Growth performance, carcass quality, muscular characteristics and meat quality traits of Charolais steers and heifers

M.P. Oury[1], J. Agabriel[2], B. Picard[2], R. Jailler[2], H. Dubroeucq[2], D. Egal[2], D. Micol[2]*
[1]ENESAD, BP87999, 21079 Dijon, France
[2] INRA, 63122 St-Genès-Champanelle, France
** Corresponding author E-mail address : mp.oury@enesad.fr*

Abstract
In France, the number of bovine females is decreasing and lead to a deficiency of heifer's meat. So, the aim of this study was to compare Charolais steers (n=11) and heifers (n=11) slaughtered at the same age of 27 months to evaluate if young steers may act as an alterative to heifers for meat production. Animals were fed with grass and hay at the Monts Dore experimental station. The following growth characteristics and slaughtering results were studied: live-weights, gains, fattening marks, carcass weights and compositions. Muscular characteristics (lactate dehydrogenase: LDH and isocitrate dehydrogenase: ICDH activities, collagen content and solubility, intramuscular fat content) and meat quality traits (tenderness, juiciness, flavour intensity) of muscles *rectus abdominis* (RA), *triceps brachii* (TB) and *longissimus thoracis* (LT) were also analysed. From birth (51 vs 41 kg) to slaughter (713 vs 625 kg), steers have had a higher live-weight than heifers. This may be linked with a higher daily gain all life long (823 vs 712 g/ d of life). Heifers had a higher fattening mark at slaughtered (3.3 vs 2.8/5) and a higher carcass fat content (20.3 vs 17.4%). There had a lower content of total (23.4 vs 29.4 mg/g DM) and soluble (17.0 vs 20.2 %) collagen in RA muscles and a higher metabolic activity (ICDH and LDH; $p<0.10$) in TB and LT muscles than steers. Nevertheless no significant differences were found on meat quality traits of RA and TB muscles. Whereas gender has no impact on meat quality traits of muscles RA and TB, few differences appeared on meat quality traits of LT muscle. Indeed, if meat samples of steers seemed to be as tender as those from heifers, there appeared a little bit less juicy and less flavoured ($p=0.072$ and $p=0.051$ respectively). As there are quite few significant differences between young steers and heifers, it seems that it is possible to replace missing heifers by young steers slaughtered at the same age of 27 months.

Key words: gender, meat quality, growth, Charolais, carcass characteristics

1. Introduction
In France, Charolais males use to be exported to Italy or Spain as lean grasser. Some of grasser may also be fattened in the French territory as young bulls. More rarely, these males may be castrated to produce steers, that could be slaughtered at various ages and various slaughter weights (Dumont *et al*., 2006). Young bulls grow more rapidly, utilize feed more efficiently and produce higher yielding carcass than steers (Field, 1971 ; Seideman *et al*., 1982), but there are generally marketed younger and leaner. Steers also allow the production of a carcass lending itself to traditional French marketing. There lead to more edible products than young bulls. Indeed, bulls were considered to have less marbling, darker lean colour and less tender meat than steers. Nevertheless, in the French beef production, only 9% of the meat comes from steers and among these, 30% are from the sucking herd (Bastien et Mourier, 2000). This type of management system is mostly given up because of the carcasses variability and the cycles length steers being traditionally slaughtered between 30 and 36 months (Dumont *et al*., 2006).

The total number of females that are slaughtered in France decrease every year (a decrease of 3 and 1 % respectively between 2004 and 2005 and between 2005 an 2006). It could also be interesting to replace the missing heifers by young steers, slaughtered at an equivalent age than heifers and an lower slaughter-weight than traditional steers. Thus, the aim of this study was to evaluate the effects of gender on growth, carcass and meat quality traits, when steers and heifers are slaughtered at the same age.

2. Material and methods

2.1. Animal management

The study included 11 Charolais heifers and 11 Charolais steers, castrated with pliers just after weaning, at 10 months of age. The objective was to slaughter the animals at the same age of 27 months, and at a body score near to 3 on 5 (EU classification scheme).

