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Meat quality of Maremmana young bulls

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ABSTRACT. Maremmana is a local Italian breed reared in southern Tuscany and northern Latium. Twenty-two young bulls were reared in pasture system with concentrate supply (PSCS), whereas 20 young bulls were reared in feedlot intensive system (IS) in order test differences between meat typologies. The bulls were slaughtered at 18 months old. The performances at slaughtering were similar between finishing systems. IS bull meat has shown higher cooking loss than PSCS bull meat ($p < 0.001$), higher moisture content ($p < 0.01$), and fat ($p < 0.001$), and lower crude protein ($p < 0.001$). The SFA, MUFA and PUFA percentage were similar between meat typologies; whereas if considered in mg per 100 gr of muscle MUFA and SFA content was higher in PSCS meat ($p < 0.05$). Among the Healthy Indices, C18:2/C18:3 was higher in IS System (14.08 *vs*. 9.77; $p < 0.001$); the results of the PCA (Principal Component Analysis) of fatty acids composition showed that PSCS meat was characterized by MUFA and SFA, while IS meat was identified by C18:2/C18:3, and ω6/ ω3.

Keywords: husbandry system; Maremmana cattle; meat quality; fatty acids; PCA.

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Introduction

A Maremmana cattle is an Italian breed registered in the Tuscan breed Regional List (Tuscan Regional Law 64/2004) with enough 10.000 animals in 221 farms. This breed, having ancient origins, is phenotypically close to the aurochs (*Bos primigenius*) ancestors (Di Lorenzo et al., 2018). Maremmana cattle are traditionally reared in woodlands alternated with clearings. Because its large skeletal and integumentary system development, the Maremmana breed shows low slaughter yield; the muscle masses, especially in the hind quarter, are poor developed. The feed-lot system seems to improve *in vita* performances (Dias et al., 2017) and the dressing percentage (Sargentini et al., 2010). The feedlot system was introduced in Italy from America (Gallo, De Marchi, & Bittante, 2014). In Europe and in Italy, this system is uncommon because the main practice is the fattening stabulation system (Summer, Lora, Formaggioni, & Gottardo, 2019; Cozzi, Brscic, & Gottardo, 2009). As observed by Casagrande et al. (2013) in Nellore heifers raised in Brazil, the feedlot system can be carried out also in Maremmana breed in the phase from weaning to slaughter in order to promote the weight gain. The feed-lot system allows having carcasses with optimal weight and conformation throughout the year, integrating and reducing the grazing period, and/or replacing grazing, especially during the summer, when the dry climate allows to lack both in quantity and in quality of pasture.

Aim of the study was to compare the physical, chemical and nutritional meat characteristics of Maremmana cattle reared under two different systems: one, more traditional, is an extensive grazing system with concentrated supplementation, and the other one is an intensive system, in feed-lot with hay and concentrate feeding.

Material and methods

In this trial were compared the performances at slaughtering and the physical-chemical and nutritional characteristics of *Musculus Longissimus dorsi* samples deriving from Maremmana young bulls. All animals were kept together their mother in pasture from birth to weaning (at 10 months of age about). After weaning, 22 young bulls were reared on pasture system with concentrate supply (PSCS), and 20 on intensive system (IS) in feedlot with *ad libitum* poliphite hay and concentrate supply. The organic concentrate, having 1 MFU kg^{-1} of dry matter (D.M.) and 180 g kg^{-1} D.M. of crude protein, were the same in both groups: barley (80%), faba beans (10%) and peas (10%). All animals (PSCS and IS) were slaughtered at 18 months of age.

