# A cross-sectional study of factors associated with birth weights of Norwegian beef calves

Sindre T. Nelson[1§], Adam D. Martin[1], Ingrid H. Holmøy[1], Knut Karlberg[1] and Ane Nødtvedt[1]

[1]Department of Production Animal Clinical Sciences, Faculty of Veterinary Medicine and Biosciences, Norwegian University of Life Sciences, Oslo, Norway

[§]Corresponding author: Department of Production Animal Clinical Sciences, Faculty of Veterinary Medicine and Biosciences, Norwegian University of Life Sciences, P.O Box 8146 Dep. N-0033 Oslo, Norway Tel.: +47 22597496; fax: +47 22597083

Email address: sindre.nelson@nmbu.no

**ABSTRACT**

A cross-sectional study was performed to evaluate factors which influence birth weights of beef suckler calves in Norway. Data were from a national beef cattle registry, and lifetime production data of cows slaughtered between January 2010 and January 2013 were included in the study population. The study population consisted of 20,541 cows and 53,819 calves. The analysis was performed on the subset of singleton calvings from which birth weights were recorded. The study sample consisted of 9,903 cows with birth weights available for 29,294 calves. The mean birth weight was 43.47 kg (95% CI 43.40; 43.53). Two multilevel linear regression models were built; the first was for all calves and included parity of dam as one of the explanatory variables (with herd and cow as random effects), the second model was for calves born to primiparous dams only where age of first calving was included as an explanatory variable (with a random herd effect). The multilevel regression models estimated that female calves were 2.3 kg lighter than males (95% CI 2.2-2.4, $P < 0.001$), that calves of Norwegian Red, Charolais, Aberdeen Angus and “Other” born in the western part of Norway were lighter than from all other regions, and that calving in the autumn yielded lighter offspring than calving other parts of the year. Furthermore, calves born from primiparous cows were heavier than calves from older cows. Herd explained a large proportion of the variation in birth weights (40% and 37%, in the full and heifer models, respectively), and both the herd and cow random effects were highly significant. In conclusion, birth weights of beef calves in the Norwegian Beef Cattle Recording System were influenced by sex of the calf, breed of the dam, parity, age at first calving, calving season, cow, herd and region.

*Keywords:*
Bovine
Cattle
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Recording system
Suckler cows
Offspring

## 1. Introduction

There is no tradition for specialized beef production in Norway, where milk and meat for the domestic market have traditionally been produced by dual purpose Norwegian Red cattle. Over the past two decades, improvements in the breeding and management of Norwegian dairy cows have resulted in considerably higher milk yields per cow leading to a decrease in the size of the national dairy population, but still filling the nationally regulated milk quota (Kumbhakar et al., 2008). Beef is a by-product of the dairy industry and the reduction in the national dairy herd has led to a reduction in beef production in Norway. Concurrently the human population has increased and beef consumption has increased. Consequently, in 2012 more than 22% of the annual consumption of beef was imported into Norway (Animalia, 2013a). If domestically produced beef is to meet consumer demand, which is a political goal, the number of beef cattle must increase substantially over the next decade and their productivity must be improved (Ruud et al., 2013). Norwegian beef producers, as well as their veterinarians and advisors, therefore need information regarding factors affecting productivity in the national beef herd in order to increase the output in a sustainable manner.

In specialized beef production the successful rearing of calves for slaughter and replacement of breeding stock is a key factor determining herd profitability. Economic studies of the functional traits of beef production showed that fertility was the most important trait for sustainable suckler cow operations (Prince et al., 1987; Diskin and Kenny, 2014).

The optimal size of a calf will vary depending on the breed and parity of the dam, and there must be a balance between being large enough to be healthy and robust and not being so large as to cause dystocia. Birth weight is reported to be the single most important risk-factor for occurrence of dystocia (Nix et al., 1998; Bellows and Lammoglia, 2000), and dystocia can affect both the cow and calf negatively and in severe cases lead to loss of both. Dystocia is further known to negatively impact fertility in the post-partum period leading to increased occurrence of uterine disease, delays in onset of luteal activity and extended calving intervals (Zaborski et al., 2009). Calf birth weight has also been shown to influence days open in Norwegian Hereford herds (Martin et al., 2010). The factors influencing birth weights of beef calves are not fully known, but both genetic and environmental factors are involved (Holland and Odde, 1992). Important factors influencing birth weights include: parity, fetal sex, sire and dam breed, maternal nutrition and climate during last trimester (Mee, 2008). Furthermore, differences between the geographical regions of Norway might potentially influence birth weights through differences in management, climate and/or nutrition. Understanding the variability in birth weights in Norwegian beef suckler herds, and the mechanisms behind this variability, can be a means to optimizing the production. The aim of this study was therefore to document the distribution of birth weights among beef suckler calves in Norway, and to evaluate factors associated with birth weights at the individual calf level. The factors of interest were sex of the calf, breed, region, dam´s age at first calving, calving season, parity, cow and herd.

