Comparison of two feeding finishing treatments on production and quality of organic beef

Giulio Cozzi,¹ Marta Brsic,¹ Flavio Da Ronch,¹ Aziza Boukha,¹ Sandro Tenti,¹ Flaviana Gottardo¹
¹Dipartimento di Scienze Animali, Università di Padova, Italy
²Dipartimento di Agronomia Ambientale e Produzioni Vegetali, Università di Padova, Italy

Abstract

The study compared growth and slaughter performance and meat quality of organic beef cattle finished with or without pasture grazing. One group of 10 Limousin heifers was finished under confined conditions and fed ad libitum a total mixed ration based on maize silage, hay and cereal grains. A second group of 10 Limousin heifers rotationally grazed two contiguous pasture plots of 1.5 ha each with a daily supplementation of a concentrate mix based on cereal grains and roasted soybeans. Heifers were slaughtered at commercial finishing and meat quality traits were assessed on Longissimus thoracis muscle. The grazing group, due to a lower average daily gain (0.74 vs. 0.95 kg/day; P<0.05), required a prolonged finishing period (172 vs. 155 days; P<0.05) than the confined animals. Meat samples from grazing cattle were less tender (shear force: 3.92 vs. 3.24 kg/cm²; P<0.05) and showed a lower lightness (L*: 33.0 vs. 35.8; P<0.001) and a higher redness (a*: 15.4 vs. 13.7; P<0.01) and yellowness (b*: 15.6 vs. 14.6; P<0.05). Fatty acid composition of the intramuscular fat was significantly affected by the finishing system. Grazing heifers had a higher content of polyunsaturated fatty acids (4.06 vs. 3.66% of total fatty acids; P<0.05), conjugated linoleic acids (0.16 vs. 0.10% of total fatty acids; P<0.01) and o-3 (0.44 vs. 0.30% of total fatty acids; P<0.001) than confined animals. The detrimental effects of pasture grazing on growth performance and on some important meat quality traits explain the limited adoption of this finishing system in organic beef production.

Introduction

In the last decade organic markets in the world have grown strongly. The European market, which comprises more than 50% of the global revenues from organic products, has shown an estimated growth rate of 10-15% in the year 2005 and it is expected to be the fastest growing sector of the food industry in the next few years (Richter and Padel, 2007). In many European countries, organic animal derived foods like drinking milk, dairy products and eggs represent a significant segment of their total share. On the contrary, the market share of organic beef is still very low. Price, product availability and quality are the three main reasons of the limited success of organic beef. In several European countries the average price of organic beef is 50% higher than the conventional product and it has often shown to exceed the consumer’s willingness to pay (Nielsen and Thamsborg, 2005). In terms of quantity, organic cattle represent a niche product since only 2% of the total European cattle population is raised according to organic systems (Eurostat, 2010). Meat quality is another important issue especially, taking into account the higher price of organic beef. In countries with substantial organic dairy production, culled cows and young stocks from dairy breeds contribute significantly to organic beef production. The quality of beef from these animals is highly variable according to their age and degree of finishing. Also the recommended 60% roughage in the daily feed ration imposed by the European regulation on organic livestock production (European Council, 2007) has shown to affect the final product. However, as for milk (Dhiman et al., 1999) the use of grazing during the finishing period might be a way of improving the nutritional quality of organic beef by increasing the content of unsaturated fatty acids, including conjugated linoleic acid (CLA). The present study aimed at comparing two different finishing systems for organic beef cattle: a grassland based and a confined system with cattle receiving a total mixed ration (TMR). The comparison considered cattle growth and slaughter performance and meat quality evaluation.

Materials and methods

Animals, housing and management

The study was carried out at a commercial organic beef farm in the town of Bovolenta in Italy’s eastern Po valley. A batch of 20 finishing Limousin heifers was used in the study. At the outset of the study, the animals had an average live weight of 368.0±35.9 kg and were assigned to 2 balanced groups of 10 animals each according to their initial weight. One group of heifers was reared in a single pen in a stable with access to an outdoor run. The pen had a concrete floor covered with a straw bedding and clean straw was added weekly and fully renewed every 4 weeks. The pen had a space allowance of 12.5 m² per head and a manger space of 94 cm per head and it was equipped with two waterers to allow a free access to drinking water. The outdoor run had a concrete floor and allowed an additional space allowance of 10.0 m² per head. The second group of heifers rotationally grazed two contiguous pasture plots located near a shade structure with concrete floor equipped with a manger and a drinking point. The manger used to provide the feeding supplement to the pasture had a space of 60 cm/head.

