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Rearing practices in each life period of beef heifers can be used to influence the carcass characteristics

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ABSTRACT

To improve their income, European cattle breeders have to produce cattle carcasses with the best score on the EUROP system. The objectives of this study were to identify the rearing practices applied on farms at each period of a heifer's life and to study the relationship between these practices and the carcass characteristics. Farm surveys ($n = 45$) were performed to assess the rearing practices. A factorial analysis of mixed data followed by a hierarchical clustering on principal components was performed for each life period. The clusters resulting from these typologies were related to the carcass characteristics (weight, conformation and fat scores). For the suckling period, the cluster characterised by a calving season in autumn, a short pasture period and systematic supplies of stored grass and concentrate in stall gave heavy carcasses with the highest conformation scores. For the growth period, the best cluster for producing favourable carcass characteristics was characterised by the longest pasture period, feeding the most stored grass and feeding a regular concentrate supply throughout the year. For the fattening period, the cluster characterised by the oldest age at the beginning of the period and at slaughter, slaughter in winter and autumn, a long pasture period and regular concentrate supply gave the heaviest carcasses with the highest conformation scores. This study highlights several rearing practices that could be used as a means to influence the carcass characteristics, and also the life periods at which animals are sensitive to changes in management practices to improve weight and conformation scores.

HIGHLIGHTS

- Carcass characteristics are related to rearing practices applied at each life period of heifers.
- Rearing practices can be used as a means to influence carcass characteristics.

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Introduction

The income of beef cattle farmers is mainly based on fulfilling the meat chain objectives for the various existing markets. Carcass weight, conformation score and fat score are systematically used in all European slaughterhouses for the determination of the sale value of a carcass, although additional indicators to the EUROP system have been proposed to better characterise beef carcasss (Monteils et al. 2017). European breeders have to maximise management of these parameters to optimise their income.

Rearing practices are known to have an impact on beef carcasses and meat characteristics (Soulat, Picard, Leger, Ellies-Oury et al. 2018). Most studies conducted on the topic concern the last period of an animal's life, the fattening period, which is a key period influencing the sensory characteristics of meat (Schmidt et al. 2013; Blank et al. 2017; Torrecilhas et al. 2017). The accumulated knowledge of fattening rearing practices should allow management of the meat production to reach a specific goal. However, it appears that the carcasses produced have heterogeneous characteristics for the same category of animals, in particular for weight, fat score and colour (Reverter et al. 2003). This heterogeneity can lead to difficulties for carcass treatment during the butchering process, and so in the supply to market. This highlights the difficulty in controlling the production, which can be explained by the multiplicity of quality determinants of carcasses (Maltin et al. 2003). The rearing practices applied after calving have an influence on the animals' performance (ADG, live weight) at the growth period (Lowman et al. 1993; Guggeri et al. 2014; Moaeen-ud-Din and Bilal 2017). These differences in performance involve

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different animal properties at the beginning of the fattening period. They can also have an influence on the carcass characteristics, in particular by cumulative effects throughout the animal's life. A more complete consideration of the effect of rearing practices on carcass characteristics could allow identification of means to improve these characteristics, as well as their uniformity, thereby increasing breeder income.

We hypothesise that the rearing practices used at different periods of the life of a heifer can influence the characteristics of the beef carcasses produced. Surveys on farms allow collection of data about all of the rearing practices applied during the whole life (Mourits et al. 2000; Vasseur et al. 2010; Klein-Jöbstl et al. 2015; Soulat, Picard, Leger, et al. 2018). The objectives of this study were to identify the rearing practices applied at each life period of beef heifers and to study the relationship of such practices with the carcass characteristics. A better knowledge of the effects of the rearing practices on carcass characteristics, by life period, would permit improvement of the management of beef cattle and the income of breeders by specifically targeting the payment criteria currently used in the EUROP system.

Materials and methods

Choice of the partnership sector

To consider all of the rearing practices applied in a uniform way for the whole life of an animal, the authors considered it necessary to focus on a situation where there were not too many rearing practices, while ensuring a diversity of the practices applied on the farms. A 'labelled' production is considered to be the best strategy to be competitive, in particular in the meat sector (Olaizola et al. 2012; FAO 2018). Taking into account these points, the choice was made to work in partnership with the PGI (Protected Geographical Indication) 'Génisse Fleur d'Aubrac' (Légifrance 2008), which is located in a grassland area in the Massif Central, France.

Data collection of rearing practices by farm surveys

Forty-five breeders/fatteners participated in this study, which represents 23.6% of the members of the 'Génisse Fleur d'Aubrac' PGI ($n = 190$).