In PSCS the composition of pasture was: *Bromus erectus, Bromus sterilis, Bromus sp., Dactylis glomerata, Festuca sp., Lolium italicum, Lolium perenne, Poa bulbosa, Poa trivialis, Poa sp., Phleum pratense*, *Lotus corniculatus, Onobrychis viciifolia, Trifolium pratense, Trifolium repens, Achillea sp., Convolvolus sp., Plantago lanceolata, Senecio vulgaris*. The fresh pasture content was 29.2 g 100 g^{-1} of Dry Matter (D.M.) and D.M. Chemical composition was: Crude protein 8.4%, Ether extract 2.9%, Crude fibre 34.2%, Ashes 7.4%. The nutritive values of pasture were 0.56 French Meat Forage Unit (MFU)/kg of DM. Until 15 months, administered and intake concentrated feeds were 0.500 kg 100 kg^{-1} live weight. From 15 to 18 months (fattening period) the fresh grass consumption, estimated comparing grazed areas with ungrazed areas, was on average 20.0 kg/head/day. In the same age range the concentrate supplementation, entirely consumed, consisted of 0.75 kg 100 kg^{-1} live weight. In the IS the animals were fed with *ad libitum* poliphyte hay, having 88.0 g 100 g^{-1} of DM; the DM chemical composition was: Crude protein 9.6%, Ether extract 2.3%, Crude fibre 35.1%, Ashes 7.2%. The nutritive value of hay was 0.40 French Meat Forage Unit (MFU) kg^{-1} of DM. Until 15 months, administered and intake concentrate feeds were 0.500 kg 100 kg^{-1} live weight. From 15 to 18 months 1 kg of concentrate per 100 kg of body weight was supplied. The young bulls were slaughtered according to the EU Regulation (European Parliament and Council. Regulation of 22 May 2001 - Official Journal, L 147, 31/05/2001), and the dressing percentage was calculated; the carcasses were refrigerated at 4°C for 15 days and evaluated for the conformation and the fat score according to the rules of the EU (S) EUROP grid and following the scale of 15 points obtained by subdividing each EU class in three sub-classes, as reported by Sargentini et al. (2010). Fifteen days after slaughtering, in the cut from the eleventh to the thirteenth rib of each carcass, samples of *Musculus longissimus dorsi* were taken. On these samples, according to Sargentini et al. (2010) were determined: water holding capacity, determined either as cooking loss in oven, drip loss and free water. Meat colour was determined using a Minolta Chromameter CR 200 (CIE L, a* and b*). Chroma (color saturation – $(a^2+ b^2)^{1/2}$) and Hue angle (arctan b/a) were also calculated. Shear force was performed on raw and cooked meat with a Warner Bratzler Instron apparatus. Chemical analyses were carried out on each sample of muscle determining dry matter, ether extract, crude protein and ash, according to Association Official Analytical Chemistry (AOAC, 2005).

The samples were also analysed for total lipid concentration by gravimetric determination of total lipid extract and for quantitative fatty acid composition of total lipids by gas chromatographic separation of methyl esters – comprising C19 as internal standard – on capillary column oven temperature ranging from 164°C and 200 °C with 3°C/min heat increment, as reported by Sargentini et al. (2010). The fatty acid composition was expressed both a proportion of total fatty acids identified and as mg per 100 gr of fresh muscle. The following Health Indices were calculated: MUFA/SFA (monounsaturated fatty acids/saturated fatty acids); PUFA/SFA (polyunsaturated fatty acids/saturated fatty acids); ω6/ω3 (polyunsaturated ω6/polyunsaturated ω3) C18:2/C18:3 (linoleic acid/linolenic acid) C14:0 + C16:0 (myristic acid + palmitic acid); DFA (Desirable fatty acids: unsaturated fatty acids + stearic acid C18:0). Atherogenicity (AI) and Thrombogenicity (TI) Indices were calculated according to Ulbricht and Southgate (1991).

Data were submitted to analysis of variance through the least squares method (Statistical Analysis Software [SAS], 2004), and considering as source of variance the husbandry system: PSCS, IS. On the fatty acids and on the Health Indices a PCA was performed, to individuate the presence of these parameters in both farming systems through the axis deriving from the correlation matrix and extracting the Eigenvalues with different factorial load. A Kaiser-Guttman rule was considered to determinate the more significant eigenvalues. After, to maximize the factors variance, a VARIMAX rotation was performed, as reported by Sargentini, Tocci, Martini, and Bozzi (2018). The score plots for system farming, loading plots were also performed.

