Growth ability of Czech Fleckvieh bulls in modern cattle fattening stable

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ABSTRACT
The work aimed to evaluate the growth ability of Czech Fleckvieh bulls in the conditions of modern stable based on their breeding lines. A total of 94 bulls were included in the experiment. The growth curve, weight at standardized ages, and weight gain were evaluated. The average weight of fattened bulls ranged from 109.43 kg at the age of 90 days to 705.65 kg at the end of the fattening period. Statistically significant model function was created by regression analysis and included the effects of bull sire, peers, age, and age squared. Furthermore, we used a linear model with the effects: birth month of the bull, the group of peers, the breeding line of bull sire, and random repeated effect of the animal. Significant differences were observed for the month of birth and between groups of peers. The effect of the breeding line was significant for regression analysis, however in evaluation based on linear model it was significant only for the weight at the beginning of fattening. The results suggest that in the standardized conditions of a modern stable with good housing and nutrition, the genetic predisposition for the growth ability of dual-purpose Fleckvieh cattle was attenuated.

Introduction
The Czech Fleckvieh cattle, as a dual-purpose breed, is valued not only for its relatively high milk yields but also adequate beef production. The main indicator of beef production is growth during the fattening period. Growth ability is characterized mainly by daily weight gain, which proved to be one of the most influential effects on the profitability of cattle fattening (Syrůček et al. 2017). The daily gains of Fleckvieh cattle in the Hungarian condition of commercial fattening farm ranged between 1000 to 1100 g/head/day. For comparison, daily gains of Holstein cattle in the same conditions were around 90 g, while beef cattle can achieve over 1200 g per head per day (Holló et al. 2012). This comparison shows the suitability of dual-purpose breeds for certain conditions and farming systems, where the profit is formed not only by milk sales but also by competitive beef production.

Growth ability is influenced by a number of factors, such as the breed (Pesonen and Huuskonen 2015), genetic predisposition (Bureš and Bartoň 2018), nutrition (Vestergaard et al. 2019), and microclimatic conditions (Bujko et al. 2020). In addition, farm, respectively breeding conditions on the farm and month of birth can also be significant effects for growth ability (Kebede and Komlosi 2015). Studies on dual-purpose breeds focus not only on growth ability but also on carcass characteristics (Filipčík et al. 2020), respectively detailed nutritional composition of beef (Bartoň et al. 2008). An important factor is also genetically determined slaughter age. Daily weight gains can be visualized by a growth curve, which has a sigmoid character (Hozáková et al. 2020). Unequal weight gains within fattening are described in the work of Chládek et al. (2011), when they observed a decrease in daily gains for Fleckvieh cattle at the end of the fattening period.

Differences in growth ability, of course, exist among breeds, but also among individuals of the same breed, which highlights the effect of body frame on slaughter age and carcass weight (Mazzucco et al. 2016). Based on this, it can be deduced that the length of fattening significantly affects the growth parameters, and quality of the carcass. This statement is also supported by the work of Ustuner et al. (2020), who confirmed that the both initial weight at the start of fattening and the timing for the end of the fattening period are important for the final meat production performance. As reported by Filipčík et al. (2020), Czech Fleckvieh bulls are on average fattened to the age of 646 days in standard field condition. For comparison, other primarily beef breeds of cattle such as Piemontese are fattened until 540.9 ± 63.2 days of age (Savoia et al. 2019). Due to constant advances in cattle genetics, it is necessary to periodically recalculate genetic parameters (Svitáková et al. 2014). This is also confirmed by the study by Bernard et al. (2009), where it was shown that the selection of young bulls for the growth potential of muscle mass is associated with changes in the gene expression profile, especially with the regulation of glycolytic genes. Above mentioned facts call for collecting as much data from beef production as possible for further evaluation.

Therefore, the aim of our work was to evaluate the growth ability of fattened Czech Fleckvieh bulls based on their sires and breeding lines in the conditions of modern cattle fattening stable.
Materials and methodology

This experiment was carried out in accordance with Czech legislation for the protection of the animals against abuse (No. 246/1992) and with directive 2010/63/EU on the protection of animals used for scientific purposes.