The data were collected by survey in a single visit in 2015 (Ingrand and Dedieu 1996; Agabriel et al. 2005). The general data (UAA, animal number, altitude) were collected at the farm level. The data for the rearing practices were collected at the level of each group of animals, which is here defined as animals physically together and receiving the same rearing practices.

Each animal's life was considered in three key periods: suckling, growth and fattening. For each of these life periods, data about rearing practices were collected (Table 1).

Data collection of carcass characteristics

The data for the labelled PGI carcasses produced by the 45 breeders were collected at the individual level at the only slaughterhouse authorised in the PGI specification (Slaughterhouse of Gévaudan in Marvejols, France). About 1 h after slaughter, carcasses were

Table 1. Rearing practices data collected during the farm surveys by life period.

Life period	Quantitative information	Qualitative information (modalities)
Common for the three periods	Stage duration, d	Pasture use (Y/N)
	Pasture duration, d	Stored forage distribution in stall (Y/N)
	Pasture proportion, %	Stored forage distribution at pasture (Y/N)
		Concentrate distribution in stall (Y/N)
		Concentrate distribution at pasture (Y/N)
		Minerals or vitamins distribution (Y/N)
		Vaccination (Y/N)
		Internal antiparasitic treatment (Y/N)
		External antiparasitic treatment (Y/N)
Suckling period	Age at weaning, d	Calving season (winter/spring/summer/autumn)
		Dehorning (Y/N)
		Suckling method (accompanied/free/both)[a]
Growth period	Age at the beginning of the period, d	Maize silage distribution (Y/N)
	Cumulative concentrate offered, kg/heifer	
	Daily concentrate offered in stall, kg/heifer/day	
	Daily concentrate offered at pasture, kg/heifer/day	
Fattening period	Age at the beginning of the period, d	Slaughter season (winter/spring/summer/autumn)
	Age at slaughter, d	
	Cumulative concentrate offered, kg/heifer	
	Daily concentrate offered in stall, kg/heifer/day	
	Daily concentrate offered at pasture, kg/heifer/day	

(Y/N): yes or no.
[a]Accompanied: the farmer led the calves to their mothers twice daily for suckling; free: the calves were always with their mothers and suckled *ad libitum*; both: both methods were used.

Table 2. Rearing practices of the animal groups ($n = 61$) by period of life. Except other indication, presentation of the results as a number of groups with in brackets the % of each modality of the variable.

	Suckling period	Growth period	Fattening period
Duration, d (minimum–maximum)	244.0 (110.0–323.0)	488.0 (303.0–823.0)	198.0 (56.0–437.0)
Rearing place, number, %			
Pasture and stall	58.0 (95.1)	61.0 (100.0)	22.0 (36.1)
Pasture	2.0 (3.3)	0.0	3.0 (4.9)
Stall	1.0 (1.6)	0.0	36.0 (59.0)
Pasture duration, %	65.0	50.0	24.0
Forage distribution in stall, number, %			
Hay	55.0 (90.2)	60.0 (98.4)	56.0 (91.8)
Maize silage	0.0	6.0 (9.8)	0.0
Haylage	2.0 (3.3)	22.0 (36.1)	20.0 (32.8)
Grass silage	0.0	27.0 (44.3)	19.0 (31.1)
Straw	1.0 (1.6)	3.0 (4.9)	4.0 (6.6)
Forage distribution at pasture, number, %			
Hay	0.0	14.0 (23.0)	8.0 (13.1)
Maize silage	0.0	0.0	0.0
Haylage	0.0	7.0 (11.5)	0.0
Grass silage	0.0	0.0	0.0
Straw	0.0	0.0	3.0 (4.9)
Concentrate distribution in stall, number, %			
Straw cereals	3.0 (4.9)	29.0 (47.5)	33.0 (54.1)
Meals	1.0 (1.6)	17.0 (27.9)	25.0 (41.0)
By-products	1.0 (1.6)	4.0 (6.6)	4.0 (6.6)
Complete feed	35.0 (57.4)	24.0 (39.4)	34.0 (55.7)
Mash	1.0 (1.6)	0.0	3.0 (4.9)
Concentrate distribution at pasture, number, %			
Straw cereals	6.0 (9.8)	16.0 (26.2)	7.0 (11.5)
Meals	2.0 (3.3)	8.0 (13.1)	7.0 (11.5)
By-products	1.0 (1.6)	2.0 (3.3)	2.0 (3.3)
Complete feed	8.0 (13.1)	15.0 (24.6)	18.0 (29.5)
Mash	0.0	2.0 (3.3)	4.0 (6.6)
Minerals or vitamins distribution, number, %	39.0 (63.9)	45.0 (73.8)	30.0 (49.2)
Vaccination, number, %	52.0 (85.2)	26.0 (42.6)	10.0 (16.4)
Antiparasitic treatment, number, %			
Internal	44.0 (72.1)	56.0 (91.8)	38.0 (62.3)
External	35.0 (57.4)	42.0 (68.9)	29.0 (47.5)