Before weaning (0 – 10 months), the animals were only fed with mother's milk. During the first winter (10 – 16 months), there received high quality permanent meadow hay *ad libitum*. During the grazing period (16 – 22 months), animals were offered high quality native pasture grass. The botanical composition of the mountain pasture (1100 m altitude) of the Laqueuille experimental station (INRA) was composed of 24% bent grass, 22% red fescue, 13% bluegrass and 9% white clover. During the finishing period (22 to 27 months), heifers received both hay and 1 kg barley. Steers were fed with native hay from 20th of October to 15th of November. Then, from the 15th of November to the slaughter, steers received both hay and 2 kg barley.

2.2. Animal and carcass measurements

All life long, the animals were weighted every two weeks. During the finishing period, a body score, assessed by palpation at rib and at tail level, was given every month to each animal, according to the chart defined by Agabriel *et al.* (1986).

The day of slaughter, animals were carried from the barn to the INRA experimental slaughterhouse (Clermont-Ferrand – Theix, France) during 45 minutes in average. The same number of animals in each group was taken every slaughter day, in order to always have the same number staying in each group.

Slaughter live-weight (LW) and warm carcass weight (WCW) were evaluated at slaughter and allowed to calculate the dressing percentage (LW x 100 / WCW). The 6th rib joint was removed and dissected in order to assess muscle, fat and bone proportions of the carcass (Robelin and Geay, 1975).

Ultimate pH of the carcass was taken 24 hours *post mortem.* The colour of the muscle LT was measured at the 6th rib using a portable spectrophotometer (MINOLTA). Colour coordinates were calculated in the CIELAB system and results were expressed as lightness (L*), redness (a*) and yellowness (b*).

Muscles characteristics and meat quality traits were measured on three muscles, located at different places of the carcasses : *triceps brachii* (TB), *longissimus thoracis* (LT) and *rectus abdominis* (RA). Even if these three muscles are noble pieces, there are characterized by different meat quality traits and are representative of different parts of the carcass: respectively the forequarter, the hindquarter and the back.

2.3. Muscle characteristics

<u>Metabolic properties of muscles</u>

The metabolic muscle type was determined by measuring enzyme activities. The anaerobic glycolytic metabolism was assessed by lactate dehydrogenase (LDH) activity (Ansay, 1974). The aerobic oxidative metabolism was assessed by isocitrate dehydrogenase (ICDH) activity according to the method of Briand *et al*. (1981).

<u>*Connective tissue properties*</u>
The collagen content was evaluated by measurement of hydroxyproline content (Collagen = 7.5 x hydroxyproline) according to the method of Bergman et Loxley (1963). Collagen in the insoluble part was determined according to a procedure given by Bonnet et Kopp (1992).
Total lipids were extracted by mixing 5 g of meat with celite. Warm hydrolysis is used to break lipids-support links (NF V 04-402, 1968). Then occurs a 3 hours long warm extraction according to the Soxhlet standard method.

2.4. Sensory assessment
TB, LT and RA steaks (1.5 cm thick) were vacuum packaged, aged at 4°C for 14 days post-mortem and frozen. The day of the sensory assessments, steaks were thawed rapidly under flowing water, grilled to a core temperature of 55°C and immediately served to panellists. A total of 12 trained panellists were used in each test session. They had to score tenderness, juiciness and flavour intensity on a 10-point scale: from 0 (tough ; dry ; weak) to 10 (tender ; juicy; intense). Samples were matched two by two according their intramuscular lipid content.

2.5. Statistical analysis
The data were analysed using the general linear models (GLM) procedure of SAS software with the fixed effect of gender. The multiple comparison of means (LSMEAN) was done with the PDIFF procedure of the GLM model.