Results and discussion

No differences were found on slaughtering performances between farming systems (Table 1). The slaughtering performances and carcass evaluation agreed with the parameter found by Sargentini et al. (2010) in Maremmana bulls slaughtered at 18 months. The dressing percentage, conformation score and fattening condition score met the results found on Podolian young bulls fed with different hay and concentrate ratio (Marino et al., 2006); the Podolian breed is an Italian local breed having common ancestors and similar morphological characteristics of Maremmana cattle. If compared with other local breeds of other countries, the Grey Hungarian bulls in Europe and the Purunã bulls in Brazil, the dressing percentage of this study was slightly lower (Holló, Nuernberg, Somogyi, Anton, & Holló, 2012; Ito et al., 2010).

Table 1. Slaughtering performances.

		IS	PSCS	RSD	sign
Live weight	kg	536.75	536.95	63.67	n.s.
Warm carcass	kg	282.18	278.7	39.06	n.s.
Dressing percentage	%	52.54	51.69	2.04	n.s.
Conformation score*		8.00	8.33	0.56	n.s.
UE grid		R	R		
Adiposity score*		5.55	5.81	0.83	n.s.
UE grid		2+	2+		

*15 points scale – ASPA, 1991; n.s. not significant.

The physical characteristics showed that also the meat shear force on cooked meat was not different between trials, but the IS young bull meat had higher cooking loss, Lightness, and Hue Angle (Table 2). Colour parameters were higher than those found by Sargentini et al. (2010) in coetaneous animals. If compared with the Podolian bull meat (Braghieri et al., 2007) lightness and yellowness were higher in this study.

Table 2. Meat physical characteristics.

		IS	PSCS	RSD	sign
		Water holding capacity			
Cooking loss	%	37.14	30.78	5.14	***
Drip loss	%	1.76	2.01	1.00	n.s.
Free water	cm2	10.99	11.87	1.97	n.s.
		Tenderness			
Shear force on oven cooked meat	kg	9.67	7.76	2.23	n.s.
		Color (CIE L*a*b*)			
Lightness	L*	42.85	40.59	2.59	**
Redness	a*	20.02	21.36	1.78	n.s.
Yellowness	b*	10.20	8.98	1.89	n.s.
Hue angle		0.47	0.38	0.07	***
Chroma (color saturation)		22.50	24.08	2,18	n.s.

n.s. not significant; **p < 0.01; *** p < 0.001.

In PSCS meat, the cooking loss agreed with the same parameter found on Podolian bull meat deriving from animals raised outdoor and receiving a diet at 15% Crude Protein of Dry Matter (Marino et al., 2011). At the contrary of this study, the cooking loss of Podolian meat reared under intensive and extensive systems was higher in outdoor conditions (Marino et al., 2011). The meat shear force on cooked meat was on average similar to the value found by Sargentini et al. (2010) on Maremmana young bulls slaughtered at 18 months. On the contrary, in the Podolian breed the animals reared outdoor had harder meat (Marino et al., 2011). The lightness of PSCS and IS meats and the redness of PSCS meat agreed with the same parameters found in Maremmana young bulls slaughtered at 18 months (Sargentini et al., 2010). Among the chemical characteristics, the moisture and fat content were higher in the meat of animals reared under IS, and PSCS young bull meat showed higher crude protein (Table 3).

Table 3. Percentage meat chemical composition.

