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Monitoring of eating and rumination time by young fattening bulls and relationship to meat yield

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ABSTRACT

The aim of this study was to evaluate the length of eating and rumination time in young fattening bulls of different ages and also to evaluate the relationship of these parameters to the meat yield of these bulls. Monitoring was carried out on Czech Fleckvieh-Simmental bull breed. In the case of bulls, the length of eating time increases statistically from 117.62 minutes per day at 2 months of age to 314.93 minutes per day and also the length of rumination from 308.56 minutes to 515.88 minutes per day. The rumination time had an apperently positive effect on the classification of bulls according to carcass classification (SEUROP, $P < 0.05$) when bulls classified in the fleshiness class U achieved a longer rumination time during monitoring (439.48 minutes) compared to bulls who were classified in the fleshiness class R (419.43 minutes). In the case of eating time, there was an opposite trend, when bulls with a shorter eating time (212.10 minutes) were included in class U compared to class R (241.31 minutes), ($P < 0.05$). There is a positive relationship between the length of rumination and the net weight gain.

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SEUROP; cattle; carcass; dual-purpose; meat yield

Introduction

As a dual-purpose breed, Czech Fleckvieh-Simmental cattle are used not only for their relatively high milk yield, but are also suitable for beef production (Duchacek et al. 2022). Growth ability is characterized mainly by daily weight gain and body size growth, which are shown to be one of the most significant factors on the profitability of cattle fattening (Bures and Barton 2018). Growth ability in cattle is influenced by a number of factors, such as breed, genetic predisposition (Pesonen and Huuskonen 2015; Bures and Barton 2018), microclimatic conditions and nutrition (Mazzucco et al. 2016). The slaughter age of the bulls is also an important factor.

Of course, there are differences in growth, the main factor is the breed, but the difference can also be between individuals of the same breed, which emphasizes the influence on slaughter age and slaughter weight (Mazzucco et al. 2016; Savoia et al. 2019). It can be deduced from this, that the length of fattening significantly affects the growth parameters and quality of the carcass (Bures and Barton 2018). This statement is also supported by work Ustuner et al. (2020), which confirms that both, the weight at the beginning of fattening and the correct timing of the end of the fattening period are important for the resulting meat yield. According to Filipcik et al. (2020), fattened bulls of Czech Fleckvieh-Simmental cattle are slaughtered at an average age of 646 days.

The duration of feed intake itself can influence the quality of the carcass in cattle. The time during which cattle consume feed can have a significant impact on growth, fat layer deposition, and muscle development. Cattle that have an adequate duration of high-quality feed intake are more likely to develop quality muscle mass and minimize fat reserves. Thorough nutrition and sufficient feed intake duration are therefore crucial for achieving high-quality carcass in cattle (Basarab et al. 2003).

Precise breeding of fattened bulls is based on the use of modern technologies in monitoring changes in behavioural, physiological or production indicators. Furthermore, thanks to these systems, individual animal diseases can be prevented and their welfare increased (Svennersten-Sjaunja and Pettersson 2008), which partially reducing the breeder's work and thereby saving breeding costs (Rutten et al. 2013). Currently, lying time, rumination time and animal activity are examples of several indicators that can be monitored using modern technologies such as the neck responder (Stone et al. 2017). The next step to intensify and increase the efficiency of fattening is to monitor the vital signs of animals using automatic systems (e.g. neck responders), which greatly facilitate herd management. This is very important for today's cattle breeds, which are focused on highly intensive production, thus requiring constant care, health and welfare monitoring (Collier et al. 2006; Bernabucci et al. 2014; Stone et al. 2017; Muschner-Siemens et al. 2020).

The goal of the work was to evaluate the length of eating and rumination time in young bulls of the Czech Fleckvieh-Simmental breed in fattening and to evaluate the influence of eating and rumination time on parameters of meat yield,

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specifically net increase and classification according to carcass classification SEUROP (Commission of the SEUROPean Communities 1982) using smart technology for monitoring the life manifestations of animals (eating, rumination).

