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

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Abbreviations[1]

[1]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

Abstract

To meet the demands of the beef cattle sector in France, weaned beef calves are transported to sorting facilities and sorted into batches composed of animals of similar body weight (BW) before the beginning of the fattening period. This procedure aims to facilitate animal management. However, it leads to practices that affect animal welfare, health and performance, such as transporting weaned beef calves over long distances and mixing animals originating from different cow/calf farms. In contrast, other potentially beneficial practices, such as pre-weaning vaccination against bovine respiratory diseases (BRD), are seldom taken into consideration when batches are formed. This observational study, based on field data from 15,735 Charolais bulls, aimed to investigate which criteria should be favored for batch constitution by quantifying the effect of batch characteristics on the growth performance of young bulls during the fattening period. Clustering analysis was used to group young bulls exhibiting similar batch characteristics and define batch types. Associations between batch characteristics/batch types and individual growth performance/homogeneity of growth performance (mean and standard deviation (SD) of average daily gain (ADG) and fattening period duration) were studied using linear mixed models. The mean BW and the percentage of animals vaccinated against BRD before weaning were positively associated with ADG (+35 g/d for each additional 50 kg and +28 g/d for a high percentage of vaccinated animals, $P < 0.05$). In contrast, transportation distance was negatively associated with ADG (-12 g/d for each additional 120 km travelled). Mixing animals and BW homogeneity did not affect growth performance ($P > 0.05$). Only the mean BW and mixing animals negatively influenced the homogeneity of ADG ($P < 0.01$). The clustering analysis revealed that batches with the most BW heterogeneity, the least mixing, the shortest transportation distance and a high percentage of pre-weaning animals vaccinated against BRD had better growth performance compared to batches with the opposite characteristics (+ 61g/d, $P < 0.001$). Our results suggest that major improvements of growth performance of fattening young bulls could be obtained by minimizing transportation distance, providing vaccination programs against BRD before weaning, and maintaining groups from the same cow/calf farm instead of constituting groups of animals with similar BW at the beginning of fattening.

Key words:

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

Introduction

In France, most young bulls from beef breeds are produced by cow/calf breeders and fattened by specialized fatteners (Poizat et al., 2019). During the rearing period at the cow/calf farm, calves are mostly reared on pasture with their dam in groups of 25-30 couples. Apart from milk and grass, calves can also sometimes be supplemented with concentrates before weaning. At the end of this rearing period, young bulls, aged between 5 and 10 months, are weaned and immediately transported to a sorting facility to be sorted by breed and body weight (BW), forming new batches that fulfill the orders of the fatteners. The newly formed batches are then transported to the fattening operations for the entire fattening period. During the fattening period, young bulls are reared in barns consisting of pens of 10 to 20 animals for an individual space allowance of 3.5 to 5.5 m² and fed a complete diet mainly composed of corn silage, cereals and soybean meal. The main consideration guiding the constitution of batches in sorting facilities before the beginning of the fattening period is BW: animals with similar BW are grouped together. This practice is adopted by most fatteners to facilitate the management of animals during the fattening period and improve growth performance. However, the validity of this BW-homogeneity criterion is questionable since Mounier et al. (2005) showed that making groups of similar BW at the beginning of the fattening period seemed to be detrimental to animal welfare and guaranteed neither improved nor homogeneous performance.

This organization of the production system is based on practices that can affect the welfare, health and growth performance of young bulls. These practices are not, or are seldom, considered when constituting batches. The first is the transportation, at times over long distances, of young bulls from cow/calf farms to fattening operations via the sorting facilities. This transportation is recognized as a stressor for beef cattle that causes adverse effects on health (Blecha et al., 1984; Sanderson et al., 2008; Cernicchiaro et al., 2012b) and can lead to reduced subsequent performance (Schwartzkopf-Genswein et al., 2007; Cernicchiaro et al., 2012b). The second is the commonly observed practice in sorting facilities of mixing young bulls from different cow/calf farms, of varying ages, and sometimes of different breeds to form batches composed of animals with a similar BW. This practice of mixing animals from different farms increases health risks, especially with regard to the development of bovine respiratory diseases (BRD, O'Connor et al., 2005; Sanderson et al., 2008; Step et al., 2008), presumably due to an increased exposure to pathogens. It is also well-known that mixing induces acute and even chronic stress in beef cattle (McVeigh and Tarrant, 1982; Mench et al., 1990; Mounier et al., 2005) due to interactions with new animals and the establishment of a new social hierarchy with more aggressive behavior (Mench et al., 1990; Mounier et al., 2006b). This negative effect of mixing on behavior is even more acute when bulls have a similar BW due to the greater difficulty in establishing dominance relationships (Mounier et al., 2005, 2006b). All of these effects of mixing could in turn impair growth performance (Bøe and Færevik, 2003; Mounier et al., 2006a). When animal health and welfare are considered, mixing young bulls thus does not appear to favor growth.