3. Results
3.1. Growth performances, slaughter characteristics and carcass quality
Calves had significantly different birth weight depending on their gender ($p<0.001$), steers being heavier than heifers (table 1). Between birth and weaning, steers had a higher average daily gain (991 *vs* 861 g/d) than heifers (Figure 1). At the weaning, that occurred at an average age of 293 days, steers were significantly heavier than heifers (339 *vs* 295 kg).
Moreover, at the end of the first winter but also at the end of the following summer, steers were significantly heavier than heifers (466 *vs* 426 kg and 594 *vs* 529 kg respectively).
Both groups began their finishing stage with an equivalent fatness score of 2.4 on 5. The finishing stage lengthened 156 days in average. During that period, heifers had an average daily gain of 624 g/d whereas steers daily gain was equal to 796 g/d.
The slaughter appeared for both groups at the same age of 813 days (27 months). Gender had a significant impact on live and carcasses weights. Indeed, steers had a significantly heavier live weight and warm carcass weight than heifers (713 *vs* 625 and 399 *vs* 347 kg respectively). Gender seemed to have no significant influence on dressing percentage, which was in average equal to 65.9 %.
Heifers and steers carcasses had the same muscle proportion of 66.8 % in average. Steers carcasses were composed by a higher proportion of bone than heifers carcasses (15.3 *vs* 13.9 %). As steers carcasses were composed of significantly less fat (17.4 *vs* 20.3 %) carcasses, the ratio muscle / fat was found significantly higher for steers than heifers (3.95 *vs* 3.34).
Gender had no influence on LT ultimate pH evaluated 24 hours *post mortem*, which was equal to 5.5. At the carcass primary cuts, the color of the both groups LT, evaluated in the CIELAB system, was equivalent.

3.2. Muscular characteristics
<u>*Muscle metabolism*</u>
Gender had a different impact on muscle metabolism depending on the muscle (table 3). In the RA muscle, gender seemed to have no significant effect on oxidative (ICDH) and

glycolytic (LDH) metabolisms (p=0.968 and p=0.488 respectively). In the LT muscle, steers had a lower oxidative metabolism than heifers (1.40 *vs* 1.89 µmol/min/g), without any differences on glycolytic metabolism (p=0.481). To finish with, in the TB muscle, both oxidative and glycolytic metabolism of heifers was significantly higher than those from steers (2.98 *vs* 2.45 and 788 *vs* 699 µmol/min/g respectively).

Table 1 : Growth and carcass characteristics

Gender	Heifers	Steers	*P-values*
N	11	11	
Birth to weaning period (0-10 months)			
Birth weight (kg)	41,4	50,5	*<0.001*
Weaning age (d)	295	291	*0.353*
Weaning weight (kg)	295	339	*<0.001*
First Indoor winter (10 to 16 months)			
Weight at the end of the winter (kg)	426	466	*0.001*
Second outdoor summer (16 to 22 months)			
Weight 15 days after the pasture turnout (kg)	406	447	*0.003*
Weight at the end of the summer (kg)	529	594	*<0.001*
Finishing period (at the barn - 22 to 27 months)			
Length of the finishing period (d)	162	150	*0.385*
Fattening score at the beginning of the finishing period (0 to 5)	2.5	2.3	*0.164*
Fattening score at the end of the finishing period (0 to 5)	3.3	2.8	*0.002*
Weights and yield			
Age at slaughter (d)	821	805	*0.560*
Live weight: LW (kg)	625	713	*<0.001*
Warm carcass weight: WCW (kg)	347	399	*<0.001*
Dressing percentage: LW / WCW x 100 (%)	66.0	65.8	*0.682*
Carcass composition			
Fat (% WCW)	20.3	17.4	*0.031*
Muscle (% WCW)	66.2	67.3	*0.352*
Bone (% WCW)	13.9	15.3	*<0.001*
Muscle / Fat ratio (kg/kg)	3.34	3.95	*0.040*
LT ultimate pH and colour			
Ultimate pH	5.50	5.47	*0.392*
L*	41.5	42.4	*0.530*
a*	20.1	20.5	*0.545*
b*	16.9	18.1	*0.153*

Connective tissues properties

Gender had no impact on intramuscular fat content in any of the three muscles (table 3). In average, the muscle TB, LT and RA contained respectively 11.5%, 13.3% and 16.6% intramuscular fat in the dry matter.

