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1 To what extent does the composition of batches formed at the sorting facility influence the  
2 subsequent growth performance of young beef bulls? A French observational study.

3

4 Lucile Herve<sup>a</sup>, Nathalie Bareille<sup>b</sup>, Baptiste Cornette<sup>a</sup>, Pauline Loiseau<sup>a</sup>, and Sébastien Assié<sup>b\*</sup>

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6 <sup>a</sup>*Terrena Innovation, La Noëlle, 44155 Ancenis, France*

7 <sup>b</sup>*BIOEPAR, INRA, Oniris, CS 40706, F-44307 Nantes, France*

8 *\*Corresponding author: Sébastien Assié, BIOEPAR, INRA, Oniris, CS 40706, F-44307*

9 *Nantes, France, tel: +33 2 40 68 78 49, e-mail: [sebastien.assie@oniris-nantes.fr](mailto:sebastien.assie@oniris-nantes.fr)*

10

11 Abbreviations<sup>1</sup>

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<sup>1</sup>BW: Body weight; BRD: Bovine respiratory disease; ADG: Average daily gain; SD: Standard deviation; CV: Coefficient of variation; FADM: Factor analysis of mixed data; HCPC: Hierarchical classification on the principal components

## 12 **Abstract**

13 To meet the demands of the beef cattle sector in France, weaned beef calves are transported  
14 to sorting facilities and sorted into batches composed of animals of similar body weight (BW)  
15 before the beginning of the fattening period. This procedure aims to facilitate animal  
16 management. However, it leads to practices that affect animal welfare, health and  
17 performance, such as transporting weaned beef calves over long distances and mixing  
18 animals originating from different cow/calf farms. In contrast, other potentially beneficial  
19 practices, such as pre-weaning vaccination against bovine respiratory diseases (BRD), are  
20 seldom taken into consideration when batches are formed. This observational study, based on  
21 field data from 15,735 Charolais bulls, aimed to investigate which criteria should be favored  
22 for batch constitution by quantifying the effect of batch characteristics on the growth  
23 performance of young bulls during the fattening period. Clustering analysis was used to  
24 group young bulls exhibiting similar batch characteristics and define batch types.  
25 Associations between batch characteristics/batch types and individual growth  
26 performance/homogeneity of growth performance (mean and standard deviation (SD) of  
27 average daily gain (ADG) and fattening period duration) were studied using linear mixed  
28 models. The mean BW and the percentage of animals vaccinated against BRD before  
29 weaning were positively associated with ADG (+35 g/d for each additional 50 kg and +28 g/d  
30 for a high percentage of vaccinated animals,  $P < 0.05$ ). In contrast, transportation distance  
31 was negatively associated with ADG (-12 g/d for each additional 120 km travelled). Mixing  
32 animals and BW homogeneity did not affect growth performance ( $P > 0.05$ ). Only the mean  
33 BW and mixing animals negatively influenced the homogeneity of ADG ( $P < 0.01$ ). The  
34 clustering analysis revealed that batches with the most BW heterogeneity, the least mixing,  
35 the shortest transportation distance and a high percentage of pre-weaning animals vaccinated  
36 against BRD had better growth performance compared to batches with the opposite

37 characteristics (+ 61g/d,  $P < 0.001$ ). Our results suggest that major improvements of growth  
38 performance of fattening young bulls could be obtained by minimizing transportation  
39 distance, providing vaccination programs against BRD before weaning, and maintaining  
40 groups from the same cow/calf farm instead of constituting groups of animals with similar  
41 BW at the beginning of fattening.

42

43 **Key words:**

44 average daily gain, batch characteristic, bovine respiratory disease, beef cattle, fattening.

## 45 **Introduction**

46 In France, most young bulls from beef breeds are produced by cow/calf breeders and  
47 fattened by specialized fatteners (Poizat et al., 2019). During the rearing period at the  
48 cow/calf farm, calves are mostly reared on pasture with their dam in groups of 25-30 couples.  
49 Apart from milk and grass, calves can also sometimes be supplemented with concentrates  
50 before weaning. At the end of this rearing period, young bulls, aged between 5 and 10  
51 months, are weaned and immediately transported to a sorting facility to be sorted by breed  
52 and body weight (BW), forming new batches that fulfill the orders of the fatteners. The newly  
53 formed batches are then transported to the fattening operations for the entire fattening period.  
54 During the fattening period, young bulls are reared in barns consisting of pens of 10 to 20  
55 animals for an individual space allowance of 3.5 to 5.5 m<sup>2</sup> and fed a complete diet mainly  
56 composed of corn silage, cereals and soybean meal. The main consideration guiding the  
57 constitution of batches in sorting facilities before the beginning of the fattening period is BW:  
58 animals with similar BW are grouped together. This practice is adopted by most fatteners to  
59 facilitate the management of animals during the fattening period and improve growth  
60 performance. However, the validity of this BW-homogeneity criterion is questionable since  
61 Mounier et al. (2005) showed that making groups of similar BW at the beginning of the  
62 fattening period seemed to be detrimental to animal welfare and guaranteed neither improved  
63 nor homogeneous performance.

64 This organization of the production system is based on practices that can affect the  
65 welfare, health and growth performance of young bulls. These practices are not, or are  
66 seldom, considered when constituting batches. The first is the transportation, at times over  
67 long distances, of young bulls from cow/calf farms to fattening operations via the sorting  
68 facilities. This transportation is recognized as a stressor for beef cattle that causes adverse  
69 effects on health (Blecha et al., 1984; Sanderson et al., 2008; Cernicchiaro et al., 2012b) and

70 can lead to reduced subsequent performance (Schwartzkopf-Genswein et al., 2007;  
71 Cernicchiaro et al., 2012b). The second is the commonly observed practice in sorting  
72 facilities of mixing young bulls from different cow/calf farms, of varying ages, and  
73 sometimes of different breeds to form batches composed of animals with a similar BW. This  
74 practice of mixing animals from different farms increases health risks, especially with regard  
75 to the development of bovine respiratory diseases (BRD, O'Connor et al., 2005; Sanderson et  
76 al., 2008; Step et al., 2008), presumably due to an increased exposure to pathogens. It is also  
77 well-known that mixing induces acute and even chronic stress in beef cattle (McVeigh and  
78 Tarrant, 1982; Mench et al., 1990; Mounier et al., 2005) due to interactions with new animals  
79 and the establishment of a new social hierarchy with more aggressive behavior (Mench et al.,  
80 1990; Mounier et al., 2006b). This negative effect of mixing on behavior is even more acute  
81 when bulls have a similar BW due to the greater difficulty in establishing dominance  
82 relationships (Mounier et al., 2005, 2006b). All of these effects of mixing could in turn  
83 impair growth performance (Bøe and Færevik, 2003; Mounier et al., 2006a). When animal  
84 health and welfare are considered, mixing young bulls thus does not appear to favor growth.

85 In contrast, practices included in preconditioning programs have been shown to reduce  
86 stress and improve the health of young bulls, resulting in better growth performance during  
87 the fattening period (Duff and Galyean, 2007; Thrift and Thrift, 2011). Preconditioning  
88 programs are designed to reduce stress associated with weaning, enhance the immune system  
89 of calves, and accustom calves to eating from a feed bunk and drinking from a fountain (Duff  
90 and Galyean, 2007). Since most BRD cases occur at the beginning of the fattening period  
91 (Smith, 1998; Sanderson et al., 2008; Assié et al., 2009) and are responsible for decreased  
92 growth performance (Gardner et al., 1999; Schneider et al., 2009), preconditioning programs  
93 can include pre-weaning vaccination against BRD by the cow/calf breeders. This vaccination  
94 enables the development of immunity prior to the critical period of maximum pathogen

95 exposure (Taylor et al., 2010) upon arrival in the fattening operations, and prevents the well-  
96 known negative effect of BRD on growth performance (Smith, 1998). Nevertheless, this  
97 practice is not widespread, and the presence of vaccinated animals is a criterion that is seldom  
98 considered when batches are constituted.