The group of heifers housed in the stable (Confined) received a finishing diet provided as TMR for ad libitum intake in a single daily distribution (Table 1). The amount of feed offered was adjusted daily to obtain approxi-
The NDF analysis was conducted according to the same frequency for following chemical analysis. Coverage percentage of every species was determined by high performance liquid chromatography (Shimadzu Corporation, Kyoto, Japan) equipped with flame ionisation detector and a Supelco Omegawax 250 type capillary column (30 m x 0.25 mm ID). Fatty acids were identified by comparing their retention times to those of authentic fatty acids methyl ester standards (Mix C4-24, 18919-1AMP, Supelco, Bellefonte, PA, USA). Results were expressed as a percentage (w/w) of total FA methyl esters considering FA identified in at least 80% of the samples with a minimum concentration >0.1%. Weight cooking losses were determined on 2.5 cm-thick steaks heated in a water bath at 75°C for 50 min and cooled in running tap water for at least 40 min (Boccard et al., 1981). Ten cylindrical meat cores 1.25 cm in diameter were then excised from the cooked steak for the instrumental measurement of tenderness using a Warner-Bratzler shear force meter (Instron, High Wycombe, United Kingdom) (Joseph, 1979).

**Statistical analysis**

Heifer growth and slaughter performance and meat quality data were submitted to one-way ANOVA within PROC-GLM (SAS, 2001) to evaluate the effect of the finishing treatment. The Kruskal-Wallis test within PROC NPARWAY (SAS, 2001) was performed for the analysis of carcass SEURAP and fatness scores. Differences were considered significant at P<0.05 for all variables.

**Table 1. Feed and chemical composition of the control diet and the pasture supplement.**

|                       | Total mixed ration | Pasture supplement |
|-----------------------|--------------------|--------------------|
| Feed ingredients, g/kg as fed |                    |                    |
| Maize silage          | 285                | --                 |
| Dehydrated luzerne    | 148                | --                 |
| Meadow hay            | 148                | 95                 |
| Maize grain and cob silage | 120             | --                 |
| Roasted hull fat soybean | 96              | 130                |
| Barley meal           | 71                 | 328                |
| Maize meal            | 71                 | 328                |
| Wheat straw           | 39                 | 95                 |
| Minerals-vitamins premix° | 12                | 24                 |
|                       |                    |                    |
| Chemical composition  |                    |                    |
| Dry matter, %         | 59.1±3.3           | 87.8±0.5           |
| Ash, % DM             | 7.1±0.7            | 6.1±0.2            |
| Crude protein, % DM   | 13.1±0.6           | 13.2±0.4           |
| Ether extract, % DM   | 4.8±0.2            | 5.2±0.1            |
| NDF, % DM             | 39.1±1.4           | 24.1±0.8           |
| Starch, % DM          | 26.3±1.0           | 44.8±0.6           |
| UPV°, /kg DM          | 0.90               | 1.11               |

*^*Contains per kg of premix: Ca, 180 g; Na, 104 g; P, 70 g; Mg, 35 g; Zn, 3400 mg; Mn, 1500 mg; Fe, 200 mg; Cu, 200 mg; I, 60 mg; Co, 20 mg; Se, 10 mg; Mg, 10 mg; 10×10^4 U of vitamin A; 120,000 U of vitamin D; 100 mg of vitamin B1; 20 mg of vitamin K; 3000 mg of choline; 4000 mg of vitamin PP; 100 mg of vitamin B2; 50 mg of vitamin B3; 0.4 mg of vitamin B12; UPV°, Unité Fouragère Viande calculated from table values for each feed ingredient (INRA, 2002).
Results

Pasture quality

The pasture composition was referable to *Lolium multiflori* (Diehl and Lehmann, 1975) and the predominant species were *Lolium multiformum* (77.0% of the average seasonal total coverage), *Dactylis glomerata* (2.0%) and *Festuca arundinacea* (0.5%) among grasses and *Trifolium pretense* (3.5%), *Trifolium repens* (3.0%) and *Medicago sativa* (1.0%) as legumes. *Taraxacum officinale* (7.0%) was main species among forbs. The pasture had a satisfactory contents of CP and NDF (15.7%±2.6% DM and 51.7%±4.2% DM, respectively) but its nutritional quality was spoiled by the high lignin content (ADL = 33.6%±2.4% DM) likely due to a prolonged summer drought.