## 2. Materials and methods

### *2.1. Study population*

The data used in this study were extracted from the Norwegian Beef Cattle Recording System (NBCRS). Producer membership in the NBCRS is voluntary, but more than 78% (n= 66,584) of Norwegian beef suckler cows, representing 57% (n= 2,428) of the Norwegian beef herds, were enrolled at the end of 2012 (Animalia, 2013b). In the NBCRS animals are identified by a unique 12-digit number, where 8 digits identify the location of farm of origin and 4 digits identify the individual, and all the cattle must be ear-tagged with this number in accordance to EU-legislation EF 1760/2000. The database further includes individual animal information regarding date of birth, sex, breed, herd (current and of origin), ancestry, slaughter date and slaughter quality. Producers are encouraged to record weights at certain ages, e.g. at birth and 200 days of age, calving difficulties and animal losses other than slaughter.

Data on all adult cows slaughtered between 1st of January 2010 and 23rd of January 2013 were extracted from the NBCRS (Table 1). Only cows registered with a least one progeny were kept in the initial extraction along with all data of their offspring, including those born before herd membership in the NBCRS. The data set was screened for illogical observations, obvious typing errors and duplicates, and when found these were omitted. If only one obvious error occurred in the records of a cow with many parities the single offspring was removed. However, if errors occurred more than once, all the registrations concerning the cow and her progeny were deleted. Data from cows with age at first calving below 1.5 years and cows with age at first calving over 3.6 years of age where excluded from the analyses.

### *2.2. Outcome and explanatory variables*

The outcome variable of interest was the birth weight of each calf and the explanatory variables included were cow identity, sex of the calf, breed of the dam, region, age of dam at first calving, season of calving, parity of the cow and herd of birth. The breed of each animal was defined as purebred if the animal was registered genetically as 15/16 parts (or more) of the same breed, calculated from the breed composition of parents, grand- and great grandparents. If less than 15/16 parts purebred, animals were coded as crossbreed. The breed variable was retained for the most important breeds; Norwegian Red, Hereford, Charolais, Aberdeen Angus, Limousin and Simmental, while the less numerous breeds were merged into a pooled category; “Other”. The Other category consisted of the breeds Jersey, Sided Troender/Northland cattle, Telemark cattle, Doela cattle, Old Norwegian Red Polled, Norwegian South- and Western cattle, Norwegian Western Fjord cattle, Holstein, Danish Red , Blond d’Aquitaine, Highland Cattle, Tiroler Gray, Dexter, Piemontese, Galloway and cross-breeds**.** The herds’ locations were grouped into five geographical regions of Norway which are also used for the regulation of movements of cattle livestock; Costal Southeast, Inland Southeast, Western, Mid- and, Northern Norway, respectively. Age at first calving was defined by subtracting birth date from first calving date. Parity was defined by the sequence of calvings for each cow in the dataset. For twin calvings, the birth weights of both twins were excluded from the analysis but the calving still gave rise to an increase in parity. Parity was coded individually for the first 6 parities, while subsequent parities were pooled as greater than 6$^{th}$ due to the low number of observations in this group. Season of calving was dichotomized based on month of partum. “Spring calving” was defined as births between first of February and the end of July while the “Autumn calving” season was set to the first of August to the end of January. The unit of observation was the calving, and because several sequential offspring could be registered from each cow these observations were not independent of each other, which needed to be taken into account during analysis. Cows were further clustered within herds, which were located within regions.