99 The objective of this observational study was to investigate under field conditions the  
100 effect of batch constitution on the growth performance of young bulls during the fattening  
101 period. Among all of the factors characterizing a batch of young bulls formed at the sorting  
102 facility, the only ones currently considered by the French beef cattle sector are breed, mean  
103 BW and BW-homogeneity within the batch. However, other batch characteristics, such as  
104 transportation distance, mixing, and vaccination of animals against BRD before weaning,  
105 should perhaps be considered. Improved knowledge about the effect of each batch  
106 characteristic on growth performance would make it possible for the beef cattle sector to  
107 reconsider which criteria should be used for batch constitution.

108

## 109 **Materials and Methods**

110 All animals involved in this observational study were cared for according to the  
111 "Good practices guidelines in cattle, beef calves, sheep and goats" in compliance with French  
112 regulations  
113 ([https://agriculture.gouv.fr/sites/minagri/files/documents/pdf/gph\\_\\_bovins\\_veaux\\_ovins\\_caprins\\_20145952\\_0001\\_p000\\_cle0f3116.pdf](https://agriculture.gouv.fr/sites/minagri/files/documents/pdf/gph__bovins_veaux_ovins_caprins_20145952_0001_p000_cle0f3116.pdf)).

115

## 116 ***Study Design***

117 An observational study was carried out based on data acquired from a beef producers'  
118 organization located in western France (Ter'Elevage, Mésanger, France). The data set  
119 concerned a total of 19,055 Charolais young bulls in 1,062 batches operated by the beef  
120 producers' organization in 2014 and 2015. The animals were uncastrated young Charolais  
121 bulls reared by cow/calf breeders in husbandry systems that correspond to the common  
122 French system (i.e. calves reared in pasture with their dam). After weaning, the young bulls  
123 were transported to one of the six sorting facilities of the beef producers' organization.  
124 Young bulls remained on average two to four days at the sorting facility until batches were  
125 formed. To meet the demands of the fatteners, young bulls were sorted by the beef producers'  
126 organization to form batches composed of animals with a BW as similar as possible to match  
127 the batch mean BW requested by the fatterer. Batches were defined as groups of young bulls  
128 formed at the sorting facility that arrived together at the fattening operations and were  
129 managed similarly for the entire fattening period. Young bulls were reared in barns composed  
130 of pens of 10 to 20 animals. Young bulls were commonly fed with a complete diet composed  
131 of corn or grass silage and a mixture of cereals and urea. Some young bulls in our study  
132 population (8.3%) were vaccinated against BRD in the cow/calf farm before being weaned  
133 and sold to the fatteners. Animals were vaccinated with a vaccine against BRD agents  
134 (Risposal® RS, Risposal® RS-BVD or Risposal® 3, Zoetis, Parsippany-Troy Hills, NJ,  
135 USA or Bovilis® Bovigrip, MSD Animal Health, Beaucouzé, France) according to the  
136 manufacturer's recommendation and received a booster injection at the sorting facility.

137

### 138 ***Crude Data***

139 The data obtained from the beef producers' organization were individual data related  
140 to the rearing period in the cow/calf farm (cow/calf farm location, rearing period duration,



141 average daily gain (ADG) of animals during the rearing period and animal vaccinated against  
142 BRD before weaning or not), the batch constitution at the sorting facility (sorting facility  
143 location, BW and age upon arrival at the sorting facility, number of animals in the batch,  
144 number of cow/calf farms of origin within the batch, season (Winter: January to March,  
145 Spring: April to June, Summer: July to September, and Fall: October to December) and year  
146 (2014 or 2015) of entry in the fattening operations, and batch composed only of Charolais  
147 bulls or composed of Charolais bulls mixed with other breeds), and the fattening period  
148 (fattening operations location, fattening period duration, and ADG of animals during the  
149 fattening period).

150

### 151 *Calculations and Statistical Analysis*

152 All calculations and statistical analyses were performed in the open-source  
153 environment R version 3.5.1. (R Development Core Team, Vienna, Austria).

154 Some variables describing batch characteristics were directly available in crude data  
155 (number of animals in the batch, season and year of entry in the fattening operations, and  
156 batch composed only of Charolais bulls or composed of Charolais bulls mixed with other  
157 breeds), whereas others were created using the crude data. The mean BW and age of young  
158 bulls at arrival at the sorting facility within the batch were obtained by averaging individual  
159 BW and age values within the batch. The coefficient of variation (CV) of BW and age at  
160 arrival at the sorting facility within the batch were also calculated. A mixing ratio was created  
161 by dividing the number of cow/calf farms of origin by the number of young bulls in the batch.  
162 This mixing ratio ranged from 0 to 1; a mixing ratio close to 0 meant that there was little  
163 mixing of animals from different cow/calf farms, while a mixing ratio close to 1 indicated a  
164 high level of mixing of animals from many different cow/calf farms. The percentage of

165 young bulls vaccinated against BRD before weaning within the batch was calculated and, as  
166 it was not normally distributed, then categorized into four levels: None [0%] (no animal  
167 vaccinated against BRD before weaning in the batch), ]0-13%] (low percentage), ]13-50%]  
168 (medium percentage), and ]50-100%] (high percentage of animals vaccinated against BRD  
169 before weaning in the batch). The total transportation distance as the crow flies of each  
170 animal was estimated based on the locations of the cow/calf farm, the sorting facility and the  
171 fattening operations. The total transportation distance was then averaged within the batch to  
172 obtain the batch mean total transportation distance.

173 Indicators of homogeneity of growth performance within the batch then were created  
174 by calculating the SD of the ADG during the fattening period and the SD of the fattening  
175 period duration within the batch. The mean ADG during the rearing period on the cow-calf  
176 farm within the batch was also calculated.

177 In our study, young bulls were defined as animals entered the fattening operation at 5  
178 to 10 months of age at a liveweight of 230 to 470 kg. We excluded from our data set animals  
179 that do not meet these criteria leading to the exclusion of 117 animals lighter than 230 kg, 50  
180 animals heavier than 470 kg, and 1,831 animals older than 10 months. Finally, we excluded 1  
181 young bull with missing values and 1,321 young bulls from small batches (less than 10  
182 animals) due to the risk that small batches ordered by fatteners corresponds to batches that  
183 will complete larger batches and that the animals would be mixed with other young bulls  
184 when they arrived in the fattening operations. This resulted in a final population of 15,735  
185 young bulls.

186

187 *Determination of different batch types using cluster analysis.*

188 We used a clustering analysis to group young bulls from batches with similar  
189 characteristics and define batch types. To form the clusters, we used the variables  
190 corresponding to batch characteristics, with the exception of “season of entry” and “year of  
191 entry”. These were not included because the beef producers’ organization has no control over  
192 these two variables when forming batches. Firstly, a factor analysis of mixed data (FAMD)  
193 was performed using the FAMD function from the FactoMineR package to characterize  
194 associations between batch characteristics variables. A FAMD is a factorial method used to  
195 explore data tables in which individuals are described by both continuous and categorical  
196 variables; it corresponds to a principal component analysis for continuous variables and a  
197 multiple correspondence analysis for categorical variables (Pagès, 2004). This analysis  
198 ensures that there is a balance between the influence of both continuous and categorical  
199 variables in determining the dimensions of variability (Pagès, 2004). A hierarchical  
200 classification on the principal components (HCPC) was then performed using Ward’s  
201 criterion with the HCPC function from the FactoMineR package. To maximize the explained  
202 variance, all dimensions of the FAMD were kept for the HCPC. The number of clusters was  
203 determined by first calculating and then plotting the inertia for each number of clusters. The  
204 best number of clusters was indicated by a high ratio of the loss of inertia between  $n + 1$   
205 clusters and  $n$  clusters. Another decision rule was to produce several clusters to correctly  
206 represent the diversity of batch types while refraining from producing an excessive number in  
207 order to clearly characterize and differentiate one cluster from each other. A consolidation  
208 was performed based on the results of the hierarchical classification using k-means clustering  
209 and virtual centers of clusters as initial individuals. Lastly, after the final clusters were  
210 defined, leading to the creation of different batch types, descriptive statistics (means  $\pm$  SEM  
211 of the continuous variables and frequencies of the categorical variables) for the characteristics

212 which define each batch type were calculated and ANOVA were performed using the aov  
213 function to compare batch characteristics between batch types.