In contrast, practices included in preconditioning programs have been shown to reduce stress and improve the health of young bulls, resulting in better growth performance during the fattening period (Duff and Galyean, 2007; Thrift and Thrift, 2011). Preconditioning programs are designed to reduce stress associated with weaning, enhance the immune system of calves, and accustom calves to eating from a feed bunk and drinking from a fountain (Duff and Galyean, 2007). Since most BRD cases occur at the beginning of the fattening period (Smith, 1998; Sanderson et al., 2008; Assié et al., 2009) and are responsible for decreased growth performance (Gardner et al., 1999; Schneider et al., 2009), preconditioning programs can include pre-weaning vaccination against BRD by the cow/calf breeders. This vaccination enables the development of immunity prior to the critical period of maximum pathogen exposure (Taylor et al., 2010) upon arrival in the fattening operations, and prevents the well-known negative effect of BRD on growth performance (Smith, 1998). Nevertheless, this practice is not widespread, and the presence of vaccinated animals is a criterion that is seldom considered when batches are constituted.

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

Materials and Methods

All animals involved in this observational study were cared for according to the "Good practices guidelines in cattle, beef calves, sheep and goats" in compliance with French regulations (https://agriculture.gouv.fr/sites/minagri/files/documents/pdf/gph__bovins_veaux_ovins_caprins_20145952_0001_p000_cle0f3116.pdf).

Study Design

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

Crude Data

The data obtained from the beef producers' organization were individual data related to the rearing period in the cow/calf farm (cow/calf farm location, rearing period duration, average daily gain (ADG) of animals during the rearing period and animal vaccinated against BRD before weaning or not), the batch constitution at the sorting facility (sorting facility location, BW and age upon arrival at the sorting facility, number of animals in the batch, number of cow/calf farms of origin within the batch, season (Winter: January to March, Spring: April to June, Summer: July to September, and Fall: October to December) and year (2014 or 2015) of entry in the fattening operations, and batch composed only of Charolais bulls or composed of Charolais bulls mixed with other breeds), and the fattening period (fattening operations location, fattening period duration, and ADG of animals during the fattening period).

Calculations and Statistical Analysis

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

Some variables describing batch characteristics were directly available in crude data (number of animals in the batch, season and year of entry in the fattening operations, and batch composed only of Charolais bulls or composed of Charolais bulls mixed with other breeds), whereas others were created using the crude data. The mean BW and age of young bulls at arrival at the sorting facility within the batch were obtained by averaging individual BW and age values within the batch. The coefficient of variation (CV) of BW and age at arrival at the sorting facility within the batch were also calculated. A mixing ratio was created by dividing the number of cow/calf farms of origin by the number of young bulls in the batch. This mixing ratio ranged from 0 to 1; a mixing ratio close to 0 meant that there was little mixing of animals from different cow/calf farms, while a mixing ratio close to 1 indicated a high level of mixing of animals from many different cow/calf farms. The percentage of young bulls vaccinated against BRD before weaning within the batch was calculated and, as it was not normally distributed, then categorized into four levels: None [0%] (no animal vaccinated against BRD before weaning in the batch),]0-13%] (low percentage),]13-50%] (medium percentage), and]50-100%] (high percentage of animals vaccinated against BRD before weaning in the batch). The total transportation distance as the crow flies of each animal was estimated based on the locations of the cow/calf farm, the sorting facility and the fattening operations. The total transportation distance was then averaged within the batch to obtain the batch mean total transportation distance.

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

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

Determination of different batch types using cluster analysis.

