

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.

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10

11 Abbreviations¹

¹BW: 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 m² 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).

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 ± 0.21 kg/d for a fattening period
291 duration of on average 313.4 ± 55.95 d. The number of animals in the batch ranged from 11
292 to 112 with a mean of 32.1 ± 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 ± 44.67 kg. The CV of BW and age
294 within a batch were on average 6.0 ± 3.17 % and 14.9 ± 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 ± 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 ¹ , 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 ² 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 ³	0.54	0.168	0.04	0.45	0.56	0.65	0.93	815
Mean total transportation distance within the batch, km ⁴	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	¹ Average

817 e daily gain.

818 ²Body weight.

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

833

834 ¹Data 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 ²Data are from 293 batches composed only of Charolais bulls.

837 ³Bovine respiratory disease.

838 ⁴Some 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.

Variables	Mean	SD	Minimum	Q1	Median	Q3	Maximum
Indicators of homogeneity of growth performance during the fattening period within the batch							
SD of ADG ¹ , 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 ² 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 ¹Average daily gain.

847 ²Body 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 ¹ of animals within the batch, /50 kg	0.035	0.029	0.041	< 0.001	
Mean total transportation distance within the batch, /120 km ²	-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 ³ before weaning ⁴	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 ¹Body weight.

853 ²The 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 ³Bovine respiratory disease.

856 ⁴Some 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 $R^2 = 0.69$

863

Variables and levels	Estimate	95% confidence interval		P-value	
		Lower bound	Upper bound		
Intercept	575.6				
Mean BW ¹ 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 ² , /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 ³ before weaning ⁴	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 ¹Body weight.

865 ²The 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 ³Bovine respiratory disease.

868 ⁴Some 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 ¹ (kg/d) ²				Fattening period duration (d) ³			
		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 ¹Average daily gain.

877 ² Conditional R² = 0.36

878 ³ Conditional R² = 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 ¹ of animals within the batch, /50 kg	0.012	0.006	0.017	< 0.001
Mixing ratio, /0.2 ²	0.038	0.013	0.063	< 0.01

896 ¹Body weight.

897 ²The 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

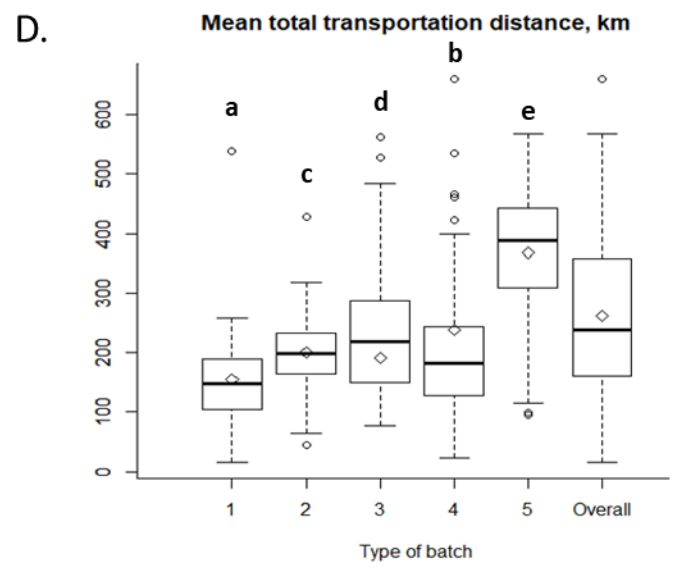
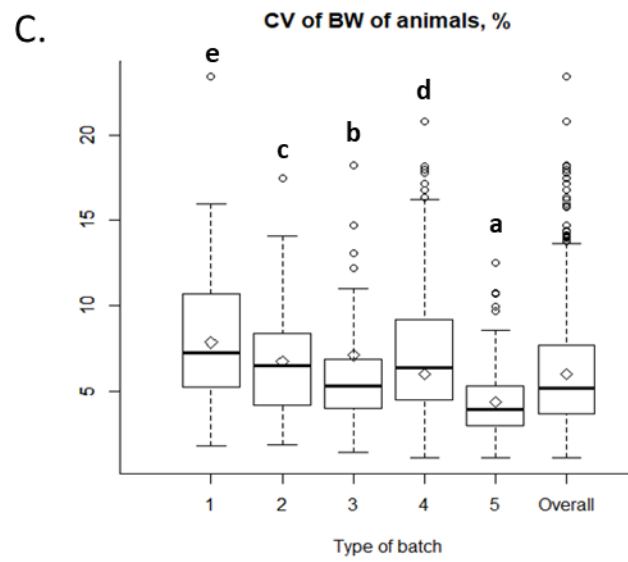
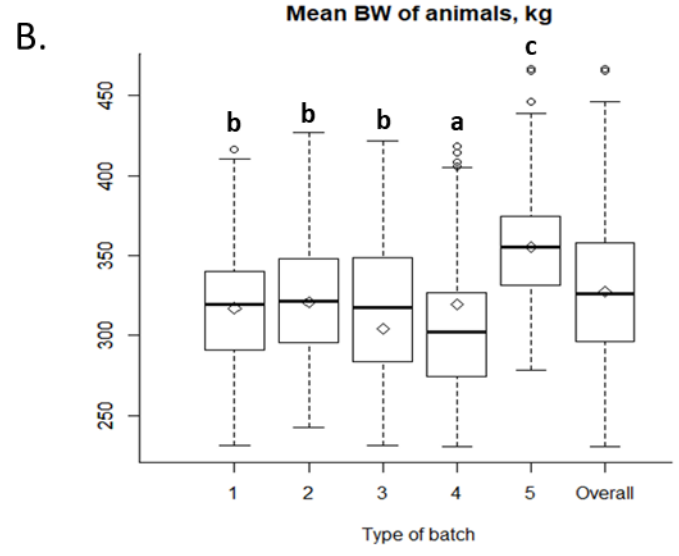
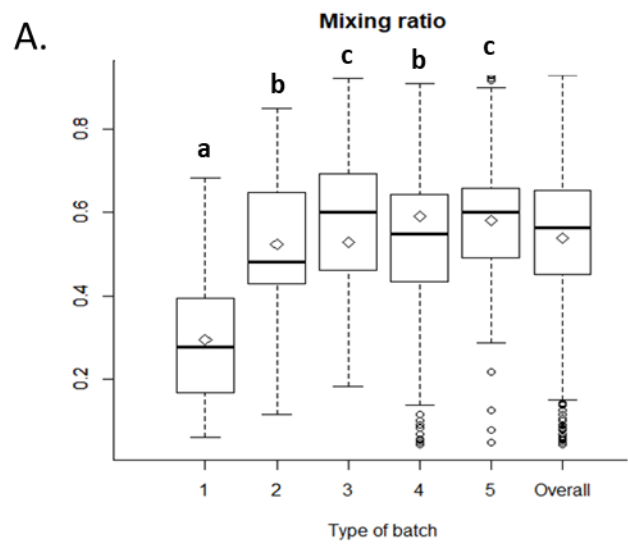


Fig 1 :