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Fattening Performance of Bulls of three Breeds Fattened Semi-Intensively in the Kostanay Region

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Abstract: The aim of this study was to determine the effect of cattle breed on carcass traits and meat quality of bulls fattened semi-intensively and slaughtered at 18 months of age. The animals were divided into three experimental groups: Group AA - 16 Angus bulls, group WK - 19 Kazakh White headed bulls, group AK - 20 Kazakh Aulie-Ata bulls. All bulls were slaughtered at the end of the fattening period. Angus bulls had the highest ($p \leq 0.05$) final body weight (494.9 kg) at 18 months of age. Average daily gain was also highest ($p \leq 0.01$ and $p \leq 0.05$) in group AA (863 g). Angus bulls were characterized by the highest carcass dressing percentage (56.8%) and the highest fat content (3.4%). Carcass length and thigh circumference were significantly ($p \leq 0.05$) higher in AA bulls than in AK bulls. The content of lean meat and fat in the carcass was highest (79.4%, $p \leq 0.05$) in AA bulls and lowest in AK bulls. Samples of semitendinosus muscle collected from AA bulls had the highest content of dry matter (24.89%), protein (22.5%) and fat (2.27%, $p \leq 0.05$).

Keywords: Fattening Performance, Beef Bulls, Daily Gains, Carcass Dressing Percentage, Carcass Conformation and Fat Cover in the Europ System, Fat, Protein, Dry Matter

Introduction

Many beef cattle breeds are renowned for their high productivity and ability to produce high-quality beef that meets consumer requirements (Bindon and Jones, 2001; Burrow *et al*., 2004; Nogalski *et al*., 2013). The most important genetic and environmental factors that contribute to beef quality are cattle breed, gender, early maturation, growth rate, management conditions, feeding regime, age at slaughter, pre-slaughter animal handling and post-slaughter carcass processing (Mandell *et al*., 1997; Honkavaara *et al*., 2003; Litwińczuk *et al*., 2006; Bures and Barton, 2012; Domaradzki *et al*., 2016). In Kazakhstan, the top beef-producing cattle breeds are Kazakh White headed, Kazakh Aulie-Ata and Steppe Cattle. Angus, Limousin and Hereford cattle, which are purchased from Europe, Canada, USA and Australia, are also raised for beef in Kazakhstan. Angus and Limousin cattle are better suited for intensive fattening systems and Hereford cattle - for semi-intensive fattening systems.

Modern nutritional strategies in cattle production promote intensive fattening and lean tissue growth (Sami *et al*., 2004b; Młynek and Guliński, 2007). The fattening performance of cattle can be improved under all production systems. The determinants of feeding intensity include adequate forage supply, appropriate feeding choices, adequate amount of feed and balanced rations. Nutrition should be adjusted to match the genetic potential of cattle in order to produce beef carcasses with desirable tissue composition (Litwińczuk *et al*., 2012). Studies investigating the influence of cattle nutrition on meat quality, conducted to date, have focused on maximizing muscle tissue growth and carcass yield as well as on the supply of nutrients that could be potentially absorbed in the gastrointestinal tract and incorporated into cell structures to enhance the nutritional and biological value of meat (Granit *et al*., 2001; Wood *et al*., 2004). Nogalski and Kijak (2001) demonstrated that crossbred bulls (Holstein-Friesian cows mated to Limousin, Hereford and Simmental bulls) fed semi-intensively

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received lower carcass fat scores in comparison with their intensively fed counterparts.

According to (Warren *et al*., 2008), meat from cattle fed silage and green forage has a longer shelf-life (by approximately 2 to 3 days) due to slower lipid oxidation and a more stable color than meat from cattle fed concentrated feed (Lee *et al*., 2008; Pedreira *et al*., 2003; Andersen *et al*., 2005). Previous research has shown that beef quality and production efficiency can be improved when cattle are fed preserved or fresh roughage, making maximal use of pasture (Granit *et al*., 2001; Wood *et al*., 2004; Warren *et al*., 2008; Makulska and Węglarz, 2001).