weighed (hot carcass weight) and graded visually (conformation and fat scores). The cold carcass weight was calculated as 0.98 × hot carcass weight. The EUROP system consists of characterisation of carcass conformation using a scoring grid divided into five classes: E (extremely well-muscled), U, R, O and P (very poorly muscled). Each class of conformation was divided into three sub-categories using '+' (high), '=' (average) and '−' (low), so that the conformation score was divided into 15 subclasses. A scale ranging from 1 (very poorly muscled) to 15 (extremely well-muscled) corresponding to each conformation sub-category was used (EC 2006; Hickey et al. 2007) to perform statistical analysis. In the EUROP system, the fat score of the carcass is divided into five classes where 1 is lean and 5 is very fat.

Data analyses

The statistical analyses were performed using R 3.4.2 software (R Core Team 2016) with the packages R commander (Fox 2005) and FactoMineR (Husson et al. 2015).

For each of the three key periods of the animal's life, a multivariate analysis of the rearing practices was done using a factorial analysis of mixed data (FAMD) on quantitative and qualitative variables selected to be discriminative and not redundant. The variables used for the analysis of the suckling period were: period duration, calving season, suckling method, pasture proportion, stored forage distribution in stall and concentrate distribution in stall and at pasture. The variables used for the analysis of the growth period were: age at the beginning of the period, period duration, pasture proportion, stored forage distribution at pasture, maize silage distribution in stall and daily concentrate offered in stall and at pasture. The variables used for the analysis of the fattening period were: age at the beginning of the period, age at slaughter, slaughter season, period duration, pasture proportion, stored forage distribution at pasture and daily concentrate offered in stall and at pasture. A classification by hierarchical clustering on principal components (HCPC) was then performed to identify clusters of rearing practices that were linked to the characteristics of the relevant carcasses.

The clusters of rearing practices identified for the three life periods were characterised by the averages of the quantitative variables or the frequencies of

each modality for the qualitative variables. For each cluster of rearing practices, the averages of the weights, the conformation scores (after conversion into numerical data) and fat scores of the associated carcasses were calculated. An ANOVA was done for the quantitative variables to determine the significant differences between the clusters at the rearing practices and the carcass characteristics levels. When the result of ANOVA was significant a *post hoc* analysis comparing the pairwise means was conducted using the Tukey test with a significance threshold of 0.05. For the qualitative variables, a chi-square test was done with a significance threshold of 0.05.

Results and discussion

All 45 farms had a large majority of their area in grassland (>90% of the UAA) and were very diverse in terms of altitude (620–1250 m) and UAA (63–312 ha). Cereals were cultivated on 34 farms (9 ha on average, with a range of 2–35 ha; i.e. 0–16.7% of the UAA), and maize silage was used on 13 farms (4 ha on average, with a range from 2 to 8 ha; i.e. 0–5.4% of the UAA). An average of 15 (range of 6–51) heifers per farm was harvested in 2014.

The main rearing practices applied at each life period are presented in Table 2. The rearing practices used by the 45 breeders allowed the characterisation of 61 groups of heifers with an average of 10.4 animals per group (range 1–30). Most of the farms had a single animal group (69%), while the others had two groups (12 farms) or three groups (2 farms). Animals spent on average 26% of their life in the suckling period, 53% in the growth period and 21% in the fattening period.

Six hundred and thirty-six heifers were slaughtered at an average age of 30.5 months (Table 3). The average carcass weight was 402 kg, and the average conformation score was 11.2 on the 15-point scale. The most represented conformation classes were U+, U= and U−, according to the EUROP grid (94% of the carcasses). Little variability in fat score was observed (99.4% of carcasses had a score of 3 on the 5-point scale).

Table 3. Carcass characteristics ($n = 636$).

	Mean	Minimum	Maximum	SD
Slaughter age, mo	30.500	24.500	42.500	3.571
Cold carcass weight, kg	402.000	310.000	566.000	34.980
Fat score, /5	2.990	2.000	3.000	0.087
Conformation score, /15	11.200	8.000	15.000	0.877
Carcass per EUROP conformation class				
Class	Number		%	
E+	1.000		0.200	
E=	1.000		0.200	
E−	24.000		3.800	
U+	216.000		34.000	
U=	237.000		37.300	
U−	147.000		23.100	
R+	9.000		1.400	
R=	1.000		0.200	
R−	0.000		0.000	
O+	0.000		0.000	
O=	0.000		0.000	
O−	0.000		0.000	
P+	0.000		0.000	
P=	0.000		0.000	
P−	0.000		0.000	

Characteristics of the rearing practices clusters for each life period and the characteristics of the associated carcasses

Suckling period

For the suckling period, three clusters of rearing practices were observed (Table 4). The cluster SUC1 was mainly characterised by calving in autumn, a short pasture duration, systematic supplies of stored grass and concentrate in stall and a lower vaccination frequency. The practices of cluster SUC2 (74% of all groups) were calving in winter, an intermediate pasture duration, and frequent supplies of stored grass and concentrate in stall. The cluster SUC3 was characterised by a low weaning age, calving in spring, a long pasture duration with no supply of stored grass and little concentrate, and in the stall little stored grass and concentrate.