	IS	PSCS	RSD	sign
Dry matter	24.42	24.85	0.63	**
Moisture	75.58	75.15	0.63	**
Crude protein	21.23	22.31	0.94	***
Fat	2.62	0.90	0.32	***
Ashes	1.10	1.12	0.07	n.s.

n.s. not significant; **p < 0.01; *** p < 0.001

IS and PSCS meat moisture, crude protein, fat and ash content met the values found in the Maremmana breed in previous studies (Sargentini et al., 2010). In a study aiming the Marismena Spanish breed, the meat deriving from feral cattle have shown higher moisture content than the meat deriving from intensive system (Nogales et al., 2017). Some authors claim that the husbandry system does not affect some meat chemical parameters. In a previous study the composition of intensively-reared beef (fed barley and protein supplements with grazing *ad libitum*) was compared with extensively-reared (grazing alone) as two extremes of husbandry practice; analysis of the same muscles from animals on the two systems didn't differ in their content of protein and fat (Harries, Hubbard, Alder, Kay, & Williams, 1968).

In Table 4 the percentage of fatty acid composition on total lipids is shown, and not differences were shown between meat typologies for the fatty acid categories.

Table 4. Fatty acid composition of total lipid (% of total lipids).

Fatty acid	IS	PSCS	RSD	sign
C14:0	1.64	2.05	0.46	***
C14:1	0.23	0.28	0.11	n.s.
C15:0	0.34	0.47	0.14	***
C16:0	22.63	21.96	2.21	n.s.
C16:1	2.23	2.12	0.52	n.s.
C17:0 ai	0.68	0.53	0.14	***
C17:0	1.32	0.90	0.53	**
C17:1	0.90	1.98	0.78	***
C18:0	15.50	16.93	2.18	*
C18:1	30.13	30.86	4.95	n.s.
C18.2	14.42	13.66	3.85	n.s.
C18:3 ω3	1.13	1.44	0.42	**
C18:4 ω3	0.16	0.27	0.12	***
C20:1	0.10	0.19	0.09	***
C20:2 ω6	0.19	0.08	0.10	***
C20:3 ω6	1.23	0.79	0.39	***
C20:4 ω6	4.80	3.78	1.44	*
C20:5 ω3 (EPA)	0.66	0.06	0.25	***
C22:5 (DPA)	1.33	0.99	0.54	*
SFA	42.13	42.86	4.02	n.s.
MUFA	33.49	35.24	4.88	n.s.
PUFA ω6	20.64	18.31	5.26	n.s.
PUFA ω3	3.29	2.76	1.01	n.s.
Total PUFA	23.93	21.07	5.92	n.s.

n.s. not significant; *p < 0.05; **P<0.01; *** p < 0.001.

Among the SFA, C18:0 was higher in PSCS meat. Ω6 single fatty acids were in higher content in IS young bull meat. Among ω3 single fatty acids, C20:5 ω3 (EPA) and C22:5 ω3 (DPA) content was higher in IS young bull meat. On Table 5 the fatty acid composition in mg per 100 grams of *Musculus longissimus thoracis* is shown.

Table 5. Meat fatty acids content (mg per 100 g of fresh muscle).

Fatty acid	IS	PSCS	RSD	sign
C14:0	16.02	25.69	11.28	***
C14:1	2.48	3.55	2.02	n.s.
C15:0	3.35	5.86	2.76	***
C16:0	217.22	274.87	96.42	n.s.
C16:1	22.33	26.04	11.83	n.s.
C17:0 ai	6.50	6.69	2.90	n.s.
C17:0	12.77	11.13	7.25	n.s.
C17:1	8.84	21.00	6.09	***
C18:0	150.09	204.89	72.95	**
C18:1	287.82	387.77	163.52	n.s.
C18.2 ω6	135.32	148.19	30.26	n.s.
C18:3 ω3	13.20	15.53	8.19	n.s.
C18:4 ω3	1.51	3.71	1.16	***
C20:1	0.89	2.16	1.10	***
C20:2 ω6	1.77	0.97	1.17	**
C20:3 ω6	12.20	8.52	4.36	***
C20:4 ω6	45.90	39.35	12.70	n.s.
C20:5 ω3 (EPA)	3.51	4.68	1.41	**
C22:5 ω3 (DPA)	12.31	10.17	3.73	n.s.
SFA	405.96	529.13	188.89	*
MUFA	322.23	440.53	177.02	**
PUFA ω6	149.29	157.58	33.55	n.s.
PUFA ω3	30.31	32.40	9.89	n.s.
Total PUFA	179.59	189.99	37.45	n.s.

n.s. not significant; * P<0.05; **p < 0.01 ***p < 0.001.