*2.3. Statistical methods*

The generation of the initial database from the NBCRS was performed using SAS 9.2 (SAS Institute Inc., Cary, NC, USA). Further data management and statistical analysis was performed using Stata SE/12 (Stata Corp., College Station, TX, USA)

The mean birth weights, with standard errors and 95% confidence intervals (CI), for offspring were calculated overall and for sub-groups defined by sex, breed, region, age at first calving, season of calving and parity. Two multilevel linear regression models were built; one for all animals (with herd and cow as random effects) which included parity as an explanatory variable, and a second model for first calvings only where age of (first) calving was included as an explanatory variable and with a herd random effect. The command *xtmixed* in Stata was used, assuming equal correlations between animals within a herd and hence applying a *compound symmetry* correlation structure. Variables were tested in the multilevel linear regression models with a manual backward stepwise regression strategy until all included variables were significant at a p-value of $\leq 0.01$. Potential confounding variables were identified a priori through the construction of a causal diagram. Variables considered potential confounders were tested running the model with and without the variables in question and changes in estimates were explored. Overall significance of groups of categorical variables, e.g. breed and region, were tested using likelihood ratio tests. The amount of variation present at each level in the hierarchical models (calving/cow/herd) was calculated. Biologically plausible interaction effects between statistically significant explanatory variables were tested by adding interaction terms to the main-effects model. The cut-off for keeping an interaction term in the model was set to $p<0.01$. When significant interactions were present, the effects were estimated and compared for subgroups defined by combinations of different levels of the interacting variables.

The linearity of the association between outcome and explanatory variables was assessed through a locally weighted scatterplot smoother. After the regression process, the assumption of normally distributed residuals was assessed through a normal quantile plot of standardized residuals at all levels of the models in question. The final model raw and standardized residuals were plotted against predicted values at all levels of the model in question to check for heteroscedasticity as well as for potential outliers. Assessment of multicollinearity was based on variance inflation factors provided by a regression analysis including all predictors of the final models.

## 3. Results

### *3.1. Study population*

Table 1 states the number of animals and herds originally available for inclusion from the NBCRS (cows: n= 20,541 and calves: n= 62,813), the numbers that were excluded in order to obtain the study sample of 9,903 cows and 29,294 calves, as well as brief descriptions of the reasons for exclusion. The study sample included 29,294 calves with a recorded birth weight, which was 54.4% of the calves in the study population. The number of observations per group and the mean birth weights by sex, breed, region, age at first calving, birth season and parity are presented in Table 2 (for all calves) and Table 3 (for calves of primiparous dams only). The mean birth weight of the calves was 43.47 kg (95% CI 43.40; 43.53).

### *3.2 Model including all animals*

Results from the multivariable model including all animals are given in Table 4. The regression model estimated that female calves were 2.3 kg lighter than males ($P$<0.001) and that calvings in the autumn yielded 0.5 kg lighter offspring than spring calvings ($P$<0.001). Furthermore, calves born from primiparous animals were heavier than calves from older animals ($P$<0.001).

There was an interaction between breed and region, i.e. the effect of breed of dam was dependent on which region of Norway the calf was born in, and vice versa. Based on results from the multivariable model including the interaction, estimated birth weights were calculated for all combinations of breed and region of Norway, shown in Figure 1. Calves of Norwegian Red, Charolais, Aberdeen Angus and "Other" born in the western part of Norway were lighter than equivalent calves from all other regions- this effect was most pronounced for Aberdeen Angus calves. Calves from Charolais dams were heaviest, except those born in Western Norway where Hereford calves were heaviest. Both the herd and cow random effects were highly significant. Herd explained 40% of the variation in birth weights, whereas 11% of the variation was explained by the cow level.

*3.3. Model including first calving only*

Results from the multivariable model including birth weights for calves born to first parity dams are given in Table 5. The heifer model was comparable to the full model in that it estimated that female calves were 2.3 kg lighter than males ($P< 0.001$) and that calvings in the autumn yielded 0.5 kg lighter offspring ($P<0.001$). Calves born to beef breeds were lighter when born to heifers aged ≥2.5 years at calving compared to heifers aged <2.5 years at calving. Other factors significantly influencing birth weights from first parity animals were breed of dam, age at first calving and region. A significant interaction term between age at first calving and breed was present i.e. the effect of age at first calving was dependent on the breed of the dam. Across all breeds the calves were heavier when age at first calving was less than (or equal to) 2.5 years of age, however, the magnitude of the effect differed by breed. Based on results from the multivariable model, estimated birth weights were calculated for all combinations of age at first calving and dam breed (Table 6). The herd random effect was highly significant and explained 37% of the variation in birth weights.