Farm and Animals

The work was carried out on a beef/dairy farm in the Pardubice region (at an altitude of 440 to 580 m above sea level), which is focused on breeding Czech Fleckvieh cattle. A total of 94 bulls born from June to October 2018 were fattened on the farm and included into the evaluation. Bulls were fattened from 87 days until 521 to 669 days of age. The age variance at the end of the fattening period was due to fluctuations in purchase prices of beef. Fattened bulls in the test came from 12 different sires (with selection index for beef performance in the range of 74 to 117) from a total of 5 breeding lines (Aimant – AMT, Huch – HCH, Honig – HG, Morelo – MOR, and Radi – RAD). The fattening took place in a modern stable with a maximum capacity of 364 fattened animals. The stable was constructed in 2019 and was based on novel recommendations for living conditions during fattening (high cubic capacity 90 m x 29 m x 9 m; PUR panels on the roof; pens divided into three sections – resting (straw bedding), living (straw bedding), feeding (no bedding); lighting by Agrilight (Agrilight B.V.; Monster; Netherlands); feed pusher (Moov Pro; JOZ B.V.; Westwoud; Netherlands)). There was 26 pens in the stable (13 pens on each side of the central passage), which differed according to the age of the fattened animals (pens for calves were for 24 heads and pens for bulls were for 12 heads). Therefore, the animals within one pen were together from the start to the end of fattening and created a group of peers, which was one of the evaluated effects. Fattened animals were gradually moved during the fattening process from calf pens, through young bulls pens, and ended up in the pens for fully fattened bulls – ready for transport to slaughterhouse. The animals were not weighted during the final stages of fattening, and final weights were measured at the slaughterhouse.

In our study, fattening started at around 90 days, when bull calves were transported into the fattening stable and stocked into pens. At this time, calves weighed on average 109.43 kg with a standard deviation of 15.15 kg. Naturally, the average weight and standard deviation increased until the end of fattening period. The fattening period ended at around 600 days (542 days to 642 days of age for the animals in the test), when the bulls weighed on average 705.65 kg with a minimum of 581.38 kg and a maximum of 848.78 kg. Selection of bulls for slaughter was based on length of fattening period (around 600 days), weight (600-800 kg) but also purchase price at the slaughterhouse. In some cases, tested animals had a prolonged fattening period due to a drop in beef prices, and the decision of the farmer to wait for better prices at the slaughterhouse. The average daily weight gains from birth were 1126.28 g, with a standard deviation of 84.51 g. At last, the bulls achieved an average daily weight gain of 1169.06 g with a minimum of 890.94 g to a maximum of 1435.84 g during the fattening period.

The feeding ratio for fattening bulls consisted of 3 to 5 components (Tables 1 and 2), which were collected and mixed by a self-propelled feed-mixer wagon. The feed rations for fattened bulls was corn silage and pea silage plus other components, according to the current fattening phase (Tables 1 and 2). Feeding ratio was complemented with mineral and vitamin supplements. The TAURUS PLUS was used in the feed ratio for younger animals and PETAVIT for older animals. These products have physiologically balanced composition of vitamins (A, D, E . . . ) and minerals (Ca, P, Mg, Zn, Se . . . ) for a given age category of fattened bulls. Thus, these products are similar to other mineral and vitamin supplements commonly used in bull fattening. The feed was periodically pushed towards the feeding area during the day by an automatic feed pusher.

The evaluated animals were weighed using standard cattle scales at monthly intervals during early fattening phases and later at irregular intervals. Each animal was weighed 5 to 10 times during the fattening period.