In Kazakhstan, in the group of young beef cattle, bulls that are raised under semi-intensive systems and grazed are best suited for fattening. Two grazing cycles are usually carried out. Average daily gain is approximately 800 g. The animals are slaughtered at 15 or 18 months of age, when they reach body weight of around 550-600 kg. In Poland, the most popular and the most profitable beef cattle production system also involves semi-intensive fattening of young bulls (Litwińczuk *et al*., 2012). However, intensive fattening of beef cattle increases carcass fat content which enhances meat flavor (Sami *et al*., 2004a).

The proportion of the most valuable cuts in the carcass is a good indicator of the slaughter value of cattle (Wulf and Wise, 1999; Page *et al*., 2001; Gońi *et al*., 2007; Wajda *et al*., 2011; Renand *et al*., 2001; Miciński *et al*., 2012; 26]. Carcasses that had better conformation in the EUROP classification system were characterized by higher weight of five primal cuts: Round of beef, shoulder, best ribs, brisket and rump (Bindon and Jones, 2001).

Taking the increasing consumers demands for beef derived from different young beef cattle into account the research was undertaken in order to determine the slaughter value of local kazakh beef cattle in comparison to the imported Angus bulls.

The objective of this study was to determine the effect of cattle breed on carcass traits and meat quality of bulls fattened semi-intensively and slaughtered at 18 months of age in the Kostanay Region in Kazakhstan.

Materials and Methods

The study was conducted in 2014-2016. The experimental materials comprised bulls of three breeds, Angus, Kazakh White headed and Kazakh Aulie-Ata (a total of 55 bulls), fattened from 6 to 18 months of age in the Kostanay Region in Kazakhstan.

Calves were born in early spring in 2014 and they stayed with their mothers on pasture until 6 months of age. In autumn, after weaning, young bulls were kept indoors. The animals were divided into three experimental groups. Group AA consisted of 16 Angus bulls that were born and raised on the “Sever Agro N’ farm in the northern part of the region. Their mothers were purchased from Australia. Group WK consisted of 19 Kazakh White headed bulls that were born and raised to 6 month age on the “Agrofirma Borovskoje” farm. Group AK consisted of 20 Kazakh Aulie-Ata bulls that were born and raised to 6 month age on the “Agrofirma Karkyn” farm.

During the fattening period (from 6 to 18 months of age), the bulls were housed in tie-stall barns on the “Sever Agro N’ farm in the northern part of the region, where all of the bulls from the examined groups came after reaching age of 6 months age. All animals were slaughtered at 18 months (±10 days) of age.

During semi-intensive fattening, the average daily feed ration per bull consisted of maize silage offered *ad libitum*, 1 kg of grass hay, 0.5 kg of barley straw, 1 kg of ground wheat grain and 1 kg of ground barley grain, supplemented with Polfamix premix (50 g). The amounts of silage fed to bulls were increased at 30-day intervals, allowing for 10% leftover from a daily allotment. The nutritional value of diets was determined based on the analyzed chemical composition and nutrient digestibility coefficients, in accordance with the Nutrient Requirements of Cattle (Kalashnikov and Fisinin 2003; Makarcev, 2012). The chemical composition of diets is presented in Table 1 and nutrient intake per kg of body weight gain is shown in Table 4.