## 4. Discussion

The difference in mean birth weight between male and female calves was found to be 2.3 kg in this study, which concurs with other studies (Andersen and Plum, 1965; Holland and Odde, 1992; Cundiff et al., 2010). The differences between the breeds regarding birth weight of calves in this study is also well known and described (Cundiff et al., 1993). Earlier studies have shown that the weights of dam and sire are positively correlated with the birth weight of their offspring (Bennett and Gregory, 1996). This study showed an interaction between breed and region which might indicate that certain breeds are better adapted to the climate and geography of specific regions. This interaction could be further explored for the purpose of providing better management advice to producers, such as choosing the best suited breed for each region.

The results show that birth weights of the calves from primiparous animals were higher than birth weights by multiparous cows. These results contradict the findings of most other studies which have reported that birth weights of calves born to primiparous dams are lighter than to those born to multiparous dams (Cundiff et al., 1992; Holland and Odde, 1992; Colburn et al., 1997; Johanson and Berger, 2003; Cundiff et al., 2010). Birth weights are related, among other factors, to gestation length and heifers normally have shorter gestation lengths than cows (Andersen and Plum, 1965; Johanson and Berger, 2003). Gestation length data were unavailable in the studied dataset and this association could not be explored further. It is possible that the retrospective method in which cows were included in this study has introduced some bias because of an age-period-cohort effect. The number of animals in the NBCRS database increased considerably during the study period from 63% to 78% of the suckler cow population (Animalia, 2013a) primarily due to legislative changes in Norway. Inclusion criteria for this study was that the dam had been slaughtered between January 2010 and January 2013, and that the cow came from a herd in the NBCRS database. Therefore, more primiparous animals became eligible for inclusion during the study period. Higher calf birth weight is a known risk factor for dystocia in heifers and adult cows (Nix et al., 1998; Berry et al., 2007) and the risk of slaughter in heifers is higher after dystocia (Rogers et al., 2004; Szabó et al., 2009). Consequently, the observed higher birthweights of calves born from the slaughtered heifers might be an effect of the expanding NBCRS-membership across the study-period and an over-representation of primiparous animals being culled following dystocia due to high birthweights. In order to try to account for this potential bias the variable of 'slaughter in parity X' was added to the multivariable model. However, the tendency for heavier calves being born to animals calving for the first time was still seen (analysis not shown).

In this study, calves born in the spring were heavier than those born in the autumn. This is consistent with earlier studies, where autumn born calves were lighter than the spring born calves in temperate zones (Johanson and Berger, 2003; Cundiff et al., 2010). However, other studies have reported that autumn born calves are the heaviest (Andersen and Plum, 1965; Holland and Odde, 1992). Researchers in Nebraska reported that calves born in colder climates were heavier than calves born in warmer climates (Colburn et al., 1997; Deutscher et al., 1999). The highest mean birth weights in this study were seen in the regions with the coldest climate, but this effect could also be mediated through regional differences in herd management factors such as feeding strategies and time of housing the herd for the winter.

Generally, this study found that the lowest birth weights were found in Western Norway and the highest in Mid-Norway. The Norwegian regions are naturally divided by geography, and the climate, pasture use, and the soil mineral content differs between regions. Western Norway has the mildest climate with smaller temperature differences between the seasons, temperatures rarely drop below $0^{o}$C and the levels of precipitation are high. The Mid-Norway region has greater differences in seasonal temperature, similar to those in eastern Norway, but higher precipitation and windier conditions are found here than in eastern Norway during the autumn (Anonymous, 2015). The effect of cold stress elevates the levels of the nutritional substances in the blood due to increased metabolism (Young, 1975), and increases the demand for energy. This might be particularly relevant if pregnant cattle are still in growth (Arango et al., 2002) and could potentially contribute to the differences in birth weights between breeds in different regions because the heavier breeds are expected to reach mature weight later. The observed interaction between breed and age at first calving might also be an effect of the different age at which lighter and heavier breeds reach mature weight. Regional differences in macro- and trace mineral concentration in pasture plants (Sivertsen et al., 2015) might also contribute to regional differences in calf birth weights.