Table 1. Composition of feed ration for bulls during fattening.

| Components          | Up to 9 months of age – the requirement for a piece (kg/day) | Above 9 months of age – the requirement for a piece (kg/day) |
|---------------------|-------------------------------------------------------------|-------------------------------------------------------------|
| Clover haylage      | 2.2                                                         | 11                                                          |
| Corn silage         | 2.7                                                        | 3                                                           |
| Pea silage          | 1                                                          | 0.5                                                         |
| Meadow hay          | 0.2                                                        |                                                             |
| Molasses            | 0.08                                                       | 2                                                           |
| Feed mixture        | 3                                                          | 4                                                           |
| Basic feed ration   | 5.1                                                        | 14.5                                                        |
| + feed mixture      | 8.1                                                        | 18.5                                                        |

Table 2. Composition of feed mixture for bulls during fattening.

| Components          | Up to 9 months of age – the requirement for a piece (kg/day) | Above 9 months of age – the requirement for a piece (kg/day) |
|---------------------|-------------------------------------------------------------|-------------------------------------------------------------|
| Components          | kg | % | kg | % |
| Wheat scrap         | 1.1 | 35 | 1.6 | 40 |
| Barley scrap        | 0.55 | 19.9 | 0.8 | 20 |
| Rapseed extracted meal 32% NS | 0.15 | 5 | 0.4 | 10 |
| PETAVIT             | 0.003 | 0.1 | 0.08 | 2 |
| Sunflower extr. Scrap partially peeled | 0.08 | 2 | 0.02 | 0.5 |
| Feed salt           | 0.08 | 2 | 0.02 | 0.5 |
| Ground limestone    | 0.08 | 2 | 0.02 | 0.5 |
| TAURUS PLUS         | 0.3 | 7.5 | 0.3 | 7.5 |
the effect of age squared (quadratic function), the effect of bull sire (based on selection indices for beef performance), the effect of bull sire squared (quadratic function) and fixed effect of a group of peers (groups of co-housed animals within pens). Moreover, the REGG procedure was used to determine the regression dependences of age and age squared to the achieved weight of fattened bulls according to breeding lines.

Daily weight gain from birth, and daily weight gain during the fattening period were calculated from continuous weighing. With these parameters, we were able to calculate the weight of fattened bulls at standardized ages, even though they were weighed a few days earlier or later. The growth ability of bulls was further recalculated and evaluated for standardized ages (live weight at 90 days of age – LW90; live weight at 180 days of age – LW180; live weight at 365 days of age – LW365; live weight at 540 days of age – LW540; live weight at 600 days of age – LW600). Model equation in the MIXED procedure for the evaluation of weights from 90 to 600 days, respectively daily weight gains from birth and during fattening included the effects: the birth month of the bull (June, n = 6; July, n = 23; August, n = 25; September, n = 21; October, n = 18), the group of peers (group 1, n = 9; group 2, n = 3; group 3, n = 18; group 4, n = 10; group 5, n = 12; group 6, n = 22; group 7, n = 20), breeding line of the bull sire (AMT, n = 25; HCH, n = 16; HG, n = 30; MOR, n = 14; RAD, n = 9) and random repeated effect of the animal (repeated weighing of one animal). The breeding line effect was chosen instead of the direct effect of bull sire due to the relatively low number of fattened bulls in the test, and to better investigate the genetic potential of bull sires in the test. Furthermore, breeding lines had fewer levels, and they could have been better assessed during statistical evaluation. Monitored bulls were offspring of a total 12 bulls in 5 breeding lines. Breeding lines in the test were of a different origin, therefore with different breeding focus. The Tukey-Kramer method was used for the evaluation of differences of least square means. Significance levels \( P < 0.05 \) and \( P < 0.01 \) were used in the evaluation.

### Results

The first objective of our study was to evaluate the growth ability of tested bulls based on their bull sire, respectively genetic predisposition for the beef performance of their bull sire (beef performance index – IMUFW).

