\$ sciendo

CARCASS AND MEAT QUALITY TRAITS IN YOUNG BULLS FED VIRGINIA FANPETALS SILAGE*

Zenon Nogalski¹, Maciej Starczewski², Cezary Purwin², Paulina Pogorzelska-Przybyłek¹, Monika Sobczuk-Szul¹, Monika Modzelewska-Kapituła³

 ¹Department of Cattle Breeding and Milk Evaluation, Faculty of Animal Bioengineering, University of Warmia and Mazury, Oczapowskiego 5, 10-179 Olsztyn, Poland
²Department of Animal Nutrition and Feed Science, Faculty of Animal Bioengineering, University of Warmia and Mazury, Oczapowskiego 5, 10-179 Olsztyn, Poland
³Department of Meat Technology and Chemistry, Faculty of Food Sciences, University of Warmia and Mazury in Olsztyn, Pl. Cieszyński 1, 10-719 Olsztyn, Poland
*Corresponding author: zena@uwm.edu.pl

Abstract

The aim of this study was to determine the effect of Virginia fanpetals (*Sida hermaphrodita*) silage on carcass and beef quality characteristics. Forty Polish Holstein-Friesian bulls aged 16 months were assigned to 4 dietary treatments (n=10) and were fed different types of silage during a 7-month fattening period. The proportion (g/kg dry matter) of silage in the diets was as follows: (1) grass silage (GS) (600); (2) Sida silage (SS) (600); (3) SS (300) and GS (300); and (4) SS (300) and maize silage (MS) (300). Silage was supplemented with concentrate at 400 g/kg DM in each diet. The animals were slaughtered at the end of the fattening period. Silage type had no significant effect on BWG or feed to gain ratio. The carcasses of bulls fed Sida silage and maize silage received higher scores for conformation than the carcasses of bulls fed grass silage (P<0.05). The meat of bulls fed Sida silage had the lowest value of Warner-Bratzler shear force. Meat from SS+MS group bulls had the highest intramuscular fat (IMF) content and was lightest in color, whereas meat from bulls fed Sida silage and grass silage received the highest scores for color uniformity, aroma, taste and overall acceptability.

Key words: beef, diet composition, meat quality, shear force, sensory evaluation

Sida silage fed to finishing bulls can improve carcass and meat quality characteristics without any adverse effects on fattening performance when compared with

^{*}The study was carried out as part of research project No. 1/270745/2/NCBR/2015 "Dietary, power, and economic potential of Sida hermaphrodita cultivation on fallow land", acronym SIDA, under the BIOSTRATEG program funded by the National Centre for Research and Development.

bulls fed a control diet based on grass silage. Sida silage combined with grass silage improved the overall acceptability of beef, compared with SS and SS+MS. The carcasses of bulls fed Sida silage and maize silage received higher scores for conformation than the carcasses of bulls fed grass silage.

Virginia fanpetals (Sida hermaphrodita) is a little-known plant species with potential for agricultural use. Botanically, the genus Sida belongs to the family Malvaceae. Sida hermaphrodita is a polycarpic perennial herb characterized by low soil requirements, which can produce 10-20 t of dry matter annually (Borkowska et al., 2009; Tîtei, 2015). Sida leaves, which contain mucus-like substances and flavonoids. can be used for pharmaceutical purposes (Borkowska and Styk, 2006). The potential use of Sida as a fodder crop remains insufficiently investigated. The chemical composition of Virginial fanpetals, in particular its protein content, is comparable with that of alfalfa. In the bud development stage, Sida herbage had the highest total protein content (17–28% of a dry matter basis) (Tarkowski, 2008). The plant could also be suitable for forage production due to its high yield potential, resistance to lodging and freezing, low soil nutrient requirements, and high drought tolerance (Franzaring et al., 2014). A disadvantage of Virginia fanpetals is that the plant is difficult to wilt prior to ensiling. Antinutritional factors (tannins, phytic acid, antitrypsin activity), present in small amounts in Sida leaves, do not pose a health risk even to young animals (Borkowska, 1994). In a study by Tarkowski (2008), total replacement of supplemental concentrate (4 kg DM) with protein-fibrous extruderate produced from dry Sida and faba beans increased the fat and protein content of milk in dairy cows. According to some researchers (Hoving-Bolink et al., 1999; O'Sullivan et al., 2002), maize silage is considered the best diet because it produces better daily gain, better carcass conformation, and lighter and more tender meat than grass silage. Tarkowski (2008) fed Sida extruderate to dairy cows, Fijałkowska et al. (2017) analyzed the ensiling suitability and microbiological quality of Virginia fanpetals biomass but the efficiency of Sida silage in animal fattening has not been studied to date.

It was hypothesized that Sida silage could partially or completely replace other types of silage in finishing cattle diets. However, the relationship between Sidabased diets and meat quality has not yet been analyzed. Therefore, the objective of this study was to determine the effect of Sida silage on carcass and beef quality characteristics.

Material and methods

Animals

The experimental material comprised 40 Polish Holstein-Friesian bulls reared at the Agricultural Experiment Station in Bałcyny (53°35′29 N; 19°50′58 E; Poland). The climate of the region is described as temperate marine-continental. The average length of the growing season is 190 days (15 April–25 October). Young bulls were raised in a conventional system, and were fed milk replacer, hay and concentrate.