The herd effect was large in this study, and could be influenced both by genetics and environment. The prevalence of use of artificial insemination (AI) in Norwegian beef cattle management is low, with less than 20% of cows receiving AI across all breed categories (Animalia, 2013a). Widespread use of local bulls might lead to a higher degree of shared genetic material within a beef suckler operation than what is common in Norwegian dairy herds, where AI use is almost 85% (Geno, 2013). Differences in management, including AI use, are hence likely to be important drivers behind the large herd effect observed. The direct heritability of birth weight is estimated to be between 30-50% (Simm, 1998; Eriksson et al., 2004). In this study, the paternal effect is included in the herd effect because the extensive use of on-farm bulls made it impossible to investigate the effect of sire and herd separately. The full model estimated that 11% of the variation in birth weights could be attributed to the effect of dam, controlling for breed, region, season, parity and sex (Table 4). The maternal heritability of birth weights is estimated to be 8 - 15% (Eriksson et al., 2004). Thus, the importance of choosing good breeding animals in beef suckler operations, and keeping good records of cow (and offspring) performance is a valuable tool for the herd in the animal selection process.

It can be assumed the study sample represents the Norwegian beef suckler population reasonably well. The database included 78% of beef suckler cows and 57% of the beef herds. Herds were located throughout Norway which makes the results relevant for the national beef cattle population. The results might also apply to small-scale beef suckler herds in other temperate areas. Membership in the NBCRS is voluntary and members might typically have a greater focus on production goal improvement compared to non-member producers. Thus, our sample of herds might be biased towards including farms that were more focused on production targets than the 'average' producer. However, non-members are probably less likely to be in the target group when herd advisors seek to implement changes in management based on new knowledge gained from investigations based on the NBCRS database.

Data quality is essential when using secondary data, such as this registry. Only about 50% of calvings were recorded with a birth weight in the NBCRS database, and it is not known if the values are missing at random or if systematic lack of reporting is causing bias. The extent of weighing in beef herds might be linked to the level of "professionalism" of the herd because the recording of birth weights is done on a volunteer basis. It is also possible that farmers will report weights from only the best (heaviest) calves, especially if they plan on selling these animals. If the practice of selecting the "best" calves for weighing occurs more commonly in heifers, this might provide a potential explanation for the contradictory finding of primiparous animals producing heavier offspring than older cows. Even though the sex differences in birth weights are consistent with other studies, which increases the plausibility of the data, it is important to appreciate that the database has not been validated for use in research in the same way as the Norwegian Dairy Herd Recording System (Espetvedt et al., 2013). Formal validation of the NBCRS database would improve the certainty of the results of this, and other studies based upon it.

## 5. Conclusion

A large proportion of the variation in beef suckler birth weights was attributed to the herd and cow random effects. Further, birth weights of beef calves in the NBCRS were influenced by sex of the calf, breed of dam, parity, age at first calving, season and region. The choice of the right breed for the different regions and conditions will be one of several management choices to considerer in order important consideration to achieve optimal birth weights.

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**Table 1**

Generation of the study sample in a cross-sectional study of birth weights among Norwegian beef calves based on the Norwegian Beef Cattle Recording System (NBCRS) database.

| Herds (n) | Cows (n) | Calves (n) | Explanation |
|---|---|---|---|
| 2,176 | 20,541 | 62,813 | Study population, extracted animals from the NBCRS |
| | -55 | -234 | Excluded: Obvious recording errors |
| | | -1,459 | Excluded: Twin calves |
| | -661 | -2,245 | Excluded: Age at first calving below 1.5 or over 3.6 years |
| | -1875 | -5,056 | Excluded: First calving missing in NBCRS |
| | 17,950 | 53,819 | |
| | | -24,525 | Birth weight missing |
| 1,192 | 9,903 | 29,294 | Study sample |

**Table 2**

A descriptive presentation of the Norwegian Beef Cattle Recording System study population, all calves included. The number (n), mean birth weight of calves (kg) and 95% confidence interval (CI) are presented for the subgroups sex, dam breed, region of birth, the dams age at calving, birth season, and dam parity. The table includes 29,294 calves with birthweights, born to 9,903 dams from 1,192 herds.