214

215 *Effect of batch characteristics on individual performance during the fattening period.*

216 The effect of batch characteristics on individual growth performance during the  
217 fattening period was analyzed using generalized linear mixed models considering individuals  
218 as the statistical unit and using the lmer function from the lme4 package. For this analysis, all  
219 individual Charolais bulls were considered, whether they were part of a batch composed only  
220 of Charolais bulls or a batch composed of Charolais mixed with other breeds. A herd random  
221 effect was added to the models to take into account management differences between  
222 fattening operations. Growth performance indicators (ADG during the fattening period and  
223 fattening duration) were considered as outcome variables. The fattening period duration  
224 rather than the BW at the end of the fattening period was considered as a growth performance  
225 indicator. In the French beef cattle sector, the BW at the end of the fattening period is very  
226 homogeneous because animals are required to have a BW of between 750 and 800 kg when  
227 sent to the slaughterhouse. This results in a heterogeneous fattening period duration that  
228 reflects the growth performance of animals. The tested independent variables corresponded to  
229 the batch characteristics and to the ADG during the rearing period since it was considered as  
230 a possible confounding factor. Before including an independent variable, the distribution of  
231 the variable was checked and the variable was considered as a continuous variable only if it  
232 was normally distributed. The linear relationship between each continuous independent  
233 variable and the outcome variable was also checked. Independent variables were then tested  
234 for their association with indicators of growth performance during the fattening period in  
235 univariate analyses. Only independent variables that were associated with growth

236 performance indicators at  $P < 0.20$  in the univariate analysis were then included in the  
237 multivariate model. To avoid including collinear independent variables in the multivariate  
238 model, the rcorr function from the Hmisc package was used to generate the Pearson  
239 correlation coefficient, which measures the strength of association between pairs of variables  
240 without specifying dependencies. When the value of the correlation coefficient between 2  
241 variables was  $|0.70|$  or greater at a 5% significance level ( $P < 0.05$ ), the 2 variables were  
242 considered to be collinear and only one was selected for inclusion in the multivariate model.  
243 Due to the collinearity between the mean BW and the mean age of animals at arrival at the  
244 sorting facility within a batch, only the mean BW was included in the multivariate model.  
245 The best fit model selection was based on a manual backward step-wise elimination of  
246 independent variables leading to the selection of the multivariate model containing only  
247 independent variables significantly associated with growth performance during the fattening  
248 period ( $P < 0.05$ ) based on the Fisher's test P-value. An interaction between the year and the  
249 season of entry was included in the statistical model.

250         The effect of the batch characteristics on the individual growth performance of young  
251 bulls during the fattening period was also assessed by considering the type of batch defined  
252 by the hierarchical classification as the independent variable, instead of each batch  
253 characteristic one by one. The effect of batch type was analyzed using generalized linear  
254 mixed models with a herd random effect using the lmer function from the lme4 package.

255         The proportion of variance explained by each final statistical models was assessed by  
256 calculating the conditional R squared using the rsquared function.

257

258 *Effect of batch characteristics on the homogeneity of performance within the batch during*  
259 *the fattening period.*

260 Homogeneity of growth performance was analyzed using generalized linear mixed  
261 models with the lmer function from the lme4 package, considering the batch as the statistical  
262 unit. For this analysis, only batches with 100% Charolais bulls were considered. The  
263 indicators of homogeneity of growth performance (SD of ADG and SD of the fattening  
264 period duration within the batch) were considered as outcome variables, and the independent  
265 variables tested corresponded to the batch characteristics. The same method as the one used  
266 to characterize the effects of batch characteristics on individual performance during the  
267 fattening period was used to select the best multivariate model (checking of the distribution  
268 and the linear relationship between each continuous independent variable and the outcome  
269 variable, univariate analysis to determine the association between outcome variables and  
270 independent variables, exclusion of collinear independent variables, manual backward step-  
271 wise elimination of independent variables leading to the selection of the best multivariate  
272 model). A herd random effect was added to the models and the mean ADG during the rearing  
273 period within the batch was tested as a possible confounding factor and was retained in the  
274 final model only when it was significantly associated with indicators of homogeneity of  
275 growth performance during the fattening period ( $P < 0.05$ ).

276 The effect of batch characteristics on the homogeneity of growth performance within  
277 the batch was also assessed. To do so, the batch type defined by the hierarchical classification  
278 was considered as the independent variable, and a generalized linear mixed model with a herd  
279 random effect was used by employing the lmer function from the lme4 package.

280

## 281 **Result**

### 282 *Descriptive Statistics*

283 For the analysis of the effect of batch characteristics on the individual performance of  
284 young bulls during the fattening period, all individual Charolais bulls were considered. This  
285 resulted in a final population of 15,735 young bulls which were from 744 different cow/calf  
286 farms, were sorted at the sorting facilities into 740 batches, and were fattened in 224 different  
287 fattening operations. The descriptive statistics of the continuous independent variables  
288 observed for the final study population are presented in Table 1, and the frequencies of  
289 distribution of animals within each level of categorical variables are presented in Table 2.  
290 The ADG of young Charolais bulls was on average  $1.46 \pm 0.21$  kg/d for a fattening period  
291 duration of on average  $313.4 \pm 55.95$  d. The number of animals in the batch ranged from 11  
292 to 112 with a mean of  $32.1 \pm 15.41$  young bulls. Mean BW upon arrival at the sorting facility  
293 ranged from 230.3 to 466.5 kg with a mean of  $327.3 \pm 44.67$  kg. The CV of BW and age  
294 within a batch were on average  $6.0 \pm 3.17$  % and  $14.9 \pm 3.99$  %, respectively. In our study  
295 population, the mixing ratio was high since 75% of animals belonged to a batch with a  
296 mixing ratio greater than 0.45, which means that on average 14 cow/calf breeders provided  
297 young bulls for a mean of 32 animals in a batch. The mean total transportation distance of  
298 animals from the cow/calf farm of origin through the sorting facility to the fattening  
299 operations was  $261.1 \pm 125.16$  km. Most batches were composed only of Charolais bulls  
300 (55.6%) and contained no animals vaccinated against BRD before weaning (74.7%); only  
301 6.7% of the batches were composed of a high percentage of animals vaccinated against BRD  
302 before weaning. The greatest number of batches were constituted in the fall (35.0%), the  
303 fewest in winter (14.2%).

304 For the analysis of the effect of batch characteristics on the homogeneity of  
305 performance within the batch during the fattening period, only batches with 100% Charolais  
306 bulls were considered, resulting in a final population of 293 batches. The descriptive statistics  
307 of the continuous independent variables observed for the final study population are presented

308 in Table 3, and the frequencies of distribution of batches within each level of categorical  
309 variables are presented in Table 2. The SD of ADG of young bulls within the batch was 170  
310 g/d and the SD of the fattening period duration was 23 d.

311

### 312 *Description of the Different Batch Types*

313 The first 3 dimensions of the FAMD explained 21.6, 15.7 and 15.3% of the inertia,  
314 respectively. The next dimensions explained each less than 10% of the inertia. The three  
315 variables that contributed the most to the first dimension were the mean total transportation  
316 distance (24.2%), the CV (22.1%) and the mean BW of animals (14.3%) within the batch.  
317 The variables that contributed the most to the second dimension were the mixing ratio  
318 (33.8%), the percentage of animals vaccinated against BRD before weaning (24.4%) and the  
319 CV of age of animals within the batch (24.0%). That which contributed the most to the third  
320 dimension was the number of animals in the batch (47.4%).

321 Hierarchical classification was performed on the 10 dimensions of the FAMD and  
322 resulted in 5 batch types. In Fig 1, for each type of batch obtained, the details of the mean, the  
323 median and the first and third quartile values of batch characteristics are presented for the  
324 continuous variables. Of the 15,735 animals sorted in 740 batches included in the hierarchical  
325 classification analysis, 1,050 (6.7%) in 56 batches were classified in type 1, 1,204 (7.6%) in  
326 56 batches in type 2, 1,733 (11.0%) in 70 batches in type 3, 5,790 (36.8%) in 331 batches in  
327 type 4, and 5,958 (37.9%) in 227 batches in type 5.

