Fattening performance of crossbred (Polish Holstein-Friesian × Hereford, Limousin or Charolais) bulls and steers offered high-wilted grass silage-based rations

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ABSTRACT

In Poland beef cattle are usually fed high-wilted grass silage offered *ad libitum* and supplemented with concentrate, whereas 'Limousin', 'Charolais' and 'Hereford' bulls are the most frequently crossed with dairy cows to produce beef hybrids. The aim of this study was to determine the fattening performance of hybrids produced by crossing 'Polish Holstein-Friesian' (PHF) cows with 'Hereford' (HH), 'Limousin' (LM) and 'Charolais' (CH) bulls, fed silage made from high-wilted grass and supplemented with a small amount of concentrate, depending on sire breed and category. The experimental materials comprised 24 bulls and 24 steers, including 8 PHF × HH, 8 PHF × LM and 8 PHF × CH crosses with initial body weight of approximately 300 kg in each group. The animals were fed grass silage with a DM content of 417 g kg^{-1}, supplemented with concentrate at 35 g DM kg^{-1} $W^{0.75}$, for 250 d. Steers were characterized by higher total DM intake per unit of metabolic body weight ($P < 0.05$): 92.8 *vs*. 87.0 g; 94.1 *vs*. 84.6 g; 88.6 *vs*. 87.0 g (PHF × HH; PHF × LM; PHF × CH, respectively) and bulls – by higher average carcass weight gains ($P < 0.01$): 700 *vs*. 631 g; 654 *vs*. 579 g; 633 *vs*. 574 g and carcass dressing percentage ($P < 0.01$): 60.0 *vs*. 56.4%; 60.2 *vs*. 58.9%; 60.2 *vs*. 56.6% (PHF × HH; PHF × LM; PHF × CH, respectively) and better ($P < 0.01$) silage DM, total DM, crude protein, and net energy utilization. Sire breed had no significant effect on the analyzed parameters of fattening performance but numerically PHF × HH crosses had the highest productivity parameters.

Key words: Breed, bulls, fattening performance, high-wilted grass silage, steers.

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INTRODUCTION

The lifting of milk quotas in the European Union has increased competition between dairy producers. As a result, many farms have converted from milk production to beef production by crossing dairy cows with beef bulls whose offspring are characterized by higher values of average daily gains, carcass dressing percentage, carcass lean content, feed efficiency and meat quality than dairy cattle (Kamieniecki et al., 2009; Pesonen et al., 2013a). The breed of beef sires used for crossing is the main determinant of performance parameters and carcass quality traits in crossbred calves (Simcic et al., 2009; Huuskonen et al., 2013). In Poland, 'Limousin', 'Charolais', and 'Hereford' bulls are most frequently crossed with dairy cows to produce beef hybrids (Nogalski et al., 2014). The above breeds are characterized by different growth rate and fattening ability. Cattle breeds used in breeding programs should be carefully selected to produce calves well adapted to environmental conditions, and to meet market demand (Albertí et al., 2008).

In Poland, mostly young bulls are fattened due to their higher average daily gains, carcass dressing percentage and feed efficiency, as compared with steers (Nogalski et al., 2013; 2014). However, growing consumer expectations for high-quality beef, even at high prices, have led to the increased popularity of meat from steers. Beef from steers owes its high sensory quality to a higher intramuscular fat content, in comparison with beef from young bulls (Nogalski et al., 2014). Due to their lower blood testosterone levels, steers are mild-tempered and less prone to stress, which is particularly important during the pre-slaughter period as it prevents the depletion of energy reserves required for decreasing muscle pH (Nogalski et al., 2013).

Due to the low profitability of cattle fattening in Poland, beef cattle are fed roughage exclusively or roughage-based diets supplemented with a small amount of concentrate. Maize silage is too expensive to be fed to cattle due to high costs of maize production, including expenses associated with disease and pest control and the use of specialist harvesting equipment (Purwin et al., 2010). In Poland, where grasslands have a high share of total land area and the growing season is relatively short, beef cattle are usually fed grass silage offered *ad libitum* and supplemented with concentrate up to 40% total DM intake (Nogalski et al., 2013). In most cases, silage is made from grass wilted to 40% DM and placed in bunker silos, which prevents secondary fermentation without the need to use expensive additives. However, it may also lead to non-uniform packing density and insufficient compaction of the forage in horizontal silos, excessive heating and feedout losses,

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thus decreasing the energy value of silage, protein quality and silage intake (Purwin et al., 2014a). Silage made from high-wilted grass is characterized by a lower rate of organic matter digestibility in comparison with silage made from unwilted grass. In the latter case, more intensive hydrolysis of structural carbohydrates is observed during the ensiling process (Purwin et al., 2009). In most studies investigating the fattening performance of 'Hereford', 'Limousin', and 'Charolais' cattle and their crosses, the animals were fed direct-cut grass silage or silage made from grass wilted to 30% DM (Huuskonen et al., 2007; Huuskonen, 2008; Pesonen et al., 2013a; 2013b). The existing knowledge could be expanded by analyzing the performance of dairy/beef crosses fed silage made from high-wilted grass and comparing the fattening ability of young bulls and steers.