| Variable | Level | n | Mean | 95% CI |
|---|---|---|---|---|
| Sex | Male | 14,641 | 44.6 | 44.5; 44.7 |
| | Female | 14,653 | 42.3 | 42.2; 42.4 |
| Dam breed | Norwegian Red | 2,386 | 43.9 | 43.7; 44.2 |
| | Hereford | 7,507 | 42.9 | 42.7; 43.0 |
| | Charolais | 7,682 | 45.6 | 45.5; 45.8 |
| | Aberdeen Angus | 4,428 | 40.4 | 40.3; 40.6 |
| | Limousin | 3,911 | 43.3 | 43.2; 43.5 |
| | Simmental | 1,649 | 45.6 | 45.3; 45.8 |
| | Other[1] | 1,731 | 42.0 | 41.7; 42.4 |
| Region of Norway | Costal Southeast | 8,753 | 43.4 | 43.3; 43.5 |
| | Inland Southeast | 8,375 | 43.7 | 43.6; 43.8 |
| | Western | 3,594 | 42.1 | 41.9; 42.3 |
| | Mid | 6,529 | 44.0 | 43.8; 44.1 |
| | North | 2,043 | 43.5 | 43.3; 43.8 |
| Age of dam at first calving | ≤ 2.5 years | 27,632 | 43.5 | 43.4; 43.6 |
| | > 2.5 years | 1,662 | 42.9 | 42.6; 43.1 |
| Birth season | Feb.-July | 24,124 | 43.5 | 43.4; 43.6 |
| | Aug.-Jan | 5,170 | 43.3 | 43.1; 43.4 |
| Parity of dam | 1st | 8,738 | 43.9 | 43.7; 44.0 |
| | 2nd | 6,085 | 43.4 | 43.3; 43.6 |
| | 3rd | 4,362 | 43.1 | 43.0; 43.3 |
| | 4th | 3,192 | 43.4 | 43.2; 43.6 |
| | 5th | 2,301 | 43.3 | 43.1; 43.6 |
| | 6th | 1,648 | 43.2 | 42.9; 43.5 |
| | > 6th | 2,968 | 43.3 | 43.1; 43.5 |

[1] Includes crossbreds, unknown breeds, Dexter, Galloway, Blonde d'Aquitaine, Highland cattle and various local breeds.

**Table 3**

A descriptive presentation of the Norwegian Beef Cattle Recording System study population, calves of primiparous dams only. The number (n), mean birth weight of calves (kg) and 95% confidence interval (CI) are presented for the subgroups sex, dam breed, region of birth, the dams age at calving, birth season, and dam parity. The table includes 17,950 calves with birthweights, born to 8,738 dams from 1,098 herds.

| Variable | Level | n | Mean | 95% CI |
|---|---|---|---|---|
| Sex | Male | 4,295 | 45.0 | 44.9; 45.2 |
| | Female | 4,443 | 42.7 | 42.6; 42.9 |
| Dam breed | Norwegian Red | 739 | 43.8 | 43.4; 44.3 |
| | Hereford | 2,058 | 43.3 | 43.1; 43.5 |
| | Charolais | 2,470 | 45.6 | 45.4; 45.8 |
| | Aberdeen Angus | 1,199 | 41.2 | 40.9; 41.5 |
| | Limousin | 1,256 | 43.7 | 43.4; 44.0 |
| | Simmental | 483 | 45.8 | 45.2; 46.3 |
| | Other[1] | 533 | 42.5 | 41.9; 43.1 |
| Region of Norway | Costal Southeast | 2,336 | 43.7 | 43.4; 43.9 |
| | Inland Southeast | 2,599 | 44.0 | 43.8; 44.3 |
| | Western | 1,112 | 42.7 | 42.4; 43.1 |
| | Mid | 2,026 | 44.3 | 44.1; 44.6 |
| | North | 665 | 44.2 | 43.8; 44.7 |
| Age of dam at first calving | ≤ 2.5 years | 7,076 | 44.1 | 43.9; 44.2 |
| | > 2.5 years | 1,662 | 42.9 | 42.6; 43.1 |
| Birth season | Feb.-July | 7,059 | 43.9 | 43.8; 44.0 |
| | Aug.-Jan | 1,679 | 43.6 | 43.3; 43.9 |

[1] Includes crossbreds, unknown breeds, Dexter, Galloway, Blonde d'Aquitaine, Highland cattle and various local breeds.