The rearing practices of cluster SUC1 gave heavy carcasses with the highest conformation scores. The carcasses fell in only four classes of the EUROP system with 84% in classes U= and U+. Cluster SUC2 had the heaviest carcasses ($n = 497$; i.e. 78.1% of the carcasses), with intermediate conformation scores (71% of the carcasses in the U= and U+ classes). Cluster SUC3 had the lightest carcasses, with the lowest conformation scores (65% of the carcasses in classes U− and U=). The rearing practices of cluster SUC1 were the most favourable for obtaining carcasses with heavier weights and higher conformation scores. Those of cluster SUC3 were the least favourable for these traits.

In our study, a late weaning age generated heavier carcasses with higher conformation scores. Our results confirmed those of Schoonmaker et al. (2004) and Sexten et al. (2012) with ages at weaning close to ours. However, an earlier weaning age led to significantly heavier carcasses for Blanco, Villalba, et al. (2008) (90 d vs. 150 d) and Shoup et al. (2015) (78 d vs. 186 d), while Guerrero et al. (2013) did not observe any effect of weaning age (90 d to 120 d vs. 210 d). Several authors have shown that early weaning has little effect on the carcass characteristics when the

Table 4. Rearing practices by cluster taken as characterising the suckling period (SUC) and carcass characteristics. Except other indication, presentation of the results as a number of groups with in brackets the % of each modality of the variable.

	SUC1	SUC2	SUC3	SEMc	*p*-valued
Rearing practices					
Number of animal per group	7.00	45.00	9.00		
Age at weaning, d	245.00[a]	253.00[a]	200.00[b]	5.11	***
Calving season, number, %					***
Winter	1.00 (14.30)	45.00 (100.00)	1.00 (11.10)		
Spring	0.00	0.00	8.00 (88.90)		
Summer	0.00	0.00	0.00		
Autumn	6.00 (85.70)	0.00	0.00		
Dehorning, number, %	2.00 (28.60)	21.00 (46.70)	5.00 (55.60)		ns
Suckling method, number, %					ns
Accompanied	1.00 (14.30)	16.00 (35.60)	5.00 (55.60)		
Free	1.00 (14.30)	14.00 (31.10)	3.00 (33.30)		
Both	5.00 (71.40)	15.00 (33.30)	1.00 (11.10)		
Pasture duration, d	97.00[b]	167.00[a]	173.00[a]	5.15	***
Pasture duration, %	35.00[c]	67.00[b]	82.00a	2.48	***
Stored grass distribution, number, %					
Stall	7.00 (100.00)	43.00 (95.60)	5.00 (55.60)		**
Pasture	0.00	1.00 (2.20)	0.00		*
Concentrate distribution, number, %					
Stall	7.00 (100.00)	28.00 (62.20)	2.00 (22.20)		***
Pasture	1.00 (14.30)	8.00 (17.80)	1.00 (11.10)		**
Minerals or vitamins distribution, number, %	2.00 (28.60)	32.00 (71.10)	5.00 (55.60)		+
Vaccination	4.00 (57.10)	41.00 (91.10)	7.00 (77.80)		*
Antiparasitic treatment, number, %					
External	3.00 (42.90)	27.00 (60.00)	5.00 (55.60)		ns
Internal	3.00 (42.90)	34.00 (75.60)	7.00 (77.80)		ns
Carcass characteristics					
Number of carcasses	68.00	497.00	71.00		
Cold carcass weight, kg	404.00[ab]	404.00[a]	391.00[b]	1.53	*
Fat score, /5	3.00	2.99	3.00	0.00	ns
Conformation score, /15	11.50[a]	11.20[b]	10.90[c]	0.04	***
Carcasses per EUROP conformation class (number, %)					**
E+	0.00	1.00 (0.20)	0.00		
E=	0.00	1.00 (0.20)	0.00		
E−	3.00 (4.40)	18.00 (3.60)	3.00 (4.20)		
U+	33.00 (48.50)	166.00 (33.40)	17.00 (23.90)		
U=	24.00 (35.30)	188.00 (37.80)	25.00 (35.20)		
U−	8.00 (11.80)	118.00 (23.70)	21.00 (29.60)		
R+	0.00	4.00 (0.80)	5.00 (7.00)		
R=	0.00	1.00 (0.20)	0.00		