During the fattening period, the animals were weighed at 6, 12 and 18 months of age and the following live body measurements were performed: Height at withers, trunk length and spiral thigh circumference [cm]. Nutrient intake per kg of body weight gain of bulls was calculated at the end of fattening (Table 4). At 18 months (±10 days) of age, the bulls were transported to the abattoir where they were fasted for 24 h, weighed and slaughtered in accordance with the relevant Kazakh meat industry regulations (GOST R 54315, 2011). Carcass weight and pH were determined immediately post mortem (GOST R 51478-99, 1999). Carcasses were halved by cutting through the middle of vertebral column. After 24 h of chilling at +4°C, half-carcasses were weighed (including the kidneys and perirenal fat) and carcass length, thigh length and thigh circumference were measured. The results of measurements were used to calculate the Carcass Compactness Index (CCI) and Leg Compactness Index (LCI) from the following formulas:

$$CCI = (\text{Carcass weight}/\text{Carcass length})*100;$$
$$LCI = (\text{Thigh circumference}/\text{Thigh length})*100$$

Carcass conformation and fatness were evaluated based on the EUROP system criteria (conformation: E-1 point, U-2 points, R-3 points, O-4 points, P-5 points; degree of fat cover: 1 point - none up to low, 5 points - very high).

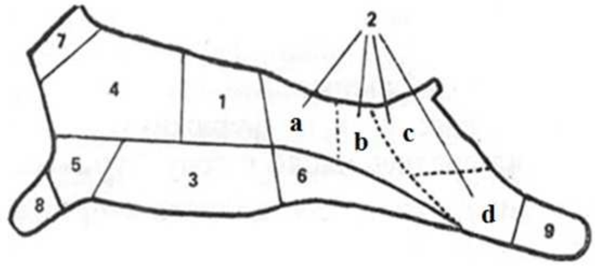

Fig. 1. Primal cuts in the right half-carcass: Quality class 1: 1 - dorsal portion, 2 - round, 2a + 2b - loin + sirloin, 2c - rump, 2d - leg, 3 - brisket; Quality class 2: 4 - fore ribs, 5 - shoulder, 6 - flank; Quality class 3: 7 - neck, 8 - fore shank, 9 - hind shank

Carcass dressing percentage (percentage ratio of carcass weight to live body weight at slaughter) was calculated. The pH_{24} and pH_{48} of meat were determined. Right half-carcasses were divided into primal cuts according to Standard (GOST 31797, 2012).

Primal cuts were weighed and assigned to quality classes 1, 2 and 3. Class 1: 1 - dorsal portion, 2 - round, 2a + 2b - loin + sirloin, 2c - rump, 2d - leg, 3 - brisket; Class 2: 4 - fore ribs, 5 - shoulder, 6 - flank; Class 3: 7 - neck, 8 - fore shank, 9 - hind shank (Fig. 1). Cuts of each quality class were dissected to determine the percentage content of soft tissues (meat, fat, tendons) and bones.

Samples of semitendinosus (*M. semitendinosus*) muscle were collected to determine the chemical composition and physicochemical properties of meat. The muscle was cut out from the thigh 48 h post mortem. Samples were vacuum-packaged and transported to the laboratory. 600 g samples were ground to pass through a 3mm mesh sieve and homogenized. The proximate chemical composition of meat was determined with the use of an infrared analyzer, in three replications. Beef samples were assayed for the content of dry matter, total protein, crude fat and crude ash.

The results were analyzed statistically using Statistica software ver. 10.0 (Statsoft Inc., 2010) by one-way Analysis Of Variance (ANOVA) for non-orthogonal designs at a significance level of $p \leq 0.05$ and $p \leq 0.01$. Arithmetic means (x) and standard deviations (Sd) were calculated. The significance of differences was determined by Fisher's test (Least Significant Difference).

Results

The proximate chemical composition and nutritional value of diets fed to bulls are presented in Table 1.

The nutrient content of maize silage was consistent with the recommended values, typically noted under production conditions. The quality of grass hay was satisfactory and its nutritional value was maintained constant throughout the experiment. The average daily feed intake in bulls of different breeds is shown in Table 2. No significant differences in feed intake were found between the groups.

