Effects of two protein sources and energy level of diet on the performance of young Marchigiana bulls.  
2. Meat quality

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ABSTRACT

The aim of this trial was to study the influence of two protein sources (faba bean-FB vs soybean meal s.e.-SBM) and two energy levels of diets given to young Marchigiana bulls on meat quality: water holding capacity (WHC), chemical composition, hydroxyproline and cholesterol contents, fatty acids profile of intramuscular, subcutaneous and perirenal adipose tissues. While chemical composition and WHC was determined only on muscle Longissimus thoracis (LT), hydroxyproline and cholesterol contents were evaluated also on muscles Semitendinosus (ST) and Ileopsoas plus Psoas minor (IP). Eighteen young bulls were divided into three groups. Until the slaughter weight (620 kg) was achieved, two groups, FB and SBM, were fed diets with similar protein and energy contents but differing in protein sources, and the third group was fed high energy (HE) diets. Protein sources did not affect meat nutritional characteristics; but meat of group SBM had high hydroxyproline content: 62.6 vs 60.0 mg 100g\(^{-1}\), respectively, for SBM and FB groups (P<0.05), while compression losses were higher for FB group (7.6 vs 5.7%, respectively, for FB and SBM groups; P<0.01). As respects the comparison among content of hydroxyproline in the different muscles: IP, corresponding to the tenderloin, showed significantly lower concentrations than the other muscles (55.2 vs 60.7 and 63.5 mg 100g\(^{-1}\) for IP, LT and ST, respectively; P<0.01). Feeding regimes did not affect muscular cholesterol content (average values of 53.6, 55.5 and 52.1 mg 100g\(^{-1}\) of fresh muscle for FB, SBM and HE, respectively) which was similar to the levels found in meat from specialised Italian beef breeds and lower than those from other breeds. As respects the differences in cholesterol contents among the muscles, IP showed lower contents than other muscles (50.9 vs 54.1, 56.0 mg 100g\(^{-1}\), respectively for IP, ST, LT; P<0.05). The higher energy diets induced higher concentration of saturated fatty acids, in particular of palmitic and of stearic acid, in intramuscular fat which worsened significantly atherogenic (AI) and thrombogenic (TI) indexes (AI: 0.67 vs 0.55, 0.50; P<0.05; TI: 1.98 vs 1.61, 1.32; P<0.01; for HE, FB and SBM groups, respectively), and lower content of hydroxyproline (60.0, 62.6 vs 56.8 mg 100g\(^{-1}\), P<0.01 for FB, SBM and HE groups, respectively). The fatty acid profile of subcutaneous and perirenal adipose tissues was not affected by any of studied factors. A part of feeding scheme adopted, from these results it is possible to formulate a favourable assessment of the nutritional characteristics of Marchigiana meat.

Key words: Marchigiana young bulls, Faba bean, Soya bean meal s.e., Dietary energy level, Meat quality.
RIASSUNTO

EFFETTO DI DUE FONTI PROTEICHE E DI DUE LIVELLI ENERGETICI DELLA RAZIONE SULLE PERFORMANCE DI VITELLONI DI RAZZA MARCHIGIANA. 2. QUALITÀ DELLA CARNE.