328 The three first batch types contained young bulls from batches with animals  
329 vaccinated against BRD before weaning. The first batch type was characterized by young  
330 bulls from batches with a high percentage of animals vaccinated against BRD before weaning  
331 (i.e. ]50%-100%]). The young bulls from type 1 were also the least BW-homogeneous, with



332 the lowest mixing ratio and the shortest transportation distance. Types 2 and 3 contained only  
333 young bulls from batches with a medium percentage (i.e., ]13%-50%]) and a low (i.e., ]0%-  
334 13%]) of animals vaccinated against BRD before weaning, respectively. Both types presented  
335 a high mixing ratio (0.52 and 0.59, respectively), a medium CV of BW (6.8 and 6.0%,  
336 respectively) and a medium transportation distance (200.2 and 237.6 km, respectively). Types  
337 4 and 5 were both characterized by animals belonging to batches with no animals vaccinated  
338 against BRD before weaning (i.e. None [0%]) and by a high mixing ratio (0.53 and 0.58,  
339 respectively) but were differentiated by the mean and CV of BW of animals and the mean  
340 total distance within the batch: type 4 presented on average lighter (304.1 vs 355.4 kg) and  
341 less BW-homogenous (CV of BW: 7.7 vs 4.4%) animals with a shorter distance of  
342 transportation (190.8 vs. 367.5 km) than type 5.

343

344 ***Characteristics of Batches Formed at the Sorting Facility were associated with the Growth***  
345 ***Performance of Young Charolais Bulls during the Fattening Period***

346 An increased mean BW of animals within the batch was associated with better growth  
347 performance, namely a greater ADG and a shorter fattening period duration (+ 35 g/d and -  
348 37.9 d, respectively, when the mean BW of animals within the batch was 50 kg greater,  $P <$   
349 0.001, Table 4 and Table 5). An increased CV of animals' age within the batch was  
350 associated with a decreased fattening period duration (-1.0 d for + 5% of CV,  $P = 0.03$ , Table  
351 5). An increase in the mean total transportation distance of the batch was associated with  
352 reduced growth performance: the ADG during the fattening period decreased by 11 g/d and  
353 the fattening period duration increased by 1.6 d when the mean total transportation distance  
354 of the batch increased by 120 km ( $P < 0.001$ , Table 4 and Table 5). Whether or not the batch  
355 was composed only of Charolais bulls, and the percentage of animals vaccinated against BRD

356 before weaning within the batch, were also associated with growth performance. Animals  
357 belonging to batches composed of Charolais bulls mixed with other breeds had a greater  
358 ADG during the fattening period (+22 g/d,  $P < 0.001$ , Table 4) and a shorter fattening period  
359 duration (-4 d,  $P < 0.001$ , Table 5). The higher the percentage of animals vaccinated against  
360 BRD before weaning, the greater the ADG during the fattening period (+13, +15 and +28 g/d  
361 when batches were composed of ]0-13%], ]13-50%], and ]50-100%] of animals vaccinated,  
362 respectively, compared with batches without animals vaccinated against BRD before  
363 weaning,  $P < 0.05$ , Table 4). The fattening duration was also shorter when batches contained  
364 vaccinated animals compared with batches without animals vaccinated against BRD before  
365 weaning ( $P < 0.05$ , Table 5), but no clear relationship between the proportion of animals  
366 vaccinated against BRD before weaning and the fattening period duration was shown. The  
367 season of entry at the sorting facility was also associated with growth performance with the  
368 greatest ADG and the shortest fattening period duration for batches formed during spring (+  
369 39 g/d and -11.7 d compared with batches formed during fall,  $P < 0.05$ , Table 4 and Table 5).  
370 This effect of the season on ADG was even greater in 2015 (Table 4). The adjustment  
371 variable ADG during the rearing period also influenced growth performance; its increase  
372 resulted in a decrease in ADG during the fattening period ( $P < 0.001$ , Table 4) and an  
373 increase in the fattening period duration ( $P < 0.05$ , Table 5). Finally, the CV of BW of  
374 animals within the batch, the mixing ratio and the number of animals in the batch were not  
375 associated with either the ADG during the fattening period nor the fattening period duration.

376         The type of batch as defined by the hierarchical classification influenced growth  
377 performance of young bulls during the fattening period (Table 6). The ADG during the  
378 fattening period was the greatest for young bulls from type 1 and the lowest for young bulls  
379 from type 5. The type of batch with the longest fattening period was type 5, and with the  
380 shortest, types 1 to 3.

381

382 *Characteristics of Batches Formed at the Sorting Facility had Little Influence on the*  
383 *Homogeneity of Performance within a Batch during the Fattening Period*

384         Only the mean BW of animals and the mixing ratio were associated with the SD of  
385 ADG: an increase in these two characteristics resulted in an increased SD of the ADG during  
386 the fattening period within a batch ( $P < 0.01$ , Table 7). None of the batch characteristics  
387 affected the SD of the fattening period duration. The batch types as defined by the  
388 hierarchical classification did not influence the homogeneity of growth performance within  
389 the batch.

390

391 **Discussion**

392         This observational study based on a large field data set is to our knowledge the first to  
393 focus on the association between the characteristics of batches formed at sorting facilities and  
394 the growth performance of young Charolais bulls during the entire fattening period and  
395 showed that these batch characteristics affect the further growth performance of young bulls.  
396 The large number of individuals involved the present study gives it a high statistical power to  
397 analyze the investigated effects. However, as an observational study, this study was based on  
398 field data with all the attendant drawbacks. In this study, we obtained crude data from a beef  
399 producers' organization knowing field data are less accurate than experimental studies as is it  
400 the case for the measurement of BW of animals. Indeed, bulls were weight only once at their  
401 arrival at the sorting facility and thus had different rumen filling levels causing variability in  
402 the BW measurement. However, the large number of young bulls and batches allowed  
403 highlighting the effects despite the variability.

404           The main and almost only criteria currently considered by the French beef cattle  
405 sector for batch constitution is BW-homogeneity within a batch. This choice is based on the  
406 fact that forming groups of BW-homogeneous animals before the start of the fattening period  
407 facilitates fattening management. However, in the present study, the CV of BW of animals  
408 within a batch formed at the sorting facility had no effect on the individual growth  
409 performance of young bulls during the fattening period (ADG and fattening period duration).  
410 Moreover, animals from the batch type with the most BW-homogenous animals had the  
411 lowest ADG over the fattening period. The practice of forming BW-homogeneous groups at  
412 the beginning of fattening is also commonly used in pig husbandry. However, the effect on  
413 production appears unclear, as various studies have alternatively shown it to be beneficial,  
414 have no effect, or even be detrimental for the growth rate of finishing pigs (Sherritt et al.,  
415 1974; Graves et al., 1978; Francis et al., 1996; O'Connell et al., 2005). This practice is poorly  
416 documented in beef cattle. Nevertheless, the absence of an effect of BW-homogeneity within  
417 a batch on growth performance of young bulls was reported previously in a study in which  
418 young bulls from BW-homogeneous batches had similar ADG as young bulls from BW-  
419 heterogeneous batches (Mounier et al., 2005). The latter study also showed a homogenization  
420 of the BW for young bulls from an originally BW-heterogeneous batch and, in contrast, a  
421 heterogenization for young bulls from an originally BW-homogeneous batch. In our study, no  
422 effect of the CV of BW on the homogeneity of performance within the batch was observed.  
423 However, our study was based on field data in which the range of CV of BW within the batch  
424 was limited (between 1.1 and 23.4% with a mean of 6%) due to the beef cattle sector's desire  
425 to form BW-homogeneous batches. The present study showed that the CV of BW had no  
426 effect neither on the individual growth performance nor on the homogeneity of performance  
427 within the batch in the range of CV of BW observed in the data. Further investigations are  
428 thus needed to study the extent to which BW-homogeneity does not influence growth

429 performance (experimental studies comparing BW-homogeneous and BW-heterogeneous  
430 batches or observational study with more variability in the CV of BW within the batch).  
431 Nevertheless, all of these findings call into question the supposed benefit of forming BW-  
432 homogeneous groups at the beginning of the fattening period, and suggest that it could be  
433 possible for the French beef cattle sector to accept more BW-heterogeneous batches without a  
434 deleterious effect on growth performance.

