treatments. In slaughter trial, feeding to extruded flaxseed and pasture had a positive effect on the meat lipid component leading to lower perirenal fat accumulation and to higher conjugated linoleic acids (CLA), arachidonic acid, polyunsaturated fatty acids (PUFA) and n-3 fatty acids contents. Additionally, in both groups fed extruded flaxseed (EFS and EFSP) the carcass fat, meat *L** (lightness) values as well as meat n-3 and n-6/n-3 ratio were similar, resulting however improved compared to SB-control group. Moreover, the higher vitamin E content in extruded flaxseed-diet with pasture reduced meat lipid oxidation during storage. Our findings indicate that extruded flaxseed in concentrate can be advantageously used in grazing Podolica bulls, maintaining the growth performance and improving meat lipid profile.

Keywords: Podolica bulls, extruded flaxseed, performance, meat quality, fatty acid profile.

INTRODUCTION

The Podolica cattle is an autochthonous breed belonging to the grey steppe cattle group and it is one of the grey breeds reared in Italy and is part of a larger European family (D'Andrea *et al.,* 2011). Breeding of some autochthonous breeds, such as the Podolica cattle, can be a good opportunity for the socio-economic development of the marginal areas. In fact, this breed represents a genetic resources of considerable significance (Dario *et al*., 2009; Matassino and Ciani, 2009; Selvaggi *et al.,* 2011) having also a high adaptability to climatic extremes and poor pasture of the southern part of the Mediterranean basin (Tufarelli *et al.,* 2013). Therefore, the Podolica breed could play a leading role for environmental protection as well as for quality and safety of animal production (Selvaggi and Dario, 2013). Moreover, the use of local breeds and low-input production systems is being ever more appreciated by consumers that are glad to rediscover traditional healthy food products. Recently, consumption of animal products containing low levels of saturated fats has been recommended because of a possible link between some saturated fatty acids (SFA) and cardiovascular diseases. With increased consumption of highly saturated fat foods, it seems feasible that modern diets do not meet healthy eating guidelines and deficient in certain long chain n-3 fatty acids (Kim *et al.,* 2004). Research has shown several health benefits of n-3 fatty acids to humans including a decrease in the incidence of cancer, cardiovascular diseases, hypertension, and arthritis and an improvement of visual acuity (Wright *et al.,* 1998). As a result, attention has been directed towards producing animal products containing high levels of

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unsaturated fatty acids (UFA).

Flaxseed is an important oil seed having high content of α-linolenic acid (ALA) containing also all essential amino acid (Petit, 2003). The health benefits are related with the ingestion of polyunsaturated fatty acids (PUFA) and dietary fiber. Inclusion of n-3 fatty acids from flaxseed into meat is an efficient process tool to increase the PUFA content of meat products. However, it is more difficult to produce animal products with increased levels of UFA in ruminants because of biohydrogenation of dietary UFA by ruminal microorganisms. Heat treatment is commonly used to protect oilseeds from ruminal degradation (Mustafa *et al.,* 2002). It was suggested that the application of heat to high-fat products such as flaxseed can denature the protein matrix surrounding the fat droplets and, therefore, protects fat from ruminal biohydrogenation (Kennelly, 1996). Extrusion is a heat treatment that can be used to protect oilseeds from ruminal degradability (Gonthier *et al.,* 2002; Raes *et al.,* 2004). Data on meat quality and fatty acid profiles from steers fed heat-treated flaxseed are limited. Therefore, the aim of this study was to evaluate the effects of extruded flaxseed dietary supplementation on the growth performances, meat characteristics and meat lipid fatty acid profile of young Podolica bulls.