Starting from 5 months of age, the animals were fattened semi-intensively, and were fed ad libitum a total mixed ration (TMR) composed of grass silage (the same grass silage was used during the feeding trial) supplemented with 2 kg of concentrate $(g \cdot kg^{-1} DM)$: crude protein – 191, neutral detergent fiber – 214, acid detergent fiber – 88; meat production units -1.11; protein digested in the small intestine depending on rumen degraded protein -125; protein digested in the small intestine depending on rumen fermented organic matter -118). The nutritional values of feeds including net energy (meat production units, UFV), protein digested in the small intestine depending on rumen degraded protein (PDIN) and protein digested in the small intestine depending on rumen fermented organic matter (PDIE), were determined using the WINWAR program (Kowalski and Kański, 1993). At 16 months of age, when bulls reached a body weight (BW) of around 450 kg, they were assigned to four groups by the analogue method (the animals were at a similar age, and they were divided into groups based on BW) of ten individuals each, and were placed in a monitored fattening facility, in four separate pens on deep bedding. Pen size was 20×13 m. The animals had enough space to move freely around, and they had free access to water and salt licks. During a 7-month fattening period, the animals were fed different types of silage supplemented with concentrate (Table 1). Sida silage was made from first-harvest biomass cut in the bud formation stage, grass silage was made from first-harvest herbage cut in the heading stage and wilted for 24 hours, and maize silage was made from herbage cut in the dough stage (Table 1). The dietary treatments were as follows (Table 2): group 1 (control) – basal diet of grass silage (GS), group 2 – basal diet of Sida silage, group 3 – basal diet of Sida silage and grass silage (1:1, SS+GS), group 4 – basal diet of Sida silage and maize silage (1:1, SS+MS). The animals were fed ad libitum TMR composed of silage and concentrate, which was dosed from a self-propelled feed cart. The concentrate to silage ratio, on a DM basis, was 40:60 and the amounts of triticale and rapeseed meal were dosed to obtain an isonitrogenous diet (Table 2). The animals were weighed once a week. Fresh TMR was offered every day, after the leftovers had been removed. The feed intake of each animal was monitored individually using the Roughage Intake Control System (Insentec BV, Marknesse, the Netherlands). All feed samples, collected once a week, were assayed for the content of basic nutrients - with standard methods (AOAC, 2005), NDF, ADF and ADL – with the method of Van Soest et al. (1991). Silage samples were assayed for: pH – with the HI 8314 pH-meter, concentrations of lactic acid, acetic acid and butyric acid in water extract - by high-performance liquid chromatography (HPLC) with the Shimadzu system and a Varian Meta Carb 67H column, and the content of water-soluble carbohydrates - by the anthrone method (Thomas, 1977), protein nitrogen (N-protein) - with the use of trichloroacetic acid (TCA), and ammonia nitrogen (N-NH₂) – by the Conway method (Licitra et al., 1996). Amino acid nitrogen was calculated based on the number of free amino acids which were determined with the AAA 400 INGOS automatic amino acid analyzer (Czech Republic) with the use of a lithium column after deproteinization of TCA samples.

		0)	F	(
Item	*MS	GS	SS	Triticale	Rapeseed meal
Dry matter g·kg ⁻¹	324±0.96	271±0.95	198±0.89	875±1.12	878±1.05
Organic matter	964±2.12	905±2.31	901±1.56	956±1.25	921±1.58
Crude protein	88.5±1.32	132±1.39	174±1.62	122±1.21	386±1.32
NDF	336±5.32	540±4.32	429±5.12	172±1.36	298±1.98
ADF	194±1.32	317±1.69	315±2.03	42±0.68	212±0.84
ADL	12.4±0.65	26.7±0.62	31.5±0.85	-	_
NFC	503±3.25	199±3.29	278±4.12	634±4.31	237±4.36
pН	3.54±0.09	4.21±0.12	4.57±0.17		
Lactic acid	27.8±7.32	43.8±11.3	65.8±9.25		
Acetic acid	6.3±1.32	12.6±2.62	20.3±2.98		
Butyric acid	0.08 ± 0.03	0.09 ± 0.03	4.4±0.56		
N-NH ₃ (g kg ⁻¹ TN)	33.6±11.4	75.6±14.3	105±15.2		
UFV	0.85 ± 0.02	0.9 ± 0.02	0.80 ± 0.03	1.18 ± 0.01	1.05 ± 0.02
PDIN	50±0.44	86±0.89	124±1.22	88±0.20	253±1.12
PDIE	68±0.63	74±1.02	86±1.02	108±0.25	160±0.55

Table 1. Chemical composition ($g \cdot kg^{-1}$ DM) of experimental diets (mean ± standard error)

*MS – maize silage; GS – grass silage; SS – Sida silage; NDF – neutral detergent fiber; ADF – acid detergent fiber; ADL – acid detergent lignin; NFC – non-fiber carbohydrate; NH₃-N – ammonia nitrogen; TN – total nitrogen; UFV – Meat Production Units; PDIN – protein digested in the small intestine depending on rumen degraded protein; PDIE – protein digested in the small intestine depending on rumen fermented organic matter.