Materials and methods

The research was carried out on a commercial farm engaged in the intensive fattening of bulls of dual-purpose cattle in the Czech Republic. The farm is located at an altitude of 467 m.a.s.l. A total of 85 purebred Czech Fleckvieh Simmental bull calves at the age 45–60 days and reached slaughter weight at the age of 704 ± 33 days. The animals were slaughtered at a slaughter weight of 457 ± 40 kg and the carcass body weight was classified according to the SEUROP system. The bulls were housed freely in pens at the age of 2–4 months (2.5 m^2/animal) and at the age of 4–6 months (5 m^2/animal).

The animals were fed ad libitum, a mixed feed ration twice a day. Feed was pushed regularly every hour using a Lely Juno automatic feed pusher (Lely, The Netherlands). The composition of the feed ration is calculated in long-term to an average daily gain of 1.5 kg/day and is compiled and controlled by the farm's independent nutritional specialist. Table 1 shows all the components of the mixed feed ration, including the amount for individual categories of fattened bulls. Individual categories are divided according to the live weight of the bulls.

Eating and rumination time was monitored in different age categories (2, 3, 4, 5 and 6 months old animals) with the help of SCR Heatime PRO neck responder (SCR, Israel). Eating time data (minutes) were evaluated according to age (E2, E3, E4, E5 and E6) and rumination time (minutes) according to age (R2, R3, R4, R5 and R6) and then the average was calculated for the entire monitored period (E – eating time, R – rumination).

Statistical analysis

Statistical evaluation was performed in the R program (R Core Team 2022). Analysis of variance was used to evaluate the effect of age on eating and rumination time and the effect of classification into the SEUROP system (ANOVA, post hoc analysis Tukey test). Regression and correlation analysis were used to evaluate and describe the relationship between eating and rumination time as well as the relationship to net weight gain.

Table 1. The composition of the feed ration as fed basic.

	Category according to body weight of animals				
Component of the feed ration	250–300 kg	300–350 kg	350–500 kg	500–700 kg	700 kg and more
Maize silage	6.6 kg	8.2 kg	10.9 kg	13.7 kg	16.4 kg
Clover-grass silage	4.0 kg	5.0 kg	6.7 kg	8.3 kg	10.0 kg
Crushed wheat and barley	3.0 kg	3.0 kg	3.0 kg	3.0 kg	3.0 kg
Mineral mixture	0.1 kg	0.1 kg	0.1 kg	0.1 kg	0.1 kg

Composition of the mineral mixture: calcium 230,000 mg, sodium 90,000 mg, magnesium 50,000 mg, phosphorus 30,000 mg, vitamin A 600,000 UI, vitamin D3 90 000 UI, zinc – ZnO 4000 mg, manganese – MnO 2700 mg, vitamin E (as alpha tocopherol) 1000 mg, copper – $CuSO_4{\cdot}5H_2O$ 600 mg, iodine – $Ca(IO_3)_2$ 110 mg, selenium – Na_2SeO_3 25 mg, cobalt – $Co(CH_3COO)_2{\cdot}4H_2O$ 20 mg.

The ANCOVA analysis models are presented in Table 5.

The evaluation of the influence of the age of the bulls on eating and rumination time was carried out with the following one-factor analysis of the variance model:

$$y_{ij} = \mu + age_j + e_{ij},$$

where y is the dependent variable (eating time or rumination) for the i-th animal (i = 85), μ is the intercept, *age* is the fixed effect of the j-th age of the bull (j = 5, age 2–5 months) and e is the residual error.

Factorial analysis of variance was used to evaluate the effect of classification according to the SEUROP system:

$$y_{ijk} = \mu + age_j + ur_k + age{*}ur_{jk} + e_{ijk},$$

where y is the dependent variable (eating time or rumination) for the i-th animal ($i = 85$), μ is the intercept, *age* is the fixed effect of the j-th month ($j = 5$, age 2–6 months), *ur* is the fixed effect of the k-th classification according to the SEUROP system ($k = 2$, class U and R) and e is the residual error. The effects of interaction and effect of month were nonsignificant. Therefore, only means for the *ur* effect are presented in the results.