Growth and slaughter performance

As shown in Table 2, heifers allowed grazing during the finishing period reached an acceptable commercial maturity 17 days later than the confined animals fed a TMR (P<0.001). On average, the daily gain of the grazing group was about 0.2 kg lower than that of confined animals (P<0.01).

There were no significant difference between the two finishing systems for carcass weight and dressing percentage (Table 3). Both finishing treatments showed a very good carcass conformation and an average fatness score well targeted to meet the demand of the Italian beef market.

Meat quality traits

A significant difference between finishing treatments was observed for meat pH that was lower in meat from pasture grazing animals (P<0.01). Meat chemical composition was not affected by the finishing treatment (Table 4).

The effect of the finishing treatment on the FA composition of *Longissimus thoracis* m. intramuscular fat is reported in Table 5. In both groups of cattle over 95% of the total FA were identified. The effect of the finishing treatment was never significant on saturated FA, either on their cumulative percentage or on single FA percentages. Significant differences between the two groups regarded the unsaturated fraction. In particular, while the cumulative percentage of the monounsaturated fatty acids was similar between finishing treatments, the single percentages of C14:1 and of C16:1 were respectively lower (P<0.05) and higher (P<0.05) in the meat from pasture grazing heifers. Regarding the polyunsaturated FA, both the cumulative percentage contri-

### Table 2. Effect of the finishing system on the growth performance of organic beef cattle.

|                   | Confined | Pasture grazing | Significance | SE |
|-------------------|----------|-----------------|--------------|----|
| Live weight, kg   | 367.0    | 369.0           | ns           | 11.7 |
| Initial           |          |                 |              |     |
| Final             | 497.0    | 497.0           | ns           | 11.8 |
| Finishing days, n | 155      | 172             | ***          | 2   |
| Average daily gain, kg/d | 0.95 | 0.74 | ** | 0.04 |

### Table 3. Effect of the finishing system on the slaughter performance of organic beef cattle.

|                   | Confined | Pasture grazing | Significance | SE |
|-------------------|----------|-----------------|--------------|----|
| Carcass traits    |          |                 |              |     |
| Weight, kg        | 314.4    | 304.1           | ns           | 8.0 |
| Dressing percentage, % | 61.0 | 61.2 | ns | 0.7 |
| SEUROP, score°    | 4.1±0.3° | 4.2±0.3         | ns           |     |
| Fatness, score¹   | 2.5±0.4  | 2.3±0.4         | ns           |     |

*1= poor to 6=super; standard deviation; °1= minimum to 5= maximum; ns: not significant (P>0.05); SE, standard error.

### Table 4. Effect of the finishing system on pH and chemical composition of organic beef.

|                   | Confined | Pasture grazing | Significance | SE |
|-------------------|----------|-----------------|--------------|----|
| Meat pH           | 5.55     | 5.46            | **           | 0.02 |
| Chemical composition |          |                 |              |     |
| Dry matter, %     | 26.0     | 26.1            | ns           | 0.2 |
| Ash, % DM         | 1.1      | 1.1             | <0.1         |     |
| Crude protein, % DM | 22.5 | 22.5            | ns           | 0.2 |
| Ether extract, % DM | 2.8    | 2.6             | ns           | 0.2 |

**P<0.01; ns: not significant (P>0.05); SE, standard error.

### Table 5. Effect of the finishing system on the fatty acids composition (% of total fatty acids) of *Longissimus dorsi* intramuscular fat from organic beef.