MATERIALS AND METHODS

Animal management, diets and growth trial

This trial was carried out observing the rules in force about animal welfare (91/629/EEC directive, received in Italy by D. Lgs. 533/92 and modified by D. Lgs. 331/98). The study was conducted on 18 Podolica bulls, from the same farm in the Basilicata region, Southern Italy, where they were reared in an extensive breeding system with their dams on hill pasture rich in annual grasses. At 240 days of age and with an average body weight of 236 kg, bulls were moved to a stall and divided into three homogeneous groups of six animals each. During the trial period, the animals were fattened in three different stalls, each with a trough, manger and outdoor paddock without grass. The total area available for each group was 16 × 26 m. The trial period lasted 180 days, from January to July. Before starting the feeding trial, in order to avoid stress and to facilitate adaptation to the new treatments, the young bulls were fed on a temporary diet for two weeks with an increasing amount of experimental diets. During the trial period, the bulls were fed durum wheat (*Triticum durum* L.) straw and two complete isoenergetic and isonitrogenous pelleted feeds having 14.7% CP and metabolizable energy of 11.50 MJ/kg DM (NRC, 2000) and balanced for PDIN (Intestinal Digestible Proteins Nitrogen) and PDIE (Intestinal Digestible Proteins Energy) values (INRA, 1989). The experimental treatments were: (1) diet containing 350 g/kg of dry matter (DM) of extruded flaxseed (EFS); (2) diet containing 350 g/kg DM of extruded flaxseed for the first 90 days, then bulls had also 10 h/days grazing on a natural pasture (EFSP); and (3) a control diet containing 600 g/kg DM of soybean (SB) seeds. The EFSP group received o were grazed for 10 h a day. Wheat straw, pelleted diets and fresh drinking water were provided *ad libitum* to all the animals.

Body weight of each bull was recorded at 07:00 h at the beginning of the trial period (day 0), at 94 and 180 days (before slaughtering). Feed efficiency was calculated as the ratio of weight gain to DM concentrate intake. Feed refusals were collected, weighed and individually bulked for analysis. Samples of daily refusals and feeds offered were dried at 105 °C for 24 h to determine the intake.

Chemical analysis of feeds

Samples of basal feed ingredients and concentrates were ground in a hammer mill with a 1 mm screen and analysed in triplicate for dry matter (DM, 945.15), ash (967.05), crude protein (CP, Kjeldahl N × 6.25; 990.03) and ether extract (945.16) according to AOAC (2004). The NDF (using heat-resistant α-amylase without sodium sulphite), ADF, and ADL were analysed according to Mertens (2002), AOAC (2004) (973.187) and Van Soest *et al.* (1991), respectively, using the sequential procedure and the filter bag system (Ankom Technology, New York). The NDF and ADF fractions include residual ash. Chemical composition of basal feed ingredients and concentrates as well as their fatty acid profile are shown in Tables I and II, respectively.

Table I.- Chemical composition (% as fed basis) of feeds and concentrates fed to bulls.

Item	Feeds				Concentrates[1]	
	Pasture[2]	Soybean	Extruded Flaxseed	Wheat Straw	EFS	SB
Moisture	72.17	10.00	10.00	12.00	12.50	12.50
Crude protein	2.91	36.70	21.50	3.20	14.78	14.70
Fat	0.45	19.10	35.00	1.25	4.55	4.50
Crude fiber	8.31	6.30	7.50	39.00	6.56	6.50
Ash	2.35	5.20	5.50	9.20	5.53	5.50
NDF	18.02	13.50	21.00	74.10	20.76	20.60
ADF	9.62	8.80	10.00	46.20	8.90	8.95
ADL	1.52	3.40	3.40	15.00	1.54	1.50
vitamin E, mg/kg	10.20	-	6.12	-	11.75	7.29

[1] EFS, extruded flaxseed-based concentrate; SB, soybean-based concentrate.
[2]Mean of three different collection periods.

Table II.- Fatty acid profile (% on total fatty acid) of feeds and concentrates fed to bulls.

Item	Feeds		Concentrates[1]	
	Pasture[2]	Extruded flaxseed	EFS	SB
C16:0	13.50	5.60	13.21	14.51
C18:0	2.44	4.60	3.01	3.66
C18:1	6.29	18.38	22.61	26.23
C18:2	16.30	18.77	41.03	48.00
C18:3	60.36	52.03	18.50	5.69

[1] EFS, extruded flaxseed-based concentrate; SB, soybean-based concentrate.
[2]Mean of three different collection periods.

Carcass data collection and meat analysis

At the end of the feeding period (180 days), the 14 month old bulls were weighed and transferred to the slaughterhouse, and after 24 h of feeding deprivation were slaughtered. The slaughter and post-slaughter processing were carried out in accordance with the current meat industry regulations (DPR 320/54). Immediately after slaughter, the data reported in Table IV were recorded. Then, the carcasses were divided into two half sides. The pH was measured on the *Longissimus lumborum* (Ll) muscle of the right half carcass using a pH-meter (Eutech Instruments mod. pH 110) immediately at slaughter (pH_1) and after the carcass refrigeration for 24 h at 4°C (pH_2). The half carcasses were divided into two quarters (anterior and posterior, respectively). Two sample cuts, pelvic limb and lumbar region, were separated and dissected into their tissue components: lean, fat and bone, respectively. At the same time, three days after slaughter, samples of Ll muscles were taken to evaluate meat quality parameters. Meat samples were assayed for moisture (945.15), ash (967.05), and CP (990.03) by oven, muffle furnace, and Kjeldahl methods, respectively, as described by AOAC (2004). Total lipids were extracted according to the method of Folch *et al.* (1957).