When analyzing all regression models (Table 5), the vector of residuals was orthogonal to the vector of predictive values, the data did not show problems with a significant violation of normality (Normal Q-Q residual plot) and no trend was observed between standardized residuals and explanatory variables. Using the same diagnostic graphs, the suitability of variance analysis models for evaluating the age effect of eating time and rumination measurements (Table 2) and the effect of classification according to the SEUROP system (Table 3) was assessed. The variance of the residuals did not show a violation of the homogeneity of the variance. Critiques of the models were based on standard diagnostic plots for the 'lm' function in the R program.

Results

Descriptive statistics of the default file are shown in the table. The length of eating and rumination time for individual age categories of young bulls is also listed here.

The average eating time for the entire period of observation from 2 to 6 months of age of the bulls was 222.05 minutes and

Table 2. Descriptive statistics of dataset and influence of age on eating and rumination time.

Trait	Mean	Median	Std.dev.	SEM	C.V.
E2	117.62[a]	117.00	32.08	3.48	2.96
E3	174.33[b]	184.00	43.94	4.77	2.74
E4	224.22[c]	227.00	50.01	5.42	2.42
E5	279.33[d]	271.00	49.89	5.41	1.94
E6	314.93[e]	312.00	56.83	6.16	1.96
E (avg)	222.05	225.74	37.48	4.07	1.83
R2	308.56[a]	312.00	75.08	8.14	2.64
R3	397.71[b]	398.00	50.84	5.51	1.39
R4	454.81[c]	465.00	44.48	4.83	1.06
R5	486.34[d]	486.00	37.94	4.11	0.85
R6	515.88[e]	521.00	34.15	3.70	0.72
R (avg)	432.64	433.60	34.21	3.71	0.86

N, number of observations; E, eating time; R, rumination; Std.dev., standard deviation; SEM, standard error of the mean; C.V., coefficient of variation; means with different superscript are significantly different at the $P < 0.05$.

Table 3. Effect of SEUROP classification on eating and rumination time.

SEUROP	U ($N = 56$)			R ($N = 29$)			
Trait (minutes)	Mean	SEM	C.V.	Mean	SEM	C.V.	*p*-value
E2	104.50[a]	3.55	3.40	142.83[b]	4.94	3.46	*<0.0001*
E3	161.08[a]	5.35	3.32	199.93[b]	7.44	3.72	*<0.0001*
E4	215.43[a]	6.52	3.03	241.10[a]	9.06	3.76	*0.0240*
E5	271.19 [a]	6.53	2.41	294.99[b]	9.08	3.08	*0.0364*
E6	308.28[a]	7.54	2.45	327.71[a]	10.48	3.20	0.1359
E (avg)	212.10	4.68	2.21	241.31	6.50	2.69	*0.0005*
R2	311.78[a]	10.07	3.23	302.32[a]	14.00	4.63	0.5849
R3	407.19[a]	6.59	1.62	379.27[b]	9.16	2.42	*0.0154*
R4	464.90[a]	5.66	1.22	435.20[b]	7.87	1.81	*0.0029*
R5	494.80[a]	4.85	0.98	469.95[b]	6.73	1.43	*0.0036*
R6	518.71[a]	4.56	0.88	510.40[a]	6.33	1.24	0.2901
R (avg)	439.48	4.42	1.01	419.43	6.14	1.46	*0.0096*

E, eating time; R, rumination; U, class of the SEUROP system; R, class of the SEUROP system; *N*, number of observation; SEM, standard error of the mean; C.V., coefficient of variation; *p*-value, significancy of differnce between means for class U and R (considered level of significancy $P < 0.05$).

rumination 432.64 minutes per day (Table 2). Two-month-old bulls had an average feeding time of only 117.62 minutes, which increased with age and reached an average of 314.93 minutes for six-month-old bulls. The average eating time between individual age categories of bulls was statistically significantly different ($P < 0.05$). The same development was also recorded in rumination, the lowest age category had an average rumination of 308.56 minutes, while the oldest bulls ruminated an average of 515.88 minutes. The differences between ruminations in individual categories were also statistically significantly different ($P < 0.05$). In the case of eating time, the youngest bulls achieved the highest variability (2.96%) and the lowest variability was observed at the age of 5 and 6 month (1.94, resp. 1.96%). In rumination, the highest variability was observed in two-month-old bulls (2.64%) and the lowest (0.72%) in bulls from the oldest category.