435         In the present study, we hypothesized that the characteristics of batches that are  
436 formed at the sorting facility at the beginning of the fattening period could affect the further  
437 growth performance of young bulls. Since our statistical models explained between 36 and  
438 69% of the variance of the indicators of growth performance, even if the batch characteristics  
439 are obviously not the only factors, the present study provides evidence that certain batch  
440 characteristics which are seldom considered for batch constitution had influence, positive and  
441 negative, on growth performance of young bulls. Some of the batch characteristics tested for  
442 their association with growth performance in the present study are notably already known to  
443 be either protective or risk factors for BRD (Sanderson et al., 2008; Taylor et al., 2010).  
444 Bovine respiratory diseases are a major health issue in the beef cattle sector, accounting for  
445 65 to 85% of all morbidity in US feedlots (Edwards, 1996; Lechtenberg et al., 1998). The  
446 beginning of the fattening period is a critical period since most BRD cases occur during the  
447 first six weeks following arrival at the fattening operations (Smith, 1998; Faber et al., 1999;  
448 Thompson et al., 2006; Sanderson et al., 2008; Assié et al., 2009; Babcock et al., 2009). Since  
449 these BRD are responsible for decreased growth performance (Bateman et al., 1990; Gardner  
450 et al., 1999; Babcock et al., 2009; Schneider et al., 2009), the impact of these batch  
451 characteristics on growth performance could be linked to the development of BRD.

452         The distance that animals are transported, from the cow/calf farm to the fattening  
453 operations via the sorting center, had as expected a negative impact on growth performance:

454 the longer the transportation distance, the lower the ADG and the longer the fattening period  
455 duration. In our study and in the French context in general, young bulls are transported over  
456 relatively short distances (between 15 and 659 km with an average of 261 km in our study)  
457 compared to other countries such as the United States or Australia where animals are  
458 transported on average over longer distances of up to more than 1,300 km (Cernicchiaro et  
459 al., 2012b; Ribble et al., 1995b). Nevertheless, the negative effect of the transportation  
460 distance that we observed in the French context is consistent with a previous American study  
461 in which a long transportation distance to the fattening operations (i.e., longer than 250 km)  
462 negatively influenced ADG at the batch level over the entire fattening period (Cernicchiaro et  
463 al., 2012b). The stress induced by transportation has been highlighted through several stress  
464 indicators (Crookshank et al., 1979; Kent and Ewbank, 1983; Cole et al., 1988; Arthington et  
465 al., 2003; Buckham Sporer et al., 2008). This transportation-induced stress temporarily  
466 impairs the immune function (Murata et al., 1987; Murata, 1989; Stanger et al., 2005) and,  
467 consequently, negatively influences the ability of the young bulls to respond to health  
468 challenges. Transportation is thus recognized as a risk factor for BRD (Sanderson et al.,  
469 2008; Hay et al., 2014); the risk of BRD morbidity has been shown to increase by 10% for  
470 each additional 160 km traveled to the fattening operations (Sanderson et al., 2008). As a  
471 consequence, transportation increases mortality (Cernicchiaro et al., 2012b) and has a  
472 negative impact on growth performance (Sanderson et al., 2008; Van Engen and Coetzee,  
473 2018). The negative impact of transportation could be alleviated if transportation conditions  
474 were more respectful of animal welfare.

475 To form batches that are as BW-homogeneous as possible, young bulls from multiple  
476 cow/calf farms of origin are commonly mixed at the sorting facility. In our study, we  
477 investigated the effect of the mixing degree by creating a mixing ratio (i.e., the number of  
478 cow/calf farms of origin divided by the number of young bulls in the batch). This mixing

479 ratio showed no effect on individual growth performance. This result is unexpected since  
480 mixing animals from several cow/calf herds was already shown to decrease growth  
481 performance in beef cattle (Mounier et al., 2006a; Step et al., 2008). However, in the latter  
482 two studies, the effect of mixing was investigated through a comparison of mixed vs.  
483 unmixed bulls, and not through the degree of mixing. Moreover, the present study showed  
484 that the mixing ratio negatively influenced the homogeneity of ADG within the batch.  
485 Furthermore, the batch type containing the animals with the highest ADG during the fattening  
486 period was the “low-mixed” batch type, while the batch type with the lowest ADG was the  
487 "high-mixed" type. The reduced growth performance of young bulls from the “high-mixed”  
488 batch type may have resulted from the stress associated with the interactions with new  
489 congeners and the establishment of a new hierarchy. Indeed, mixing at the start of the  
490 fattening period was already associated with increased aggressive interactions in pigs  
491 (O’Connell et al., 2005) and beef cattle (Mounier et al., 2006b). These post-mixing  
492 aggressive behaviors were in turn associated with negative implications, including health  
493 problems, reduced growth performance and poor meat quality in pigs (Rundgren and  
494 Löfquist, 1989; Tan and Shackleton, 1990; Tan et al., 1991;Stookey and Gonyou, 1994;  
495 O’Connell et al., 2005). The aggressive interactions resulting from mixing last even longer  
496 and are more frequent when BW variability between animals is small (Rushen, 1987; Francis  
497 et al., 1996; Mounier et al., 2005, 2006b) due to the greater difficulty in establishing  
498 dominance relationships. In contrast, aggressive behavior could be reduced by forming  
499 groups containing a wider range of BW than the usual commercial practice (Marchant-Forde  
500 and Marchant-Forde, 2005). The stress associated with the establishment of the new  
501 hierarchy in a group of cattle does not only depends on the BW variability but can also be  
502 modulated by the space allowance or the accessibility of the feed bunk. Moreover, in  
503 commercial conditions, mixing involves animals from different cow/calf farms, and thus with

504 different pathogen backgrounds, which has long been recognized as being strongly associated  
505 with an increased risk of subsequent BRD development (Martin et al., 1982; Martin and  
506 Meek, 1986; Ribble et al., 1995a, 1995b; Assié et al., 2009), presumably due to an increased  
507 exposure to pathogens. More recent studies also agree that mixing cattle from multiple  
508 sources at the beginning of fattening increases the risk of BRD (O'Connor et al., 2005;  
509 Sanderson et al., 2008; Step et al., 2008; Hay et al., 2014). Since BRD are known to  
510 negatively influence growth performance (Bateman et al., 1990; Gardner et al., 1999;  
511 Schneider et al., 2009), the reduced performance of animals from “high-mixed” batch types  
512 might be explained by a higher incidence of BRD in these types. The maintenance of rearing  
513 groups could thus maximize growth performance by minimizing health risks related to BRD.

514         To reduce the unavoidable health risk related to BRD when young bulls from different  
515 origins are mixed, and to minimize the negative effect of BRD on growth performance  
516 (Smith, 1998), it is possible to vaccinate the animals. Ideally, this vaccination must be done  
517 before weaning at the cow/calf farm to enable the development of immunity prior to the  
518 critical period of maximum pathogen exposure represented by the arrival at fattening  
519 operations (Taylor et al., 2010). Our study confirmed the beneficial effect of this pre-weaning  
520 vaccination against BRD on growth performance since the higher the percentage of  
521 vaccinated animals within the batch, the greater the individual ADG. Moreover, animals from  
522 batches with a high percentage of animals vaccinated against BRD before weaning (i.e.,  
523 composed of [50-100%] of vaccinated animals) had the greatest ADG. Our results also  
524 suggest that pre-weaning vaccination could prevent the negative effect of mixing since  
525 animals from the “medium” and the “low percentage of vaccinated animals” batch types had  
526 better performance compared with “no vaccinated animals” batch types for a similar mixing  
527 ratio. The positive effect of vaccination against BRD on growth performance of young bulls  
528 during the fattening period observed in our study could be directly related to the lower risk of



529 developing BRD for vaccinated animals compared to non-vaccinated animals (Macartney et  
530 al., 2003; Hay et al., 2016b). It could also be assumed that vaccinated animals are raised by  
531 cow/calf breeders and then by fatteners that have concerns regarding BRD and probably have  
532 improved overall management practices and particularly improved health-related practices.  
533 This vaccination could also have been a part of a preconditioning program that improve the  
534 welfare and the health status of the weaned calf prior to sale to the beef producer's  
535 organization and could explain the better further growth performance (Duff and Galyean,  
536 2007; Thrift and Thrift, 2011). Moreover, in our study, only a small part of the animals  
537 (8.3%) has been vaccinated against BRD before weaning. Nevertheless, given the beneficial  
538 effect of pre-weaning vaccination against BRD, the French beef cattle sector should promote  
539 this practice as a part of a preconditioning program. However, it can be difficult for cow/calf  
540 breeders to carry out a vaccination program. For example, to be part of the pre-weaning  
541 vaccination program proposed by the beef producers' organization that we worked with for  
542 the present study, animals must receive two injections spaced three weeks apart. The  
543 injections must be given at least 3 weeks, and not more than 6 months, before the transfer to  
544 the sorting facility. This corresponds to when the animals are between 4 and 9 months old  
545 and are being reared in pasture, which is a difficult setting for the administration of vaccines.  
546 Moreover, the beneficial effect on growth performance was observed during the fattening  
547 period, which means that vaccine injections are performed by cow/calf breeders for the  
548 benefit of fatteners.