Among the fatty acid categories, PSCS young bull meat showed higher SFA and MUFA content. Among the Health Indices, only C18:2ω6/C18:3ω3 was higher in IS young bull meat (Table 6). DFA were not different between meats. AI and TI were similar in both farming systems.

Table 6. Health Indices

	IS	PSCS	RSD	sign.
MUFA/SFA	0.80	0.82	0.09	n.s.
PUFA/SFA	0.57	0.51	0.18	n.s.
ω6/ω3	6.62	6.82	1.57	n.s.
C18:2/C18:3	14.08	9.77	3.96	***
C14:0 + C16:0	24.28	24.02	2.55	n.s.
DFA	72.93	73.24	5.50	n.s.
AI	0.56	0.58	0.08	n.s.
TI	0.81	0.84	0.09	n.s.

n.s. not significant; ***p < 0.001.

On PCA for the percentage of fatty acids on total lipids, the Kaiser test individuated 5 eigenvalues that reached 82.92% of the total variability; PC1 explained 39.10%, while PC2 17.40% of the total variability (Figure 1).

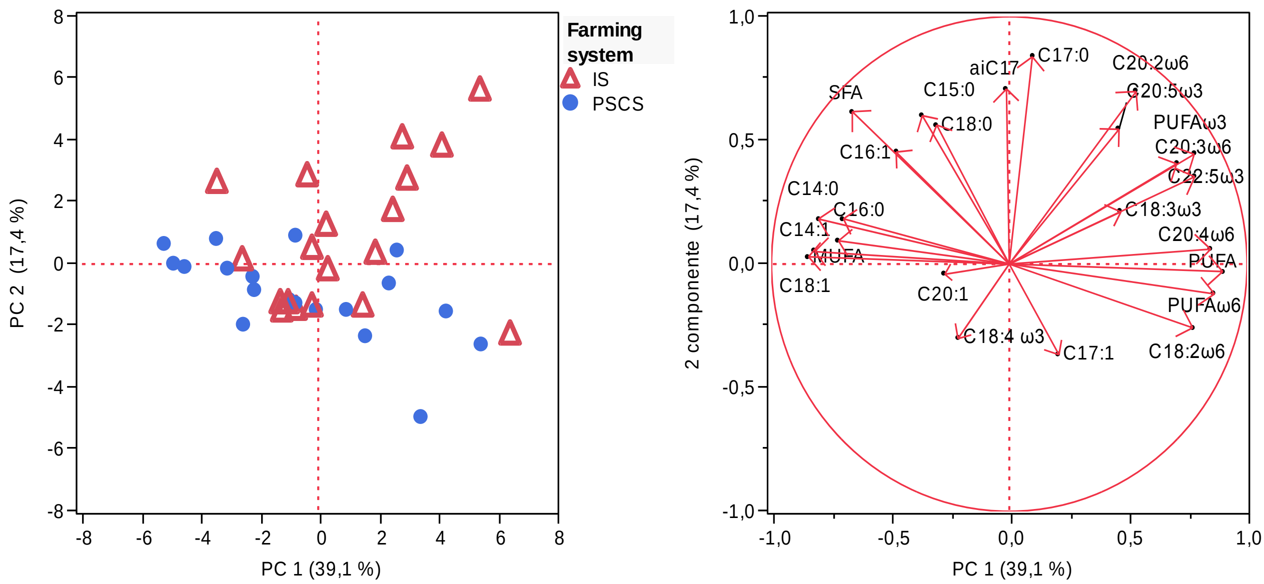

Figure 1. Load and score plots of fatty acids composition (% of total lipids)