Scopo di questa prova è stato quello di valutare gli effetti di due fonti proteiche (favino-FB vs soia f.e.-SBM) e di due livelli energetici (normale vs alto) di diete per vitelli di razza Marchigiana, su alcune caratteristiche qualitative della carne: capacità di ritenzione idrica (WHC), composizione chimica, tenori in idrossiprolina e colesterolo, nonché composizione acidica del grasso intramuscolare e del tessuto adiposo perirenale e sottocutaneo. La composizione chimica e la WHC sono state determinate su campioni di Longissimus thoracis (LT), mentre i contenuti in idrossiprolina e colesterolo sono stati determinati anche sui muscoli Semitendinosus (ST) e Ileopsoas più Psoas minor (IP). Diciotto vitelloni dallo svezzamento sono stati divisi in tre gruppi. Fino al raggiungimento del peso di macellazione (620 Kg), due gruppi, FB e SBM, sono stati alimentati con diete isoenergetiche e isoproteiche, ma differenti per fonte proteica, mentre al terzo gruppo, HE, sono state somministrate in ogni fase diete a più elevato apporto energetico. La fonte proteica non ha influenzato sostanzialmente le caratteristiche nutrizionali della carne: mentre la carne del gruppo SBM, è risultata meno ricca in idrossiprolina: 62,6 vs 60,0 mg 100g⁻¹, rispettivamente per i gruppi SBM e FB (P<0,05), la capacità di ritenzione idrica della carne del gruppo FB è risultata più bassa (perdite di compressione: 7,6 vs 5,7%, rispettivamente per i gruppi FB e SBM; P<0,01). Relativamente al confronto dei contenuti di idrossiprolina nei diversi muscoli testati: la concentrazione di idrossiprolina dell'IP, che corrisponde al filetto, è risultata in ogni caso significativamente più bassa rispetto agli altri due muscoli (55,2 vs 60,7, 63,5 mg 100g⁻¹, rispettivamente per IP, LT e ST; P<0,01). La razione non ha influenzato i contenuti di colesterolo (valori medi di 53,6, 55,5 e 52,1 mg 100g⁻¹ di muscolo) che sono risultati simili ai dati presenti in letteratura per le razze italiane specializzate per la produzione della carne, ma più bassi di quelli di altre razze. Per quanto concerne la concentrazione di colesterolo nei diversi muscoli l'IP ha mostrato più basse concentrazioni rispetto a ST e LT (50,9 vs 54,1 e 56,0 mg 100g⁻¹, rispettivamente per IP, ST e LT; P<0,05). L’adozione di livelli energetici più elevati ha provocato una maggiore concentrazione di acidi grassi saturi, in particolare palmitico e stearico, nel grasso intramuscolare, cosa che ha peggiorato significativamente gli indici aterogenico (AI) e trombogenico (TI) (AI: 0,67 vs 0,55 e 0,50; P<0,05; TI: 1,98 vs 1,61 e 1,32; P<0,01; rispettivamente per i gruppi HE, FB e SBM). Tuttavia tale piano alimentare ha migliorato le caratteristiche sensoriali della carne (idrossiprolina: 60,0 e 62,6 vs 56,8 mg 100g⁻¹, rispettivamente per i gruppi FB, SBM e HE; P<0,01). La composizione acidica del grasso sottocutaneo e di quello perirenale non è risultata influenzata da nessuno dei fattori presi in esame. A prescindere dai piani alimentari impiegati dai nostri risultati è possibile formulare un giudizio favorevole sulle caratteristiche nutrizionali della carne di vitelloni di razza Marchigiana.

Parole chiave: Vitelloni Marchigiani, Favino, Farina di estrazione di soia, Livello energetico, Qualità della carne.

Introduction

In the intensive livestock of meat bulls, soya bean meal s.e. is largely used. However, the possible risk associated with GMO use in animal breeding has led to the reconsideration of animal production processes with special reference to the use of alternative protein sources (e.g. faba bean, dried peas, lupine seeds, chickpeas) able to replace soy bean. These legumes have agronomic importance because they improve soil fertility and reduce nitrogenous dressing, with positive effects on environmental pollution. Moreover, they need a limited initial investment for their modest requirements of chemical and energetic inputs and their short culture cycle. In particular, the climactic conditions of the internal areas of the Campania Region have always favoured the faba bean culture.

Several studies on beef production were carried out to improve animal performance
and carcass characteristics. In recent years, as consumer requirements regarding meat quality have largely improved, research has changed its target.

The International Organization for Standardization (ISO) defines quality as “a whole of characteristics able to satisfy the explicit or indefinite consumer’s requirements.” Also, meat quality is a set of attributes, related to hygienic, sensorial, structural, nutritional, and technological characteristics. All these characteristics contribute to influence the consumer’s decision to purchase beef. In particular, the consumer is influenced by the perception of healthiness and a variety of sensory traits (Verbeke and Viaene, 1999).

The variation in beef quality is wide and influenced by many factors, such as breed, age, sex, management, feeding scheme (Moloney et al., 2001; Raes et al., 2003; Sami et al., 2004) the latter being considered one of the most important factors.

Since the early 1980s the interest of medical researchers and consumers in the relationship between nutrition and health has gradually increased. In 1984 the Committee on Medical Aspects of Food Policy (COMA) recognised seven dietary factors which are implicated in coronary heart disease (CHD) development: two are recognised as promoting and the others as protective. The implication of fatty acids in CHD development may be summarised as follows: stearic acid (C18:0) does not raise serum cholesterol; the short-chain (C7-C11) saturated fatty acids (SFA) do not influence the cholesterol concentration in the blood, while lauric acid (C12:0), myristic acid (C14:0) and palmitic acid (C16:0) are recognised as atherogenic factors. As described by Keys et al. (1965), myristic acid is the most atherogenic (with about four times the cholesterol-raising potential of palmitic acid). The longer-chain fatty acids (myristic, palmitic and stearic acids) are thrombogenic; the polyunsaturated fatty acids (PUFA) of the ω-6 (linoleic) and ω-3 (linolenic) acid series and the monounsaturated fatty acids (MUFA) are able to reduce the oxidation of cholesterol.