**Table 4**

Variables significantly associated with birth weights of Norwegian beef calves. Multivariable estimates, 95% confidence intervals (CI) and *P*-values from a multilevel linear regression model. Herd and cow random effects were applied to account for intra-herd and intra-cow correlation. The analysis included 29,294 calves born from 9,903 cows in 1,192 Norwegian beef herds.

| Variable | Levels | Estimates | 95% CI | *P* |
|---|---|---|---|---|
| | Intercept | 44.9 | 44.1; 45.6 | <0.001 |
| Sex | Male | Baseline | | |
| | Female | -2.3 | -2.4; -2.2 | <0.001 |
| Region of Norway[2] | Costal Southeast | Baseline | | |
| | Inland Southeast | 0.0 | -1.0; 0.9 | 0.931 |
| | Western | -0.6 | -1.7; 0.6 | 0.326 |
| | Mid | 0.7 | -0.2; 1.7 | 0.139 |
| | North | -0.5 | -1.9; 0.9 | 0.502 |
| Dam breed[3] | Norwegian Red | Baseline | | |
| | Hereford | -0.2 | -0.9; 0.4 | 0.462 |
| | Charolais | 0.2 | -0.4; 0.9 | 0.536 |
| | Aberdeen Angus | -1.0 | -1.8; -0.2 | 0.014 |
| | Limousin | 0.0 | -0.7; 0.7 | 0.977 |
| | Simmental | -0.3 | -1.3; 0.8 | 0.634 |
| | Other[1] | -0.9 | -1.7; -0.1 | 0.035 |
| Dam breed x Region[4] | Hereford x Costal S. | Baseline | | |
| | Hereford x Inland S. | 0.0 | -0.9; 0.9 | 1 |
| | Hereford x Western | 1.0 | -0.1; 2.2 | 0.085 |
| | Hereford x Mid | -0.2 | -1.1; 0.7 | 0.641 |
| | Hereford x North | 0.8 | -0.5; 2.1 | 0.204 |
| | Charolais x Costal S. | Baseline | | |
| | Charolais x Inland S. | -0.2 | -1.1; 0.7 | 0.733 |
| | Charolais x Western | 0.0 | -1.1; 1.2 | 0.941 |
| | Charolais x Mid | 0.1 | -0.8; 1.0 | 0.898 |
| | Charolais x North | 1.4 | 0.0; 2.8 | 0.057 |
| | A.Angus x Costal S. | Baseline | | |
| | A.Angus x Inland S. | 1.0 | -0.1; 2.0 | 0.079 |

| | | | | |
|---|---|---|---|---|
| | A.Angus x Western | -1.3 | -2.6; -0.1 | 0.04 |
| | A.Angus x Mid | 0.1 | -1.0; 1.2 | 0.863 |
| | AAngus x North | 0.7 | -0.9; 2.2 | 0.401 |
| | | | | |
| | Limousin x Costal S | Baseline | | |
| | Limousin x Inland S. | -0.2 | -1.2; 0.8 | 0.658 |
| | Limousin x Western | 0.6 | -0.6; 1.9 | 0.322 |
| | Limousin x Mid | -0.5 | -1.6; 0.6 | 0.384 |
| | Limousin x North | 0.0 | -1.8; 1.9 | 0.982 |
| | | | | |
| | Simmental x Costal S. | Baseline | | |
| | Simmental x Inland S. | 0.6 | -0.8; 1.9 | 0.4 |
| | Simmental x Western | 0.8 | -1.2; 2.9 | 0.418 |
| | Simmental x Mid | 0.0 | -1.4; 1.4 | 0.999 |
| | Simmental x North | -0.3 | -2.6; 2.0 | 0.809 |
| | | | | |
| | Other[1] x Costal S. | Baseline | | |
| | Other[1] x Inland S. | -0.3 | -1.4; 0.9 | 0.654 |
| | Other[1] x Western | -0.1 | -1.5; 1.3 | 0.881 |
| | Other[1] x Mid | 0.3 | -0.8; 1.5 | 0.58 |
| | Other[1] x North | 1.4 | -0.4; 3.2 | 0.139 |
| | | | | |
| Birth season | Feb.-July | Baseline | | |
| | Aug.-Jan. | -0.5 | -0.7; -0.4 | <0.001 |
| | | | | |
| Parity of dam[5] | 1st | Baseline | | |
| | 2nd | -0.4 | -0.5; -0.2 | <0.001 |
| | 3rd | -0.6 | -0.8; -0.5 | <0.001 |
| | 4th | -0.3 | -0.5; -0.1 | <0.001 |
| | 5th | -0.3 | -0.5; -0.1 | 0.009 |
| | 6th | -0.4 | -0.6; -0.1 | 0.002 |
| | >6th | 0.1 | -0.1; 0.3 | 0.5 |
| | | | | |
| Variance herd | | 14.2 | 12.6; 15.8 | |
| Variance cow | | 3.8 | 3.5; 4.1 | |
| Variance residual | | 17.4 | 17.4; 17.0 | |

[1] Includes crossbreds, unknown breeds, Dexter, Galloway, Blonde d'Aquitaine, Highland cattle and various local breeds.