549         Batches are composed so that the batch mean BW matches the request of each  
550 fatterer. The choice of this batch mean BW is not a trivial matter since our study showed a  
551 positive association between the batch mean BW and growth performance; young bulls from  
552 heavier batches grew faster than young bulls from lighter batches. Batch mean BW is  
553 considered an important factor for predicting subsequent health risks as heavier young bulls

554 have less risk of BRD (Lechtenberg et al., 1998; Sanderson et al., 2008; Babcock et al., 2010;  
555 Cernicchiaro et al., 2012b; Hay et al., 2016a). Given the close relationship between BW and  
556 age in young bulls, which was confirmed by the positive correlation between these two  
557 variables in our data, the effect of the batch mean BW on growth performance may be related  
558 to the age of animals. Indeed, the age at arrival in the fattening operation is also a risk factor  
559 for BRD development as younger bulls have a higher risk of BRD than older ones (Faber et  
560 al., 1999). Younger, and thus lighter, animals are likely to have a more naïve immunity  
561 system and to have had less opportunity to be exposed to potential pathogens over time  
562 (Sanderson et al., 2008), explaining the reduced growth performance of bulls from lighter  
563 batches.

564 In our study, the season of entry also influenced growth performance. Young bulls  
565 from batches formed in the spring showed a greater ADG and a shorter fattening period. This  
566 finding is in accordance with a previous study in which young bulls exhibited a 140 g/d-  
567 greater ADG when they entered fattening operations in the spring compared with the fall  
568 (Cernicchiaro et al., 2012b). Once again, these differences in growth performance of young  
569 bulls between seasons could be related to the health risk for BRD. The season of entry has  
570 already been strongly associated with risk of BRD in Australia (Hay et al., 2016a) and North  
571 America (Cernicchiaro et al., 2012b); the fall/winter seasons being the months with the  
572 highest risk of BRD (Cernicchiaro et al., 2012b) and death due to BRD (Miles, 2009). This  
573 effect of the season could be due to weather conditions rather than the season itself: a low  
574 mean daily temperature, a high daily range of temperature and a high wind speed favor the  
575 development of BRD (Cusack et al., 2007; Cernicchiaro et al., 2012a).

576 Our study also showed that when Charolais bulls are received by fatteners and enter in  
577 fattening operations with young bulls from other breeds, these Charolais bulls had a better  
578 growth performance (i.e., a greater ADG and a shorter fattening period duration). In our

579 study, the other breeds mixed with Charolais bulls were mostly Limousine, Blonde  
580 d'Aquitaine and Rouge des Prés. These breeds have a lower feed intake capacity (INRA,  
581 2007), and therefore require a diet with a higher energy level to cover the needs of young  
582 bulls. We thus hypothesize that farmers fattening Charolais alongside these other breeds fed  
583 the animals with an intermediate diet in term of energy level to approximately fit with the  
584 needs of the different breeds. Charolais bulls fattened with young bulls from other breeds  
585 may have been fed with a more energetic diet than Charolais bulls fattened alone, thus  
586 explaining the difference in growth performance.

587         Finally, based on our results, the number of animals within a batch seems to have  
588 neither positive nor detrimental effects on individual growth performance or the homogeneity  
589 of growth performance within the batch over the fattening period. If we again draw the  
590 parallel between growth performance and BRD, group size appears to have contradictory  
591 effects; while one study found a reduced risk for groups larger than 50 animals (Hay et al.,  
592 2014), most studies agree that larger groups increase the risks of BRD (Martin et al., 1982;  
593 O'Connor et al., 2005; Cernicchiaro et al., 2012b). The absence of batch size effect on growth  
594 performance in our study could be explained by the fact that the batches studied were too  
595 small to increase BRD risk.

596         To conclude, this study showed that the characteristics of batches formed at the  
597 sorting facilities had a negative impact that could go up to a loss of 19 kg over the entire  
598 fattening period (with an average duration of 313 d) when all practices that affect animal  
599 health and welfare were implemented (i.e. a high mixing ratio, a long transportation distance,  
600 a low CV of BW and no animal vaccinated within the batch such as in batch type 5).  
601 Optimizing the growth performance of young bulls and preventing BRD thus involves  
602 management choices that minimize risk factors related to batch characteristics. Pre-weaning  
603 vaccination seems to be beneficial for individual growth performance. It could thus be

604 interesting for the French beef cattle sector to promote vaccination against BRD as part of  
605 preconditioning program to reduce health risk and improve growth performance during the  
606 fattening period. Within the range of variability of BW we could investigate, our findings  
607 argue against the common practice of making BW-homogeneous batches at the beginning of  
608 the fattening period because this relies on mixing young bulls, which is detrimental for  
609 production. This conclusion should be verified in a broader range of variability of BW at  
610 entry and we could then recommend maintaining groups from the same cow-calf farm to  
611 reduce the unavoidable health risk related to BRD when animals of various origins are mixed.  
612 To maximize the growth performance of young bulls, the beef producers' organization could  
613 form more batches similar to the batch type that we identified as minimizing the risk factors  
614 for BRD, namely one composed of vaccinated, BW-heterogeneous animals with a low  
615 mixing ratio and minimal transportation distance.

616

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624

## 625 **Author contributions**

626 NB and SA conceived the experimental design; LH and BC performed the statistical analysis;  
627 LH, NB, BC, PL, and SA contributed to interpretations; LH wrote the manuscript and NB,  
628 BC, PL and SA revised the manuscript. All authors read, edited and approved the manuscript.

629

630 **Declarations of interest:** none

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800

801 TABLES

802 **Table 1:** Descriptive statistics for indicators of individual growth performance and characteristics of batches formed at the sorting facility. Data  
 803 are from 15,735 Charolais bulls sorted at the sorting facility into 740 batches composed only of Charolais bulls or composed of Charolais bulls

Variables	Mean	SD	Minimum	Q1	Median	Q3	Maximum	804 mixed 805 with 806 other 807 breeds.
Indicators of individual growth performance during the fattening period								
ADG <sup>1</sup> , kg/d	1.46	0.21	0.22	1.32	1.46	1.60	2.58	808
Fattening period duration, d	313.4	55.95	123	274	309	349	567	809
Characteristics of batches formed at the sorting facility								
Number of animals in the batch	32.1	15.41	11	25	29	40	112	810
Mean BW <sup>2</sup> of animals within the batch, kg	327.3	44.67	230.3	296.0	325.8	357.8	466.5	811
Mean age of animal within the batch, d	244.9	25.17	173.8	226.3	246.3	263.0	299.0	812
CV of BW of animals within the batch, %	6.0	3.17	1.1	3.6	5.2	7.7	23.4	813
CV of age of animals within the batch, %	14.9	3.99	2.6	12.2	14.5	17.3	29.2	814
Mixing ratio <sup>3</sup>	0.54	0.168	0.04	0.45	0.56	0.65	0.93	815
Mean total transportation distance within the batch, km <sup>4</sup>	261.1	125.16	15.0	159.9	237.3	358.4	658.8	816
ADG during the rearing period, kg/d	1.18	0.214	0.34	1.03	1.18	1.31	2.13	<sup>1</sup> Average

817 e daily gain.

818 <sup>2</sup>Body weight.

819 <sup>3</sup>The mixing ratio was created by dividing the number of cow/calf farms of origin of young bulls by the number of animals in the batch.

820 <sup>4</sup>The mean total transportation distance within the batch was obtained from the location of the cow/calf farms, the sorting facility and the  
 821 fattening operation of each animal.