In the LT and TB muscles, gender didn't affect nether the total collagen content (p=0.124 and p=0.870 respectively) nor the collagen solubility (p=0.295 and p=0.725 respectively). In the RA muscle, steers appeared to have a higher content in total collagen (29.4 *vs* 23.6 mg/g in the dry matter) but also a more soluble collagen (20.2 *vs* 17.0 %) than heifers.

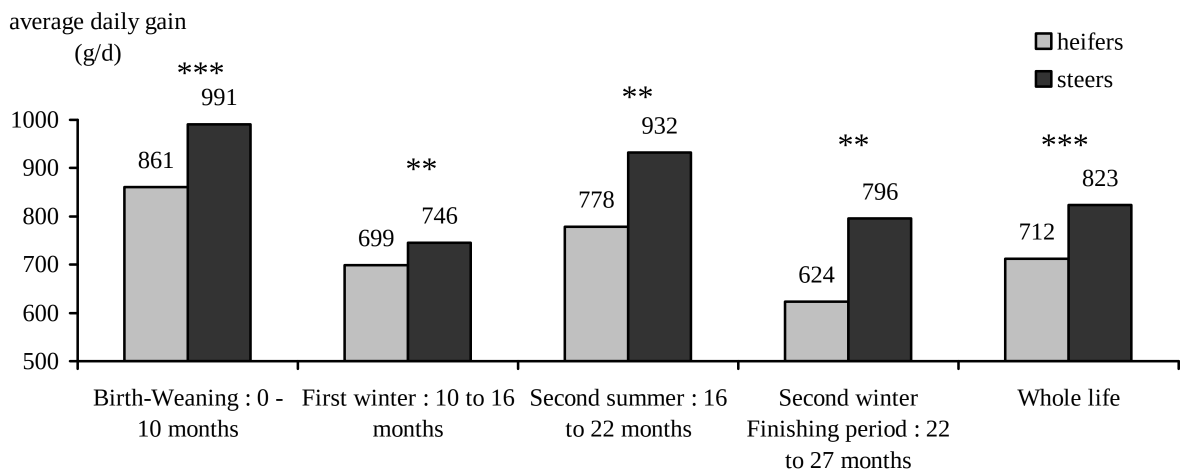

Figure 1 : Average daily gain of steers and heifers depending on the period
*** : p<0.01 ; *** p<0.001*

3.3. Meat quality traits

Despite the differences on connective tissues properties in the RA muscle, no significant impact of gender was observed on the tenderness of this muscle (6.4 on 10 in average; p=0.909). The tenderness of steers and heifers TB muscles was as well equivalent (5.8 on 10 in average; p=0.780). In these two muscles, there were no significant influences of gender nether on juiciness nor on flavour intensity scores (table 4).
Steers LT samples seemed to be as tender as heifers ones (p=0.096), but light differences appeared on juiciness and flavour intensity scores between genders. Indeed, heifers had slightly better scores than steers for both descriptors (6.0 *vs* 5.5, p=0.072 and 6.3 *vs* 6.0 on 10, p=0.089 respectively).