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

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

The effect of batch characteristics on individual growth performance during the fattening period was analyzed using generalized linear mixed models considering individuals as the statistical unit and using the lmer function from the lme4 package. For this analysis, all individual Charolais bulls were considered, whether they were part of a batch composed only of Charolais bulls or a batch composed of Charolais mixed with other breeds. A herd random effect was added to the models to take into account management differences between fattening operations. Growth performance indicators (ADG during the fattening period and fattening duration) were considered as outcome variables. The fattening period duration rather than the BW at the end of the fattening period was considered as a growth performance indicator. In the French beef cattle sector, the BW at the end of the fattening period is very homogeneous because animals are required to have a BW of between 750 and 800 kg when sent to the slaughterhouse. This results in a heterogeneous fattening period duration that reflects the growth performance of animals. The tested independent variables corresponded to the batch characteristics and to the ADG during the rearing period since it was considered as a possible confounding factor. Before including an independent variable, the distribution of the variable was checked and the variable was considered as a continuous variable only if it was normally distributed. The linear relationship between each continuous independent variable and the outcome variable was also checked. Independent variables were then tested for their association with indicators of growth performance during the fattening period in univariate analyses. Only independent variables that were associated with growth performance indicators at $P < 0.20$ in the univariate analysis were then included in the multivariate model. To avoid including collinear independent variables in the multivariate model, the rcorr function from the Hmisc package was used to generate the Pearson correlation coefficient, which measures the strength of association between pairs of variables without specifying dependencies. When the value of the correlation coefficient between 2 variables was $|0.70|$ or greater at a 5% significance level ($P < 0.05$), the 2 variables were considered to be collinear and only one was selected for inclusion in the multivariate model. Due to the collinearity between the mean BW and the mean age of animals at arrival at the sorting facility within a batch, only the mean BW was included in the multivariate model. The best fit model selection was based on a manual backward step-wise elimination of independent variables leading to the selection of the multivariate model containing only independent variables significantly associated with growth performance during the fattening period ($P < 0.05$) based on the Fisher's test P-value. An interaction between the year and the season of entry was included in the statistical model.

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

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

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

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

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

Result

Descriptive Statistics

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

For the analysis of the effect of batch characteristics on the homogeneity of performance within the batch during the fattening period, only batches with 100% Charolais bulls were considered, resulting in a final population of 293 batches. The descriptive statistics of the continuous independent variables observed for the final study population are presented in Table 3, and the frequencies of distribution of batches within each level of categorical variables are presented in Table 2. The SD of ADG of young bulls within the batch was 170 g/d and the SD of the fattening period duration was 23 d.

Description of the Different Batch Types

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

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

The three first batch types contained young bulls from batches with animals vaccinated against BRD before weaning. The first batch type was characterized by young bulls from batches with a high percentage of animals vaccinated against BRD before weaning (i.e.]50%-100%]). The young bulls from type 1 were also the least BW-homogeneous, with the lowest mixing ratio and the shortest transportation distance. Types 2 and 3 contained only young bulls from batches with a medium percentage (i.e.,]13%-50%]) and a low (i.e.,]0%-13%]) of animals vaccinated against BRD before weaning, respectively. Both types presented a high mixing ratio (0.52 and 0.59, respectively), a medium CV of BW (6.8 and 6.0%, respectively) and a medium transportation distance (200.2 and 237.6 km, respectively). Types 4 and 5 were both characterized by animals belonging to batches with no animals vaccinated against BRD before weaning (i.e. None [0%]) and by a high mixing ratio (0.53 and 0.58, respectively) but were differentiated by the mean and CV of BW of animals and the mean total distance within the batch: type 4 presented on average lighter (304.1 vs 355.4 kg) and less BW-homogenous (CV of BW: 7.7 vs 4.4%) animals with a shorter distance of transportation (190.8 vs. 367.5 km) than type 5.