822 **Table 2:** Frequency distribution of young bulls and batches by characteristics of batches formed at the sorting facility.

Characteristics of batches formed at the sorting facility	Levels	Frequency of young bulls (%) <sup>1</sup>	Frequency of batches (%) <sup>2</sup>	823
Batch only composed of Charolais bulls	No	55.6	-	825
	Yes	44.4	-	826
Percentage of animals vaccinated against BRD <sup>3</sup> before weaning <sup>4</sup>	None [0%]	74.7	77.1	827
	Low ]0-13%]	11.0	8.5	828
	Medium ]13-50%]	7.6	6.1	829
	High ]50-100%]	6.7	8.2	830
Season of entry	Winter	14.2	12.3	831
	Spring	24.4	23.5	832
	Summer	26.4	27.6	833
Year of entry	Fall	35.0	36.5	834
	2014	51.6	57.0	835
	2015	48.4	43.0	836

833

834 <sup>1</sup>Data are from 15,735 Charolais bulls sorted at the sorting facility into 740 batches composed only of Charolais bulls or composed of Charolais  
835 bulls mixed with other breeds.

836 <sup>2</sup>Data are from 293 batches composed only of Charolais bulls.

837 <sup>3</sup>Bovine respiratory disease.

838 <sup>4</sup>Some animals of the study population were vaccinated against BRD agents in the cow/calf farm before weaning with Rispoval® RS, Rispoval®  
839 RS-BVD, Rispoval® 3 (Zoetis, Parsippany-Troy Hills, NJ, USA) or Bovilis® Bovigrip (MSD Animal Health, Beaucauzé, France) according to  
840 the manufacturer's recommendation and received a booster injection at the sorting facility.

841

842

843 **Table 3:** Descriptive statistics for indicators of homogeneity of growth performance within the batch and characteristics of batches formed at the  
 844 sorting facility. Data are from 293 batches composed only of Charolais bulls.

<b>Variables</b>	<b>Mean</b>	<b>SD</b>	<b>Minimum</b>	<b>Q1</b>	<b>Median</b>	<b>Q3</b>	<b>Maximum</b>
Indicators of homogeneity of growth performance during the fattening period within the batch							
SD of ADG <sup>1</sup> , kg/d	0.17	0.043	0.08	0.14	0.16	0.19	0.37
SD of the fattening period duration, d	23.0	15.27	0.0	13.9	22.6	31.2	76.0
Characteristics of batches formed at the sorting facility							
Number of animals in the batch	24.1	11.39	11	15	21	29	70
Mean BW <sup>2</sup> of animals within the batch, kg	328.6	45.28	231.0	297.6	328.6	358.4	446.3
CV of BW of animals within the batch, %	4.7	2.43	1.1	2.9	4.1	5.7	12.7
CV of age of animals within the batch, %	13.5	4.07	2.6	11.0	13.4	15.7	25.6
Mixing ratio	0.56	0.190	0.04	0.47	0.59	0.67	0.92
Mean total transportation distance within the batch, km	270.7	125.25	21.0	166.4	254.2	373.5	568.0
Mean ADG during the rearing period within the batch, kg/d	1.19	0.125	0.72	1.11	1.19	1.27	1.48

845

846 <sup>1</sup>Average daily gain.

847 <sup>2</sup>Body weight.

848 **Table 4:** Associations between the characteristics of batches formed at the sorting facility and the average daily gain (kg/d) of Charolais young  
849 bulls during the fattening period. Data are from 15,735 Charolais bulls sorted at the sorting facility into 740 batches composed only of Charolais  
850 bulls or composed of Charolais bulls mixed with other breeds. Conditional  $R^2 = 0.37$

Variables and levels	Estimate	95% confidence interval		P-value	
		Lower bound	Upper bound		
Intercept	1.246				
Mean BW <sup>1</sup> of animals within the batch, /50 kg	0.035	0.029	0.041	< 0.001	
Mean total transportation distance within the batch, /120 km <sup>2</sup>	-0.011	-0.016	-0.007	< 0.001	
Batch only composed of Charolais bulls	Yes	Reference			
	No	0.022	0.015	0.030	< 0.001
Percentage of animals vaccinated against BRD <sup>3</sup> before weaning <sup>4</sup>	None [0%]	Reference			
	Low ]0-13%]	0.013	-0.001	0.024	0.03
	Medium ]13-50%]	0.015	0.001	0.028	0.03
	High ]50-100%]	0.028	0.012	0.044	< 0.001
Season of entry	Fall	Reference			
	Winter	0.005	-0.015	0.026	0.62
	Spring	0.039	0.026	0.052	< 0.001
	Summer	0.025	0.013	0.036	< 0.001
Year of entry	2014	Reference			
	2015	0.011	-0.001	0.023	0.08
Season x Year of entry	Winter x 2015	0.036	0.012	0.060	< 0.01
	Spring x 2015	0.023	0.004	0.041	0.01
	Summer x 2015	0.006	-0.012	0.023	0.53
ADG during the rearing period, kg/d	-0.058	-0.073	-0.042	< 0.001	

851

852 <sup>1</sup>Body weight.

853 <sup>2</sup>The mean total transportation distance within the batch was obtained from the location of the cow/calf farms, the sorting facility and the  
854 fattening operation of each animal.



855 <sup>3</sup>Bovine respiratory disease.

856 <sup>4</sup>Some animals of the study population were vaccinated against BRD agents in the cow/calf farm before weaning with Rispoval® RS, Rispoval®  
857 RS-BVD, Rispoval® 3 (Zoetis, Parsippany-Troy Hills, NJ, USA) or Bovilis® Bovigrip (MSD Animal Health, Beaucouzé, France) according to  
858 the manufacturer's recommendation and received a booster injection at the sorting facility.

859

860 **Table 5:** Associations between the characteristics of batches formed at the sorting facility and the fattening period duration (d) of Charolais  
 861 young bulls. Data are from 15,735 Charolais bulls in 740 batches composed only of Charolais bulls or composed of Charolais bulls mixed with  
 862 other breeds. Conditional R<sup>2</sup> = 0.69

863

Variables and levels	Estimate	95% confidence interval		P-value	
		Lower bound	Upper bound		
Intercept	575.6				
Mean BW <sup>1</sup> of animals within the batch, /50 kg	-37.9	-39.1	36.8	< 0.001	
CV of age of animals within the batch, /5 %	-1.0	-2.0	-0.1	0.03	
Mean total transportation distance within the batch <sup>2</sup> , /120 km	1.6	0.8	2.4	< 0.001	
Batch only composed of Charolais bulls	Yes	Reference			
	No	-4.0	-5.4	-2.7	< 0.001
Percentage of animals vaccinated against BRD <sup>3</sup> before weaning <sup>4</sup>	None [0%]	Reference			
	Low ]0-13%]	-4.0	-6.1	-2.0	< 0.001
	Medium ]13-50%]	-3.1	-5.6	-0.7	0.01
	High ]50-100%]	-3.2	-6.2	-0.2	0.03
Season of entry	Fall	Reference			
	Winter	0.1	-3.7	3.9	0.95
	Spring	-11.7	-14.0	-9.4	< 0.001
	Summer	-5.0	-7.1	-2.9	< 0.001
Year of entry	2014	Reference			
	2015	-8.1	-10.2	-5.9	< 0.001
Season x Year of entry	Winter x 2015	-6.4	-10.7	-2.0	< 0.01
	Spring x 2015	9.2	5.9	12.5	< 0.001
	Summer x 2015	7.2	4.0	10.4	< 0.001
ADG during the rearing period, kg/d	3.0	0.2	5.8	0.04	

864 <sup>1</sup>Body weight.

865 <sup>2</sup>The mean total transportation distance within the batch was obtained from the location of the cow/calf farms, the sorting facility and the  
866 fattening operation of each animal.

867 <sup>3</sup>Bovine respiratory disease.

868 <sup>4</sup>Some animals of the study population were vaccinated against BRD agents in the cow/calf farm before weaning with Rispoval® RS, Rispoval®  
869 RS-BVD, Rispoval® 3 (Zoetis, Parsippany-Troy Hills, NJ, USA) or Bovilis® Bovigrip (MSD Animal Health, Beaucouzé, France) according to  
870 the manufacturer's recommendation and received a booster injection at the sorting facility.