To describe this trend, we performed regression analysis to model the growth curve. This model, and its effects explained the unequal growth of animals with age and the influence of genetic predisposition on the growth of fattened animals. The model equation was as followed:

\[
y = -54.363 + 1.543 \times (\text{age}) + 5.378 \times (\text{sire}) - 0.0005 \times (\text{age}^2) - 0.413 + (\text{value for group of peers})
\]

The model explained 97.47% of the variability in weight gain of fattened bulls. All effects in the model equation, including the intercept, were statistically significant \( (P < 0.01) \). As shown in Figure 1, the data for the analysis of growth ability was not homogeneous, but the variance of values is still evident. There were only small differences among the fattened bulls from the different bull sires, which become slightly more pronounced during the final phase of fattening. Supplementary results for regression analysis of growth ability based on breeding lines are presented in Table 3. All effects in the regression equations were statistically significant. From this evaluation, it is clear that there were some differences in the genetic

![Figure 1. Growth ability development of bulls in fattening process grouped based on their bull sire.](image-url)
foundation among lines. Therefore, another evaluation was performed in the MIXED procedure to further investigate this relationship.

For further evaluation, partial growth abilities for the standardized ages of 90, 180, 365, 540, and 600 days were evaluated. The model equation was statistically significant for all parameters (P < 0.05) and, depending on the evaluated growth parameter, explained variability from 20.22% (average daily weight gain from birth) to 51.22% (LW90). The effect of the birth month of the bull and the group of peers was statistically significant (P < 0.05) for weight at all standardized ages, and daily weight gains. The effect of the breeding line was statistically significant (P < 0.05) only for the LW90. We observed increases in P-value with increasing age, and thus the statistical significance of the results had decreased.

A detailed evaluation for the fixed effects of the birth month of the bulls, the group of peers, and the breeding line of the bull sire is shown in Table 4. We found significant differences based on the birth months of fattened bulls. The lowest values for most weights, and growth during fattening were reached by bulls born in July, except for LW90. In contrast, the highest values were achieved by animals born in September and October. The differences between the lowest and highest value increased during the fattening period, from 16.62 kg at LW90 (August vs. October) to 104.11 kg at LW600 (July vs. September). The differences based on the birth month were statistically significant for LW365, LW540, and LW600 (P < 0.05) (Table 4).

Animals of similar age were grouped, as is the standard practice. Nevertheless, this effect is not the same as the month of birth, because at least 2 pens of fattened bulls could be stocked up within the same month of birth. Some peers differed significantly during fattening (P < 0.05 - 0.01; Table 4).

The effect of the breeding line of the bull sire showed significant differences only for LW90. At this age, the weight of calves from AMT line was higher by 11.19 kg compared to HG line calves (P < 0.05). Despite the differences becoming statistically insignificant during later phases of fattening, it was distinguishable that the offspring from the HG and HCH line reached lower values in all growth and weight parameters compared to other lines. The fattened bulls from breeding line AMT, RAD, and MOR reached higher weights by 1 to 10 kg at all standardized ages than lines HG and HCH.

### Discussion

Bulls in our test achieved standard, non-linear, growth curve with the average weight gain of 1169 g during the 452 to

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**Table 3.** Evaluation of growth curve for bulls based on breeding line of bull sire.

| Breeding line of bull sire | Regression equation | $r^2$ | $P$ |
|----------------------------|---------------------|-------|-----|
| AMT                        | $y = -33.351 + 1.581x - 0.0006x^2$ | 0.98  | <0.001 |
| HG                         | $y = -29.239 + 1.437x - 0.0004x^2$ | 0.97  | <0.001 |
| HCH                        | $y = -57.423 + 1.651x - 0.0006x^2$ | 0.98  | <0.001 |
| MOR                        | $y = -25.62 + 1.427x - 0.0004x^2$ | 0.98  | <0.001 |
| RAD                        | $y = -87.511 + 2.017x - 0.0011x^2$ | 0.98  | <0.001 |