From all these considerations Ulbricht and Southgate (1991) suggested to calculate the Atherogenic Index (AI) and the Thrombogenic Index (TI) as follows:

\[ AI = \frac{(C12:0 + 4 \times C14:0 + C16:0)}{(ω-3 + ω-6 + MUFA)} \]

\[ TI = \frac{(C14:0 + C16:0 + C18:0)}{(0.5 \times C18:1) + (0.5 \times other \ MUFA) + (0.5 \times 3 \ ω-3) + (ω-3/ω-6)} \]

The utilisation of diets characterised by low AI and TI values could reduce the risk of CHD development.

The most important technological characteristics of meat are pH and water-holding capacity (WHC). The amount of water naturally retained is usually found in the range of 70-80%. Part of this water is lost during processing, such as dripping, evaporation or cooking. However, excessive loss of water generates great dissatisfaction among customers for the following reasons: 1. dripping around the meat generates an unpleasant appearance; 2. during cooking size of meat reduces; 3. loss of sensory properties (i.e. tenderness or juiciness) makes meat less attractive.

As described by Toldrá (2003), the amount of immobilised water depends on the available space within the myofibrillar structure. There are some variations between muscles due to the types of muscle fibres, degree of fibre contraction and pre-rigor pH. Water retention will also depend on the ultimate pH reached after rigor mortis and this has great influence on the activity of muscle enzymes involved in proteolysis and lipolysis during ageing and further processing. Variations may be also expected among animal
species and slaughter age. In particular, the metabolic processes in post-mortem muscle directly affected the WHC.

The aim of this study was to evaluate the influence of dietary protein sources (faba bean vs soya bean meal s.e.) and energy levels on livestock consisting of Marchigiana young bulls. In particular, the effects of both factors on growth dynamics, post-mortem performances have been reported in a previous paper (Cutrignelli et al., 2008), while meat quality parameters, chemical composition and fatty acid composition of intramuscular, subcutaneous, perirenal adipose tissues and WHC are discussed in this paper.

Material and methods

Animals and dietary treatments

Eighteen weaned young bulls (129 d of age) were equally divided into three groups. Each animal was placed in an individual cowshed until the slaughter. Two groups were fed diets with similar protein and energy contents with the same forage/concentrate ratios (F/C), but differing in protein source: faba bean (Vicia faba minor L.) vs soya bean meal s.e. (Soja hispida). The animals of the third group were fed diets higher in energy than the other two groups and with both protein sources in the concentrates. The groups were named according to the administered protein source: faba bean-FB; soya bean meal s.e.-BM and energy level: high energy-HE. For more details on the feeding schemes and food characteristics see the companion paper of Cutrignelli et al. (2008).

All subjects were slaughtered at the fixed live weight of 620 kg (540 and 500 d of age, for FB, SBM, and HE group, respectively) in an authorised slaughterhouse according to EU legislation.

After 9 days of refrigeration at 4±1°C, dissection of the carcasses was carried out. Samples of Longissimus thoracis (LT), Semitendinosus (ST), Iliopsoas plus Psoas minor (IP) muscles, perirenal (PF) and subcutaneous (SF) adipose tissues were collected and rapidly transported, upon refrigeration temperature, to the laboratories for the chemical analysis.

Analytical determinations

To estimate WHC, weight losses were determined on fresh LT sample, collected by the sample cut (Cutrignelli et al., 2008) using the following methods which simulate the usual meat manipulations:

- gravimetric method: refrigeration of a piece (50x50x15 mm) at 4°C for 48 h in a box with a grate (Lundström and Malmfors, 1985);
- compression method: compression of a piece (30x30x15 mm) under a weight of 1 kg for 10 minutes (Grau and Hamm, 1957);
- cooking loss method: cooking of a piece (30x30x15 mm) on electric grill at 300°C until the internal temperature of 70°C was reached (Wheeler et al., 1990);
- cooking loss method: cooking of a piece (30x30x15 mm) in a bain-marie at 70°C for 30 minutes (Gault, 1985).

Part of the muscles and adipose tissues samples were homogenised, divided into different aliquots and frozen (-20°C) until the analysis (chemical composition, cholesterol and hydroxyproline contents, fatty acid composition).

A sample of LT was used to determine the chemical composition according to the AOAC (1990). Samples of LT, ST and IP were used to determine the cholesterol content: the extraction was made according to Naaemi et al. (1995); for its quantification, as suggested by Indyk (1990), a HPLC (Waters) equipped with diode-array detector (mod. 996, Waters) and computer integration system Millennium® was utilised. The operative conditions were the following: temperature 20°C; mobile phase hexane/isopropyl
alcohol (99/1); flow 1 ml/min; Phenomenex Bondclone C18 column (250x4.6 mm); loop 10 μl; wave-length 212 nm; external standard Cholesterol (SIGMA C-8667).