Table 3 shows the influence of carcass classification (SEUROP) on eating and rumination time of bulls. The bulls of the monitored group were classified at the slaughterhouse into class R or U. The total average length of eating time (E) and rumination (R) shows statistically significant differences in bulls that were classified in class R or U. In the case of age categories, it was statistically significantly different length of eating time between individual classes of fleshiness at 2–5 months of age (E2–E5). The time of feed intake at the age of 6 months (E6) was no longer statistically significantly different between the fleshiness classes. The length of rumination differed statistically significantly between fleshiness classes at the age of bulls 3, 4 and 5 months (R3–R5), rumination at two months of age (R2) and at 6 months of age (R6) differed statistically non-significant.

In all cases, a trend observed was that with a better classification (class U) there was a longer rumination time and, conversely, a shorter eating time. The variability (see coefficients of variation in Table 3) of eating time decreases with age. On the contrary, for the length of rumination, the variability also decreases with age, the highest is for R2, and lowest for R6.

Table 4 shows the correlations between eating and rumination time for individual age categories of bulls. The strongest correlation coefficients were between individual consecutive eating times (E2–E6) and individual consecutive ruminations (R2–R6). The highest correlation was achieved between E5 and E6 0.87, then between E5 and E4 0.74 and between R3 and R4 0.73 and between R2 and R3 0.6. As the age difference increases, the correlation decreases, e.g. the R2–R3 correlation of 0.6 gradually drops to 0.06 in the case of R2-R6. Similarly, the E2–E3 correlation of 0.65 drops to 0.16 for E2–E6.

The correlation coefficients between eating and rumination time are negative or almost zero among all age categories. The values of these correlations range from −0.24 for R5-E3 to −0.55 for the correlation between R3-E6. For the correlations between E and R, an observed trend is that a stronger negative correlation is between more distant age categories, i.e. the opposite of the case for correlations E2-E6 and between correlations R2-R6. E.g. the R2-E2 correlation is only 0.2 and in the case of R2-E6 it reaches a stronger negative value of −0.43. similarly, for R3-E2, the correlation is almost zero and, on the contrary, between R3-E6 it reaches a value of −0.55. This trend is well captured in Figure 1, specifically in the segment where average rumination is plotted on the x-axis and average eating time on the y-axis. Here, a neutral trend in the amount of eating time is evident for lower values of rumination, and on the contrary, for high values of rumination, there is a strong decrease in eating time values.

Tables 5 and 6 presents the results of the analysis for eating and rumination time and net weight gain in bulls.

Regression analysis of the influence of rumination time on net weight gain shows that the length of rumination does not have a statistically significant effect on net weight gain (Table 5). Conversely, the highly conclusive regression coefficient of eating time on net weight gain demonstrates a higly negative relationship between net weight gain and eating time (Tables 5 and 6).

In the analysis, age-specific measurements (E2-E6) were taken into account as explanatory variables. Of these parameters, coefficients for all months had a statistically significant effect on net weight gain (see Table 6). If the eating time is increased at 2 months of age of the bull by 1 minute, the net

Table 4. Correlations among eating E2-E6 and rumination time R2-R6.

	R3	R4	R5	R6	E2	E3	E4	E5	E6
R2	**0.6**	**0.34**	0.09	0.06	0.2	−0.13	**−0.32**	**−0.41**	**−0.43**
R3		**0.73**	**0.37**	0.2	−0.08	−0.18	**−0.39**	**−0.5**	**−0.55**
R4			**0.43**	**0.24**	−0.08	−0.19	**−0.35**	**−0.51**	**−0.5**
R5				**0.47**	−0.19	**−0.24**	−0.17	−0.15	−0.18
R6					−0.14	**−0.32**	**−0.28**	−0.16	−0.15
E2						**0.65**	**0.32**	**0.25**	0.16
E3							**0.7**	**0.48**	**0.4**
E4								**0.74**	**0.68**
E5									**0.87**

E, eating time; R, rumination; correlation coefficients in bold numbers are statistically significantly non-zero ($P < 0.05$).