[2] LRT= *P*<0.01, [3] LRT= *P* <0.001, [4] LRT= *P* <0.001, [5] LRT= *P* <0.001

**Table 5**

Variables significantly associated with birth weights of Norwegian beef calves born to primiparous animals. Multivariable estimates, 95% confidence intervals (CI) and *P*-values from a multilevel linear regression model. A herd random effect was applied to account for intra-herd correlation. The analysis included calves born from 8,738 heifers from 1,098 Norwegian beef herds.

| Variable | Levels | Estimates | 95% CI | *P* |
|---|---|---|---|---|
| | Intercept | 44.8 | 44.2; 45.5 | <0.001 |
| Sex | Male | Baseline | | |
| | Female | -2.3 | -2.5; -2.1 | <0.001 |
| Region of Norway[2] | Costal Southeast | Baseline | | |
| | Inland Southeast | 0.1 | -0.6; 0.8 | 0.771 |
| | Western | -0.8 | -1.6; 0.0 | 0.048 |
| | Mid | 0.8 | -0.1; 1.5 | 0.028 |
| | North | 0.4 | -0.6; 1.4 | 0.405 |
| Dam breed[3] | Norwegian Red | Baseline | | |
| | Hereford | 0.1 | -0.4; 0.6 | 0.635 |
| | Charolais | 0.8 | 0.3; 1.3 | 0.003 |
| | Aberdeen Angus | -0.8 | -1.4; -0.2 | 0.008 |
| | Limousin | 0.6 | 0.1; 1.2 | 0.033 |
| | Simmental | 0.5 | -0.3; 1.3 | 0.229 |
| | Other[1] | -0.2 | -0.8; 0.5 | 0.634 |
| Age of dam at first calving | ≤ 2.5 years | Baseline | | |
| | > 2.5 years | -0.5 | -1.4; 0,4 | 0.263 |
| Dam breed x Age at first calving[4] | Hereford x >2.5 years | -0.8 | -1.9; 0.3 | 0.147 |
| | Charolais x >2.5 years | -0.3 | -1.3; 0.7 | 0.555 |
| | A. Angus x >2.5 years | -0.1 | -1.3; 1.1 | 0.870 |
| | Limousin x >2.5 years | -1.7 | -2,8; -0.7 | 0.002 |
| | Simmental x >2.5 years | -0.8 | -2.2; 0.7 | 0.311 |
| | Other[1] x >2.5 years | -1.6 | -2.9; -0.2 | 0.021 |
| Birth season | Feb.-July | Baseline | | |
| | Aug.-Jan. | -0.5 | -0.8; -0.3 | <0.001 |
| Variance herd | | 12.4 | 10.8; 14.3 | |
| Variance residual | | 21.5 | 20.1; 22.2 | |

[1] Includes crossbreds, unknown breeds, Dexter, Galloway, Blonde d'Aquitaine, Highland cattle and various local breeds.

[2] LRT: $P<0.001$, [3] LRT: $P< 0.005$, [4] LRT: $P < 0.001$

**Table 6**

Estimated birth weights (kg) of spring-born male calves for combinations of age at first calving and breed. Estimated birth weights were based on the multivariable estimates from the mixed-effects linear regression model in Table 5 (n=8,738).

| | Breed | | | | | | |
|---|---|---|---|---|---|---|---|
| Age at calving | Norwegian Red | Hereford | Charolais | Aberdeen Angus | Limousin | Simmental | Other[1] |
| ≤2.5 years | 44.3 | 43.9 | 44.6 | 43.0 | 44.4 | 44.3 | 43.7 |
| >2.5 years | 43.8 | 43.1 | 44.3 | 42.9 | 42.7 | 43.5 | 42.1 |

[1] Includes crossbreds, unknown breeds, Dexter, Galloway, Blonde d'Aquitaine, Highland cattle and various local breeds.

**Fig. 1.**

Estimated birth weights (kg) of spring-born male calves born to first parity cows for combinations of breed and region. Estimated birth weights were based on the multivariable adjusted estimates from the mixed-effects linear regression model in Table 3 (n=9,903).