Item	*GS	SS	SS+GS	SS+MS
Grass silage	60	-	30	_
Sida silage	_	60	30	30
Maize silage	-	_	-	30
Triticale grain	28	37	33	28
Rapeseed meal	9	_	4	9
Premix ¹	3	3	3	3
Dry matter (g·kg ⁻¹ FM)	344.7±0.98	287.4±0.88	324.8±1.02	345.3±1.08
In g/kg DM				
Organic matter	893.6±2.15	894.3±2.32	894.1±2.14	910.1±2.64
Crude protein	148.3±1.21	149.5±1.54	147.6±1.36	$148.0{\pm}1.24$
NDF ²	398.9±4.63	321.0±4.87	359.4±5.23	304.4±5.78
ADF ³	221.0±1.39	204.5±1.54	211.9±1.69	183.5±1.89
NFC ⁴	318.2±3.28	401.4±3.41	361.8±3.58	433.3±3.11
UFV	$0.90{\pm}0.01$	0.92 ± 0.04	0.91±0.03	0.92 ± 0.02
PDIN	99.0±0.91	106.9±1.04	102.1±1.25	99.6±1.08
PDIE	89.1±1.12	91.5±0.87	90.0±0.91	91±0.99

Table 2. Ingredients (% DM) and chemical composition of diets (mean ± standard error)

*GS - grass silage; SS - Sida silage; MS - maize silage.

¹Commercial mineral-vitamin premix for fattening cattle (code of product 7619; Cargill Poland Ltd., Warsaw, Poland) consisting of per kg: Ca, 235 g; Na, 79 g; P, 48 g; Mg, 28 g; Fe, 500 g; Mn, 2000 mg; Cu, 375 mg; Zn, 3750 mg; I, 50 mg; Co, 12.5 mg; Se, 12.50 mg; vitamin A, 250,000 IU; vitamin D₃, 50,000 IU; vitamin E, 1000 mg; dl-alpha-tocopherol, 909.10 mg; ²NDF – neutral detergent fiber; ³ADF – acid detergent fiber; ⁴NFC – non-fiber carbohydrate; UFV – Meat Production Units; PDIN – protein digested in the small intestine depending on rumen degraded protein; PDIE – protein digested in the small intestine depending on rumen fermented organic matter.

Carcass quality

At the end of the fattening period, the animals were transported to a meat processing plant where they were kept in individual boxes with access to water for 15 to 20 h. Experimental units were slaughtered in two different sessions (n=20 per session) in two consecutive weeks. The animals were weighed before and after slaughter with an accuracy of 0.5 kg. Slaughter and post-slaughter processing were carried out in accordance with Council Regulation (EC) No 1099/2009 of 24 September 2009 on the protection of animals at the time of slaughter. Carcass conformation and fat cover were evaluated based on the EUROP system criteria by a trained grader (Kien, 2004).

Chemical composition, physical and sensory properties of the *longissimus* thoracis muscle

The value of pH₄₈ was measured after 48 h of carcass chilling, in the longissimus thoracis (LT) muscle, between the 10th and 11th thoracic vertebrae with the use of a Double Pore combination electrode (Hamilton) and a pH 340i pH-meter with a TFK 150/E temperature sensor (WTW). During carcass dressing, LT samples were collected from right half-carcasses postmortem to evaluate beef quality. Meat samples weighing approx. 1300 g were packaged in polyamide/polyethylene vacuum bags and stored at an ambient temperature of around 4°C, under standard industrial conditions until 14th day. Meat color was evaluated based on the values of components L*, a*, b* in the CIE LAB (CIE, 1978) system, and the values of saturation index (C*) were calculated according to the formula $(a^2 + b^2)1/2$. Color space parameters L^{*}, a^{*} and b^{*} were measured three times by the reflectance method, using the MiniScan XE Plus device (HunterLab, Reston, USA), at different points over the muscle cross-section area. Color measurements were performed on meat samples stored for 30 min at 4°C, covered with foil permeable to O₂ and impermeable to H₂O. After color measurements, each meat sample was divided into portions: the one used to determine the proximate chemical composition, pH and water-holding capacity (approx. 300 g), the second portion used to evaluate cooking loss (approx. 300 g), the third portion was used to determine Warner-Bratzler shear force (WBSF, 350 g), and the fourth used to determine the sensory attributes of meat (approx. 350 g). Moisture content was determined using the oven drying method (dying at $103 \pm 2^{\circ}$ C to a constant weight, PN-ISO1442, 2000), crude protein content was determined by the Kjeldahl method (AOAC, 2006 b, No. 992.15), fat content was determined by the Soxhlet method (AOAC, 2006 a, No. 991.36), and the ash content was determined according to Standard PN-ISO 936 (2000). Water-holding capacity in raw meat was determined according Grau and Hamm (Van Oeckel et al., 1999) method. Measurements of pH were performed directly in ground meat using an FC 200 combination electrode and the HI 8314 pH-meter (Hanna Instruments Polska, Olsztyn, Poland). Before measurements, the device was calibrated using pH 7 and pH 4 buffers. Cooking loss was determined according to the method proposed by Honikel (1998): 80 g meat samples were weighed, packaged in plastic bags and placed in a water bath (Aquarius M/150Z, Aqua Lab, Warsaw, Poland) at a temperature of 80°C, and kept there for 1 h. The temperature was monitored continuously with an electronic thermometer integrated with the water bath device. Then the samples were cooled for 30 min under running water, dried and weighed again to determine their weight after cooking; the analysis was performed in triplicate. Cooking loss was calculated as the difference between sample weights before and after heat treatment. WBSF was determined in the 3.5 cm thick samples cooked under conditions described above. WBSF values (N) were measured using an Instron 5542 universal testing machine (Instron, Norwood, Mass., USA) equipped with a shear blade. Cylindrical core samples (1.27 cm in diameter, approx. 40 mm in length) were cut out with a cork borer in the direction of muscle fibers. Each sample was cut into 5 slices. The shear blade (V-shaped, with a triangular aperture of 60°) was applied perpendicularly to the fiber direction at a crosshead speed of 2 mm/s (Walsh et al., 2010). The test was performed at room temperature (approx. 18°C). The data were processed using Bluehill 3 software (Instron, Norwood, Mass., USA). The temperature of meat samples was around 10°C. The analyses were performed in triplicate.