$r^2$... coefficient of determination for regression model equation; $P$... statistical significance for regression model equation.
552 days of fattening. Other studies also observed differences in weights and weight gain for Fleckvieh cattle. For example, in the study of Dráčková et al. (2016), bulls were slaughtered at the age of 565 to 585 days with an average weight of 591 kg to 601 kg. In contrast, our average weight at the end of fattening was over 800 kg, for the age of 600 days. This difference can be explained by optimized breeding conditions in the modern stable, adequate nutrition, and the creation of peer groups with regard to social and physiological balance among animals. Furthermore, the results may be affected by the dam parity, respectively the age of the dam at the first calving (López-Paredes et al. 2018). The fattening of bulls is influenced by a number of factors, such as genetic predisposition, the age at the start, and at the end of fattening (Ustuner et al. 2020). The potential of genetic predisposition to affect the growth of bulls was evident from our evaluation (Figure 1 and Table 3). The effect of age was also taken into account due to the unequal length of fattening in our work. Similarly, Bezdíček et al. (2010) described significant differences in slaughter age and weight of slaughtered Czech Fleckvieh bulls. In general, growth and daily weight gain values decrease with the age of the animal, as was observed by Andrýsek et al. (2015) in their study on the fattening of Czech Fleckvieh heifers.

Another strong influence is the breeding conditions, respectively technological condition on the farm (Kebede and Komlosi 2015). The conditions for the fattened bulls in our study were uniform, therefore this effect was eliminated. Kebede and Komlosi (2015) confirmed the influence of the birth month of calving on its growth ability, which was also proven in our study. However, compared to our results, Kebede and Komlosi (2015) observed lower growth ability for animals of Hungarian Simmental cattle born from July to December compared to animals born from January to June. Similar results were obtained in the work by Bujko et al. (2020), in which they observed not only a significant effect of the month of birth in Slovak Fleckvieh cattle but also the significance of the birth year. Our findings, as well as findings of other studies, suggest that certain months of the year are more viable for the birth of calves used for fattening. Different climatic conditions, availability, and quality of feed can play an important role for this effect. These differences based on birth month are taken into account for beef cattle breeding in the form of seasonal calving, which is, however, not applicable to dairy cattle due to the need for year-round calving.

The direct genetic effect, the effect of the bull sire, and the genetic predisposition are very important throughout the fattening process (Phocas and Laloié 2004). The importance of genetic predisposition was confirmed in our work primarily through the results from GLM and REGG evaluations. The differences between the breeding lines decreased, and were subsequently inconclusive in a more detailed evaluation in the MIXED procedure. Nevertheless, Fleckvieh cattle achieved significantly lower weights at the age of 365 days in the study of Bujko et al. (2020) compared to our results. This finding suggests a slightly different genetic predisposition among Fleckvieh breeds in compared countries, and breeding conditions during fattening than in our study.

The results of our work only partially confirm the effect of genetics, respectively effect of bull sire on the growth ability. However, our results also underlined the strong influence of the farmer, and the environment. Differences in growth ability, and weight gains among the most used breeding lines of Czech Fleckvieh cattle were, in most cases, statistically insignificant. This result does not coincide with works such as Engellandt and Tier (2002) on German Gelbvieh, Tousova et al. (2014) on Charolais or Filipčík et al. (2020) on Fleckvieh, who confirmed the influence of bull sire and genetics on growth ability, as well as on the parameters of beef production. This result of our work partially confirmed the predominant focus of this dual-purpose breed on milk production, as well as the focus within the breeding plan on the selection of bulls with excellent milk traits, and sufficient beef traits. The growth ability of Czech Fleckvieh bulls was especially during later phases of fattening probably influenced by other factors or by the possibility of genetic expression in certain specific conditions. Neugebauer et al. (2010) in their work described manifestations of different genes on different parameters of beef production from the paternal and maternal positions. These authors observed the effect of genomic imprinting (transmission of alleles from parents) in 10 beef production traits, for which they estimated their effect at 8 and 25% of the total additive genetic variance. Neugebauer et al. (2010) suggest that some traits of beef production may be influenced more by the dam and some by the bull sire. Significant influence of different factors outside of environmental ones, and the interaction between bull sire and population, respectively breeding conditions on the farm were also confirmed by Földös et al. (2010) on the Hungarian Fleckvieh cattle population.