[a,b]Within a row means without a common superscript are different.
[c]Standard error of mean.
[d]$+p < .1$, $*p < .05$, $**p < .01$, $***p < .0001$, ns not significant.

nature of the diet is adapted after weaning (Myers et al. 1999; Fluharty et al. 2000; Lobato et al. 2007; Moriel et al. 2014). Early weaning led to higher conformation scores in the study of Blanco et al. (2009), but other authors did not observe differences in conformation scores due to this management practice (Blanco, Ripoll, et al. 2008; Guerrero et al. 2013; Lambertz et al. 2015). Our results did not agree with those in these latter studies. A significant interaction between weaning age and use of concentrate in the diet reported by Blanco, Villalba, et al. (2008) could explain this result. Also, Blanco, Villalba, et al. (2008) showed higher fat scores with early weaning, but Guerrero et al. (2013) showed the opposite effect, and no effect was observed in our study.

No effect of calving season (autumn vs. winter) on the carcass weights was observed by McIntyre et al. (2009). Our results confirmed this observation. However, the calving season effect is difficult to separate out, because it is strongly linked to other practices. The clusters defined in our study were characterised both by calving season and feeding management, for example, the duration of pasture. This result is consistent with that of Durunna et al. (2014) who observed a significant interaction between the calving season and the nature of the diet, which did not lead to a clear conclusion about the effect of the calving season alone.

In our study, an increase in the proportion of pasture before weaning was associated with decreased weight and lower conformation scores of carcasses. The calves put out to pasture during the suckling period consumed grass in addition to milk. Abdelsamei et al. (2005) reported a high forage intake for calves when milk production at the peak of

Table 5. Rearing practices by cluster taken as characterising the growth period (GRO) and carcass characteristics. Except other indication, presentation of the results as a number of groups with in brackets the % of each modality of the variable.

	GRO1	GRO2	GRO3	GRO4	SEMc	*p*-valued
Rearing practices						
Number of animal per group	16.00	6.00	24.00	15.00		
Stage duration, d	628.00[a]	446.00[b]	414.00[b]	474.00[b]	16.40	***
Age at the beginning of growth, d	226.00	251.00	250.00	249.00	5.11	ns
Pasture duration, d	252.00[ab]	190.00[b]	217.00[b]	275.00[a]	8.93	*
Pasture duration, %	39.00 c	43.00[bc]	53.00[ab]	58.00[a]	1.35	***
Stored grass distribution, number, %						
Stall	16.00 (100.00)	6.00 (100.00)	24.00 (100.00)	15.00 (100.00)		*
Pasture	4.00 (25.00)	1.00 (16.70)	0.00	12.00 (80.00)		***
Maize silage distribution, number, %						
Stall	0.00	6.00 (100.00)	0.00	0.00		***
Pasture	0.00	0.00	0.00	0.00		*
Concentrate, kg/heifer	653.00[a]	147.00[ab]	199.00[b]	345.00[ab]		*
Concentrate, kg/day/heifer						
Stall	0.84[a]	0.35[ab]	0.46[ab]	0.37[b]	0.06	*
Pasture	0.15[ab]	0.00[ab]	0.03[b]	0.33[a]	0.04	**
Minerals or vitamins distribution, number, %	13.00 (81.30)	1.00 (16.70)	19.00 (79.20)	12.00 (80.00)		*
Vaccination	9.00 (56.30)	0.00	13.00 (54.20)	4.00 (26.70)		*
Antiparasitic treatment, number, %						
External	12.00 (75.00)	1.00 (16.70)	16.00 (66.70)	13.00 (86.70)		*
Internal	15.00 (93.80)	5.00 (83.30)	22.00 (91.70)	14.00 (93.30)		ns
Carcass characteristics						
Number of carcasses	167.00	90.00	227.00	152.00		
Cold carcass weight, kg	408.00[a]	398.00[ab]	396.00[b]	407.00[a]	1.53.00	**
Fat score, /5	2.99	2.99	2.99	3.00	0.00	ns
Conformation score, /15	11.10[b]	11.20[ab]	11.00[b]	11.40[a]	0.04	***
Carcass per EUROP conformation class, number, %						**
E+	0.00	0.00	1.00 (0.40)	0.00		
E=	0.00	0.00	1.00 (0.40)	0.00		
E−	8.00 (4.80)	2.00 (2.20)	7.00 (3.10)	7.00 (4.60)		
U+	51.00 (30.50)	32.00 (35.60)	58.00 (25.60)	75.00 (49.30)		
U=	66.00 (39.50)	38.00 (42.20)	85.00 (37.40)	48.00 (31.60)		
U−	38.00 (22.80)	16.00 (17.80)	72.00 (31.70)	21.00 (13.80)		
R+	4.00 (2.40)	2.00 (2.20)	3.00 (1.30)	0.00		
R=	0.00	0.00	0.00	1.00 (0.70)		