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

An increased mean BW of animals within the batch was associated with better growth performance, namely a greater ADG and a shorter fattening period duration (+ 35 g/d and -37.9 d, respectively, when the mean BW of animals within the batch was 50 kg greater, $P < 0.001$, Table 4 and Table 5). An increased CV of animals' age within the batch was associated with a decreased fattening period duration (-1.0 d for + 5% of CV, $P = 0.03$, Table 5). An increase in the mean total transportation distance of the batch was associated with reduced growth performance: the ADG during the fattening period decreased by 11 g/d and the fattening period duration increased by 1.6 d when the mean total transportation distance of the batch increased by 120 km ($P < 0.001$, Table 4 and Table 5). Whether or not the batch was composed only of Charolais bulls, and the percentage of animals vaccinated against BRD before weaning within the batch, were also associated with growth performance. Animals belonging to batches composed of Charolais bulls mixed with other breeds had a greater ADG during the fattening period (+22 g/d, P < 0.001, Table 4) and a shorter fattening period duration (-4 d, P < 0.001, Table 5). The higher the percentage of animals vaccinated against BRD before weaning, the greater the ADG during the fattening period (+13, +15 and +28 g/d when batches were composed of]0-13%],]13-50%], and]50-100%] of animals vaccinated, respectively, compared with batches without animals vaccinated against BRD before weaning, P < 0.05, Table 4). The fattening duration was also shorter when batches contained vaccinated animals compared with batches without animals vaccinated against BRD before weaning (P < 0.05, Table 5), but no clear relationship between the proportion of animals vaccinated against BRD before weaning and the fattening period duration was shown. The season of entry at the sorting facility was also associated with growth performance with the greatest ADG and the shortest fattening period duration for batches formed during spring (+ 39 g/d and -11.7 d compared with batches formed during fall, P < 0.05, Table 4 and Table 5). This effect of the season on ADG was even greater in 2015 (Table 4). The adjustment variable ADG during the rearing period also influenced growth performance; its increase resulted in a decrease in ADG during the fattening period (P < 0.001, Table 4) and an increase in the fattening period duration (P < 0.05, Table 5). Finally, the CV of BW of animals within the batch, the mixing ratio and the number of animals in the batch were not associated with either the ADG during the fattening period nor the fattening period duration.

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

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

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

Discussion

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

The main and almost only criteria currently considered by the French beef cattle sector for batch constitution is BW-homogeneity within a batch. This choice is based on the fact that forming groups of BW-homogeneous animals before the start of the fattening period facilitates fattening management. However, in the present study, the CV of BW of animals within a batch formed at the sorting facility had no effect on the individual growth performance of young bulls during the fattening period (ADG and fattening period duration). Moreover, animals from the batch type with the most BW-homogenous animals had the lowest ADG over the fattening period. The practice of forming BW-homogeneous groups at the beginning of fattening is also commonly used in pig husbandry. However, the effect on production appears unclear, as various studies have alternatively shown it to be beneficial, have no effect, or even be detrimental for the growth rate of finishing pigs (Sherritt et al., 1974; Graves et al., 1978; Francis et al., 1996; O'Connell et al., 2005). This practice is poorly documented in beef cattle. Nevertheless, the absence of an effect of BW-homogeneity within a batch on growth performance of young bulls was reported previously in a study in which young bulls from BW-homogeneous batches had similar ADG as young bulls from BW-heterogeneous batches (Mounier et al., 2005). The latter study also showed a homogenization of the BW for young bulls from an originally BW-heterogeneous batch and, in contrast, a heterogenization for young bulls from an originally BW-homogeneous batch. In our study, no effect of the CV of BW on the homogeneity of performance within the batch was observed. However, our study was based on field data in which the range of CV of BW within the batch was limited (between 1.1 and 23.4% with a mean of 6%) due to the beef cattle sector's desire to form BW-homogeneous batches. The present study showed that the CV of BW had no effect neither on the individual growth performance nor on the homogeneity of performance within the batch in the range of CV of BW observed in the data. Further investigations are thus needed to study the extent to which BW-homogeneity does not influence growth performance (experimental studies comparing BW-homogeneous and BW-heterogeneous batches or observational study with more variability in the CV of BW within the batch). Nevertheless, all of these findings call into question the supposed benefit of forming BW-homogeneous groups at the beginning of the fattening period, and suggest that it could be possible for the French beef cattle sector to accept more BW-heterogeneous batches without a deleterious effect on growth performance.