The sensory attributes were determined in the samples (approx. 350 g) cooked in a 0.6% NaCl solution (meat to solution weight ratio of 1:2) at a temperature of 96°C (±2°C) until the temperature inside the sample reached 75°C. The analyses were performed immediately after cooking, in accordance with Standard PN-ISO 4121 (1998), by a five-person team with proven sensory sensitivity (ISO 8596, 1993), experienced in sensory analyses of meat. The team consisted of non-smokers. The team members were trained for three months (36 h in total). They have passed a sensory sensitivity test. Warm samples were cut into approximately 2 mm thick slices, coded with three-digit numbers and presented to the panelists randomly on white plates. The panelists scored each sample for color uniformity on the surface (1, not even; 9, uniform), aroma (1, imperceptible; 9, extremely intense), juiciness (1, extremely dry; 9, extremely juicy), tenderness (1, extremely tough; 9, extremely tender), taste (1, imperceptible; 9, extremely intense); overall acceptability (1, not acceptable; 9, highly acceptable). Water and bread were provided for cleansing the palate. The samples were presented to the panelists at room temperature (20°C), in fluorescent light. The panelists assessed 5 meat samples during each session; each panelist received coded samples in the same order, and each sample was tested by all panelists. In total, 8 sensory analysis sessions were carried out during which a maximum of 5 meat samples were assessed per session. Three samples were presented at the same time followed by an approximately 20 min interval before the evaluation of the next samples.

Statistical analysis

A statistical analysis of the results was conducted using Statistica 13.1 (StatSoft Inc., Tulsa, OK, USA) software. To examine the differences between mean values, excluding the results of a sensory analysis, one-way ANOVA for orthogonal designs was performed. The differences between treatment means were determined by Tukey's test. To analyze the results of a sensory analysis, non-parametric Scheirer–Ray–Hare tests were applied to evaluate the effects of two factors and compare several averages (Scheirer et al., 1976). The significance level was set at P<0.05 and at P<0.01.

Results

Daily gain and carcass traits

Silage type had no significant effect on body weight gain (BWG), feed intake and feed consumption per kg body weight gain (Table 3). However, the BWG of animals fed Sida silage combined with maize was 0.072 kg higher, compared with bulls receiving Sida silage. Bulls from the Sida silage group consumed the least feed (8.70 kg dry matter) and obtained the lowest BWG (1.079 kg). Bulls from different dietary treatments were slaughtered at a similar age and final body weight (BW) (Table 4). Different types of silage did not cause significant changes in hot carcass weight or dressing percentage. The carcass conformation score of the bulls fed Sida silage combined with maize was 14% higher than that of the bulls fed Sida silage (P<0.05). The SS+MS bulls had 39% higher carcass fat score compared with the SS bulls (P<0.05). The analyzed beef was characterized by normal pH₄₈ values ranging from 5.62 to 5.67 (Table 4).

Itom		Silag	e type	SEM	Divoluo			
Item	*GS	SS	SS+GS	SS+MS	SEM	i value		
Initial age (days)	509	516	512	515	10.38	0.956		
Initial BW ¹ (kg)	455	456	477	464	10.190	0.796		
Final BW (kg)	696	686	715	708	7.905	0.602		
Body weight gain (kg)	241	231	238	244	7.320	0.756		
Fattening period (days)	214	214	211	212	5.179	0.993		
Daily gain (kg)	1.126	1.079	1.129	1.151	0.026	0.365		
Feed intake (kg DM ²)	9.04	8.70	9.11	9.25	0.162	0.231		
DM/kg BWG (kg)	8.03	8.06	8.07	8.04	0.141	0.865		

Table 3. Fattening performance of bulls fed different types of silage

*GS - grass silage; SS - Sida silage; MS - maize silage.

¹BWG - body weight gain; ²DM - dry matter

Itom		Silag	SEM	D volue			
Itelli	*GS	SS	SS+GS	SS+MS	SEIVI	I -value	
Age at slaughter (days)	724	732	724	728	11.570	0.979	
Body weight before slaughter (kg)	638	634	652 661		8.429	0.544	
Hot carcass weight (kg)	358.6	353.1	366.5	372.2	5.277	0.450	
Dressing percentage (%)	56.03	55.63	56.22	56.31	0.134	0.294	
Conformation score ¹ (pts)	4.4 b	4.5 ab	4.9 ab	5.0 a	0.117	0.043	
Fatness score ² (pts)	5.3 ab	4.9 b	5.4 ab	6.8 a	0.261	0.027	
pH ₄₈	5.64	5.62	5.64	5.67	0.023	0.974	

Table 4. Carcass quality parameters of bulls

*GS - grass silage. SS - Sida silage. MS - maize silage; SEM: Standard error of the mean.

¹EUROP conformation was 15 for class E⁺ and 1 for class P⁻.

 $^2\text{EUROP}$ degree of fat cover was 15 for class 5+ and 1 for class 1-.

a, b, c - means with different letters within a row are significantly different (P<0.05).