The score plot showed how single fatty acids and fatty acid categories were evenly distributed in the PC1. PC1 and PC2 quite identified both farming systems: ω3 and ω6 fatty acids identified PSCS meat. The percentage of fatty acid categories in IS and PSCS meat agreed with the Maremmana literature results (Sargentini et al., 2010), and only PUFA ω3 content was lower in this study. Among the SFA, C18:0 was on average similar to that found by Sargentini et al. (2010). SFA content of both meats of the trial was lower than the Marismena cattle breed reared under feral conditions (Nogales et al., 2017). Among the MUFA C18:1 content was higher than the same parameter found by Sargentini et al. (2010). EPA in IS meat was slightly lower than the EPA content found on Maremmana young bulls slaughtered at 18 months, whereas the same parameter in PSCS meat was very lower; DPA content in IS farming agreed with Sargentini et al. (2010), while in PSCS meat was higher.

Among the SFA, C18:0 content, higher in PSCS meat, was similar in IS meat to C:18 content found in Maremmana young bulls meat slaughtered at 18 months (Sargentini et al., 2010). Among the MUFA, C18:1 content in IS meat met the Maremmana literature (Sargentini et al., 2010). Ω6 single fatty acids were more represented in the IS young bull meat, while PSCS have shown higher ω3 content. C22:5ω3 (DPA) content, similar between meats, agreed with the same parameter found by Sargentini et al. (2010), while C20:5ω3 (EPA) content was comparable only with IS meat. The results of the trial for MUFA and SFA content didn't agreed with the Marismena meat, that showed very high values, especially in the meat of bulls reared under

Intensive system (Nogales et al., 2017); also PUFA content of this study was slightly lower than the Marismena meat. The fatty acid composition of the trial, both in % and in mg per 100 gr of meat sample, partially agreed the literature aiming different farming systems. A range of controlled animal experiments showed that high grazing and forage-based diets reduce the total fat and/or nutritionally undesirable SFA (C 12:0, C 14:0 and/or C 16:0) content. On the contrary an increasing concentration of total PUFA, n-3 PUFA and VLC (very long chain) ω3 PUFA (EPA and DHA) in meat, compared with concentrate-based diets (typical for intensive conventional farming systems) (Średnicka-Tober et al., 2016).

Most of Health Indices of IS and PSCS bull meat met the same parameters of Maremmana young bulls slaughtered at 18 months (Sargentini et al., 2010). PUFA/SFA ratio in the meats of this study showed good values in both farmer systems. In this study PUFA/SFA was slowly higher than the Marismena meat, whereas ω6/ω3 was very higher than the feral bull meat and very much lower than the intensively reared Marismena meat (Nogales et al., 2017).

PUFA/SFA ratio is one of the more used Healthy Index to evaluate the nutritional value of fat. The PUFA/SFA ratio is a measure of the propensity of the diet to influence the incidence of coronary heart disease. From a consumer-Health viewpoint, the recommended value for this ratio is 0.4 or higher; some authors (Hunt, Abraham, Marshal, Feldman, and Francis, 2005; Kang, Shin, Park, & Lee, 2005) define an optimum value of 1.0 ± 0.2: i.e. PUFA/SFA ratios should be preferable within the range from ⩾ 0.45 to 1.0. The meats of this trial showed ω6/ω3 ratio slightly higher than 5. A balanced ω6/ω3 ratio 1–2/1 is one of the most important dietary factors in the prevention of obesity (Simopoulos, 2016; Simopoulos, 2002). Nutritionists claim that the desirable ratio ω6/ω3 should be 5 (Özogul & Özogul, 2007).

C18:2/C18:3 ratio in PSCS meat agreed with that of Maremmana young bulls slaughtered at 18 months (Sargentini et al., 2010), whereas C18:2/C18:3 ratio on IS meat was higher. A lower C18:2/C18:3 ratio has been recognized as an important factor driving the bioconversion of C18:3 into DHA because of the competition between the parent ω3 and ω6 fatty acids for desaturation and elongation pathways (Simopoulos, 2016; Simopoulos, 2002). DFA, not different between meats, didn't agree with De la Fuente et al. (2009), which found different values in the meat of bulls reared indoor and outdoor.