The fattening performance of animals is determined based on their body weights and average daily gains. Table 3 presents the body weights and daily gains of bulls, indicating statistically significant differences between the groups. No significant differences were noted between bulls at 6 months of age (beginning of the experiment). A significant effect of breed on the body weights and daily gains of bulls was observed at 18 months of age (end of fattening). At the beginning of the fattening period, the average body weight of bulls ranged from 177.5 kg in group WK to 185.1 kg in group AK. At 18 months of age, significant differences in body weight were noted between the groups. Group AA bulls were characterized by the highest average body weight (494.9 kg), which was significantly ($p \leq 0.05$) higher than the body weights of bulls in groups WK (478.1 kg) and AK (465.4 kg). The highest body weight achieved by Angus bulls indicates that this breed is best suited for semi-intensive fattening.

Throughout the experiment (from 6 to 18 months of age), AA bulls were characterized by significantly ($p \leq 0.01$) higher average daily gain than AK bulls (863g vs. 769 g). The average daily gain of WK bulls reached 824 g and was significantly higher ($p \leq 0.05$) than that of AK bulls.

An analysis of the body measurements of bulls revealed that AA bulls were characterized by the highest values of height at withers, trunk length and spiral thigh circumference (Table 3). Attention should be paid to the fact that WK bulls had a high value of spiral thigh circumference (188.8 cm), but the lowest values of height at withers and trunk length, in comparison with the remaining groups.

Apart from daily gains, nutrient intake per kg of body weight gain is also a reliable indicator of fattening performance in cattle. Nutrient intake per kg of body weight gain was affected by cattle breed (Table 4).

Angus bulls needed significantly less feed to produce 1 kg of gain in terms of oats feed units ($p \leq 0.05$), metabolizable energy (measured as Megajoules, MJ) and dry matter, compared with the remaining breeds.

Breed had a considerable influence on the fattening performance and carcass quality of bulls (Table 5).

The average body weight at slaughter was highest in AA bulls (approx. 475 kg) and lowest in AK bulls (436.2 kg), which resulted from their lowest daily gains over the fattening period (768 g). Carcass dressing percentage was highest in group AA (56.8%), followed by group AK (55.3%) and group WK (54.1%). Similar dressing percentage values of Angus bulls were reported by (Holló *et al*., 2012) who also noted the highest carcass fat content in the Angus breed. In our study, the lowest content of internal fat was noted in the carcasses of WK bulls (2.8%, Table 5). The scores for carcass conformation, assessed on a 5-point scale, were as follows: Group AA - 2.45 points, group WK - 3.17 points, group AK - 4.02 points. The scores for carcass fat cover, evaluated on a 5-point scale, were as follows: group AA - 4.87 points, group WK - 4.14 points, group AK - 2.96 points.

Table 1. Proximate chemical composition (%) and nutritional value of diets

Specification	Dry matter	Crude ash	Crude protein	Crude fat	Crude fiber	Nitrogen-free extracts	Content per kg DM of feed: Net energy, oats feed units	Net energy, MJ	Crude protein [g]
Maize silage	19.4	4.3	2.0	1.25	7.9	10.8	0.16	0.94	18.3
Grass ay grass	82.5	6.1	10.5	1.58	25.9	36.1	0.42	3.48	104.3
Barley straw	87.6	7.0	3.9	0.48	38.8	48.0	0.34	2.01	44.6
Wheat grain	87.0	5.7	11.8	2.76	6.0	62.3	1.06	5.43	155.6
Barley grain	86.8	5.6	11.0	2.78	6.6	71.4	1.02	5.84	156.7

Explanatory notes: DM - Dry Matter

Table 2. Daily feed intake over the entire production period

Feed [kg]	Breed (x ± Sd) Feed intake [kg]: AA	WK	AK
Maize silage	21.42±2.4	18.11±2.9	19.33±1.9
Grass hay	0.97±0.03	0.98±0.05	0.97±0.05
Barley straw	0.48±0.04	0.49±0.04	0.47±0.04
Wheat grain	0.96±0.03	0.97±0.04	0.97±0.05
Barley grain	0.95±0.05	0.98±0.03	0.96±0.03