				J P	-	
It can		Silage	GEM	D		
Item	*GS	SS	SS+GS	SS+MS	SEM	P-value
Chemical composition						
Fat (%)	2.01 b	2.44 b	2.83 ab	3.01a	0.170	0.037
Protein (%)	23.38	22.93	23.55	23.17	0.113	0.228
Moisture (%)	75.12a	74.71 ab	73.59 ab	73.45 b	0.231	0.016
Ash (%)	1.11	1.10	1.08	1.13	0.017	0.234
Physicochemical properties						
WBSF ¹ (N)	39.65 a	28.15 b	37.21 a	31.51 ab	1.910	0.046
Cooking loss (%)	39.35	31.15	32.28	28.95	13.546	0.530
Water-holding capacity (Grau and Hamm) (%)	28.13	28.34	27.03	29.79	0.824	0.735
pH after 14 days aging	5.63	5.61	5.61	5.62	0.020	0.184
L^2	31.64 b	38.24 ab	32.55 b	44.55 a	1.618	0.011
a ³	16.38	16.12	17.77	14.85	0.480	0.214
b^4	6.93	8.26	7.43	8.91	0.293	0.079
C ⁵	24.77 ABab	18.21 a	27.98 Ab	17.37 B	1.292	0.003

Table 5. Effect of silage type on meat quality parameters

*GS - grass silage. SS - Sida silage. MS - maize silage

 $^1WBSF-Warner-Bratzler\ shear\ force;\ ^2L-lightness,\ ^3a-redness,\ ^4b-yellowness,\ ^5C-saturation\ index$

a, b, c – means with different letters within a row are significantly different (P<0.05);

A, B, C – means with different letters within a row are significantly different (P<0.01).

Item	Type of silage (TS)				Sensory evaluation session (SES)		SEM	P-value		
	GS	SS	SS+GS	SS+MS	Ι	Π		TS	SES	TS×SES
Color uniformity	8.0 ab	7.3 b	8.5 a	7.4 b	7.8	7.8	0.153	0.000	0.900	0.732
Aroma	7.2 ab	6.7 b	7.5 a	7.1 ab	7.1	7.2	0.118	0.015	0.570	0.703
Juiciness	4.4	4.4	5.1	4.7	4.6	4.7	0.182	0.245	0.607	0.752
Tenderness	5.3	5.9	5.7	5.0	5.3	5.1	1.105	0.108	0.500	0.541
Taste	6.3 ABab	6.1 a	7.3 Ab	6.0 B	6.6	6.3	0.152	0.000	0.118	0.102
Overall acceptability	6.1 ab	5.7 a	6.7 b	5.7 a	6.1	6.0	0.141	0.011	0.596	0.598

Table 6. Sensory properties of meat

a, b, c – means with different letters within a row are significantly different (P<0.05);

A, B, C - means with different letters within a row are significantly different (P<0.01).

The chemical composition, physical traits and sensory properties of meat

The chemical composition of meat from bulls was affected by the type of silage (Table 5). The animals fed Sida silage combined with maize silage accumulated more (P<0.05) fat than the groups receiving grass silage and Sida silage. The moisture content of meat increased with decreasing fat content (P<0.05). The difference between groups GS and SS+MS reached 1.67% (P<0.05). The meat of bulls fed SS as sole forage was characterized by lower maximum cutting force compared with the GS and SS + GS bulls (P<0.05) (Table 5). The difference in WBSF values between groups GS and SS reached 41%. Silage type had no influence on cooking loss, water-holding capacity and pH after 14 days aging. Silage type analyzed in our study affected beef color. Meat from group SS+MS bulls was lighter in color (P<0.05) than meat from bulls in groups GS and SS+GS; it was also characterized by a lower contribution of yellowness (b) and, in consequence, lower color saturation (C*, P<0.01). The results of a sensory evaluation of beef are presented in Table 6. The type of silage affected the color (P<0.05), aroma (P<0.05), taste (P<0.01) and overall acceptability (P<0.05) of meat from bulls. The LT muscles of group SS+GS bulls had the most desirable color, aroma and taste, and received the highest total score in the sensory analysis.

Discussion

Daily gain and carcass traits

In the current study, Sida silage had a higher content of total protein and NFC, and lower NDF content than grass silage. Harvest delayed by 2 weeks contributed to an increase in NDF content and stem lignification (Kwiatkowski et al., 2014). Forage-based beef production systems in temperate climates rely mostly on maize and grass. Higher daily gains and shorter fattening periods can be expected when maize silage is used (Juniper et al., 2005), due to its higher starch content and digestibility compared with grass silage (Mayne and O'Kiely, 2005), making the latter system less competitive in terms of growth performance. In the current study, Sida silage, which is complementary to maize silage, did not significantly improve the performance of fattening bulls. Bartoň et al. (2007) reported that intensively fattened beef bulls fed alfalfa silage were characterized by lower average daily gain (by 0.319 kg) and lower feed efficiency (DM kg/kg weight gain) than those fed maize silage. In the cited study, the carcasses of bulls fed maize silage received a higher score for conformation and a lower score for fatness, in comparison with the carcasses of bulls fed alfalfa silage. As reviewed by Herd et al. (2004), several plausible mechanisms exist by which variation in the efficiency of nutrient use may be explained. One of them is the higher energy expenditure for depositing fat tissue compared with lean tissue. In our study, Sida silage contributed to reduced feed intake, but had no negative effect on feed efficiency (DM kg/kg weight gain). The carcasses of bulls fed Sida silage and maize silage received the highest average scores for conformation and fat cover. Feed efficiency in this group was comparable to that in the remaining groups, which could result from high nutrient digestibility. Higher carcass fatness is positively correlated with dressing percentage (Nogalski et al., 2014). In the present study, bulls fed Sida silage and maize silage achieved the highest dressing percentage and their meat contained the most fat. Beef quality is considerably affected by pH measured 48 h postmortem (Kołczak, 2008). In an earlier experiment (Nogalski and Kijak,

2001), high pH values typical of DFD (dark, firm and dry) meat were noted more frequently in the meat of dairy bulls and less frequently in dairy/beef crosses. In the current study (dairy bulls), the analyzed beef was characterized by normal pH_{48} . Adequate pre-slaughter conditions, in particular the fact that the animals were kept in the lairage in individual boxes with free access to water, could have contributed to optimal pH levels.