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

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

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

To form batches that are as BW-homogeneous as possible, young bulls from multiple cow/calf farms of origin are commonly mixed at the sorting facility. In our study, we investigated the effect of the mixing degree by creating a mixing ratio (i.e., the number of cow/calf farms of origin divided by the number of young bulls in the batch). This mixing ratio showed no effect on individual growth performance. This result is unexpected since mixing animals from several cow/calf herds was already shown to decrease growth performance in beef cattle (Mounier et al., 2006a; Step et al., 2008). However, in the latter two studies, the effect of mixing was investigated through a comparison of mixed vs. unmixed bulls, and not through the degree of mixing. Moreover, the present study showed that the mixing ratio negatively influenced the homogeneity of ADG within the batch. Furthermore, the batch type containing the animals with the highest ADG during the fattening period was the “low-mixed” batch type, while the batch type with the lowest ADG was the "high-mixed" type. The reduced growth performance of young bulls from the “high-mixed” batch type may have resulted from the stress associated with the interactions with new congeners and the establishment of a new hierarchy. Indeed, mixing at the start of the fattening period was already associated with increased aggressive interactions in pigs (O’Connell et al., 2005) and beef cattle (Mounier et al., 2006b). These post-mixing aggressive behaviors were in turn associated with negative implications, including health problems, reduced growth performance and poor meat quality in pigs (Rundgren and Löfquist, 1989; Tan and Shackleton, 1990; Tan et al., 1991;Stookey and Gonyou, 1994; O’Connell et al., 2005). The aggressive interactions resulting from mixing last even longer and are more frequent when BW variability between animals is small (Rushen, 1987; Francis et al., 1996; Mounier et al., 2005, 2006b) due to the greater difficulty in establishing dominance relationships. In contrast, aggressive behavior could be reduced by forming groups containing a wider range of BW than the usual commercial practice (Marchant-Forde and Marchant-Forde, 2005). The stress associated with the establishment of the new hierarchy in a group of cattle does not only depends on the BW variability but can also be modulated by the space allowance or the accessibility of the feed bunk. Moreover, in commercial conditions, mixing involves animals from different cow/calf farms, and thus with different pathogen backgrounds, which has long been recognized as being strongly associated with an increased risk of subsequent BRD development (Martin et al., 1982; Martin and Meek, 1986; Ribble et al., 1995a, 1995b; Assié et al., 2009), presumably due to an increased exposure to pathogens. More recent studies also agree that mixing cattle from multiple sources at the beginning of fattening increases the risk of BRD (O'Connor et al., 2005; Sanderson et al., 2008; Step et al., 2008; Hay et al., 2014). Since BRD are known to negatively influence growth performance (Bateman et al., 1990; Gardner et al., 1999; Schneider et al., 2009), the reduced performance of animals from "high-mixed" batch types might be explained by a higher incidence of BRD in these types. The maintenance of rearing groups could thus maximize growth performance by minimizing health risks related to BRD.

To reduce the unavoidable health risk related to BRD when young bulls from different origins are mixed, and to minimize the negative effect of BRD on growth performance (Smith, 1998), it is possible to vaccinate the animals. Ideally, this vaccination must be done before weaning at the cow/calf farm to enable the development of immunity prior to the critical period of maximum pathogen exposure represented by the arrival at fattening operations (Taylor et al., 2010). Our study confirmed the beneficial effect of this pre-weaning vaccination against BRD on growth performance since the higher the percentage of vaccinated animals within the batch, the greater the individual ADG. Moreover, animals from batches with a high percentage of animals vaccinated against BRD before weaning (i.e., composed of]50-100%] of vaccinated animals) had the greatest ADG. Our results also suggest that pre-weaning vaccination could prevent the negative effect of mixing since animals from the "medium" and the "low percentage of vaccinated animals" batch types had better performance compared with "no vaccinated animals" batch types for a similar mixing ratio. The positive effect of vaccination against BRD on growth performance of young bulls during the fattening period observed in our study could be directly related to the lower risk of developing BRD for vaccinated animals compared to non-vaccinated animals (Macartney et al., 2003; Hay et al., 2016b). It could also be assumed that vaccinated animals are raised by cow/calf breeders and then by fatteners that have concerns regarding BRD and probably have improved overall management practices and particularly improved health-related practices. This vaccination could also have been a part of a preconditioning program that improve the welfare and the health status of the weaned calf prior to sale to the beef producer's organization and could explain the better further growth performance (Duff and Galyean, 2007; Thrift and Thrift, 2011). Moreover, in our study, only a small part of the animals (8.3%) has been vaccinated against BRD before weaning. Nevertheless, given the beneficial effect of pre-weaning vaccination against BRD, the French beef cattle sector should promote this practice as a part of a preconditioning program. However, it can be difficult for cow/calf breeders to carry out a vaccination program. For example, to be part of the pre-weaning vaccination program proposed by the beef producers' organization that we worked with for the present study, animals must receive two injections spaced three weeks apart. The injections must be given at least 3 weeks, and not more than 6 months, before the transfer to the sorting facility. This corresponds to when the animals are between 4 and 9 months old and are being reared in pasture, which is a difficult setting for the administration of vaccines. Moreover, the beneficial effect on growth performance was observed during the fattening period, which means that vaccine injections are performed by cow/calf breeders for the benefit of fatteners.