AI and TI of this trial showed good characteristics. It is assumed that AI below 0.5 is beneficial for human health (Popova, Ignatova, Petkov, & Stanišić, 2016), while other authors claimed that for lipids of animal origin, the recommended Index of atherogenicity is from 0.5 to 1.0 (Senso, Suárez, Ruiz-Cara, & García-Gallego, 2007). According to Sinanoglou, Batrinou, Mantis, Bizelis, and Miniadis-Meimaroglou (2013), the appropriate values of AI and TI for a healthy diet are under 1.0.

On PCA for mg of fatty acids per 100 g of *Musculus longissimus thoracis*, the Kaiser test individuated 6 eigenvalues that reached 92.12% of the total variability; PC1 explained 46.70%, while PC2 18.80% of the total variability (Figure 2).

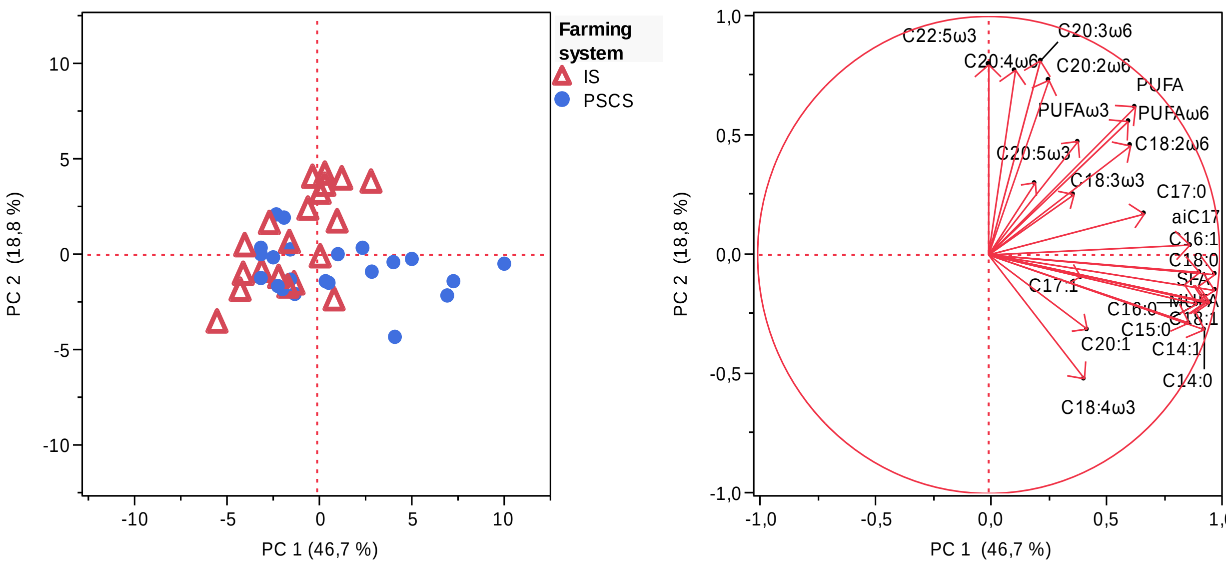

Figure 2. Load and score plots of fatty acids composition (mg per 100 gr of fresh muscle)

PC1 identified enough both groups considered in this trial. PSCS young bull meat was identified mainly for MUFA and SFA categories, while IS young bull meat was not identifiable (Figure 2). On PCA for Health Indices, the Kaiser test individuated 3 eigenvalues that reached 78.75% of the total variability; PC1 explained 41.20%, while PC2 22.50% of the total variability (Figure 3).