Color measurements (L^* = lightness, a^* = redness, b^* = yellowness) were assessed on meat samples using HunterLab Mini-ScanTM XE Spectrophotometer (Model 4500/L, 45/0 LAV, 3.20 cm diameter aperture, 10° standard observer, focusing at 25 mm, illuminant D65/10; Hunter Associates Laboratory, Inc.; Reston, Virginia, USA) taking five readings for each sample. The a^* and b^* values were used to determine Chroma = $(a^2 + b^2)^{1/2}$ and Hue (°) = $\tan^{-1}$ (b/a) according to Little (1975) and Mancini and Hunt (2005).

On each of the muscles, the degree of tenderness was tested through Warner-Bratzler shear (WBS) force using an Instron 1140 apparatus (Instron, High Wycombe, UK). The cut sample had a cylindrical form with a 1.27-cm diameter cut that was parallel to the muscle fiber direction. The force-deformation curve obtained served to calculate meat hardness. Shear forces were determined perpendicular to the fiber direction. Each sample was sheared 3 times. Thiobarbituric acid-reactive substances, expressed as mg malondialdehyde

(MDA) per kg meat, were determined on meat samples after 9 and 14 days of storage at 4 °C meat as described by McDonald and Hultin (1987). The content of vitamin E was determined in muscle as described by Zaspel and Csallany (1983). Briefly, muscle samples (100 mg) were thawed and homogenized in a tissumizer (IKA Labortechnik, Janke and Kunkel, Staufen, DE) with 20 vol of acetone. The homogenate was centrifuged (1300 *g* × 10 min). The supernatant was filtered through a 0.2 µm filter and evaporated to dryness under a stream of nitrogen. The residue was resuspended in diethyl ether (30 µL) and methanol (80µL) and 50 µL was injected into a Kontron HPLC equipped with a C18 reverse-phase column (250 × 4.6 mm × 5 µm, Waters, Milford, USA) and diode array detector model 440. The mobile phase was 100% methanol with a flow rate of 1.5 mL/min. Retention times were α-tocopherol, 4.1 min and α-tocopheryl acetate, 5.0 min. Tocopherols were monitored at 292 nm. The α-tocopherol concentrations in the sample were calculated from peak area responses using a standard curve established by chromatography of known amounts of pure α-tocopherol. Standard stock solution of α-tocopherol and α-tocopheryl acetate (100 and 200 mmol/L ethanol, respectively) was used to establish the calibration curves.

In preparation for fatty acid (FA) composition analysis, samples of diets and meat were freeze-dried and then ground. Briefly, FAs were methylated using a BF3-methanol solution (12% v/v). The FA profile was assessed using a gas chromatograph (Chrompack CP 9000), with a capillary column of silicate glass (70% Cyanopropyl Polysilphenylene-siloxane BPX 70 of SGE Analytical Science, length = 50 m, internal diameter = 0.22 mm, film thickness = 0.25 µm). Temperature programme: 135° for 7 min, increase of temperature of 4°C up to a maximum of 210 °C. Composition was expressed as percentages of the total FA.

The atherogenic and thrombogenic indexes were calculated according to Ulbricht and Southgate (1991) as follows:

Atherogenic Index = (C12:0 + 4 × C14:0 + C16:0)/[ΣMUFA + Σ(n-6) + Σ(n-3)];

Thrombogenic Index = (C14:0 + C16:0 + C18:0)/[0.5 × ΣMUFA + 0.5 × Σ(n-6) + 3 × Σ(n-3) + Σ(n - 3)/Σ(n-6)]; where: MUFA = monounsaturated FA, PUFA = polyunsaturated FA.

Statistical analysis

Data were analyzed for variance (ANOVA) using the GLM procedure of SAS (2004). One way ANOVA was used to analyze the data and the main effect tested was the dietary treatment. Means were compared using the Student's *t*-test.