Batches are composed so that the batch mean BW matches the request of each fattener. The choice of this batch mean BW is not a trivial matter since our study showed a positive association between the batch mean BW and growth performance; young bulls from heavier batches grew faster than young bulls from lighter batches. Batch mean BW is considered an important factor for predicting subsequent health risks as heavier young bulls have less risk of BRD (Lechtenberg et al., 1998; Sanderson et al., 2008; Babcock et al., 2010; Cernicchiaro et al., 2012b; Hay et al., 2016a). Given the close relationship between BW and age in young bulls, which was confirmed by the positive correlation between these two variables in our data, the effect of the batch mean BW on growth performance may be related to the age of animals. Indeed, the age at arrival in the fattening operation is also a risk factor for BRD development as younger bulls have a higher risk of BRD than older ones (Faber et al., 1999). Younger, and thus lighter, animals are likely to have a more naïve immunity system and to have had less opportunity to be exposed to potential pathogens over time (Sanderson et al., 2008), explaining the reduced growth performance of bulls from lighter batches.

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

Our study also showed that when Charolais bulls are received by fatteners and enter in fattening operations with young bulls from other breeds, these Charolais bulls had a better growth performance (i.e., a greater ADG and a shorter fattening period duration). In our study, the other breeds mixed with Charolais bulls were mostly Limousine, Blonde d'Aquitaine and Rouge des Prés. These breeds have a lower feed intake capacity (INRA, 2007), and therefore require a diet with a higher energy level to cover the needs of young bulls. We thus hypothesize that farmers fattening Charolais alongside these other breeds fed the animals with an intermediate diet in term of energy level to approximately fit with the needs of the different breeds. Charolais bulls fattened with young bulls from other breeds may have been fed with a more energetic diet than Charolais bulls fattened alone, thus explaining the difference in growth performance.

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

To conclude, this study showed that the characteristics of batches formed at the sorting facilities had a negative impact that could go up to a loss of 19 kg over the entire fattening period (with an average duration of 313 d) when all practices that affect animal health and welfare were implemented (i.e. a high mixing ratio, a long transportation distance, a low CV of BW and no animal vaccinated within the batch such as in batch type 5). Optimizing the growth performance of young bulls and preventing BRD thus involves management choices that minimize risk factors related to batch characteristics. Pre-weaning vaccination seems to be beneficial for individual growth performance. It could thus be interesting for the French beef cattle sector to promote vaccination against BRD as part of preconditioning program to reduce health risk and improve growth performance during the fattening period. Within the range of variability of BW we could investigate, our findings argue against the common practice of making BW-homogeneous batches at the beginning of the fattening period because this relies on mixing young bulls, which is detrimental for production. This conclusion should be verified in a broader range of variability of BW at entry and we could then recommend maintaining groups from the same cow-calf farm to reduce the unavoidable health risk related to BRD when animals of various origins are mixed. To maximize the growth performance of young bulls, the beef producers' organization could form more batches similar to the batch type that we identified as minimizing the risk factors for BRD, namely one composed of vaccinated, BW-heterogeneous animals with a low mixing ratio and minimal transportation distance.