Table 3 : Muscle metabolism and connective tissues properties
H : Heifers ; S : Steers ; P-v : P-values

Muscle	RA			TB			LT		
Gender	*H*	*S*	*P-v*	*H*	*S*	*P-v*	*H*	*S*	*P-v*
LDH (µmol/min/g)	647	617	*0.488*	788	699	*0.060*	852	811	*0.481*
ICDH (µmol/min/g)	1.26	1.25	*0.968*	2.98	2.45	*0.071*	1.89	1.40	*0.026*
Intramuscular lipid content (% DM)	16.3	16.9	*0.769*	11.5	11.5	*0.965*	13.8	12.8	*0.406*
Total collagen content (mg/g DM)	23.6	29.4	*0.001*	38.5	37.7	*0.870*	17.4	18.8	*0.124*
Collagen solubility (% total)	17.0	20.2	*0.042*	23.4	22.1	*0.725*	19.6	21.2	*0.295*

Table 4 : Meat quality traits
H : Heifers ; S : Steers ; P-v : P-values

Muscle	RA			TB			LT		
Gender	*H*	*S*	*P-v*	*H*	*S*	*P-v*	*H*	*S*	*P-v*
Tenderness (on 10)	6.3	6.4	*0.909*	5.8	5.7	*0.780*	6.3	6.8	*0.096*
Juiciness (on 10)	6.3	6.7	*0.186*	5.8	5.6	*0.675*	6.0	5.5	*0.072*
Flavour (on 10)	6.4	6.3	*0.476*	5.9	6.1	*0.384*	6.3	6.0	*0.089*

4. Discussion

The lower live-weights of heifers persisted through each of their subsequent management phases, from birth to slaughter. At weaning age (10 months), just before males castration, heifers produced a 44-kg lower weight on average in comparison to steers. These findings were consistent with the previous results of Szabo *et al*. (2006), who established an advantage of male calves live-weights equal to 17-kg, at 7 months of age. A difference of weaning-weight, in favour of males was also found in the previous studies of Garcia de Siles *et al*. (1982), Jakubec *et al*. (2000) and Lengyel *et al*. (2003).
Our results point the differences between steers and heifers in their growth path. Indeed, steers were found to have significantly higher growth rates than heifers during the whole life, as already found by Hennessy et Morris (2003). These authors noted that steers generally had higher growth rates than heifers during the whole life, but pasture phase was this difference significant only during the post-weaning. Moreover, when evaluating the post-weaning period, Garcia de Siles *et al*. (1982) found that heifers had a lower average daily gain in comparison to steers, for the same number of days on feed.
At the same age at slaughter, steers produced carcasses 52-kg heavier than those produced by heifers. The superiority of steers over heifers in terms of carcass weight for equivalent age is in agreement with the results of Garcia de Siles *et al*. (1982), Keane et Drennan (1987, 1990), Steen (1995), Hennessy et Morris (2003) and Choat *et al*. (2006). The equivalent dressing percentages between steers and heifers was also consistent with previous results. Indeed, in the literature, heifers yielded a comparable dressing percentage as steers (Steen, 1995) but also as bulls (Mukhoti and Berg, 1971; Geay *et al*., 1975; Geay, 1978).

Even if steers and heifers began their finishing stage at an equivalent fatness score, steers had at slaughter a significantly lower fattening score than heifers. These findings are consistent with previous ones, which indicated that steers had less subcutaneous fat (Marchello *et al*., 1970; Klastrup *et al*., 1984), less fat cover at the P8 rump site (Hennessy et Morris, 2003) and less fat thickness at the 12th rib (Garcia de Siles *et al*., 1982; Choat *et al*., 2006) than heifers.
This higher fat covering score of heifers is in agreement with the higher fat content in the carcass, as already seen by Steen et Kilpatrick (1995) and Fiems *et al*. (2003). In our findings, heifers contained 2.9%-unit less fat in their carcasses than steers, so that the meat / fat ratio was 18% lower. As a result, the meat production coefficient (dressing percentage x meat content in the carcass) was nearly 14% higher for steers than heifers. These findings are consistent with the previous results of Fiems *et al*. (2003), who found that the meat / fat ratio and the meat production coefficient were respectively 34% and 10% between 2-years old bulls and 3-years old cows. These conclusions may be linked to the significant difference of composition of the carcass gain between genders: heifers have more fat (44 *vs* 38%) and less lean (47 *vs* 52%) in the carcass gain than steers, for the same proportion of bone (Steen, 1995).