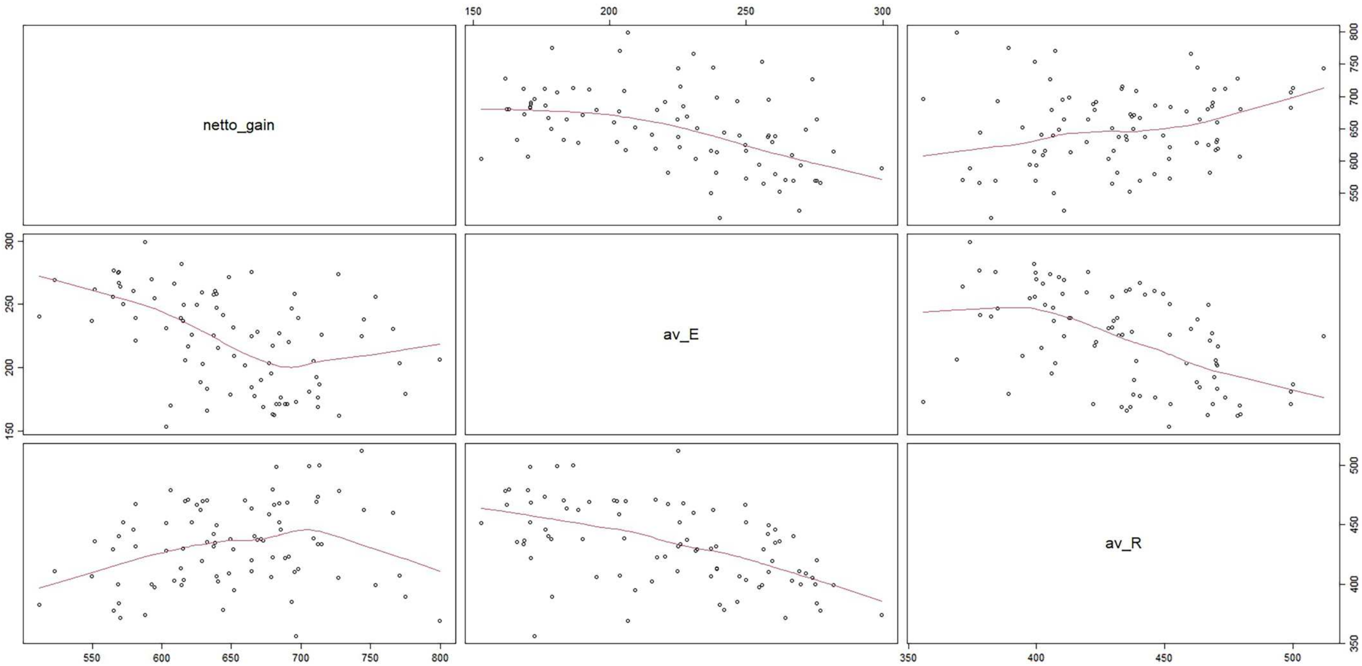

Figure 1. Relationship between net weight gain, eating and rumination time. av_E, average eating time; av_R, average rumination.

weight gain will decrease by 1.5 g/day. From these results, it can be concluded that there is a significantly negative effect of eating time on net weight gain and that it is well explained by the linear regression model, this is also evidenced by the graphic representation of this relationship in Figure 2. In the following months, the relationship between eating time and nett weight gain is also negative, but the regression coefficients and thus the slope of the curves are lower with increasing age (Figure 2). There is therefore a significant influence of the interaction of age and eating time. At the age of 6 months, the regression coefficient is only −0.256. In the case of rumination time, all regression coefficients (including the interaction of age) are statistically nonsignificant, so it is not possible to point to the relationship between rumination time and nett weight gain, nor to the influence of the age of the bulls.

The negative effect of the length of eating time on net weight gain is also evident from Figure 1 (upper middle segment), where lower values of net gain are also evident here as the length of eating time increases, this negative dependence increases with higher values of eating time. Similarly, in Figure 1, the influence of the length of rumination time on net weight gain can be observed (upper right segment), where the increasing value of net weight gain with increasing value of the length of rumination time can be seen.