Samples of the same muscles were used to determine the hydroxyproline concentration by spectrophotometer method (ASPA, 1996). This amino-acid represents about 14% of the collagen proteins (Sörensen, 1981) and it is correlated with the values of shear force and with tenderness evaluation by panel test.

Finally, the fatty acid profile of LT fat, PF and SF adipose tissues were determined by gas chromatography (GC). To this purpose the total fat was previously extracted (Folch et al., 1957) and subsequently turned into methyl esters (Christie, 1989). For the quantitative determination a GC ThermoQuest (mod. 8000 Top) connected to “Millennium 32” software was utilised in the following conditions: temperature: oven 1 min at 175°C → 2.5°C/min → 225°C; injector 300°C; detector 280°C; gas: carrier helium 66 kPa; combustible hydrogen 50 kPa; burning air 20 kPa; injection volume 10 μl; split rate 1/50; Omega-Wax™ 320:30 m x 0.32 mm x 0.25 μm film thickness (Supelco) fused silica capillary column; external standard: a solution of 16 single Fatty acid Methil esters (Supelco) was prepared.

Statistical analysis
All data were analysed statistically using the SAS (2000) GLM procedure, according to the following model:

\[ y_{ij} = \mu + \alpha_i + \varepsilon_{ij} \]

where:
- \( y \) = dependent variable; \( \mu \) = mean; \( \alpha \) = dietary effect (\( i \) = FB, SBM, HE); \( \varepsilon \) = error.

For the hydroxyproline and cholesterol data, the statistical analysis was performed with the following model:

\[ y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk} \]

where:
- \( y \) = dependent variable; \( \mu \) = mean; \( \alpha \) = dietary effect (\( i \) = FB, SBM, HE); \( \beta \) = muscle effect (\( j \) = LT, ST, IP); \( \alpha\beta \) = interaction diet x muscle; \( \varepsilon \) = error.

Planned comparison among the groups (FB+SBM vs HE) and among the muscles (LT+ST vs IP) was estimated using orthogonal contrasts.

Results and discussion
In Table 1 the water holding capacity and chemical composition of Longissimus thoracis muscle are reported. WHC was never influenced by the administration of high energy diets (HE). As observed by Fiems et al. (1999) and by Sami et al. (2004) diet energy level had no significant effect on cooking losses. By contrast, Vestergaard et al. (2000a) found higher cooking loss in extensively than in intensively fed bulls.

The animals fed FB showed significantly higher water losses, with the compression method. Due to the high variability of the results the method of cooking on electric grill, proposed by Wheeler et al. (1990), could be considered less reliable. Our grilling loss data were higher than those reported by Sami et al. (2004) in Simmental young bulls but they were in agreement with those reported by Den Hertog-Meischke et al. (1997) for crossbreed Piemontese x Friesian young bulls. Pen et al. (2005) found results similar to the ones of this trial, cooking ST samples of Holstein steers in an oven, on the contrary our drip loss data resulted higher than that reported by these authors.

The chemical composition of LT was not statistically different among groups. Nevertheless, the meat of group HE had higher fat content than the other two. Therkildsen et al. (1998) reported for Friesian young bulls that high dietary energy level significantly increases the fat score, which largely reflects
the amount of subcutaneous fat on the carcass, generally accompanied by an increase in marbling fat which can influence meat composition and palatability. Meat from all the groups showed a very low fat content (<3%) and higher protein concentrations than the Holstein steers (Pen et al., 2005), confirming the high quality of the Marchigiana meat.

In Table 2, hydroxyproline and cholesterol contents of Longissimus thoracis, Semitendinosus and Iliopsoas plus Psoas minor were reported. Hydroxyproline content were significantly (P<0.01) higher in groups FB and SBM than in HE, probably due to the higher fat deposition registered (Cutrignelli et al., 2008) in the latter animals, which, as indicated by Wood et al. (1999), determines a dilution of fibrous protein by soft fat. Our results agree with those reported by Leander et al. (1978), Martin et al. (1978), Aberle et al. (1981) and Vestergaard et al. (2000b); on the other hand Bidner et al. (1981), Hall and Hunt (1982) and Maltin et al. (2001) found that energy intake had no steady effect on meat tenderness. The differences are probably due to the different age and weight at slaughtering among the trials. The IP samples, which correspond to the tenderloin, showed in all the groups significantly (P<0.01) lower hydroxyproline concentrations than the other two muscles; also between the LT and ST muscles the differences were statistically significant (P<0.05) being lower for the former.