The objective of this study was to determine the fattening performance of hybrids produced by crossing Polish 'Holstein-Friesian' cows with 'Hereford', 'Limousin', and 'Charolais' bulls, fed silage made from high-wilted grass and supplemented with a small amount of concentrate, depending on sire breed and category.

MATERIALS AND METHODS

Animals, feeds, housing and diets

A fattening trial was conducted at the Agricultural Experiment Station in Bałcyny (53°35' N, 19°51' E) in northeastern Poland. A 3×2 factorial design was used to study the effects of sire breed ('Hereford' HH, 'Limousine' LM, and 'Charolais' CH) and category (bulls and steers). The experimental materials comprised 24 bulls and 24 steers, including respectively eight hybrids produced by crossing Polish 'Holstein-Friesian' cows with 'Hereford' bulls (PHF × HH), eight with 'Limousin' bulls (PHF × LM) and eight with 'Charolais' bulls (PHF × CH).

Calves of known origin purchased at 2 or 3 wk of age were placed in a rearing facility. One half of the calves were castrated at purchase. Bloodless castration was carried out by looping an industrial rubber elastrator ring, in accordance with the generally accepted standards. The calves were fed milk replacer, hay and concentrate, followed by haylage. From 130 kg BW until the transfer to the fattening unit, the animals were fed grass silage *ad libitum*, which was also offered *ad libitum* during fattening, and concentrate at 2.5 kg animal^{-1} d^{-1}. Control fattening was started at approximately 300 kg BW, after a 30-d adaptation period in the fattening unit. After 250 d, animals were transported over a distance of 90 km to the abattoir. After 24 h fasting and weighing, they were slaughtered in accordance with industrial standards.

Over the entire fattening period, the animals received 35 g DM kg^{-1} W$^{0.75}$ concentrate in four portions per day, from a concentrate feeding station (Insentec, Marknesse, The Netherlands), and grass silage *ad libitum*. Silage intake was monitored individually using the Roughage Intake Control System (Insentec BV, Marknesse, The Netherlands). There were five animals per roughage feeding station on average. Silage was dosed from a self-propelled feed cart (Seko, Curtarolo, Italy) and delivered to feeding stations twice daily (at 08:00 and 16:00 h). The amount of concentrate offered to animals was adjusted at 14-d intervals, at control weighing before the morning feeding.

Experimental silage was produced in concrete horizontal silos, from first-cut grasses (*Lolium perenne* L., *Phleum pratense* L., *Festuca rubra* L., *Poa pratensis* L.) Adequate mineral fertilization was applied. Grass was mown at the ear formation stage, with a drum mower. Green forage was tedded once and it was wilted for 24 h under favorable weather conditions. Wilted green material was harvested using a precision chop forage harvester (7050, John Deere, Moline, Illinois, USA) and it was compacted in horizontal silos with a tractor (laden weight 7770 kg) in 0.5 m layers. Each silo was covered with a polyethylene sheet and weighted down. Silage was produced without additives.

Concentrated feed was composed of 77% triticale grain, 19% rapeseed meal, and 4% mineral-vitamin mix for beef cattle (Cargill, Warsaw, Poland) containing per kg: 235 g Ca, 79 g Na, 48 g P, 28 g Mg, 500 g Fe, 2000 mg Mn, 375 mg Cu, 3750 mg Zn, 50 mg I, 12.5 mg Co, 12.50 mg Se, 250 000 IU vitamin A, 50 000 IU vitamin D_3, 1000 mg vitamin E, 909 mg DL-alpha-tocopherol. Salt licks (Lisal M, LNB, Kiszkowo, Poland) were also offered to supplement minerals.

Procedures and chemical analysis

Silage samples were collected before fattening and once a month during fattening, and were stored at -25 ºC. Thawed samples were dried at 60 ºC in Binder dryers, and were ground in an ultra centrifugal mill (ZM 200, Retsch, Haan, Germany) to a 1 mm particle size. Concentrate samples were collected together with silage samples.

The proximate chemical composition, D-value and nutritional value of all feeds and concentrations of carboxylic acids, fractions of structural carbohydrates (neutral detergent fiber NDF, acid detergent fiber ADF, and acid detergent lignin ADL), water-soluble carbohydrates (WSC), pH, content of buffer-soluble N (BSN), protein N, acid detergent-insoluble N (ADIN), ammonium N of silages were determined by methods described by Purwin et al. (2010).