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Author contributions

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

Declarations of interest: none

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TABLES

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

Variables	**Mean**	**SD**	**Minimum**	**Q1**	**Median**	**Q3**	**Maximum**
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	2.53
Fattening period duration, d	313.4	55.95	123	274	309	349	567
Characteristics of batches formed at the sorting facility							
Number of animals in the batch	32.1	15.41	11	25	29	40	112
Mean BW[2] of animals within the batch, kg	327.3	44.67	230.3	296.0	325.8	357.8	466.5
Mean age of animal within the batch, d	244.9	25.17	173.8	226.3	246.3	263.0	299.0
CV of BW of animals within the batch, %	6.0	3.17	1.1	3.6	5.2	7.7	23.4
CV of age of animals within the batch, %	14.9	3.99	2.6	12.2	14.5	17.3	29.2
Mixing ratio[3]	0.54	0.168	0.04	0.45	0.56	0.65	0.93
Mean total transportation distance within the batch, km[4]	261.1	125.16	15.0	159.9	237.3	358.4	658.8
ADG during the rearing period, kg/d	1.18	0.214	0.34	1.03	1.18	1.31	2.13

[1]Average daily gain.

[2]Body weight.

[3]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.

[4]The mean total transportation distance within the batch was obtained from the location of the cow/calf farms, the sorting facility and the fattening operation of each animal.

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]
Batch only composed of Charolais bulls	No	55.6	-
	Yes	44.4	-
Percentage of animals vaccinated against BRD[3] before weaning[4]	None [0%]	74.7	77.1
	Low]0-13%]	11.0	8.5
	Medium]13-50%]	7.6	6.1
	High]50-100%]	6.7	8.2
Season of entry	Winter	14.2	12.3
	Spring	24.4	23.5
	Summer	26.4	27.6
	Fall	35.0	36.5
Year of entry	2014	51.6	57.0
	2015	48.4	43.0

[1]Data are from 15,735 Charolais bulls sorted at the sorting facility into 740 batches composed only of Charolais bulls or composed of Charolais bulls mixed with other breeds.

[2]Data are from 293 batches composed only of Charolais bulls.

[3]Bovine respiratory disease.

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

Table 3: Descriptive statistics for indicators of homogeneity of growth performance within the batch and characteristics of batches formed at the 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

[1]Average daily gain.
[2]Body weight.

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

			95% confidence interval		
Variables and levels		**Estimate**	**Lower bound**	**Upper bound**	***P*-value**
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

[1]Body weight.

[2]The mean total transportation distance within the batch was obtained from the location of the cow/calf farms, the sorting facility and the fattening operation of each animal.

[3]Bovine respiratory disease.

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

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

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

[1]Body weight.

[2]The mean total transportation distance within the batch was obtained from the location of the cow/calf farms, the sorting facility and the fattening operation of each animal.

[3]Bovine respiratory disease.

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

Table 6: Association between the type of batch defined by the hierarchical classification and the growth performance (average daily gain and fattening period duration) of Charolais young bulls during the fattening period. Data are from 15,735 Charolais bulls in 740 batches composed 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

[1]Average daily gain.