In the three muscles, ICDH and LDH activities were higher in the heifers muscles than in steers ones, the differences being significant for the muscles TB (LDH and ICDH activities) and LT (ICDH activity). Heifers also seemed to have a higher metabolism than steers. Quite few results are published about metabolism enzyme activities and our results are also difficult to compare with the literature.
The differences in carcass fatness had no consequences for the meat intramuscular fat content. Indeed, in the current study, steers muscles contained the same amount of intramuscular fat than the heifers muscles. The current findings are consistent with previously results of Hoving-Bolink *et al*. (1999), who reported a comparable intramusuclar fat content between

longissimus muscles of heifers and young bulls. Heifers also produced lower carcass weights with comparable intramuscular fat contents at the same age than steers.
The amount of total intramuscular collagen and heat soluble collagen in the muscles TB and LT were similar for steers and heifers, as already observed by Klastrup *et al*. (1984) in the LT muscle. These authors indicated that the majority of the data points toward a generally higher content of collagen in bulls than in males castrates or females. Nevertheless, in the current study, steers were found to have a higher amount and a more soluble collagen in the muscle RA than heifers. The higher collagen content and solubility of steers may be linked to androgens that stimulate the neo-synthesis of intramuscular collagen in the 10 first months of steers life (before the castration). However, this significantly higher collagen content in the RA muscle of steers did not result in significantly lower meat quality traits.
The current findings relative to the effects of gender on RA and TB steaks tenderness are consistent with previously reported results on LT muscle of Gracia *et al*. (1970), Prost *et al*. (1975), Marion *et al*. (1980) and Klastrup *et al*. (1984), who concluded that gender had no effect on cooked beef steaks tenderness. Moreover, in the RA and TB muscles, there were no differences between genders in sensory evaluation scores for juiciness and flavour intensity, as already found by Klastrup *et al*. (1984) and Choat *et al*. (2006) on the LT muscle. This lack of difference between steers and heifers meat on juiciness and flavour intensity scores may be linked to the comparable content in intramuscular fat for the meat of these two types of animal. Nevertheless, it is important to note that most of the sensory analysis results presented in the literature concern the muscle LT and rather few are about RA or TB muscles. It is also difficult to confront the results obtained for muscles RA and TB in the current study to the results of the literature.
The small differences that appeared on LT tenderness of steers and heifers muscles confirm the findings of Choat *et al*. (2006). Indeed, these authors observed differences in tenderness between steers and heifers, with an advantage for steaks from steers carcasses compared with steaks from heifers carcasses. However, in this particular case, the ultimate effect of gender on consumer acceptability of beef was expected to be minimal, consumer acceptability being estimated similar between steers and heifers meat. Moreover, in the current study the results were not significant (p=0.096). The conclusions about the effect of gender on LT tenderness should also be temperate, all the more as other authors found inconsistent results. For example, Touraille (1982) observed that the tenderness of heifers steaks is significantly higher than those from steers steaks. Moreover, in the LT muscle, steers seemed to have less intense meat flavour and lighter juiciness than heifers. These findings are consistent with the previously reported results of Hennessy and Morris (2003), who found that meat from heifers had higher scores of meat quality (sum of the tenderness, juiciness, flavour intensity and overall-like scores) than meat from steers. Concerning the LT colour, no difference between steers and heifers were found on lightness (L*), redness score (a*) or yellowness score (b*), as previously observed by Klastrup *et al*. (1984), Boles et Swan (2002) and Hennessy et Morris (2003).

5. Conclusion

The findings of the current experiment suggest that young steers produce samples with equivalent lipid content and meat quality traits than heifers slaughtered at the same age. Theses steers, younger and lighter than the traditional steers, could also compete with heifers in term of meat quality traits. New ways of steers production may also be investigated to replace the missing heifers.

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