| Fatty acids      | Confined | Pasture grazing | Significance | SE |
|------------------|----------|-----------------|--------------|----|
| Total identified | 96.0     | 96.5            | ns           | 0.22 |
| Saturated        | 45.02    | 46.22           | ns           | 1.23 |
| C14:0            | 2.44     | 2.41            | ns           | 0.13 |
| C15:0            | 0.32     | 0.35            | ns           | 0.02 |
| C16:0            | 26.1     | 25.7            | ns           | 0.65 |
| C17:0            | 0.93     | 0.87            | ns           | 0.06 |
| C18:0            | 14.88    | 16.53           | ns           | 0.60 |
| Monounsaturated  | 47.33    | 46.25           | ns           | 1.23 |
| C14:1 c9         | 0.51     | 0.39            | *            | 0.04 |
| C15:1 c10        | 0.11     | 0.14            | <0.01        |     |
| C16:1            | 2.70     | 3.26            | *            | 0.16 |
| C17:1 c10        | 0.70     | 0.62            | *            | 0.03 |
| C18:1 c9         | 41.40    | 39.78           | ns           | 1.04 |
| C18:1 t11        | 1.71     | 1.91            | ns           | 0.11 |
| Polyunsaturated  | 3.66     | 4.06            | *            | 0.11 |
| CLA²             | 0.10     | 0.16            | **           | 0.02 |
| o-3              | 0.30     | 0.44            | ***          | 0.02 |
| o-9              | 3.22     | 3.44            | ns           | 0.10 |

*CLA = Σ(C18:2 n-6, C18:3 n-3, C20:3 n-3, C20:5 n-3, C22:6 n-3); o-3 = Σ(C18:3 n-3, C18:3 n-3, C18:1 n-9, C18:1 n-5); o-9 = Σ(C18:2 n-6, C18:3 n-3, C20:3 n-3, C20:5 n-3, C22:6 n-3); °1= minimum to 5= maximum; ns: not significant (P>0.05); SE, standard error.
bution (P<0.05) and the single percentages of conjugated linoleic acids (CLA) (P<0.01) and of ω-3 (P<0.001) were significantly higher when cattle were finished on pasture.

Finishing treatments did not differ for drip and cocking losses (Table 6). Meat from pasture grazing heifers was significantly darker than that from confined animals finished with the TMR as the outcome of a lower lightness (P<0.001) and a higher redness (P<0.01) and yellowness (P<0.05). Moreover, the instrumental measurement of tenderness showed meat from pasture grazing being less tender (P<0.05).

## Discussion

Heifers allowed to graze during the finishing period had a lower daily gain and reached a commercial maturity later than animals confined indoors and fed a TMR. These results were expected since it is known that the use of pasture increases energy expenditure for locomotion lowering the energy available for gain (INRA, 1988). Recently, Brosh et al. (2010) estimated a daily energy cost ranging from 89.4 to 103.2 kJ per kg of metabolic weight for pasture grazed by beef cows.

In addition to the increased maintenance requirements, the lower growth performance of grazing heifers during the finishing could have been linked to the feeding plan. When compared to a maize silage based TMR, a highly lignified pasture as that of the present study is supposed to limit the intake of net energy available for gain due to its low quality and to the high rumen fill caused by its slow degradation and passage rate (Andrigiello et al., 1996). Moreover, fresh grass intake shifts microbial fermentations in the rumen towards acetic acid production that is mainly used by microbial fermentations in the rumen towards a com commercial maturity later than animals confined indoors and fed a TMR.

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Table 6. Effect of the finishing system on meat quality traits of organic beef.

|                         | Confined  | Pasture grazing | Significance | SE |
|-------------------------|-----------|-----------------|--------------|----|
| Drip loss, %            | 1.21      | 1.89            | ns           | 0.29 |
| Meat colour             |           |                 |              |     |
| Lightness, L            | 35.8      | 33.0            | ***          | 0.3 |
| Redness, a              | 13.7      | 15.4            | **           | 0.3 |
| Yellowness, b           | 14.6      | 15.6            | *            | 0.3 |
| Cocking loss, %         | 31.2      | 32.9            | ns           | 0.6 |
| Shear force, kg/cm²     | 3.24      | 3.92            | *            | 0.18 |

### Metabolites and Carotenoids

Reduced energy supply and growth rate as the consequence of the extensive production method, organic production could lead to a lower carcass and meat quality. This concern was supported by several trials that obtained lighter carcasses with less fat from steers finished on pasture compared to those of confined animals fed diets rich in concentrates (Bennett et al., 1995; Camfield et al., 1999; Kerth et al., 2007). In the present study, while no difference was observed between treatments regarding slaughter performance and carcass quality, meat pH from heifers finished on pasture was unexpectedly lower than that of confined cattle receiving a TMR. According to Bowling et al. (1977), feedlot cattle finished with grain diets should potentially reach a lower meat pH than free-range forage-finished cattle since they are less susceptible to pre-slaughter stress which become accustomed to people and confinement. At this regard though, it must be pointed out that, under the experimental conditions of the present study, grazing heifers likely had a greater opportunity to get used to the farm personnel during the daily administration of the feeding supplement and the periodic transfers to the new pasture plot.