Based on our results can also be stated, that bulls after specific sires are more suitable for longer fattening. On the other hand, the question about the carcass value of these bulls remains and should be explored in follow-up research. Bezdíček et al. (2010) found various relationships, both positive and negative, between weight, slaughter age, and yield of valuable cuts.

**Conclusion**

Czech Fleckvieh cattle is a dual-purpose breed with a dairy focus, which nevertheless can be characterized by their great-growth ability. This statement was confirmed in this study, when bulls fattened in conditions of a modern stable with optimized microclimate, and adequate nutrition were able to achieve daily weight gains over 1000 g. The results also show that under good breeding conditions, differences in the genetic predisposition of fattened cattle are significantly suppressed to the detriment of non-genetic effects such as peer groups, nutrition, or birth month. The results also indirectly confirm the importance of the physiological balance feed as a key factor for the growth of the animals. However, despite small and mostly statistically insignificant differences, the bulls from certain breeding lines are probably more suitable for the fattening process, respectively longer duration of fattening. However, a larger study in the conditions of modern stables would be needed to confirm this hypothesis. Fattening results can be optimized with the help of nutrigenomics, thanks to which the feed composition could be adapted to breeds, bull
lines, respectively genetic basis for growth. This may be the subject of further cooperation with breeders and farmers to optimize the fattening process of Fleckvieh breeds to achieve a competitive farm economy.

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References
Andrýsek J, Večeřa M, Javorová J, Velecká M, Falta D, Chládek G. 2015. The Effect of Growth Rate on Some Beef Performance Characteristics of Czech Fleckvieh Heifers. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis. 63(4):1095–1100.

Bartoň L, Marounek M, Kudrma V, Bureš D, Zahrádková R. 2008. Growth, Carcass Traits, Chemical Composition and Fatty Acid Profile in Beef from Charolais and Simmental Bulls Fed Different Types of Dietary Lipids. Journal of the Science of Food and Agriculture. 88(15):2622–2630.

Bernard C, Cassar-Malek I, Renand G, Hocquette JF. 2009. Changes in Muscle Gene Expression Related to Metabolism According to Growth Potential in Young Bulls. Meat Science. 82(2):205–212.

Bezděček J, Říha J, Kučera J, Dufek A, Bjelka M, Šubrt J. 2010. Relationships of Sire Breeding Values and Cutting Parts of Progeny in Czech Fleckvieh Bulls. Archives Animal Breeding. 53(4):415–425.

Bujko J, Candrák J, Žitný J, Hrnčár C, Korstek J, Zemanová J. 2020. Factors Influencing on Growth Traits in Selected Breeding Conditions of the Slovak Fleckvieh Calves. Scientific Papers Animal Science and Biotechnologies. 53(2):65–69.

Bureš D, Bartoň L. 2018. Performance, Carcass Traits and Meat Quality of Aberdeen Angus, Gascon, Holstein and Fleckvieh Finishing Bulls. Livestock Science. 214:231–237.

Chládek G, Žižlavlý J, Šubrt J. 2011. A Comparison of Carcass Proportions in Czech Pied and Montbéliarde Bulls with a High Carcass Weight. Czech Journal of Animal Science. 50(3):109–115.

Dráčková E, Filipčík R, Šubrt J. 2016. The Effect of Genotype (Purebred Czech Fleckvieh and their Crosses) on Some Beef Quality Characteristics in Bulls. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis. 64(3):769–773.

Engellandt TH, Tier B. 2002. Genetic Variances due to Imprinted Genes in Cattle. Journal of Animal Breeding and Genetics. 119(3):154–165.

Filipčík R, Falta D, Kopec T, Chládek G, Večeřa M, Rečková Z. 2020. Environmental Factors and Genetic Parameters of Beef Traits in Fleckvieh Cattle Using Field and Station Testing. Animals. 10(11):2159.