RESULTS AND DISCUSSION

Body weight and gain, feed intake and feed efficiency of Podolica bulls fed the experimental diets are reported in Table III. Intermediate and final body weight as well as daily gains were not different among treatments. Similarly, no effect of the extruded flaxseed inclusion was observed for the daily feed concentrate intake and feed efficiency. Similarly, feeding up to 15% of whole or extruded flaxseed had no negative effect on DM intake in bulls and dairy cows (Gonthier *et al.*, 2005; Kim *et al.*, 2009). Other Authors found no negative effects on DM intake when feeding flaxseed to dairy cows up to 17% (Mustafa *et al.*, 2003). Moreover, Kennelly (1996) suggested that the addition of fat to

Table III.- Growth performances of bulls fed the experimental diets.

Item	Diet			SED
	EFS	EFSP	SB	*df* = 15
Live weight (kg)				
Initial	235.50	238.50	241.16	26.906
Intermediate	387.50	375.04	390.83	30.292
Final	495.33	496.16	506.16	38.692
Body weight gain (kg/d)				
0-90 d	1.63	1.45	1.64	0.170
91-180 d	1.29	1.36	1.30	0.287
0-180 d	1.47	1.41	1.48	0.180
Feed intake, kg/d [1]				
0-90 d	7.43	7.30	7.66	2.066
91-180 d	7.85	5.35	9.40	2.233
0-180 d	7.62	6.34	8.46	2.011
Feed efficiency, kg/kg				
0-90 d	4.74	5.03	4.65	1.755
91-180 d	6.28	3.93	7.75	2.187
0-180 d	5.37	4.49	5.94	1.869

SB, soybean-based diet; EFS, extruded flaxseed-based diet; EFSP, extruded flaxseed-based diet + pasture;
[1] Average daily concentrate intake.

ruminant diets in the form of oilseeds will have less detrimental effects on DM intake than if a similar amount was fed as free oil. This implies that oilseeds result in slower release of the oil in the rumen and, thereby, minimize potential adverse effect of fat on feed intake. Our findings resulted slightly higher than those reported by other authors on the same breed (Braghieri *et al.*, 2005; Vicenti *et al.*, 2009). In agreement with our results, Zahrádková *et al.* (2010) found that extruded flaxseed feeding did not significantly influence the growth and carcass traits in Limousin and Charolais heifers.

Table IV.- Slaughtering data of bulls fed the experimental diets.

Item	Diet			SED
	EFS	EFSP	SB	*df* = 15
Body wt. at slaughter, kg	471.50	473.17	494.50	42.183
Warm yield, %[1]	62.57	59.30	61.20	2.340
Cold yield, %[1]	61.57 a	58.27 b	60.12 b	2.386
Carcass weight, kg	290.33	277.33	297.33	34.356
Perirenal fat, %[2]	1.95 a	1.09 b	2.05 a	0.385
Pelvic limb, %[2]	32.54	31.50	32.07	1.867
Lumbar region, %[2]	3.79	3.56	3.75	0.264

SB, soybean-based diet; EFS, extruded flaxseed-based diet; EFSP, extruded flaxseed-based diet + pasture;
[1] % on live body weight
[2] % on carcass weight
a, b: $P < 0.05$

The slaughtering data of the Podolica bulls fed the experimental diets are given in Table IV. The stalled body weight (after 24 h of food deprivation) and the carcass weight were similar among the three experimental treatments. However, the cold carcass yield of the Podolica bulls fed EFS was significantly higher ($P < 0.05$) than those fed extruded flaxseed and pasture or soybean. On carcass weight, the percentage incidence of perirenal fat was lower ($P < 0.05$) in EFSP group compared to the other dietary treatments. These findings are in agreement with Keane and Moloney (2009) who stated that in steers fed *ad libitum* concentrates the perirenal fat percentage increased compared to those animals fed pasture. In a previous study, Holló *et al.* (2008) reported that the diet with extruded flaxseed supplementation had no effect on slaughtering and dressing traits in fattening young Hungarian Grey and Holstein Friesian bulls.

Table V.- Dissection data.