Explanatory notes: AA - Angus imported from Australia; WK - White headed Kazakh breed; AK - Aulie-Ata Kazakh breed

Table 3. Body weights and daily gains of bulls

Specification	Breed (x ± Sd): AA	WK	AK
Body weight at 6 months of age [kg]	179.9±3.4	177.5±2.8	185.1±1.1
Body weight at 18 months of age [kg]	494.9^a±9.6	478.1±9.8	465.4^b±2.5
Total body weight gain from 6 to 18 months of age [kg]	315.0^a±8.0	300.6±6.0	280.3^b±4.4
Total daily gains from 6 to 18 months of age [g]	863^A±30	824^a±32	768^{Bb}±36
Height at withers [cm]	124.4±0.4	121.3±0.4	122.1±0.3
Trunk length [cm]	166.7^a±0.6	152.5^b±0.9	155.1^b±0.6
Spiral thigh circumference [cm]	195.7^a±0.7	188.8±0.7	179.3^b±0.6

Explanatory notes as in Table 2; A,B - statistically significant differences at p≤0.01; a,b - statistically significant differences at p≤0.05

Table 4. Nutrient intake per kg of body weight gain in bulls

Specification	Breed (x ± Sd): AA	WK	AK
Oats feed units per kg of gain	7.59^a±0.41	8.21^b±0.87	8.12^b±0.76
Energy intake (MJ) per kg of gain	44.9±4.67	46.1±3.82	47.4±2.31
Crude protein intake (g) per kg of gain	1017±128	1024±126	1042±114
Dry matter intake (kg) per kg of gain	8.92±1.74	9.13±1.15	9.38±1.63

Explanatory notes as in Table 2; a,b - statistically significant differences at p≤0.05

Carcass fatness, measured as fat content, is associated with feeding intensity during fattening. Pogorzelska (1999) found no significant differences in carcass fatness (including fat weight and percentage) between groups of semi-intensively fattened bulls and concluded that fat deposition is not genetically determined and varies in response to feeding intensity.

Carcass measurements and proportions affect the slaughter value of cattle. In the present study, differences in carcass measurements were noted between groups of bulls (Table 6).

Significant differences to the advantage of AA bulls were found in carcass length, thigh circumference and the leg compactness index. The highest carcass compactness index (135.7%) was noted in group AA and the values of this index were significantly ($p \leq 0.05$) lower in the remaining groups. The leg compactness index was also highest in AA bulls (114.4%).

Carcass lean content and the content of lean meat in the most valuable cuts are indicators of bovine carcass meatiness. A high percentage of cuts assigned to quality class 1 points to desirable carcass proportions. The weight (kg) and percentage (%) of carcass cuts representing quality classes 1, 2 and 3 are shown in Table 7. Group AA bulls had the highest percentage of cuts representing quality class 1 (67.2%), whereas the percentage of quality 2 cuts ranged from 28.1% in AA bulls to 30.6% in AK bulls.

Data presented in Table 8 show that carcass tissue composition was affected by cattle breed. The carcasses of AA bulls had the highest ($p \leq 0.05$) content of lean meat and fat and the lowest bone content, in comparison with the remaining groups. The meat-to-bone ratio was also most desirable in AA bulls (4.7).

Beef quality is determined not only by morphological composition, but also by physicochemical properties (Table 9).