Table 5. Analysis of net weight gain, eating and rumination time.

Model	Effect	*p*-value	Significancy
Net weight gain = μ + E*Month + e	Eating time	6.29E-06	***
	Month	3.75E-09	***
	Interaction E: Month	3.90E-08	***
Net weight gain = μ + R*Month + e	Rumination time	0.1202	n.s.
	Month	0.2733	n.s.
	Interaction R: Month	0.1648	n.s.

p-value, significancy of each factor (*F*-test); *E*, eating time; R, rumination time; *μ*, intercept; *e*, standard error; ***, $P < 0.001$; n.s., nonsignificant.

Table 6. Regression coefficients of eating time.

Estimated coefficients for eating time			
Intercept	Regression coefficient		*p*-value
827.38***	Month 2	−1.50***	2.20E-16
	Month 3	−0.65***	1.84E-04
	Month 4	0.28***	3.01E-08
	Month 5	−0.33***	1.10E-07
	Month 6	−0.26***	6.22E-09

p-value, significancy of regression coefficient (*t*-test, null hypothesis: regression coefficient = 0); ***, $P < 0.001$.

Discussion

In the experiment, eating and rumination time were evaluated in relation to the meat yield of inclusion in the SEUROP system and net weight gain in Czech Fleckvieh-Simmental bulls. According to our results, it is evident that the length of eating and rumination time had an effect on the net weight gain and fleshiness of the monitored animals. These results were achieved with the help of smart neck responders that are able to monitor eating and rumination time. Only a few experiments were carried out in this form, for this reason the amount of available literature is also limited. According to some studies, the very structure and composition of the ration has a significant influence on the rumination time, from the point of view of the higher content of the fibre component. Longer rumination time can increase gain by 300 g/day (Islam et al. 2021). Our results correlate with these conclusions, where bulls assigned to class U with a longer rumination time had a higher gain of 6.4 grams per day. In our study, all bulls had the same feed dose, which stimulated the same

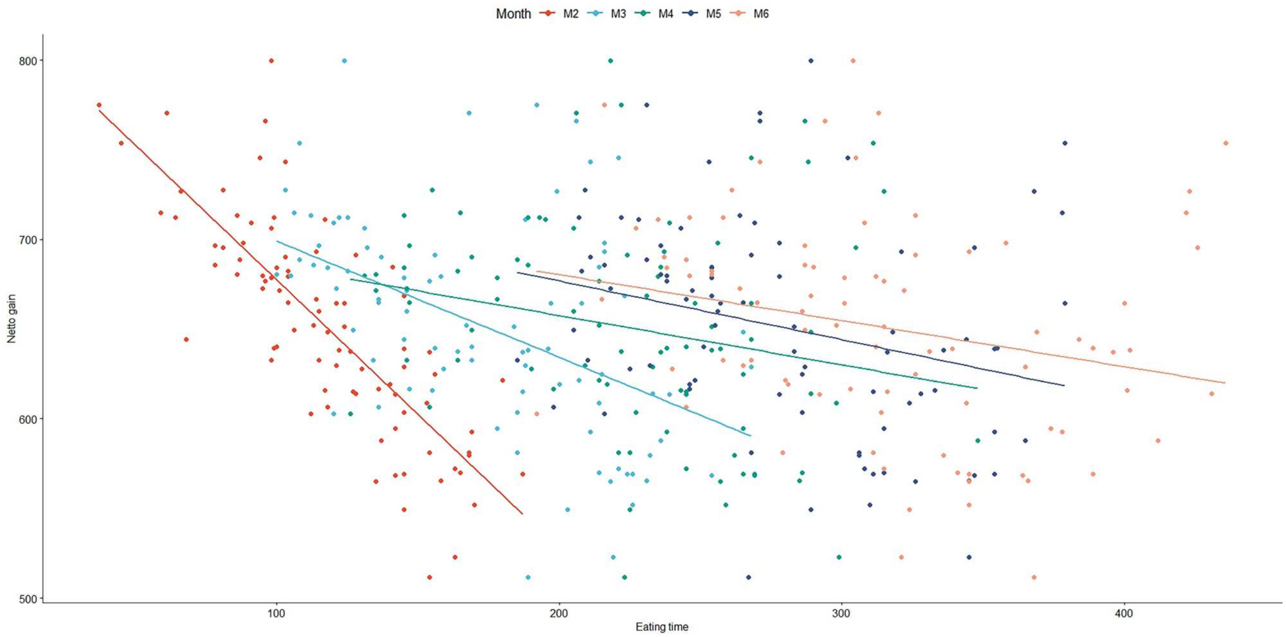

Figure 2. Regression Eating time on net weight gain.