Item	Diet			SED
	EFS	EFSP	SB	*df* = 15
Pelvic limb, kg	47.26	43.39	47.64	5.048
Lean, %	74.06 Aa	71.77 B	72.59 b	1.043
Fat, %	7.50 B	7.38 B	9.33 A	0.639
Bone, %	18.43 B	20.83 A	18.07 B	0.992
Lean/fat	10.02 A	9.74 A	7.79 B	0.907
Lean/bone	4.03 A	3.45B	4.02 A	0.231
Lean + fat/bone	4.44A	3.81B	4.54A	0.256
Lumbar region, kg	5.50 a	4.90 b	5.56 a	0.496
Lean, %	64.58	62.51	62.79	3.734
Fat, %	5.03a	4.20 b	5.91 a	1.443
Bone, %	30.37b	33.27 a	31.29 b	3.218
Lean/fat	14.00	15.13	11.63	3.787
Lean/bone	2.20	1.88	2.02	0.360
Lean + fat/bone	2.37	2.01	2.22	0.386

SB, soybean-based diet; EFS, extruded flaxseed-based diet; EFSP, extruded flaxseed-based diet + pasture;
a, b: $P < 0.05$; A, B: $P < 0.01$

The dissection data of pelvic limb and lumbar region (Table V) suggest that the bulls fed SB diet led greater fat percentage than those fed EFS with or without pasture ($P<0.01$); as regards lean incidence, the EFS group showed higher values than control-SB ($P< 0.05$) and EFSP ($P<0.01$) groups, whereas the highest bone incidence was recorded in EFSP ($P<0.01$). These findings are in accordance with those observed in lambs by Karim *et al.* (2007). The lean to fat ratio relating the distal and proximal pelvic limbs was significantly higher ($P < 0.01$) in groups fed EFS and EFSP than the control diet; while the lean to bone ratio was lower ($P < 0.01$) in group EFSP compared to the other dietary treatments. Regarding the lumbar region, SB and EFS groups showed a significantly lower ($P < 0.05$) bone incidence and an higher fat percentage than EFSP group. A favourably high meat to bones and tendons ratio in bulls was also confirmed in a study by Chambaz *et al.* (2003).

Dietary treatment did not influence the *Ll* muscle pH values (Table VI). Similarly, Bidner *et al.* (1986) and Morris *et al.* (1997) observed no change in muscle pH between cattle fed pasture and concentrate. The L* colorimetric index of *Ll* samples from control-SB group showed the lower value ($L^* = 34.16$; $P < 0.01$) compared to those of

EFS and EFSP dietary groups (Table VI). No significant differences were observed between experimental groups regarding WBS force of *Ll* muscle. The chemical analysis of *Ll* muscle (Table VII) showed that feeding pasture influenced the meat in terms of higher moisture than the other two groups (P<0.01); moreover, when steers fed flaxseed (with or without pasture) a lower protein content was reported compared to the control-SB group (*P*<0.05). The meat fat percentage of steers fed EFSP was significantly lower (1.08%) than those in EFS (1.85%; P<0.01) and SB (1.62%; P<0.05) groups. This findings is also confirmed by the anatomical dissection data and by the accumulation of kidney fat. These results have the same trend reported in *Longissimus dorsi* muscle from animals fed concentrate and pasture (Yang *et al.*, 2002; Keane and Moloney, 2009).

Table VI.- The pH, colour indices and Warner-Bratzler Shear (WBS) force values of *Longissimus lumborum* muscle.

Item	Diet			SED
	EFS	EFSP	SB	*df* = 15
pH_1	6.08	6.08	6.92	0.119
pH_2	5.51	5.48	5.54	0.076
*L**	37.72 A	37.62 A	34.16 B	1.642
*a**	15.48	16.15	15.58	2.101
*b**	11.79	13.15	11.94	1.781
Chroma	19.52	20.30	19.68	1.327
Hue	37.15	37.23	37.14	4.134
WBS, kg/cm^2	3.35	3.53	2.81	0.465

SB, soybean-based diet; EFS, extruded flaxseed-based diet; EFSP, extruded flaxseed-based diet + pasture;
pH_1, pH at slaughter; pH_2, pH at 24 h post mortem
A, B : *P*<0.01

Table VII.- Proximate meat chemical composition (%).