[2] Conditional $R^2 = 0.36$

[3] Conditional $R^2 = 0.62$

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

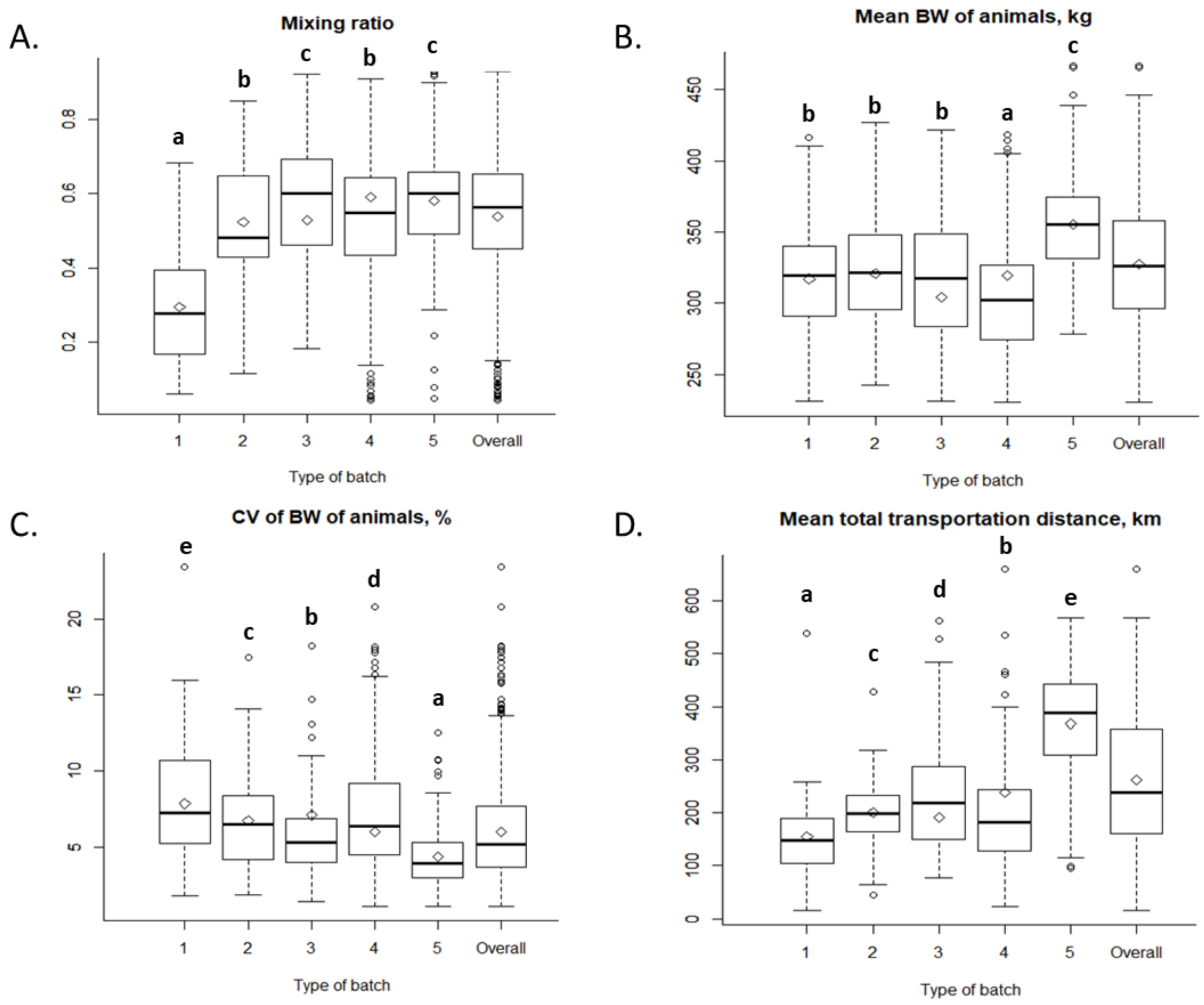
		95% confidence interval		
Variables and levels	**Estimate**	**Lower bound**	**Upper bound**	***P*-value**
Intercept	0.069			
Mean BW[1] of animals within the batch, /50 kg	0.012	0.006	0.017	< 0.001
Mixing ratio, /0.2[2]	0.038	0.013	0.063	< 0.01

[1]Body weight.

[2]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.

Figure Captions

Fig 1: Batch characteristics for each type of batch resulting from the hierarchical classification analysis. Boxplots were obtained from data of 15,735 Charolais bulls in 740 batches composed only of Charolais bulls or composed of Charolais bulls mixed with other breeds. The batch type 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 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.
Means within a chart without a common superscript differ ($P < 0.05$).
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 animals in the batch.
B. Mean body weight (BW) of animals within the batch.
C. Coefficient of variation (CV) of BW of animals within the batch.
D. Mean total transportation distance of animals within the batch. The mean total transportation distance within the batch was obtained from the location of the cow/calf farms, the sorting facility and the fattening operation of each animal.



A.
Mixing ratio
a
b
c
b
c
0.2
0.4
0.6
0.8
1
2
3
4
5
Overall
Type of batch
B.
Mean BW of animals, kg
b
b
b
a
c
250
300
350
400
450
1
2
3
4
5
Overall
Type of batch
C.
CV of BW of animals, %
e
c
b
d
a
5
10
15
20
1
2
3
4
5
Overall
Type of batch
D.
Mean total transportation distance, km
a
c
d
b
e
0
100
200
300
400
500
600
1
2
3
4
5
Overall
Type of batch

Fig 1 :