Regardless of the lower pH, meat from grazing cattle was appreciably darker and less tender. The darker meat colour was the result of a lower lightness and a higher redness and yellowness and it was consistent with the findings of previous studies on grassland systems for finishing beef cattle and sheep (Vestergaard et al., 2000; Priolo et al., 2001; Dannenberger et al., 2006). According to Varan and Sutherland (1995), it could be associated to a higher muscle myoglobin content promoted by the locomotion activity which should lower meat L* index increasing the redness index (a*). A further causative factor is the transfer and accumulation of fresh grass pigments into the intramuscular fat (Miur et al., 1998). Yang et al. (2002) proved that β-carotene concentration increases in muscle and fat tissues according to the duration of the grazing period resulting in a lower lightness and a higher yellowness of the meat. Yellow fat is less desirable by consumers since it is associated with old or diseased cattle (Dikeman, 1990). The increased shear force observed in the current study for pasture grazing heifers is in line with the results obtained on steers (Bennett et al., 1995) and bulls (Dannenberger et al., 2006). However, differently from expected, in the current study the lower tenderness of meat from grazing heifers was not associated to a lower intramuscular fat content. Treatment difference may have been related to the difference in growth rate, as suggested by Aaber et al. (1981). Shackelford et al. (1994) reported that postmortem calpastatin activity, which negatively affects postmortem tenderization, has a negative genetic correlation with growth rate in steers (rg = −0.52±0.37).

An appreciable positive result regarding meat quality obtained by finishing the heifers on pasture was linked to the intramuscular FA profile, considered an important parameter in determining nutritional properties of beef meat. Pasture grazing increased polyunsaturated FA concentration in the intramuscular fat and CLA and ω-3 content, in particular. This result is consistent with those reported by several authors using diets based on fresh grass and/or pasture (Varela et al., 2004; García et al., 2005). Positive biological functions have been attributed to these FA (Jp et al., 1994; Hayek et al., 1999; Wilson et al., 2000) and the consumption of beef meat enriched in their content could be, therefore, a healthy nutritional choice. A possible drawback of the increased content of polyunsaturated FA could be a higher sensitivity of the intramuscular fat to oxidative processes which could reduce meat shelf life. However, it has been proven that in meat from grazing cattle there is a natural protection against fat oxidation coming from the enriched content of vitamin E and other antioxidants brought by the intake of fresh grass (Gettelier et al., 2004 Descazlo and Sancho, 2008).
Conclusions

The results of the present study, which compared two finishing strategies on organic beef production, showed the negative effect of pasture grazing on cattle daily gain. This outcome, along with the worsening of two of the main meat quality traits for the consumers such as colour and tenderness, certainly do not spur the adoption of grazing pasture on a large scale for the finishing of organic cattle. Some interest for this finishing system could arise from a nutritional point of view since meat for their positive effects on health. However, consumer should be properly informed about these nutritional benefits in order to make them accept the detrimental effects on meat colour and tenderness as well as to justify the likely higher retail price due to the lower cattle growth performance.

References

Aberle, E.D., Reeves, E.S., Judge, M.D., Hunsley, R.E., Perry, T.W., 1981. Palatability and muscle characteristics of cattle with controlled weight gain: Time on a high energy diet. J. Anim. Sci. 52:757-763.

Andrighetto, I., Berzaghi, P., Cozzi, G., 1996. Dairy feeding and milk quality: the extensive systems. Zoot. Nutr. Anim. 22:241-250.

AOAC, 1990. Official Methods of Analysis, 15th ed. AOAC, Washington, DC, USA.