Item	Diet			SED
	EFS	EFSP	SB	*df* = 15
Moisture	73.97 B	74.65 A	73.72 B	0.398
Protein	21.55b	21.39 b	22.02 a	0.441
Lipid	1.85 A	1.08 Bb	1.62 a	0.391
Ash	1.20	1.22	1.30	0.066

SB, soybean-based diet; EFS, extruded flaxseed-based diet; EFSP, extruded flaxseed-based diet + pasture;
a, b: *P* < 0.05; A, B: *P* < 0.01

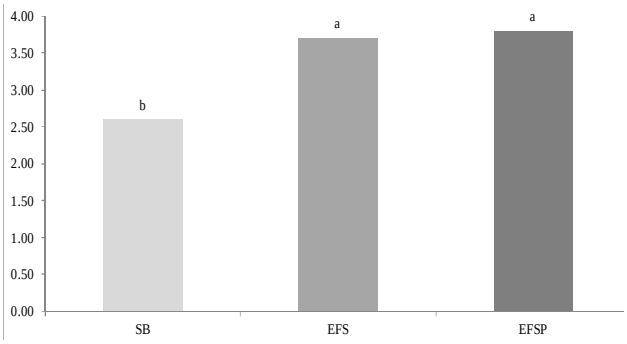

Fig. 1. α-tocopherol content (µg/g) in *Longissimus lumborum* muscle from soybean (SB), extruded flaxseed (EFS) and extruded flaxseed+pasture (EFSP) groups . [a, b] *P* < 0.05

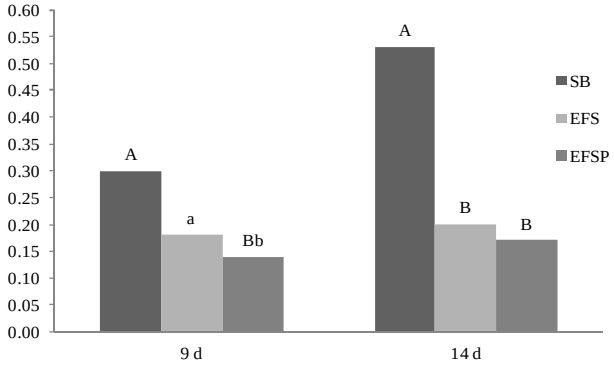

Fig. 2. Malondialdehyde (MDA, mg/kg) values at 9 and 14 days post slaughtering in *Longissimus lumborum* muscle from soybean (SB), extruded flaxseed (EFS) and extruded flaxseed+pasture (EFSP) groups. [A,B] *P* < 0.01; [a, b] *P* < 0.05

The α-tocopherol level in *Longissimus lumborum* meat of Podolica bulls fed EFS and EFSP were higher (P<0.05) than those in control-SB group (Fig. 1). The α-tocopherol level of SB group (2.68 µg/g) was considerably higher than values reported by Chan *et al.* (1995) and Liu *et al.* (1996). The α-tocopherol contents observed in *Ll* of EFS and EFSP groups were comparable despite the different amount of feed consumed (7.85 vs. 5.35 kg/d, respectively) with the relative contributions of vitamin E; this results could be attributed to the fact that the steers in EFSP group have integrated the

level of vitamin E with the pasture. The meat malondialdehyde (MDA) values, detected nine days after slaughter, of group fed EFSP (0.14 mg/kg) were significantly lower compared to control-SB ($P < 0.01$) and EFS ($P<0.05$) groups (Fig. 2). At 14 days after slaughter, the meat oxidation level of control-SB diet (0.53 mg/kg) was significantly higher ($P < 0.01$) compared to the other two dietary treatments (Fig. 2). Arnold *et al.* (1992) stated that in *Ll* muscle, in order to obtain an optimum colour and lipid stability, a level of 3.3 μg/g MDA is enough. The vitamin E content of food inhibited lipid oxidation during the storage period; in fact, at the end of the storage period, the MDA-values of meat samples of SB-group were considerably higher than those noticed in groups EFS and EFSP, respectively. This trend is also in agreement with the findings of Cifuni *et al.* (2004) and Lauzurica *et al.* (2005). Steers fed EFSP with respect to EFS, even in the presence of the same levels of tocopherol in muscles, showed a lower lipid oxidation at nine days, and this could be attributed to the presence of other antioxidants in the forage and/or to a different quantity and PUFA content of muscle lipids.