[a,b]Within a row, means without a common superscript are different.
[c]Standard error of mean.
[d]*$p < .05$, **$p < .01$, ***$p < .0001$, ns not significant.

lactation of the mother was low, which in turn was linked to low carcass weights and low fat composition (% and thickness of cover fat). In a review, Drouillard and Kuhl (1999) did not highlight any effect of pasture during the suckling period on carcass characteristics. Also, the pasture type (mountain grazing vs. cultivated lowland pasture) during this period had little impact on the carcass characteristics (Steinshamn et al. 2010).

In the suckling period, increased use of concentrate in stall resulted in increased weights and conformation scores of carcasses. This result was consistent with the conclusions from the review of Drouillard and Kuhl (1999), who reported an increase in carcass weights and fat scores with supplementation at pasture. Concentrate use at pasture has been reported as a strongly influential factor in prediction models of the carcass characteristics (Soulat, Picard, Leger, et al. 2018). This finding could be connected to the results of Hennessy and Morris (2003), who showed heavier carcasses for steers harvested at similar ages when growth before weaning was high. Conformation scores with a concentrate supply were reported to be higher with late weaning than with early weaning (150 d vs. 90 d) (Blanco, Villalba, et al. 2008).

Growth period

For the growth period, four clusters of rearing practices were defined (Table 5). Cluster GRO1 had the longest duration, the lowest proportion at pasture and the highest quantity of concentrate. Cluster GRO2 had a feeding management system that included maize silage in stall, and neither maize silage nor concentrate and very little supply of stored grass at pasture. The practices of cluster GRO3 were the shortest period duration, and pasture management with no supply of stored grass, and very little concentrate. For cluster GRO4, pasture was long (highest duration and proportion), and feeding management at pasture had the highest supplies of stored grass and concentrate, and

Table 6. Rearing practices by cluster taken as characterising the fattening period (FAT) and carcass characteristics. Except other indication, presentation of the results as a number of groups with in brackets the % of each modality of the variable.

	FAT1	FAT2	SEMc	*p*-valued
Rearing practices				
Number of animals per group	41.00	20.00		
Stage duration, d	199.00	197.00	8.48	ns
Age at the beginning of fattening, d	685.00[b]	836.00[a]	16.20	***
Lifetime, d	884.00[b]	1032.00[a]	13.70	***
Slaughter season, number, %				***
Winter	2.00 (4.90)	8.00 (40.00)		
Spring	20.00 (48.80)	1.00 (5.00)		
Summer	16.00 (39.00)	1.00 (5.00)		
Autumn	3.00 (7.30)	10.00 (50.00)		
Pasture duration, d	11.00[b]	121.00[a]	8.91	***
Pasture duration, %	5.00[b]	62.00[a]	4.30	***
Stored grass distribution, number, %				
Stall	41.00 (100.00)	16.00 (80.00)		**
Pasture	1.00 (2.40)	7.00 (350)		***
Concentrate, kg/heifer	1039.00	990.00		ns
Concentrate, kg/day/heifer				
Stall	5.20[a]	2.20[b]	0.33	***
Pasture	0.17[b]	3.00[a]	0.23	***
Minerals or vitamins distribution, number, %	18.00 (43.90)	12.00 (60.00)		ns
Vaccination	6.00 (14.60)	4.00 (20.00)		ns
Antiparasitic treatment				
External	19.00 (46.40)	10.00 (50.00)		ns
Internal	23.00 (56.10)	15.00 (75.00)		ns
Carcass characteristics				
Number of carcasses	480.00	156.00		
Cold carcass weight, kg	399.00[b]	411.00[a]	1.53	***
Fat score, /5	2.99	2.99	0.00	ns
Conformation score, /15	11.10[b]	11.30[a]	0.04	*
Carcass per EUROP conformation class, number, %				ns
E+	0.00	1.00 (0.60)		
E=	0.00	1.00 (0.60)		
E−	17.00 (3.50)	7.00 (4.50)		
U+	154.00 (32.10)	62.00 (39.70)		
U=	188.00 (39.20)	49.00 (31.40)		
U−	113.00 (23.50)	34.00 (21.80)		
R+	7.00 (1.50)	2.00 (1.30)		
R=	1.00 (0.20)	0.00		

[a,b]Within a row, means without a common superscript are different.
[c]Standard error of mean.
[d]*$p < .05$, **$p < .01$, ***$p < .0001$, ns not significant.

also a regular concentrate supply throughout the year (on average 0.35 kg/day).