Table 5. Selected parameters of bull carcasses

	Breed (x ± Sd)		
Specification	AA	WK	AK
Body weight at the end of fattening [kg]	$494.9^{a}\pm9.6$	478.1 ± 9.8	$465.4^{b}\pm2.5$
Body weight at slaughter [kg]	$475.0^{a}\pm8.0$	463.4 ± 9.5	$436.2^{b}\pm2.0$
Carcass weight [kg]	$270.0^{a}\pm5.2$	250.8 ± 5.1	$239.9^{b}\pm4.8$
Carcass dressing percentage [%]	$56.8^{Aa}\pm1.2$	$54.1^{B}\pm2.4$	$55.3^{b}\pm1.8$
Internal fat [kg]	$16.1^{a}\pm0.7$	$13.0^{b}\pm0.4$	$13.2^{b}\pm0.6$
Internal fat [%]	$3.4^{a}\pm0.7$	$2.8^{b}\pm0.4$	$3.0^{a}\pm0.6$
Carcass conformation score [pts]	$2.45^{a}\pm0.8$	3.17 ± 0.9	$4.02^{b}\pm0.9$
Carcass fatness score [pts]	$4.87^{a}\pm0.6$	$4.14^{a}\pm0.3$	$2.96^{b}\pm0.5$

Explanatory notes as in Table 2; A,B - statistically significant differences at $p \leq 0.01$; a,b - statistically significant differences at $p \leq 0.05$

Table 6. Average size of bull carcasses

	Breed (x ± Sd)		
Specification	AA	WK	AK
Carcass length [cm]	$107.8^{a}\pm2.0$	106.7 ± 0.9	$105.3^{b}\pm2.2$
Thigh length [cm]	85.1 ± 0.4	84.2 ± 0.2	84.0 ± 0.7
Thigh circumference [cm]	$97.4^{a}\pm0.5$	94.5 ± 0.3	$94.0^{b}\pm0.6$
Carcass compactness index [%]	$135.7^{a}\pm10.3$	$117.2^{b}\pm9.0$	$111.4^{b}\pm8.1$
Leg compactness index [%]	114.4 ± 12.8	112.2 ± 11.3	111.9 ± 10.5

Explanatory notes as in Table 2; a,b - statistically significant differences at $p \leq 0.05$

Table 7. Post-slaughter analysis of bull carcasses

	Breed (x ± Sd)		
Specification	AA	WK	AK
Cold carcass weight[kg]	$266.5^{A}\pm5.4$	$247.2^{B}\pm5.8$	$236.8^{B}\pm4.9$
Cold half-carcass weight[kg]	$146.4^{A}\pm4.2$	$125.4^{B}\pm2.5$	$117.3^{B}\pm2.9$
Percentage content in the half-carcass[%]:			
Cuts of quality class 1	67.2 ± 2.1	66.8 ± 3.4	65.8 ± 2.2
Cuts of quality class 2	28.1 ± 3.8	28.8 ± 4.1	30.6 ± 3.5
Cuts of quality class 3	4.7 ± 2.0	4.4 ± 2.8	3.6 ± 2.9
Weight of cuts of quality class 1 [kg]	$201.3^{A}\pm0.6$	$165.1^{Ba}\pm0.4$	$155.8^{Bb}\pm1.7$
Weight of cuts of quality class 2[kg]	$84.2^{a}\pm0.5$	$71.1^{b}\pm0.2$	$72.4^{b}\pm0.4$
Weight of cuts of quality class 3[kg]	$14.1^{Aa}\pm4.8$	$11.0^{Ab}\pm0.1$	$3.6^{B}\pm0.8$

Explanatory notes as in Table 2; A,B - statistically significant differences at $p \leq 0.01$; a,b - statistically significant differences at $p \leq 0.05$

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Table 8. Tissue composition of carcass cuts

Specification	Breed (x ± Sd) AA	WK	AK
Lean meat and fat [kg]	116.2^{a}±3.3	96.8^{b}±2.1	92.1^{b}±1.8
Lean meat and fat [%]	79.4^{a}±3.1	77.2^{b}±2.2	78.5^{b}±1.9
Bones [kg]	24.9±1.0	24.0±0.9	21.9±0.9
Bones [%]	17.0±0.9	19.2±1.0	18.7±1.1
Tendons and cartilages[kg]	5.3^{a}±2.2	4.6^{a}±1.0	3.2^{b}±0.3
Tendons and cartilages[%]	3.6±0.02	3.7±0.03	2.8±0.01
Meat-to-bone ratio	4.7^{a}±0.01	4.0^{b}±0.01	4.2^{b}±0.01