The meat FA compositions of Podolica bulls fed the experimental diets are presented in Table VIII. The dietary treatments did not cause statistical difference between SFA and MUFA content of meat, while the PUFA level was positively affected ($P < 0.01$) by pasture feeding (7.07%) compared to group control-SB group (6.01%). Pasture feeding had a positive impact on the meat FA composition decreasing ($P<0.01$) the palmitic acid content (25.0%), which is not considered good for human health, compared to the other groups (27.06%). The use of extruded flaxseed increased ($P<0.01$) the α-linolenic acid in groups EFS and EFSP (0.70 and 0.72%, respectively) than in control (0.25%). These results are also confirmed by several authors (Geay *et al.*, 2001; Scollan *et al.*, 2002). The percentage of C18:3n-6 was increased ($P < 0.05$) in grazing bulls compared to those in EFS and SB groups (0.11 *vs.* 0.08 and 0.06%, respectively); a similar trend was found for the C20:3n-3 and C20:4n-6 FAs. Moreover, the C22:5ω-3 concentration was higher ($P < 0.05$) in groups fed extruded flaxseed (with or without pasture) than in control diet. The highest values of n-3 found in groups EFS and EFSP resulted in the best ($P<0.01$) n-6/n-3 ratio (4.78 and 4.48, respectively) compared to SB-group. These values comply with the recommendations provided by the Department of Health (1994) regarding the human health quality, whereas meat from steers fed soybean provided the higher ratio (8.38). The prevention of atherosclerotic events is particularly interesting for the consumer, therefore the reduction of SFA in the diet is highly recommended (Gurr, 1992). Furthermore, the production of meat containing high concentrations of PUFA is of considerable interest because of PUFA are considered as functional ingredients capable of reducing the incidence of coronary heart disease and

Table VIII.- Fatty acid composition (% of total fatty acid) and health related indexes of *Longissimus lumborum* muscle.

Item	Diet			SED
	EFS	EFSP	SB	*df* = 15
C12:0	0.07	0.07	0.12	0.013
C14:0	3.48	2.93	3.08	0.554
C14:1	0.80 A	0.50 B	0.60	0.173
C15:0	0.36	0.41	0.39	0.058
C15:1	0.12 B	0.17 Aa	0.14 b	0.023
C16:0	27.06 A	25.00 B	27.06 A	1.259
C16:1n7	3.48	2.70	3.06	0.674
C17:0	0.87 b	1.05 a	1.00	0.144
C17:1	0.64	0.62	0.65	1.121
C18:0	14.42	16.93	15.18	2.232
C18:1n□7	1.35	1.25	1.35	0.173
C18:1n□9	40.55	40.94	41.18	1.885
C18:2n□6	3.68	3.90	3.70	0.385
CLA	0.53	0.58 a	0.43 b	0.108
C18:3n□3	0.70 A	0.72A	0.25 B	0.049
C18:3n□6	0.08 b	0.11 a	0.06 b	0.013
C20:0	0.08 b	0.12 Aa	0.07 B	0.023
C20:1n□9	0.16	0.18	0.16	0.036
C20:3n□3	0.23 b	0.33 a	0.25	0.073
C20:4n□6	1.12 b	1.16 a	1.11 b	0.034
C20:5n□3 (EPA)	0.08	0.11	0.09	0.030
C22:5n□3 (DPA)	0.10 a	0.10 a	0.06 b	0.027
C22:6n□3 (DHA)	0.02	0.04	0.03	0.016
SFA	46.34	46.53	46.85	2.625
MUFA	47.11	46.40	47.14	2.447
PUFA	6.55AB	7.07 A	6.01 B	0.508
MUFA+PUFA	53.66	53.47	53.15	2.625
n-6	5.41	5.77	5.32	0.417
n-3	1.14 Ab	1.30 Aa	0.69 B	0.129
n-6/n-3	4.78 B	4.48 B	7.89 A	0.837
Atherogenic index	0.77	0.69	0.74	0.086
Thrombogenic index	1.51	1.49	1.60	0.156

SB, soybean-based diet; EFS, extruded flaxseed-based diet; EFSP, extruded flaxseed-based diet + pasture;
a, b: $P < 0.05$; A, B: $P < 0.01$.

other chronic diseases.

In conclusion, feeding pasture associated with extruded flaxseed, despite providing growth performance and carcass yield similar to the other dietary treatments, resulted in a positive effect on the meat lipid profile, leading to a reduction of perirenal and intramuscular fat. Dietary extruded flaxseed and pasture enhanced the meat brightness, CLA and arachidonic acid contents, PUFA as well as total n-3 FA. Moreover, the high vitamin E content in feeds and pasture inhibited meat lipid oxidation during the storage. Thus, feeding extruded flaxseed and pasture improved meat nutritional value offering an alternative method for enhancing the quality and marketability of Podolica bull meat.

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