Cholesterol values were not influenced either by protein sources or by feeding plan. The latter observation agrees with the results obtained by Cutrignelli (2000) on Podolian young bulls and by Poli et al. (1996) on Chianina young bulls.

Considering the differences among the muscles, cholesterol values were signifi-
Several authors found no differences in cholesterol contents among muscles (Bohac and Rhee, 1988; Cifuni et al., 2004), while others (Eichhorn et al., 1986; Browning et al., 1990; Rusman et al., 2003) found significant differences. This contradiction is probably due to the different muscles analysed in each experiment: indeed Bohac and Rhee (1988) and Cifuni et al. (2004) utilised the Longissimus thoracis, the Semimembranosus and the Semitendinosus, while Eichhorn et al. (1986) and Browning et al. (1990) analysed the Biceps femoris and Longissimus thoracis. As theorised by Wheeler et al. (1987) the cholesterol content may be affected by the different physiological function of the muscles.

In each group, and especially for LT and ST muscles, the cholesterol contents were slightly higher than the value (less than 50 mg 100g\(^{-1}\) of muscle) indicated by the Protected Geographical Indication (PGI) of the “Vitellone Bianco dell’Appennino Centrale” (Council Regulation EEC No 2081/92; Floroni, 2002). Nevertheless, our results are very close to those reported for Italian meat breeds (Poli et al. 1996; Cifuni et al., 2004) and lower than those from other breeds (Morris et al., 1995; Migdal et al., 2004).

Tables 3, 4 and 5 report the fatty acid composition (mg 100g\(^{-1}\) of edible part) and the atherogenic (AI) and thrombogenic (TI) indexes respectively of LT, SF and PF adipose tissues.

Palmitic (C16:0), stearic (C18:0) and oleic (C18:1) acids were the most widely represented fatty acids. In particular, in intramuscular fat, the sum of oleic, stearic and palmitic acids represents over 50% of total fatty acids, according to the observations of Morris et al. (1995), Cifuni et al. (2004) and Migdal et al. (2004).

The feeding system affected fatty acids composition of LT (Table 3); in particular,
the high energy diets caused significantly higher concentrations of palmitic, stearic and total saturated fatty acids-SFA (P<0.01) and linolenic (C18:3; P<0.05) acid, while the arachidic (C20:0; P<0.05) acid was significantly lower in group HE than in the others. Consequently, these differences caused a worsening of the AI and TI which were significantly (P<0.01 and P<0.05, respectively) higher for group HE than for the other two groups. All these differences are probably due to the increased muscular lipogenesis arising from the high-energy feeding plane.

Comparing the data of groups FB and SBM, the only significant (P<0.01) difference was for stearic acid being higher for

Table 3. Fatty acid profile of Longissimus thoracis muscle (mg 100g⁻¹ of edible part).

|        | FB       | SB       | HE       | Significance          |
|--------|----------|----------|----------|-----------------------|
|        |          |          | HE vs FB+SB | FB vs SB   |
| C₁₄₀   | 15.1 ± 1.3 | 15.5 ± 0.9 | 15.3 ± 1.3 | ns         | ns         |
| C₁₆₀   | 174.3 ± 21.1 | 169.3 ± 15.8 | 224.6 ± 32.2 | **         | ns         |
| C₁₈₀   | 170.0 ± 19.0 | 140.8 ± 15.6 | 210.6 ± 10.9 | **         | **         |
| C₁₈₁   | 241.3 ± 55.4 | 269.0 ± 30.1 | 249.5 ± 20.3 | ns         | ns         |
| C₁₈₂ω₆  | 138.4 ± 19.8 | 151.4 ± 12.9 | 126.7 ± 23.9 | ns         | ns         |
| C₁₈₃ω₃  | 3.60 ± 1.00 | 3.91 ± 0.32 | 4.62 ± 0.95 | *          | ns         |
| C₂₀₀   | 2.25 ± 0.07 | 1.89 ± 0.50 | 1.45 ± 0.37 | *          | ns         |
| C₂₀₁   | 2.04 ± 0.79 | 2.12 ± 0.67 | 1.66 ± 0.38 | ns         | ns         |
| C₂₀₄ω₆  | 32.4 ± 3.9  | 33.4 ± 6.6  | 38.1 ± 7.2  | ns         | ns         |
| C₂₀₅ω₃  | 2.23 ± 0.61 | 2.42 ± 0.70 | 2.86 ± 0.52 | ns         | ns         |
| C₂₂₀   | 1.08 ± 0.44 | 0.99 ± 0.35 | 1.19 ± 0.11 | ns         | ns         |
| C₂₂₁   | 0.94 ± 0.12 | 0.84 ± 0.27 | 0.88 ± 0.26 | ns         | ns         |
| C₂₂₄ω₆  | 3.45 ± 0.74 | 3.50 ± 1.10 | 3.24 ± 1.02 | ns         | ns         |
| C₂₂₅ω₃  | 5.40 ± 1.02 | 5.87 ± 0.98 | 6.93 ± 0.87 | ns         | ns         |
| C₂₂₆ω₃  | 1.16 ± 0.30 | 1.37 ± 0.28 | 1.30 ± 0.36 | ns         | ns         |
| C₂₄₀   | 2.57 ± 0.38 | 2.05 ± 0.53 | 2.68 ± 0.40 | ns         | ns         |
| SFA    | 365.1 ± 39.1 | 330.6 ± 26.9 | 456.9 ± 53.8 | **         | ns         |
| MUFA   | 244.3 ± 39.5 | 271.7 ± 29.4 | 251.2 ± 10.5 | ns         | ns         |
| PUFA   | 186.6 ± 20.5 | 201.9 ± 15.7 | 183.7 ± 18.3 | ns         | ns         |
| ω₆     | 174.2 ± 19.9 | 188.3 ± 12.9 | 168.1 ± 23.1 | ns         | ns         |
| ω₃     | 12.39 ± 1.5  | 13.57 ± 0.8  | 15.71 ± 0.7  | ns         | ns         |
| AI     | 0.54 ± 0.04 | 0.49 ± 0.07 | 0.66 ± 0.10 | *          | ns         |
| TI     | 1.46 ± 0.12 | 1.20 ± 0.09 | 1.75 ± 0.10 | **         | ns         |