physiological stimuli (rumination). For this reason, the difference between these two studies was not so striking. However, based on the results, the findings regarding rumination time and weight gain of animals can be confirmed. Another study also looked at rumination time in fattened bulls (for 74 days) in relation to rumination. Bulls with a longer rumination time had a higher average daily gain (by 100 grams) and slaughter weight (by 5 kilograms) (Crawford et al. 2022). The authors of this study reached similar conclusions to ours. As well as in the previous study, the absolute measured values were affected by the feed dose. According to Marchesini et al. (2020), the average rumination time in Charolais bulls weighing 476 ± 36 kg was 381 minutes/day. In our study, a longer rumination time was observed in bulls of the same weight. The difference in results was again caused by the different composition of the feed ration, especially the representation of fibre (Marchesini et al. 2020). Our findings are also confirmed by another team of researchers who monitored rumination time and daily gain in fattened Charolais bulls using smart collars. The average rumination time was 404 ± 63 min per day. Animals with less rumination time had lower daily gain (Marchesini et al. 2018). The size of the TMR particles also has a fundamental influence on the eating time. In our experiment, 50–60% of the feed ration was a particle size of 3–5 cm. Which corresponds to the standard feed ration for fattened bulls. Particle size has a significant effect on the eating time of animals. Particles larger than 4 cm were less easily accepted by the animals and the animals spent less time eating it (Genis et al. 2021).

Smart technologies are currently experiencing great development in livestock in the form of various sensors. Rumination can be effectively measured using accelerometers, where the measurement accuracy can range from 86.1 (Hamilton et al. 2019) to 98.4% (Chang et al. 2022). The neck responders used in our test were based on a similar principle. The achieved results can thus be interpreted with high accuracy. Today, it is already an affordable technology that can help farmers to understand the needs of animals from the point of view of the structure of the feed ration, which is decisive for rumination (Beauchemin 2018). Our results showed that rumination monitoring can provide valuable information to breeders, regarding the structure of the feed ration or health status. Based on these results, it is possible to predict the future performance of animals with regard to the economy of breeding.

Conclusion

In conclusion, it can be stated that eating time and rumination time affect meat yield parameters in Czech Fleckvieh-Simmental bulls. In particular, there was a statistically significant effect of eating and rumination time on the classification by the SEUROP system, when bulls classified in the U fleshiness class achieved longer rumination time compared to bulls classified in the R fleshiness class. In the case of eating time, the effect was the opposite, bulls classified in the U class achieved shorter eating time in contrast to bulls classified in fatness class R. The negative influence of the length of eating time was also confirmed concerning net weight gain when bulls with a longer eating time achieved lower gains. A positive relationship between rumination and net gain was observed but not statistically significant. The described effects on net weight gain are again related to the overall average eating and rumination time. By these results, there is also a mostly negative correlation observed between individual eating and rumination time.

At the same time, as expected, the length of eating and rumination time increases statistically significantly with the age of the bulls. Monitoring of eating and rumination time provided interesting data, especially concerning parameters of meat efficiency, where the conclusion can be formulated that for optimal growth and development of slaughter bulls at a young age of up to 6 months, a shorter intensive period of feed intake and an associated longer period of rumination appear to be a suitable term. In the following research, it would be appropriate to supplement the results with monitoring eating and rumination time in older bulls, which was not possible in our study for occupational safety reasons. The results also confirm that the intensity of feed intake and rumination, and thus the growth of the body of young bulls, is important for achieving the necessary parameters of the meat yield of slaughtered bulls of dual-purpose cattle.

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Disclosure statement

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Data availability

Data are available from the corresponding author upon request.

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