Bennett, L.L., Hammond, A.C., Williams, M.J., Kunke, W.E., Johnson, D.D., Preston, R.L., Miller, M.F., 1995. Performance, carcass yield, and carcass quality characteristics of steers finished on rhizoma peanut (Arachis glabrata)-tropical grass pasture or concentrate. J. Anim. Sci. 73:1881-1887.

Boccard, R., Buchtler, L., Castaels, E., Cosentino, E., Dransfield, E., Hood, D.E., Joseph, R.L., McDougall, D.B., Tournaille, C. 1981. Procedures for measuring meat quality characteristics in beef production experiments. Report of a Working Group in the Commission of the European Communities (CEC) Beef Production Research Programme. Livest. Prod. Sci. 8:385-397.

Bowing, R.A., Smith, G.C., Carpenter, Z.L., Dutson, T.R., Oliver, W.M., 1977. Comparison of forage-finished and grain-finished beef carcasses. J. Anim. Sci. 45:209-215.

Branscheid, W., 1996. Zur Qualität von Fleisch und Milch - Ansprüche der Verbraucher und Maßnahmen der Tierproduktion. Ber. Landwirtsch. 74:103-117.

Braun-Blanquet, J., 1964. Pflanzensoziologie. Springer, Wien, Austria.

Brosh, A., Henkin, Z., Ungar, E.D., Dolev, A., Shabaty, A., Orlov, A., Yehuda, Y., Aharoni, Y., 2010. Energy cost of activities and locomotion of grazing cows: A repeated study in larger plots. J. Anim. Sci. 88:315-323.

Camfield, P.K., Brown, A.H. Jr, Johnson, Z.B., Brown, C.J., Lewis, P.K., Rakes, L.Y., 1999. Effects of growth type on carcass traits of pasture- or feedlot-developed steers. J. Anim. Sci. 77:2437-2443.

CIE, 1976. Colorimetry: Official Recommendations of the International Commission on Illumination. CIE No. 15 (E-1.3.1). CIE ed., Paris, France.

Cozzi, G., Gottardo, F., Andrighetto, I. 2005. The use of coarse maize silage as a dietary source of roughage for finishing Limousin bulls: effects on growth performance, feeding behaviour and meat quality. Anim. Sci. 80:111-118.

Dannenberger, D., Nuernberg, K., Nuernberg, G., Ender, K., 2006. Carcass- and meat quality of pasture vs concentrate fed German Simmental and German Holstein bulls. Arch. Tierzucht. 49:315-328.

Descalzo, A.M., Sancho, A.M., 2008. A review of natural antioxidants and their effects on oxidative status, odor and quality of fresh beef produced in Argentina. Meat Sci. 79:423-436.

Dhiman, T.R., Anand, G.R., Satter, L.D., Pariza, M.W., 1999. Conjugated linoleic acid content of milk from cows fed different diets. J. Dairy Sci. 82:2146-2156.

Dietl, W., Lehmann, J., 1975. Standort und Nutzungsform der Kühe auf einem Brandweidebetrieb. Landwirtsch. 74:103-117.

Dikeman, M.E. 1990. Genetic effects on the quality of meat from cattle. Proc. 4th World Congr. on Genetics Applied to Livestock Production, Edinburgh, UK, 4521-530.

European Council, 2007. Council Regulation of 26 June 2007 concerning organic production and labelling of organic products, 834/2007/EC, and repealing Regulation, 2092/91/EEC. In: Official Journal, L189, 20/07/2007, pp 1-23.

Eurostat, 2010. Homepage address: http://epp.eurostat.ec.europa.eu/portal/page/portal/ agriculture/agriculture/data/main_tables

Folch, J., Lees, M., Sloane Stanley, G.H., 1957. A simple method for isolation and purification of total lipids for animal tissues. J. Biol. Chem. 256:497-509.

Garcia, P.T., Pensel, N.A., Latimore, N.J., Kloster, A.M., Amigone, M.A., Casal, J.J., 2005. Intramuscular lipids in steers under different grass and grain regimen. Fleischwirtschaft 1:27-31.

Gatellier, P., Mercier, Y., Renerre, M., 2004. Effect of diet finishing mode (pasture or mixed diet) on antioxidat status of Charolais bovine meat. Meat Sci. 76:385-394.