Explanatory notes as in Table 2; a,b - statistically significant differences at p≤0.05

Table 9. pH and chemical composition of the semitendinosus muscle of bulls

Specification	Breed (x ± Sd) AA	WK	AK
pH_{24}	6.73±0.05	6.65±0.06	6.69±0.08
pH_{48}	5.55±0.06	5.51±0.04	5.53±0.04
Protein [%]	22.5±1.4	21.9±1.3	22.1±0.3
Fat [%]	2.27^{a}±0.1	2.14^{b}±0.1	2.16^{b}±0.1
Ash [%]	1.12±0.34	1.10±0.29	1.10±0.01
Dry matter [%]	24.89±1.1	24.24±1.5	24.36±1.7

Explanatory notes as in Table 2; a,b - statistically significant differences at p≤0.05

The semitendinosus muscles collected from AA bulls had the highest dry matter content (24.89%). The protein content of meat ranged from 21.9% in WK bulls to 22.5% in AA bulls. AA bulls had the highest fat content, which was significantly (p≤0.05) higher than in group WK. In all groups, fat content significantly exceeded 2%, which is considered optimal in beef. Meat acidity expressed as $pH_{48}$was at a normal level (approx. 5.5) in all groups.

Discussion

Holló *et al*. (2012), compared the fattening performances of 62 bulls of different breeds, including Angus, under identical management conditions. They found that in the semi-intensive fattening system, Angus bulls achieved daily gains above 1200 g when the content of concentrates in the ration was increased. Polgar (2007) also observed a correlation between average daily gain and feeding intensity. In a study by Alberti *et al*. (2008), intensively-fed Simmental bulls achieved average daily gain of 1500 g. Litwińczuk *et al*. (2012), found that bulls of different breeds raised under a semi-intensive system had high final body weights of approximately 593-619 kg despite relatively low daily gains of 880-937 g. In the cited study, the body weights of bulls had no influence on carcass fat coverage in the EUROP classification system, which was lowest in the heaviest animals.

Keady *et al*. (2007), demonstrated that replacing grass silage with maize silage contributed to higher average daily gain in beef cattle and that feeding maize silage was more effective than feeding grass silage. In a study by Młynek and Guliński (2007), fast-growing Black-and-White bulls fed hay supplemented with maize silage gained daily only 905g on average, which indicates that intensive feeding with maize silage considerably increases daily gains. According to Litwińczuk *et al*. (2013), a wider range of fodders, i.e., haylage in addition to maize silage, could contribute to higher efficiency of nutrient absorption and, consequently, to higher daily gains in young bulls. Grosse *et al*. (1991; Dijkstra *et al*., 1996), observed a correlation between higher efficiency of nutrient utilization and higher body weight gains in cattle.

Litwińczuk *et al*. (2012), demonstrated that the body measurements of bulls were affected by both cattle breed and feeding intensity. The cited authors did not note any disproportion in thigh circumference relative to trunk length and height at withers, which was observed in our study.

Wajda *et al*. (2011) reported that bulls that had the highest body weights at the end of fattening were characterized by the most desirable carcass conformation and the highest dressing percentage (57.27%), but also by the highest fat coverage, which is consistent with our findings. According to Nogalski *et al*. (2014), carcass fatness is directly proportional to the body weight at slaughter in young bulls and animals that achieve higher daily gains during fattening are characterized by more desirable carcass conformation. The carcasses of bulls slaughtered at higher body weight had higher EUROP fat cover scores than the carcasses of bulls slaughtered at lower body weight. Previous research has shown that carcass fat deposition in cattle is not genetically determined and depends on feeding intensity. According to some authors (Nogalski *et al*., 2014; Strzetelski, 1996; Młynek *et al*., 2006), fat accumulation in bovine carcasses increases with an increase in the body weights of animals. Pogorzelska *et al*. (2013), found that restricted feeding contributed to a decrease in the fat content of meat from young bulls, which was also observed in our study and reported by other authors (Nogalski *et al*., 2013; Wajda *et al*., 2011; Schöne *et al*., 2006).