The chemical composition, physical traits and sensory properties of meat

In our experiment, Sida silage decreased the intramuscular fat (IMF) content of LT muscles, compared with the group fed maize silage and Sida silage. Bartoň et al. (2010) demonstrated that the IMF content of meat was lower in bulls fed alfalfa silage than in those fed maize silage. Similar effects produced by Sida silage and alfalfa silage could be due to their similar chemical composition, in particular high protein content. Our previous study (Fijałkowska et al., 2017) revealed that the high moisture content of ensiled herbage deteriorated the quality of Sida silage and insignificantly reduced its intake. Sida plants have thick stems and delicate leaves, which makes it difficult to wilt biomass before ensiling (Tarkowski, 2006) and improve fermentation conditions. In a previous study (Fijałkowska et al., 2017), Sida silage was characterized by similar organic matter content and NDF digestibility to alfalfa silage in the bud development stage. Sida silage had higher concentrations of the analyzed acids and ammonia nitrogen than grass silage (Fijałkowska et al., 2017). The WBSF of meat, which characterizes its tenderness, depends on the structure of two main protein components of a muscle, namely proteins of intramuscular connective tissue and myofibrillar proteins. Their activity is affected by muscle type and feeding regime (Modzelewska-Kapitula et al., 2018). Research has shown that animal nutrition plays an important role in the regulation of biological processes taking place in muscles such as muscle protein turnover (Andersen et al., 2005). The leaves of Sida hermaphrodita contain mucus-like substances, flavonoids and antioxidants (Borkowska and Styk, 2006). Sida silage can increase antioxidant defense mechanisms in the bulls' body and decrease the generation of reactive oxygen species (ROS). Archile-Contreras and Purslow (2011) demonstrated that ROS affect collagen turnover in bovine muscles and, consequently, meat tenderness. Archile-Contreras and Purslow (2011) also reported that ROS increased the activity of matrix metalloproteinase-2, responsible for collagen degradation, and reduced collagen synthesis by intramuscular fibroblasts in the muscles. The reduction in collagen synthesis led to a decrease in collagen solubility, thus decreasing WBSF. Based on WBSF values, Destefanis et al. (2008) classified beef as very tender (WBSF below 32.96 N), tender (WBSF from 32.96 N to 42.77 N), acceptably tender (WBSF from 42.87 N to 52.68 N), hard (WBSF from 52.78 N to 62.59 N) and very hard (WBSF above 62.59 N). According to the above classification, in the present experiment, bulls fed SS and SS+MS diets produced very tender LT muscles, whereas the same cuts from SS+GS and GS treatments were regarded as tender. In a study by de Oliveira Monteschio et al. (2017), the lowest WBSF values were noted in the LT muscles of heifers fed a diet supplemented with bioactive substances. In our study, Sida leaves, which contain mucus-like substances and flavonoids, could lower WBSF values in group

SS. Water holding capacity is a technological parameter which indicates the ability of meat to retain water in the tissue during storage and cooking. WHC is associated with meat pH. Postmortem lactic acid formation and the decrease in pH values reduce the ability of meat to hold water. In our study, pH value measured after 14 days of aging was not affected by the type of silage. Beef color is considered as the most important quality attribute that determines consumer purchasing decisions (Kołczak, 2008). In the present study, meat from group SS+MS bulls was lighter in color than meat from bulls in other groups, except bulls fed Sida silage. Our results corroborate the findings of Hoving-Bolink et al., (1999), who reported a beneficial influence of maize silage on the color lightness of beef. Consumer assessment of the eating quality of meat, in particular juiciness and flavor, is strongly positively correlated with its chemical composition (Nogalski et al., 2016). Intramuscular fat content is the key determinant of the sensory properties of meat (Purslow, 2005; Hocquette et al., 2010). It characterizes the amount of fat in skeletal muscles and appears in the form of fat isles (marbling) in selected beef cuts. Modzelewska-Kapitula et al. (2018) and Wheeler et al. (2005) observed a positive relationship between IMF content and the desirable sensory attributes of meat. In the present experiment, meat from SS+GS group bulls, which received the highest total score from panelists, had an average IMF content of 2.83%, i.e. 0.39% and 0.82% higher than the meat of bulls from groups SS and GS, respectively. Destefanis et al. (2008) also noted a close relationship between the sensory scores of beef and WBSF values. In our study, however, meat characterized by the most desirable sensory attributes (group SS+GS) did not have the lowest WBSF value. De Zawadzki et al. (2017) found that mate (with a high content of alkaloids, saponins and phenolic acids) extract added at 1.5% to the diet of bulls resulted in more tender meat that was more accepted by consumers. Also in our study, meat from SS group bulls was characterized by the lowest WBSF value and received the highest score for tenderness, whereas meat from SS+GS group bulls received the highest scores for color uniformity, aroma, taste and overall acceptability.