Cluster GRO1 gave heavy carcasses, with low conformation scores (70% of the carcasses in classes U = and U+). Cluster GRO2 had carcasses with intermediate characteristics (78% of the carcasses in classes U = and U+). Cluster GRO3 had the lightest carcasses with the lowest conformation scores (69% of the carcasses in classes U − and U=). Cluster GRO4 had heavy carcasses with the highest conformation scores (54% of the carcasses in classes U + and E−). The rearing practices of cluster GRO4 were the most favourable for obtaining carcasses with heavier weights and higher conformation scores. Those of cluster GRO3 were the least favourable for these traits.

According to our results, a longer growth period was associated with heavier carcasses. On the other hand, Sainz and Paganini (2004) showed that the longest growth period duration led to heavier body weight of steers, but had no effect on carcass weight, and was associated with the least fat carcasses. The effect of the growth period duration was difficult to isolate because it merged with the ADG of the animals, their age at the end of this period, and with potential feed restriction (Sainz and Paganini 2004; Reuter and Beck 2013).

Our results indicated that the two growth diets based on pasture (>50% of the period duration) gave either the heaviest carcasses with the highest conformation scores or the lightest carcasses with the lowest conformation scores. For the heaviest carcasses, the heifers were fed regular supplies of stored grass and concentrate throughout the year. For the lightest carcasses, they were fed no supplement at pasture and little concentrate in stall. This suggests that rearing animals at pasture without supplementation did

not generate carcasses with optimal characteristics. Guerrero et al. (2013) did not find differences in carcass weights and conformation scores of young bulls managed either at pasture or with a concentrate-based diet. No difference in carcass weights was observed by Myers et al. (1999) for young steers managed at pasture for 82 days after weaning or fed concentrate, nor by Berge et al. (1991) for young bulls managed at pasture or fed grass or maize silage (ad lib or rationed). Furthermore, bulls fed a total mixed ration (TMR – lucerne and maize) for 5 months, managed at pasture for 6 months, then slaughtered at similar weights generated similar carcass characteristics as bulls fed concentrate for 6 months (Blanco et al. 2014). In this latter study, the rotation TMR/pasture/TMR over a period of 10 months generated carcasses with lower conformation scores and carcass yield and higher fat scores.

We also found that the diet based on maize silage offered in stall generated carcasses with relatively low weights and the most variable characteristics. These heifers were also fed on stored grass, had little concentrate in stall, and no supplement at pasture. Different studies have reported varied effects of a supply of maize silage in the diet during the growth period on weights, conformations and fat scores of carcasses. Avilès et al. (2015) showed higher conformation scores for young bull carcasses with no weight difference in comparison to bulls fed a concentrate-based diet. Schoonmaker et al. (2004) observed higher live weights for steers at the end of the growth period, but lighter carcasses, with maize silage in comparison to an orchard grass haylage-based diet.

Our results also showed that the diet with the higher concentrate supply on the one hand, and the diet with the longer period of pasture with a regular supply of concentrate and forage on the other gave heavier carcasses. This highlighted the main effects of the amount and regularity of concentrate supply, and more globally of the energy level of the diet during the growth period. Pordomingo et al. (2012) reported heavier carcasses of heifers with a higher energy-level diet at similar slaughter ages. Brito et al. (2014) also reported heavier carcasses and higher conformation scores with a diet that allowed greater ADG for steers slaughtered at similar live weights. Furthermore, no difference in carcass weights and conformation scores were observed by Roth et al. (2017) for steers managed at pasture with supplementation that allowed various ADG levels.

Fattening period

For the fattening period, the rearing practices were divided into two clusters (Table 6). In comparison to cluster FAT2, cluster FAT1 (67% of all groups) had a lower age at the beginning of the fattening period (−151 d) and a lower slaughter age (−148 d), with main slaughter period in spring and summer, a fattening period in stall and a high daily supply of concentrate (+3.0 kg/day).

The rearing practices of the FAT1 cluster generated lighter carcasses with lower conformation scores with most of the carcasses in the U = class ($n = 480$; i.e. 75.5% of the carcasses). The rearing practices of the FAT2 cluster were more favourable for obtaining carcasses with heavier weights and higher conformation scores.