871

872 **Table 6:** Association between the type of batch defined by the hierarchical classification and the growth performance (average daily gain and  
873 fattening period duration) of Charolais young bulls during the fattening period. Data are from 15,735 Charolais bulls in 740 batches composed  
874 only of Charolais bulls or composed of Charolais bulls mixed with other breeds.

		ADG <sup>1</sup> (kg/d) <sup>2</sup>				Fattening period duration (d) <sup>3</sup>			
		95% confidence interval				95% confidence interval			
		Estimate	Lower bound	Upper bound	P-value	Estimate	Lower bound	Upper bound	P-value
Intercept		1.472				328.3			
Type of batch	1	Reference				Reference			
	2	-0.017	-0.034	0.002	0.07	0.7	-3.1	4.4	0.73
	3	-0.031	-0.049	-0.014	< 0.001	-2.1	-5.7	1.6	0.27
	4	-0.045	-0.060	-0.029	< 0.001	7.9	4.6	11.1	< 0.001
	5	-0.061	-0.077	-0.046	< 0.001	-12.4	-16.0	-9.5	< 0.001

875

876 <sup>1</sup>Average daily gain.

877 <sup>2</sup> Conditional R<sup>2</sup> = 0.36

878 <sup>3</sup> Conditional R<sup>2</sup> = 0.62

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887 **Table 7:** Associations between the characteristics of batches formed at the sorting facility and the SD of ADG of Charolais young bulls during  
888 the fattening period within a batch. Data are from 293 batches composed only of Charolais bulls.

Variables and levels	Estimate	95% confidence interval		P-value
		Lower bound	Upper bound	
Intercept	0.069			
Mean BW <sup>1</sup> of animals within the batch, /50 kg	0.012	0.006	0.017	< 0.001
Mixing ratio, /0.2 <sup>2</sup>	0.038	0.013	0.063	< 0.01

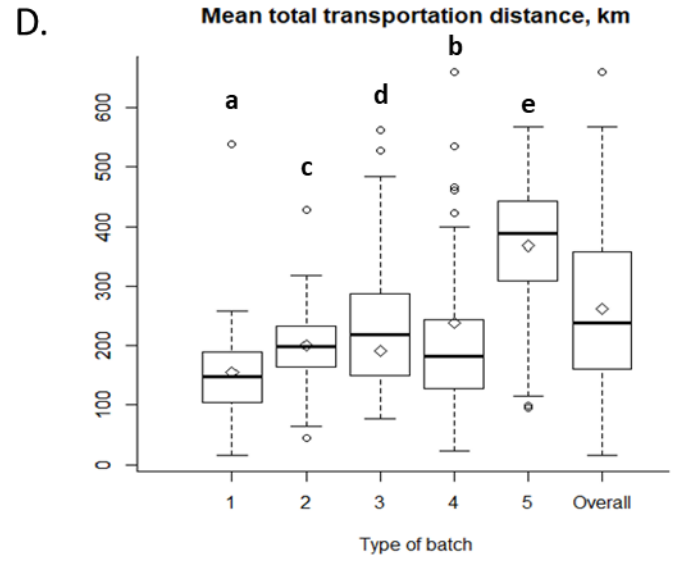
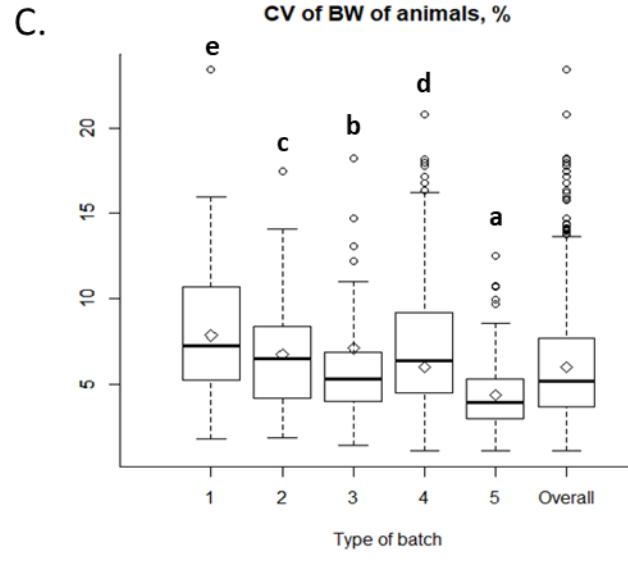
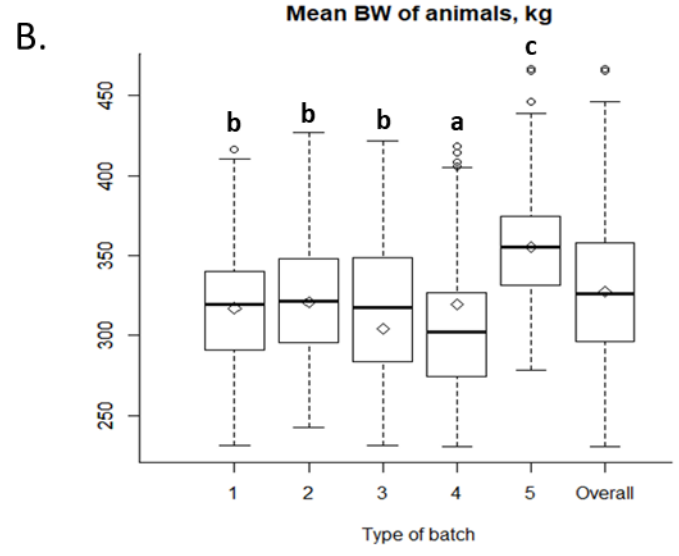
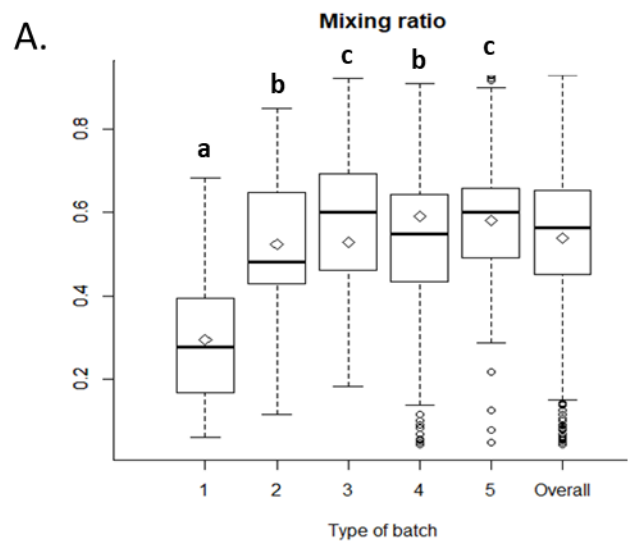
896 <sup>1</sup>Body weight.

897 <sup>2</sup>The mixing ratio was created by dividing the number of cow/calf farms of origin of young bulls by the number of animals in the batch.

898

899 **Figure Captions**

900 **Fig 1:** Batch characteristics for each type of batch resulting from the hierarchical classification analysis. Boxplots were obtained from data of  
901 15,735 Charolais bulls in 740 batches composed only of Charolais bulls or composed of Charolais bulls mixed with other breeds. The batch type  
902 1 is composed of 1,050 young bulls in 56 batches, the batch type 2 of 1,204 young bulls in 56 batches, the batch type 3 of 1,733 young bulls in  
903 70 batches, the batch type 4 of 5,790 young bulls in 331 batches and the batch type 5 of 5,958 young bulls in 227 batches.  
904 Means within a chart without a common superscript differ ( $P < 0.05$ ).  
905 A. Mixing ratio of the batch. The mixing ratio was created by dividing the number of cow/calf farms of origin of young bulls by the number of  
906 animals in the batch.  
907 B. Mean body weight (BW) of animals within the batch.  
908 C. Coefficient of variation (CV) of BW of animals within the batch.  
909 D. Mean total transportation distance of animals within the batch. The mean total transportation distance within the batch was obtained from the  
910 location of the cow/calf farms, the sorting facility and the fattening operation of each animal.  
911



**Fig 1 :**