Conclusions

It was found that Sida silage can improve carcass and meat quality characteristics without any adverse effects on fattening performance when compared with bulls fed a control diet based on grass silage. Sida silage combined with maize silage improved carcass conformation and fat cover, whereas Sida silage combined with grass silage improved the sensory properties of beef.

Declaration of interest

The authors declare that there is no conflict of interest.

Ethics statement

The experimental procedure was approved by the Local Ethics Committee for Experiments with Animals in Olsztyn, Poland (approval no. 121/2010).

References

- Andersen H.J., Oksbjerg N., Young J.F., Therkildsen M. (2005). Feeding and meat quality A future approach. Meat Sci., 70: 543–554.
- AOAC (2005). Association of Official Analytical Chemists. Official Methods of Analysis. 18th ed., Arlington.
- AOAC (2006 a). Official method of analysis method 991.36. Fat (crude) in meat and meat products (18th ed.). Gaithersburg: Association of Analytical Communities.
- AOAC (2006 b). Official methods of analysis method 992.15. Proximate analysis and calculations crude protein meat and meat products including pet foods (17th ed.). Gaithersburg: Association of Analytical Communities.
- Archile-Contreras A.C., Purslow P.P. (2011). Oxidative stress may affect meat quality by interfering with collagen turnover by muscle fibroblasts. Food Res. Int., 2: 582–588.
- Bartoň L., Kudrna V., Bureš D., Zahradkova D., Teslik V. (2007). Performance and carcass quality of Czech Fleckvieh, Charolais and Charolais × Czech Fleckvieh bulls fed diets based on different types of silages. Czech. J. Anim. Sci., 52: 269–276.
- Bartoň L., Bureš D., Kudrna V. (2010). Meat quality and fatty acid profile of the *musculus longissimus lumborum* in Czech Fleckvieh, Charolais and Charolais × Czech Fleckvieh bulls fed different types of silages Czech. J. Anim. Sci., 55: 479–487.
- Borkowska H. (1994). Antinutritional factors in Sida leaves and roots. Biul. Nauk. Przem. Pasz., 3/4: 49–52.
- Borkowska H., Styk B. (2006). Sida hermaphrodita. Cultivation and use. AR Publisher, Lublin.
- B o r k o w s k a H., M o l a s R., K u p c z y k A. (2009). Virginia fanpetals (*Sida hermaphrodita* Rusby) cultivated on light soil; height of yield and biomass productivity. Pol. J. Environ. Stud., 18: 563–568.
- CIE (1978). Recommendations on uniform color spaces-color difference equations. Psychometric color terms. Supplement no. 2 to CIE publication no. 15 (E-1.3.1.) 1978, 1971/(TC-1-3). Paris: Commission Internationale de l'Éclairage.
- Council Regulation (EC) No 1099/2009 of 24 (September 2009). On the protection of animals at the time of killing. Official Journal of European Union L, 303: 1–30.
- De Oliveira Monteschio J., de Souza K.A., Pelaes Vital A.C., Guerrero A., Velandia Valero M., Barbosa Carvalho Kempinski E.M., Nunes Do Prado I. (2017). Clove and rosemary essential oils and encapsuled active principles (eugenol, thymol and vanillin blend) on meat quality of feedlot-finished heifers. Meat Sci., 130: 50–57.
- Destefanis G., Brugiapaglia A., Barge M.T., Dal Molin E. (2008). Relationship between beef consumer tenderness perception and Warner-Bratzler shear force. Meat Sci., 78: 53–156.
- De Zawadzki A., Arrivetti L.O.R., Vidal M.P., Catai J.R., Nassu R.T., Tullio R.R., Berndt A., Oliveira C.R., Ferreira A.G., Neves-Junior L.F., Colnago L.A., Skibsted L.H., Cardoso D.R. (2017). Mate extract as feed additive for improvement of beef quality. Food Res. Int., 99: 336–347.
- Fijałkowska M., Przemieniecki S.W., Kurowski T., Lipiński K., Nogalski Z., Purwin C. (2017). Ensiling suitability and microbiological quality of Virginia fanpetals biomass. Can. J. Anim. Sci., 97: 541–544.
- Franzaring J., Schmid I., Bäuerle L., Gensheimer G., Fangmeier A. (2014). Investigations on plant functional traits, epidermal structures and the ecophysiology of the novel bioenergy species *Sida hermaphrodita* Rusby and *Silphium perfoliatum* L. J. Appl. Bot. Food Qual., 87: 36–45.
- Herd R.M., Oddy V.H., Richardson E.C. (2004). Biological basis for variation in residual feed intake in beef cattle. 1. Review of potential mechanisms. Aust. J. Exp. Agr., 44: 423–430.
- Hocquette J.F., Gondret F., Baeza E., Medale F., Jurie C., Pethick D.W. (2010). Intramuscular fat content in meat-producing animals: development, genetic and nutritional control, and identification of putative markers. Animal, 4: 303–319.
- H o n i k e l K.O. (1998). Reference methods for the assessment of physical characteristics of meat. Meat Sci., 49: 447–457.
- Hoving-Bolink A.H., Hanekamp W.J.A., Walstra P. (1999). Effects of diet on carcass, meat and eating quality of once-bred Piemontese × Friesian heifers. Livest. Prod. Sci., 57: 267–272.