FB: faba bean; SB: soya bean meal s.e.; HE: high energy.
AI: atherogenic index; TI: thrombogenic index.
*: P<0.05; **: P<0.01; ns: not significant.
meat quality of young Marchigiana bulls fed faba bean than for those fed soybean meal s.e. However this result did not significantly affect the SFA concentration, or AI and TI indexes.

Neither dietary energy nor protein source affected the fatty acids composition of the analysed adipose tissues (Tables 4 and 5). This is probably due to the very low concentration of phospholipids in subcutaneous and perirenal fat tissues (Christie, 1981). Our results conflict with those of Zembayashi and Nishimura (1996) who, using the covariance for the percentage of carcass fat, found higher concentration of SFA in subcutaneous adipose tissue when steers were fed high energy diets.

Comparing the fatty acid composition of the three adipose tissues the following differences were noted: the erucic (C22:1), docosahexaenoic (DHA, C22:6, ω-3) eicosapentaenoic (C 20:5, ω-3) and docosapentaenoic (C 22:5, ω-3) acids, were present only in intramuscular fat, due to the lower level of intramuscular fat compared to

Table 4. Fatty acid profile of subcutaneous adipose tissue (mg 100g⁻¹ of edible part).

|       | FB            | SB            | HE            | Significance |
|-------|---------------|---------------|---------------|--------------|
|       | HE vs FB+SB   | FB vs SB      |               |              |
| C_{14:0} | 16.9 ± 4.5   | 19.2 ± 5.5   | 17.1 ± 3.1   | ns           | ns           |
| C_{16:0} | 299.7 ± 60.6 | 341.4 ± 65.5 | 366.7 ± 52.4 | ns           | ns           |
| C_{18:0} | 220.2 ± 18.0 | 221.5 ± 30.9 | 192.4 ± 32.4 | ns           | ns           |
| C_{18:1} | 290.3 ± 71.7 | 271.7 ± 89.8 | 291.6 ± 59.7 | ns           | ns           |
| C_{18:2 ω-6} | 98.7 ± 10.1 | 106.9 ± 30.3 | 110.4 ± 30.6 | ns           | ns           |
| C_{18:3 ω-3} | 4.71 ± 0.32 | 4.31 ± 0.46  | 4.86 ± 0.43  | ns           | ns           |
| C_{20:0} | 2.99 ± 0.43  | 2.63 ± 0.94  | 3.12 ± 0.74  | ns           | ns           |
| C_{20:1} | 0.08 ± 0.01  | 0.07 ± 0.02  | 0.07 ± 0.01  | ns           | ns           |
| C_{20:4 ω-6} | 0.03 ± 0.01 | 0.03 ± 0.01  | 0.02 ± 0.01  | ns           | ns           |
| C_{22:0} | 5.75 ± 1.65  | 6.18 ± 1.87  | 5.71 ± 1.36  | ns           | ns           |
| C_{22:4 ω-3} | 0.75 ± 0.08 | 0.86 ± 0.10  | 0.79 ± 0.09  | ns           | ns           |
| C_{24:0} | 3.45 ± 0.35  | 3.24 ± 0.45  | 2.94 ± 0.42  | ns           | ns           |
| SFA    | 548.1 ± 86.6 | 594.2 ± 59.2 | 587.8 ± 66.7 | ns           | ns           |
| MUFA   | 290.4 ± 71.2 | 270.7 ± 65.8 | 291.7 ± 59.7 | ns           | ns           |
| PUFA   | 104.2 ± 9.7  | 112.2 ± 8.0  | 116.1 ± 30.5 | ns           | ns           |
| ω-6    | 100.4 ± 10.2 | 107.7 ± 6.9  | 110.3 ± 16.1 | ns           | ns           |
| ω-3    | 4.71 ± 0.32  | 4.31 ± 0.46  | 4.86 ± 0.43  | ns           | ns           |
| AI     | 0.93 ± 0.12  | 1.09 ± 0.09  | 1.06 ± 0.05  | ns           | ns           |
| TI     | 2.56 ± 0.18  | 2.88 ± 0.15  | 2.62 ± 0.16  | ns           | ns           |