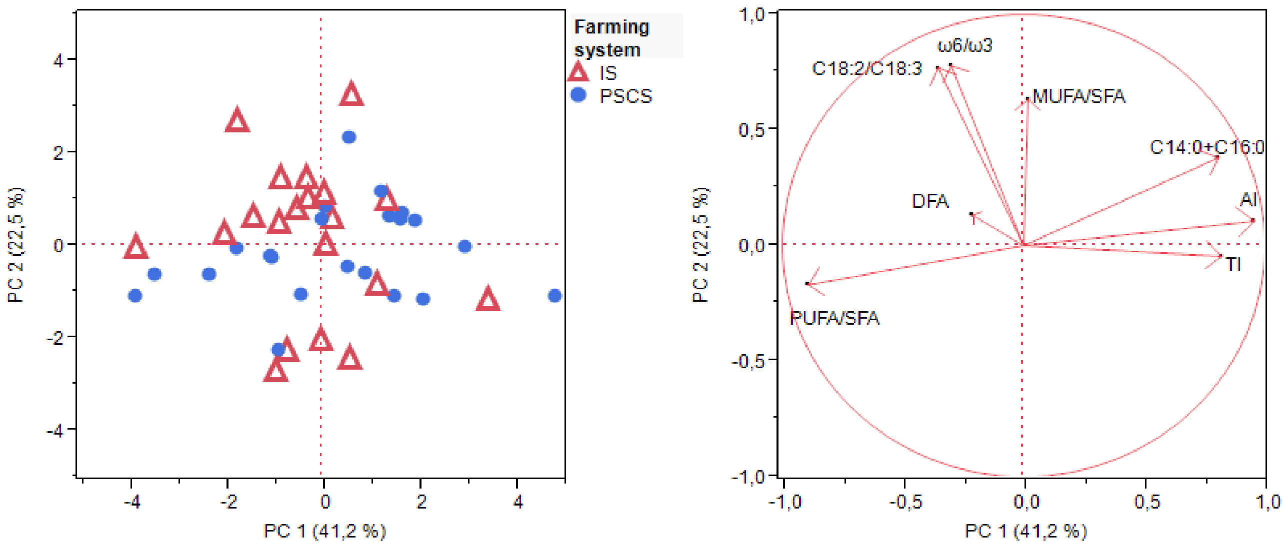

Figure 3. Load and score plots on Health Indices

Health Indices were equally distributed in the Figure. Both PC1 and PC2 didn't identify among feeding system. C18:2/C18:3 and for ω6/ω3 on the upper left quadrant identified many IS young bull meat samples. The PCA for the fatty acid composition in PS and PSCS meat, both in percentage and in mg per 100 gr of meat sample, didn't agree with Średnicka-Tober et al. (2016) for different husbandry systems. Meat deriving from animals reared under pasture system was identified in literature for a higher PUFA, PUFA ω3, EPA and DPA content, while intensive system meat is identifiable for a higher SFA content (Średnicka-Tober et al., 2016). The results of the trial partially agreed with De la Fuente et al. (2009) which compared the fatty acid meat deriving from bulls reared indoor and outdoor. De la Fuente et al. (2009) found that the indoor cattle meat was identified in PCA for C18:2, PUFA, C20:4, while the deriving outdoor beef was identified mainly for MUFA and single unsaturated fatty acids.

The Health Indices in PCA of the trial didn't agree to Średnicka-Tober et al. (2016) which found a lower TI in organic meat; organic livestock production standards prescribe that livestock are to be reared outdoors for a part of the year. As in this study, De la Fuente et al. (2009) found that ω6/ω3 ratio identified the IS deriving meat.

Conclusion

The meat of this trial was of good quality in both considered farming systems; the PSCS meat was leaner with lower SFA percentage, EPA content, and C18:2/C18:3, which plays an important role in human Health. All considered Healthy Indices confirmed the good nutritional quality of Maremmana meat. The PCA for the fatty acids and Healthy Indices on meat identified both husbandry systems: the IS meat was characterized by PUFA, C18:2/C18:3 and ω6/ω3 ratio, while PSCS meat for SFA, MUFA and TI.

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