- ISO 8586 (1993). Sensory analysis; general guidance for the selection, training and monitoring of assessors part I: Selected assessors; part II: Experts. International Organization for Standardization, Geneva, Switzerland.
- Juniper D.T., Browne E.M., Fisher A.V., Bryant M.J., Nute G.R., Beever D.E. (2005). Intake, growth and meat quality of steers given diets based on varying proportions of maize silage and grass silage. Anim. Sci., 81: 159–170.
- K i e n S. (2004). The classification of carcasses of adult bovine animals in the EUROP. Meat and Fat Research Institute, Warsaw, Division in Poznań, Poland.
- Kołczak T. (2008). Beef quality. Zywn. Nauk. Technol. Ja., l: 1, 5-22.
- K o w a l s k i M.Z., K a ń s k i J. (1993). WINWAR ver. 1.30. Support software program for determining the nutritional value of animal feeds according to the IB-INRA system 1988. University of Agriculture in Kraków.
- Kwiatkowski J., Purwin C., Sienkiewicz S., Tworkowski J., Pysera B., Wierzbowska J., Graban Ł., Lajszner W., Wyżlic I., Krzebietke S., Żarczynski P. (2014). Conversion of waste from agri-food industry to biogas – a system approach. In: The Virginia fanpetals *Sida hermaphrodita* (L.) Rusby used as feedstock for an agricultural biogas plant. UWM Olsztyn, 37–62.
- Licitra G., Hernandez T.M., Van Soest P.J. (1996). Standardization of procedures for nitrogen fraction of ruminant feeds. Anim. Feed Sci. Tech., 57: 347–358.
- M a y n e C.S., O 'K i e l y P. (2005). An overview of silage production and utilisation in Ireland. Proc. 14th International Silage Conference, Belfast, Northern Ireland, 3.07.2005, pp. 19–34.
- Modzelewska-Kapitula M., Tkacz K., Nogalski Z., Karpinska-Tymoszczyk M., Draszanowska A., Pietrzak-Fiecko R., Purwin C., Lipinski K. (2018). Addition of herbal extracts to the Holstein-Friesian bulls' diet changes the quality of beef. Meat Sci., 145: 163–170.
- Nogalski Z., Kijak Z. (2001). Fattening performance and slaughter value of the offspring of Black and White cows and Welsh Black bulls. Czech J. Anim. Sci., 46: 68–73.
- Nogalski Z., Wielgosz-Groth Z., Purwin C., Nogalska A., Sobczuk-Szul M., Winarski R., Pogorzelska P. (2014). The effect of slaughter weight and fattening intensity on changes in carcass fatness in young Holstein-Friesian. Ital. J. Anim. Sci., 13: 66–72.
- Nogalski Z., Sobczuk-Szul M., Pogorzelska-Przybyłek P., Wielgosz-Groth Z., Purwin C., Modzelewska-Kapituła M. (2016). Comparison of slaughter value for oncecalved heifers and heifers of Polish Holstein-Friesian × Limousine crossbreds. Meat Sci., 117: 1–6.
- O'Sullivan A., O'Sullivan K., Galvin K., Moloney A.P., Troy D.J., Kerry J.P. (2002). Grass silage versus maize silage effects on retail packaged beef quality. J. Anim. Sci., 80: 1556–1563.
- PN-ISO4121 (1998). Sensory analysis Methodology Evaluation of 321 food products by methods using scales.
- PN-ISO1442 (2000). Meat and meat products. Determination of water content (reference method). Warsaw: Polish Committee for Standardization.
- PN-ISO936 (2000). Meat and meat products determination of total ash. Warsaw: Polish Committee for Standardization.
- Purslow P.P. (2005). Intramuscular connective tissue and its role in meat quality. Meat Sci., 70: 435–447.
- Scheirer J., Ray W.S., Hare N. (1976). The analysis of ranked data derived from completely randomized factorial designs. Biometrics, 32: 429–434.
- Tarkowski A. (2006). Nutritional and feed value of Sida (*Sida hermaphrodita* Rusby). Habilitation dissertation. Agricultural University in Lublin, 308: 1–81.
- Tarkowski A. (2008). The yield and chemical composition of milk of cows fed the ration with protein-fibrous-extruderate. J. Cent. Eur. Agr., 9: 645–650.
- T h o m a s T.A. (1977). An automated procedure for the determination of soluble carbohydrates in herbage. J. Sci. Food Agric., 28: 639–642.
- Tîţei V. (2015). Agro biological peculiarities and economical value of *Sida hermaphrodita* in Republic of Moldova. ProEnviroment, 8: 485–489.
- Van Oeckel M.J., Warnants N., Boucquee C.V. (1999). Comparison of different methods

for measuring water holding capacity and juiciness of pork versus on-line screening methods. Meat Sci., 51: 313–320.

- Van Soest P.J., Robertson J.B., Lewis B.A. (1991). Carbohydrate methodology, metabolism and nutritional implications in dairy cattle: Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci., 74: 3583–3597.
- Walsh H., Martins S., O'Neill E.E., Kerry J.P., Kenny T., Ward P. (2010). The effects of different cooking regimes on the cook yield and tenderness of non-injected and injection enhanced forequarter beef muscles. Meat Sci., 84: 444–448.
- Wheeler T.L., Cundiff L.V., Shackelford S.D., Koohmaraie M. (2005). Characterization of biological types of cattle (cycle VII): carcass, yield, and longissimus palatability traits. J. Anim. Sci., 83: 196–207.

Received: 9 V 2019 Accepted: 10 III 2020