FB: faba bean; SB: soya bean meal s.e.; HE: high energy.
AI: atherogenic index; TI: thrombogenic index.
ns: not significant.
the two adipose tissues. Lower fat content is associated with fewer and smaller adipocytes containing fewer triglycerides, accompanied by a relative increase in the proportion of phospholipids in total lipids and an increased PUFA content (Scollan et al., 2006);

the proportion of total SFA was minimal in LT and maximal in SF (mean values 46.56 vs 54.50 and 59.35% of total fatty acids; in LT, PF and SF, respectively, Figure 1); the single saturated fatty acids amounts also showed a similar trend. These data are partly in contrast with those of Kim et al. (2004) who in Hanwoo cattle found a higher SFA proportion in perirenal than in subcutaneous fat. Even if the differences in the fatty acids profile between internal and external fat deposits have not been fully elucidated, recently Eguinoa et al. (2003) suggested that the lipogenic enzyme activities per cell could be influenced by several factors such as adipocite size, nutrient supply, etc.;

the proportion of total polyunsaturated fatty acids (PUFA) was higher in LT and lower in the perirenal adipose tissue (mean values 22.23 vs 11.36 vs 11.02% of total

| Table 5. Fatty acid profile of perirenal adipose tissue (mg 100g⁻¹ of edible part). |
|-----------------------------------------------|-----|-----|-------|----------|--------|--------|
| C₁₄:₀ | 15.3 ± 2.2 | 16.24 ± 5.0 | 16.23 ± 2.0 | ns | ns |
| C₁₆:₀ | 265.5 ± 59.9 | 246.5 ± 67.8 | 287.6 ± 49.3 | ns | ns |
| C₁₈:₀ | 173.9 ± 14.2 | 174.9 ± 26.1 | 159.7 ± 21.8 | ns | ns |
| C₁₈:₁ | 252.7 ± 20.2 | 269.3 ± 26.2 | 275.1 ± 16.8 | ns | ns |
| C₁₈:₂ | 83.7 ± 2.9 | 86.7 ± 2.7 | 85 ± 5.3 | ns | ns |
| C₁₈:₃ | 4.47 ± 0.94 | 4.11 ± 1.34 | 3.92 ± 0.66 | ns | ns |
| C₂₀:₀ | 2.39 ± 0.42 | 2.19 ± 0.69 | 2.81 ± 0.42 | ns | ns |
| C₂₀:₁ | 0.08 ± 0.02 | 0.07 ± 0.02 | 0.09 ± 0.01 | ns | ns |
| C₂₀:₄ | 0.03 ± 0.01 | 0.03 ± 0.01 | 0.03 ± 0.01 | ns | ns |
| C₂₂:₀ | 4.69 ± 1.44 | 4.41 ± 1.38 | 4.57 ± 0.97 | ns | ns |
| C₂₂:₄ ω-₃ | 0.55 ± 0.07 | 0.64 ± 0.18 | 0.59 ± 0.05 | ns | ns |
| C₂₄:₀ | 3.07 ± 0.49 | 3.02 ± 0.36 | 2.55 ± 0.80 | ns | ns |
| SFA | 465.7 ± 43.3 | 448.5 ± 21.4 | 477.2 ± 43.2 | ns | ns |
| MUFA | 253.6 ± 15.3 | 269.5 ± 13.8 | 275.8 ± 15.7 | ns | ns |
| PUFA | 89.0 ± 1.96 | 91.8 ± 0.77 | 89.5 ± 4.94 | ns | ns |
| ω-₆ | 84.6 ± 2.85 | 87.7 ± 0.46 | 89.5 ± 5.22 | ns | ns |
| ω-₃ | 4.47 ± 0.94 | 4.11 ± 0.32 | 3.92 ± 0.66 | ns | ns |
| AI | 0.96 ± 0.17 | 0.87 ± 0.07 | 0.97 ± 0.03 | ns | ns |
| TI | 2.50 ± 0.15 | 2.30 ± 0.06 | 2.42 ± 0.26 | ns | ns |