Fördös A, Fueller I, Bene S, Szabo F. 2010. Weaning Performance of Beef Hungarian Fleckvieh Calves: 3. Genotype × Environment Interaction. Archives Animal Breeding. 53(2):123–129.

Hollo G, Nurnberg K, Somogyi T, Anton I, Holló I. 2012. Comparison of Fattening Performance and Slaughter Value of Local Hungarian Cattle Breeds to International Breeds. Archives Animal Breeding. 55(1):1–12.

Hozákova K, Vavršinová K, Neirurgerová P, Bujko J. 2020. Growth of Beef Cattle as Prediction for Meat Production: A review. Acta Fytotechnica et Zootecnica. 23(2):58–69.

Kebede D, Komlosi I. 2015. Evaluation of Genetic Parameters and Growth Traits of Hungarian Simmental Cattle Breed. Livestock Research for Rural Development. 27(0):172.

López-Paredes J, Pérez-Cabal MA, Jiménez-Montero JA, Alenda R. 2018. Influence of Age at First Calving in a Continuous Calving Season on Productive, Functional, and Economic Performance in a Blonde d’Aquitaine Beef Population. Journal of Animal Science. 96(10):4015–4027.

Mazzuco JP, Gosczynski DE, Ripoli MV, Melucci LM, Pardo AM, Colatto E, Rogberg-Muñoz A, Mezzada CA, Depetris GJ, Giovambattista G, Villarreal EL. 2016. Growth, Carcass and Meat Quality Traits in Beef from Angus, Hereford and Cross-bred Grazing Steers, and their Association with SNPs in Genes Related to Fat Deposition Metabolism. Meat Science. 114:121–129.

Neugebauer N, Räder I, Schild HJ, Zimmer D, Reinsch N. 2010. Evidence for Parent-of-Origin Effects on Genetic Variability of Beef Traits. Journal of Animal Science. 88(2):523–532.

Pesonen M, Huuskonen AK. 2015. Production, Carcass Characteristics and Valuable Cuts of Beef Breed Bulls and Heifers in Finnish Beef Cattle Population. Agricultural and Food Science. 24(3):164–172.

Phocas F, Laloi D. 2004. Genetic Parameters for Birth and Weaning Traits in French Specialized Beef Cattle Breeds. Livestock Production Science. 89(2-3):121–128.

Savoiia S, Brugiapaglia A, Pauciullo A, Di Stasio L, Schiavon S, Bittante G, Albeta A. 2019. Characterisation of Beef Production Systems and their Effects on Carcass and Meat Quality Traits of Piemontese Young Bulls. Meat Science. 153:75–85.

Svitáková A, Bauer J, Přibyl J, Vesela Z, Vostrý L. 2014. Changes Over Time in Genetic Parameters for Growth in Bulls and Assessment of Suitability of Test Methods. Czech Journal of Animal Science. 59:19–25.

Syruček J, Kvpafil J, Bartoň L, Vacek M, Štěpánek L. 2017. Economic Efficiency of Bull Fattening Operations in the Czech Republic. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis. 65(2):527–536.

Toulová R, Ducháček J, Štěpánek L, Ptáček M, Beran J. 2014. The Effect of Selected Factors on the Growth Ability of Charolais Cattle. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis. 62(1):255–260.

Ustuner H, Ardilci S, Arslan O, Brave FC. 2020. Fattening Performance and Carcass Traits of Imported Simmental Bulls at Different Initial Fattening Age. Large Animal Review. 26(4):161–165.

Vestergaard M, Jorgensen KF, Cakmakci C, Kargo M, Therkildsen M, Munk A, Kristensen T. 2019. Performance and Carcass Quality of Crossbred Beef x Holstein Bull and Heifer Calves in Comparison with Purebred Holstein Bull Calves Slaughtered at 17 Months of Age in an Organic Production System. Livestock Science. 223:184–192.