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PAPER

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

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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/cm^2; P<0.05) and showed a lower lightness (L*: 33.0 *vs.* 35.8; P<0.001) and a higher redness (15.4 *vs.* 13.7; P<0.01) and yellowness (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 ω-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 wiliness 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 leading to darker meat (Vestergaard *et al*., 2000). 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 m^2 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 m^2 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-

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mately a daily feed residue of 5% (as-fed basis). The grazing heifers had free access to the pasture plots and were daily supplemented with 4.2 kg DM/head/d of a concentrate mix (Table 1). The experimental period started in June 2009 and it lasted until each heifer reached the optimal finishing status set by a beef cattle market expert. Heifers were weighed before their transfer to the abattoir and their average daily gain was calculated by dividing the difference between final and initial live weight by the number of finishing days.

Pasture management

The experimental pasture covered a total area of 3.00 ha, divided in two contiguous plots that were grazed alternatively according to a rotation system. The pasture was not irrigated and the yearly average rainfall amounted to about 820 mm with 12.3°C of average yearly temperature. The soils were loam or sandy-loam, with neutral or sub-alkaline reaction (pH 7.03-7.89), low or average carbonate content (0.5%-10.0%) and good organic matter content (3.01%-5.35%). During the grazing season, botanical surveys using the Braun-Blanquet method (1964) were performed weakly and coverage percentage of every species was recorded. Pasture samples were collected with the same frequency for following chemical analysis.

Feed sample analysis

Samples of pasture were chemically analyzed for crude protein (CP), neutral detergent fibre (NDF) and lignin content. The total mixed ration provided to the confined group of heifers and the pasture supplement were sampled throughout the study and chemically analysed for DM, CP, ether extract, and ash according to the methods of the Association of Official Analytical Chemists (AOAC, 1990). The NDF analysis was conducted according to Van Soest *et al*. (1991) while the starch content of TMR and pasture supplement was determined by high performance liquid chromatography method (AOAC, 1990). The net energy of TMR and the pasture supplement measured in *Unité Fouragère Viande* units was calculated using INRA (2002) table values for all ingredients (Table 1).

Slaughter measurement and meat quality evaluation

The heifers were slaughtered in the same abattoir located around 30 km from the beef farm. Upon arrival, the animals were immediately moved to the stunning area without lairage. Carcasses were graded for conformation (SEUROP) and fatness according to the European grading scheme (OFIVAL, 1984) and then weighed to calculate individual dressing percentage after storage in a chilling room at 4°C for 24 h. A joint sample of the m. Longissimus thoracis was excised from the 5th to the 9th rib of each right half carcass 48 hours after slaughter. These samples were vacuum packaged and stored at 4°C in a chilling room for an 8-day ageing period. After this period, meat pH was measured with a portable pH-meter (HANNA Instruments®, Inc., Woonsocket, RI, USA) equipped with a glass electrode (3 mm Ø conic tip) suitable for meat penetration. Instrumental meat colour expressed as L*(lightness), a* (redness), and b* (yellowness) according to CIElab system (CIE, 1976) was measured with a Minolta CR300colour (Minolta Camera Co., Osaka, Japan) on samples after exposure to air for 1 h at 2°C (Boccard *et al*., 1981). Meat samples were then freeze-dried and ground to measure DM, crude protein, ash and intramuscular fat content (AOAC, 1990). The fatty acids (FA) composition of *Longissimus* intramuscular fat was analyzed by Gas Chromatography after Folch extraction (Folch *et al*., 1957). Trans-methylation was carried out using a blend of methanol and sulphuric acid (96:4). Gas liquid chromatography was performed on an automated apparatus (Shimadzu GC-17A, Shimadzu Corporation, Kyoto, Japan) equipped with flame ionisation detector and a Supelco Omegawax 250 type capillary column (30 m × 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 NPAR1WAY (SAS, 2001) was performed for the analysis of carcass SEUROP 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	295	--
Dehydrated luzerne	148	--
Meadow hay	148	95
Maize grain and cob silage	120	--
Roasted full 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
UFV#, / kg DM	0.90	1.11

°Contained 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; Mb, 10 mg; 10×10^6 U of vitamin A; 120,000 U of vitamin D; 100 mg of vitamin E; 20 mg of vitamin K; 5000 mg of choline; 4000 mg of vitamin PP; 100 mg of vitamin B_1; 50 mg of vitamin B_2; 0.4 mg of vitamin B_{12}. #UFV, Unité Fouragère Viande calculated from table values for each feed ingredient (INRA, 2002).

Results

Pasture quality

The pasture composition was referable to *Lolietum multiflori* (Dietl and Lehmann, 1975) and the predominant species were *Lolium multiflorum* (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.

	Finishing system		Significance	SE
	Confined	Pasture grazing		
Live weight, kg				
Initial	367.0	369.0	ns	11.7
Final	515.0	497.0	ns	11.8
Finishing days, n	155	172	***	2
Average daily gain, kg/d	0.95	0.74	**	0.04

***P≤0.001; **P≤0.01; ns, not significant (P>0.05); SE, standard error.

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

	Finishing system		Significance	SE
	Confined	Pasture grazing		
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, score#	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.

	Finishing system		Significance	SE
	Confined	Pasture grazing		
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	ns	<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	Finishing system		Significance	SE
	Confined	Pasture grazing		
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	ns	<0.01
C16:1	2.70	3.26	*	0.16
C17:1 c10	0.70	0.62	ns	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
CLA°	0.10	0.16	**	0.02
ω-3	0.30	0.44	***	0.02
ω-6	3.22	3.44	ns	0.10

°CLA, ∑(*cis*-9-*trans*-11-C18:2;*trans*-10-*cis*-12-C18:2); ω-3, ∑(C18:3n3; C20:3n3; C20:5n3; C22:6n3); ω-6, ∑(C18:2n6; C18:3n6; C20:3n6; C20:4n6); ***P≤0.001; **P≤0.01; *P≤0.05; 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).

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

	Finishing system		Significance	SE
	Confined	Pasture grazing		
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/cm^2	3.24	3.92	*	0.18

***P≤0.001; **P≤0.01; *P≤0.05; ns, not significant (P>0.05); SE, standard error.

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 (Andrighetto *et al*., 1996). Moreover, fresh grass intake shifts microbial fermentations in the rumen towards acetic acid production that is mainly used by cattle for lipid synthesis.

In the current study, also the average daily gain observed for confined heifers was lower than expected for finishing cattle belonging to a specialized beef breed such as Limousine. There are no reference data in the literature on growth performance of Limousine heifers during the finishing period. An average daily gain of 1.35 kg was recorded for finishing young bulls under intensive farming conditions by Cozzi *et al*. (2005). It is likely therefore that part of the poor performance obtained in this study may have arisen from the dietary restrictions imposed by the European Council regulation on organic farming (2007) and from the limited use of concentrate feeds, in particular. Branscheid (1996) argued that, due to a 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 preslaughter stress because they 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 Varnan 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 Aberle *et al*. (1981). Shackelford *et al*. (1994) reported that postrigor 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; Garcia *et al*., 2005). Positive biological functions have been attributed to these FA (Ip *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 (Gatellier *et al*., 2004 Descalzo 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 pasture grazing 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 from pasture grazing cattle showed a higher content of polyunsaturated fatty acids known for their positive effects on health. However, consumers 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.

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