Hayek, M.G., Han, S.N., Wu, D., Watkins, B.A., Meydani, M., 1999. Dietary conjugated linoleic acid influences the immune response of young and old C57Bl/6NcRBR mice. J. Nutr. 129:32-38.

INRA, 1988. Alimentation des bovins, ovins et caprins. Institut National de la Recherche Agronomique ed., Paris, France.

INRA, 2002. Tables de composition et de valeur nutritive des matieres premières destine aux animaux d’élevages. Institut National de la Recherche Agronomique ed., Paris, France.

Ip, C., Singh, M., Thompson, H.J., Scimeca, J.A., 1994. Conjugated linoleic acid and suppresses mammary carcinogenesis and proliferative activity of the mammary gland in the rat. Cancer Res. 54:1212-1215.

Joseph, R.L., 1979. Recommended method for assessment of tenderness. In: J.C. Bowman and P. Susmel (eds.) The future of beef production in the European community. Martinus Nijhoff, The Hague, The Netherlands, pp 596-606.

Kerth, C.R., Braden, K.W., Cox, R., Kerth, L.K., Rankins, D.L. Jr, 2007. Carcass, sensory, fat color, and consumer acceptance characteristics of Angus-cross steers finished on ryegrass (Lolium multiformum) forage or on a high-concentrate diet. Meat Sci. 75:324-331.

Miur, P.D., Deaker, J.M., Bown, M.D., 1998. Effect of forage- and grain-based feeding systems on beef quality: A review. New Zeal. J. Agr. Res. 41:623-635.

Nielsen, B.K., Thamsborg, S.M., 2005. Welfare, health and product quality in organic beef production: a Danish perspective. Livest. Prod. Sci. 94:41-50.

OFFIVAL, 1984. Coupes et Découps. Office National Interprofessionnel des Viandes de l’Elevage et de l’Aviculture Publ., Paris, France.

Priolo, A., Micol, D., Agabriel, J., 2001. Effects of grass feeding systems on ruminant meat colour and flavour. A review. Anim. Res. 50:185-200.

Richter, T., Padel, S., 2007. The European market for organic food. In: H. Willer and M.
Yussefi (eds.) The world of organic agriculture – Statistics and emerging trends. International Federation of Organic Agriculture Movements, Bonn, Germany and Research Institute of Organic Agriculture, Frick, Switzerland, pp 143-154.

SAS, 2001. User’s Guide. Version 8.2. SAS Institute Inc., Cary, NC, USA.

Shackelford, S.D., Koohmaraie, M., Cundiff, L.V., Gregory, K.E., Rohrer, G.A., Savell, J.W., 1994. Heritabilities and phenotypic and genetic correlations for bovine post rigor calpastatin activity, intramuscular fat content, Warner-Bratzler shear force, retail product yield, and growth rate. J. Anim. Sci. 72:857-863.

Van Soest, P.J., Robertson, J.B., Lewis, B.A., 1991. Method for dietary fiber, neutral detergent fiber and non starch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74: 3583-3597.

Varela, A., Oliete, B., Moreno, T., Portela, C., Monserrat, L., Carballo, J.A., Sánchez, L., 2004. Effect of pasture finishing on the meat characteristics and intramuscular fatty acids profile of steers of the Rubia Gallega breed. Meat Sci. 67:515-522.

Varnan, A., Sutherland, J., 1995. Meat and meat products-technology, chemistry and microbiology. Chapman & Hall, London, UK.

Vestergaard, M., Oksbjerg, N., Henkel, P., 2000. Influence of feeding intensity, grazing and finishing feeding on muscle fiber characteristics and meat colour of semitendinosus, long. dorsi and supraspinatus muscle young bulls. Meat Sci. 54:177-185.

Wilson, T.A., Nicolosi, R.J., Chrysam, M., Kritchvsky, D., 2000. Conjugated linoleic acid reduces early aortic atherosclerosis greater than linoleic acid in hypercholesterolemic hamsters. Nutr. Res. 20: 1795-1805.

Yang, A., Brewster, M.G., Lanari, M.C., Tume, R.K., 2002. Effect of vitamin E supplementation on α-tocopherol and β-carotene concentrations in tissues from pasture- and grain-fed cattle. Meat Sci. 60:35-40.

Pasture grazing for organic beef