Młynek (2011), demonstrated that higher feeding intensity was correlated with an increase in the content of the most valuable cuts in the carcass, which is consistent with our findings. In the cited study (Młynek, 2011), the carcasses of bulls raised under an intensive system contained 69.1% of valuable cuts on average, whereas the content of the most valuable cuts in the carcasses of bull fed less intensively was several percent lower.

The meat-to-bone ratio noted in young bulls by Litwińczuk *et al*. (2012), was significantly higher than the value determined in our study. However, the above authors analyzed bulls of breeds that are popular in Poland (White-backed, Polish Black-and-White, Polish Holstein-Friesian, Limousin), which were raised under a semi-intensive system. The values of the meat-to-bone ratio exceeded 6.0 and were similar in all examined breeds, but our study investigated different breeds.

According to Wichłacz *et al*. (1998; Nogalski and Kijak, 2001; Śmiecińska and Wajda, 2008; Nogalski *et al*., 2014), low intramuscular fat content, particularly in the carcasses of bulls fed semi-intensively, can negatively affect the consumer acceptance of beef. An excessive decrease in energy and protein concentrations in the ration leads to lower carcass fatness (Berthiaume *et al*., 2006). Meat from bulls fed low-energy and low-protein diets is characterized by a less desirable aroma and taste and lower palatability. Litwińczuk *et al*. (2012), analyzed the chemical composition of the semitendinosus muscle in bulls of different breeds raised under semi-intensive systems in Poland. In the cited study, the percentage of dry matter in meat was lower, the content of total protein and crude ash was higher and fat content was lower in comparison with the values noted in our experiment. The proximate chemical composition of meat from Hereford bulls fed semi-intensively (Dymnicka *et al*., 2004) and Polish Holstein-Friesian bulls fed intensively (Wajda *et al*., 2011) was similar. The dry matter content of beef determined in the above studies and in our experiment was comparable.

Conclusion

Angus bulls (group AA) were characterized by the highest fattening performance, determined based on body weight, average daily gains and energy utilization. Angus bulls had also the highest final body weight and the highest values of body measurements. At the end of fattening, which lasted from 6 to 18 months of age, the average daily gain of AA bulls reached 863 g. The final body weight of AA bulls (494.4 kg) was significantly ($p \leq 0.05$) higher than the body weights of WK bulls (478.1 kg) and AK (465.6 kg) bulls. Under the semi-intensive system, AA bulls were characterized by the highest carcass weight and slaughter yield, the most desirable carcass tissue composition and measurements and the highest carcass fat content. The carcass dressing percentage (56.8%) of AA bulls was significantly higher than that of WK bulls (54.1%, $p \leq 0.01$) and AK bulls (55.3%, $p \leq 0.05$). The most desirable body dimensions of AA bulls were reflected in the highest values of carcass length, thigh circumference, leg compactness and carcass compactness. The content of lean meat and fat in the carcass was highest in AA bulls (79.4%) and significantly ($p \leq 0.05$) lower values were noted in WK and AK bulls (77.2 and 78.5%, respectively). The dry matter content of the semitendinosus muscle exceeded 24% in all groups. No significant differences in protein content were found between the groups, whereas fat content was significantly ($p \leq 0.05$) higher in group AA (1.27%) than in the remaining groups.

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Author’s Contributions

Indira Aitzhanova: Participated in all experiments, coordinated the data-analysis and contributed to the writing of the manuscript.

Doskali Naimanov: Coordinated the mouse work.

Bartosz Miciński and Sara Dzik: Designed the research plan and organized the study.

Jan Miciński: Participated in all experiments, coordinated the data-analysis and contributed to the writing of the manuscript.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved

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