In our study, the oldest animals at the beginning of the fattening period were also the oldest at slaughter, and generated carcasses with heavier weights and higher conformation scores. Ustuner et al. (2017) showed that age at the beginning of the fattening period had no effect on the carcass characteristics when animals were slaughtered at similar live weight. However, in a review, Reuter and Beck (2013) showed that weight at the beginning of the fattening period was the most influential factor on the fattening performance, which could be linked to age. Increasing age at slaughter resulted in heavier carcasses (Ahnstrom et al. 2012; Bures and Barton 2012; Aydin et al. 2013; Nogalski et al. 2018). Our results were consistent with these observations. Moreover, with increasing slaughter age, a maize and lucerne silages-based diet led to an increase in fat scores with no change in conformation scores (Bures and Barton 2012), a diet based on grass silage and concentrate led to an increase in the conformation scores with no change in fat scores (Nogalski et al. 2018), and a diet based on hay and concentrate changed neither the conformation nor the fat score (Aydin et al. 2013).

In our study, heavier carcasses were observed for slaughter in autumn and winter. These results confirmed those of Taylor et al. (1991) who reported lower carcass weights for animals slaughtered in spring. Panjono Kang et al. (2009) did not show any effect of the slaughter season on carcass weights for animals slaughtered at similar ages. In our study, the differences of age of animals and carcass weights associated with the two fattening clusters could explain with our results are not in line with those of Panjono Kang et al. (2009).

We found higher carcass weights and conformation scores when the proportion of pasture during the

fattening period was higher. This confirms the results of Thénard et al. (2006) who showed that an extensive fattening management system, with a high proportion of pasture, and with a hay supply in stall gave heavier carcass weights, lower fat proportions and similar conformation scores than a more intensive fattening management system with less pasture and grass silage offered in stall. The differences observed in this latter study could be partially explained by the older age at slaughter for the animals managed in the extensive fattening system allowing them to reach the same carcass fat level. This system corresponded to the conditions of our study. A fattening diet based on pasture gave higher fat scores in comparison to a diet with grass silage, given that the concentrate levels, ages, and live weights at slaughter, and the growth rates were similar (Huuskonen et al., 2010). No differences were reported for the carcass weights or conformation scores by these authors.

In several studies, pasture-based fattening has been compared to fattening with a concentrate-based diet in stall, often with longer pasture duration. These studies have highlighted that carcasses were less fat with pasture-based fattening systems (Schwarz et al. 1998; Realini et al. 2004; Keane and Moloney 2010; Moloney et al. 2011; Duckett et al. 2013). However, the effect on the carcass weights and conformation scores were different depending on the study.

Our study did not show an effect of the concentrate quantity offered during the fattening period. However, the regularity of the concentrate supply for the pasture and the stall was different between the two clusters. Concentrate supplementation during the fattening period increased the carcass weights, even if the animals were slaughtered at similar live weights (McCaughey et al. 1999; Jerez-Timaure and Huerta-Leidenz 2009). In this case, the fat scores were not affected, but the conformation scores decreased (Jerez-Timaure and Huerta-Leidenz 2009). Keane and Moloney (2008) and Keane et al. (2006) reported increased carcass weights, conformation scores and fat scores when the concentrate amount increased. However, in most of the studies increased use of concentrate had little effect on the carcass characteristics, even when the amounts of concentrate were very different and had similar treatment durations (French et al. 2000; Barton et al. 2007; Oury et al. 2007; Missio et al. 2010; Lage et al. 2012; Sugimoto et al. 2012; Moletta et al. 2014; Pesonen et al. 2014). However, Cooke et al. (2004) observed increased carcass weights with increasing concentrate in the fattening diet with no effect on the conformation and fat scores.

To compare our data on female cattle in the Discussion section, we had to use the current scientific literature, which mainly deals with male cattle. Consequently, caution must be used in interpreting our results.

Conclusions

Farm data can be used to examine relationships between rearing practices during each life period, considered independently of the other periods, and the subsequent carcass characteristics. This study highlights rearing practices that were the most favourable for a given life period in terms of improving the weights and conformation scores of the carcasses produced. Carcasses with higher weights and conformation scores were associated with birth in autumn and a suckling period mainly spent in stall with provision of hay and concentrate. Regarding the growth period, heifers mainly raised on pasture and fed the most stored grass with a regular concentrate supply throughout the year gave carcasses with the best characteristics. Lastly, the heifers fattened mainly at pasture with a regular concentrate supply throughout the year and slaughtered in autumn and winter at a later age gave the carcasses with the highest characteristics. Another aspect of this study was to enhance the knowledge concerning female cattle in the available scientific literature, which is lacking on this topic.

To further develop this study and to propose advice to breeders, it would be necessary to examine the rearing management system during the animal's whole life. The rearing practices identified as the most favourable for each life period can be combined in various ways during the life of the heifers. Carcass characteristics may vary depending on the combinations of rearing practices utilised. In addition, it would be necessary to collect breeding data on female and male animals of other breeds with more detailed rearing practices to refine the characterisation of management systems.

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Ethical approval

This study was not concerned by ethical approval as investigations were carried out on commercial farms and slaughterhouses.

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