FB: faba bean; SB: soya bean meal s.e.; HE: high energy.
AI: atherogenic index; TI: thrombogenic index.
ns: not significant.
fatty acids, respectively in LT, SF and PF, Figure 1). This difference may be primarily ascribed to the lower concentration of ω-6 PUFA and to the absence of DHA in SF and PF adipose tissues (Table 5 and 6);

the atherogenic and thrombogenic indexes were considerably higher in SF and PF tissues than in LT. This is due to the high SFA concentration of SF and PF adipose tissues as well as to the high PUFA concentration of LT.

The LT fatty acid profile was similar to those reported by Raes et al. (2003) for Longissimus lumborum of Belgian Blue and Limousin beef (SFA: 338 and 506 mg 100g⁻¹ edible portion; MUFA: 323 and 554 mg 100g⁻¹ edible portion; PUFA: 195 and 195 mg 100g⁻¹ edible portion; in Belgian Blue and Limousin bulls, respectively) and different from values found in Irish and Argentine beef. The latter showed significantly higher total intramuscular fatty acid content compared to the former, probably due to genetic selection. However, the values obtained by Poli et al. (1996) on Chianina young bulls were similar to ours, although they found two-fold oleic acid level (442 vs 253 mg 100g⁻¹ meat) and SFA (598 vs 384 mg 100g⁻¹ meat). This observation confirms that of Carnovale and Nicoli (2000) who concluded that Italian meat showed a favourable intramuscular fatty acid composition with high PUFA content. Muscle with a high percentage of unsaturated fatty acids (UFA) generally scored higher in taste panel evaluation (Westerling and Hedrick, 1979) and food with high UFA, especially PUFA, is good for human health (Rusman et al., 2003). The ω-6/ω-3 ratio was higher than the value (less than 3) reported by Scollan et al. (2006) but lower than that registered by Warren et al. (2003) for steers fed corn silage and concentrates (8.9).

As regards the nutritional parameters, a comparison among our results and previous findings is only feasible where the fatty acids concentration is reported as gravimetric values. The AI of the meat in this trial was particularly interesting, rather lower than the data reported by Ulbricht and Southgate (1991) for raw minced beef and than

Figure 1. Fatty acid profile (% of total fatty acids) of 3 adipose tissues.

SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids.
LT: Longissimus thoracis; SF: subcutaneous fat; P: perirenal fat.
those reported by Badiani et al. (2002) for cooked beef (0.72 and 0.77, respectively); our data were similar to those of Poli et al. (1996) on Chianina young bulls (AI: 0.58). However, the TI in this trial was higher than the findings of the above-cited authors (1.27 and 1.30 for Ulbricht and Southgate, 1991 and Poli et al., 1996, respectively); only the TI (1.77) reported by Badiani et al. (2002) was similar to our data.

**Conclusions**

Our results contribute to show that replacing soybean meal s.e. with faba bean in the diet for young bulls does not substantially influence the nutritional characteristics of meat. Although the meat of group fed faba bean had significantly higher concentrations of stearic acid compared to the level found in SBM group, neither the atherogenic and thrombogenic indexes, nor the cholesterol content were influenced. As regards the effect of protein source on hydroxyproline content and on water holding capacity our results were conflicting, while the meat of the group fed soybean meal s.e. showed a potential low tenderness (higher level of hydroxyproline, the water holding capacity measured by compression was lower for the group receiving faba bean).

The administration of high energy diets induced higher concentration of saturated fatty acids, in particular palmitic and stearic, which caused a significant worsening of both atherogenic and thrombogenic indexes. However, other characteristics of meat of the group fed high energy diets were better than those of the other two groups, as well as being more tender. Instead, the feeding regime did not affect the cholesterol content of tested muscles (LT, ST and IP) or fatty acids composition of the adipose tissues.

From our results it is possible to formulate a favourable assessment of the nutritional characteristics of the meat of Marchigiana young bulls. Indeed, the cholesterol values were very close to those indicated by the PGI of the “Vitellone Bianco dell’Appennino Centrale” and lower than those found in other breeds. Moreover, the fatty acids profile of LT confirms that the meat of the Italian breed specialised in meat production has higher unsaturated fatty acids concentration and lower saturated fatty acids levels, which in turn ensures medium-low atherogenic and thrombogenic indexes.

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