Feed conversion was expressed by silage (kg DM kg^{-1}), concentrate (kg DM kg^{-1}), total DM (kg kg^{-1}), net energy (UFV from the French "unité fourragère viande" = feed unit for meat, UFV kg^{-1}) and crude protein (g kg^{-1}) utilization per 1 kg live weight gain and 1 kg carcass weight gain.

Statistical analysis

Data were processed statistically using Statistica ver. 10.0 software (StatSoft, Tulsa, Oklahoma, USA). Within each category (bulls, steers), the animals were divided into three groups based on their breed: PHF × LM, PHF × CH, and PHF × HH. The effects of category and sire breed on fattening traits were determined by the least squares method using the formula:

$$Yijk = \mu + Ai + Bj + (AB)ij + eijk$$

where *Yijk* is the value of the analyzed parameter, μ is population mean, *Ai* is the effect of category (1, 2), *Bj* is the effect of breed (1, 2, 3), *(AB)ij* is the Category × Breed interaction, and *eijk* is random error.

RESULTS AND DISCUSSION

Feeds

The chemical composition and calculated net energy content of silage and concentrate, and the fermentation quality of silage are presented in Table 1. The chemical composition of concentrate remained unchanged throughout the experiment because the same batches of triticale and rapeseed meal were used for diet formulation. In comparison with the values reported by Manninen et al. (2011), silage produced in our experiment had a higher NDF content (by 100 to 150 g kg^{-1} DM) and a lower crude protein content (by 10 to15 g), but the noted values were typical of grass silages in Poland (Purwin et al., 2009). A high degree of grass wilting prior to ensiling eliminated secondary fermentation and had a restrictive effect on the fermentation process, as manifested by low concentrations of lactic acid, a high pH and a high proportion of WSC in silage (Purwin et al., 2010). The low D-value of silage resulted from high concentrations of NDF and ADIN, and limited fermentation. The energy value of experimental silage was below the INRA reference values (IB-INRA, 2009) for silages made from direct-cut and wilted grasses harvested at comparable growth stages. Experimental silage had a high protein nitrogen content, which is typical of wilted grass silages and points to rapid inhibition of protease activity during wilting (Purwin et al., 2014b). However, the content of ADIN, which is indigestible in the small intestine of ruminants was twofold higher in experimental silage than in wilted grass silages described in the literature, which is indicative of high temperatures during ensiling (Purwin et al., 2014b).

Performance

PHF × HH bulls and steers were characterized by the numerically highest final body weight and the highest total and daily live weight gains (Table 2). Sire breed had nonsignificant effect on the final body weight, feed intake, body weight gain or carcass dressing percentage of bulls and steers. Category significantly influenced silage intake and total feed intake per unit of metabolic body weight ($P < 0.05$), carcass dressing percentage and carcass weight gains ($P < 0.01$). Nonsignificant interactions were observed between sire breed and the category of animals. Bulls of all breed groups had numerically higher carcass dressing percentage than steers. In the group of steers PHF × LM crosses had numerically the highest carcass dressing percentage.

Feed conversion was not affected by sire breed, whereas category had a significant ($P < 0.01$) effect on silage intake, total feed intake, net energy intake and crude protein intake per kg live weight gain, and all parameters of feed efficiency per kg carcass weight gain (Table 3). Regardless of sire breed, silage intake and total feed intake per kg live weight gain and carcass weight gain were numerically higher in steers than in bulls. PHF × HH crossbreeds were characterized by numerically the lowest feed conversion. Dry matter intake per kilogram live weight gain was numerically lower in PHF × HH bulls than in PHF × LM and PHF × CH bulls (by 0.1 and 0.4 kg, respectively), and in PHF × HH steers than in PHF × CH and PHF × LM steers (by 0.2 and 1.0 kg, respectively).

Numerous studies investigating the growth potential of the three analyzed breeds have revealed that 'Charolais' and 'Hereford' cattle are characterized by the highest and lowest average daily gains, respectively (Albertí et al., 2008; Pesonen et al., 2013a). However, in our study sire breed had

Table 1. Chemical composition and nutritional value of feeds.

Signification	Silage	SEM	Triticale	Rapeseed meal	Concentrate	SEM
n	9		1	1	9	
Dry matter, g kg^{-1}	417	10.2	881	887	883	8.2
On DM basis, g kg^{-1}						
Organic matter	922	1.9	981	927	926	18.3
Crude protein	148	2.6	133	388	166	7.1
Neutral detergent fiber	571	7.9	193	310	198	7.9
Acid detergent fiber	356	6.8	44	228	72	5.8
Acid detergent lignin	49	2.2	13	108	–	–
D-value[1]	606	5.8	914	785	–	–
Water-soluble carbohydrates	62	7.0	–	–	–	–
Lactic acid	44	2.8	–	–	–	–
Acetic acid	10	1.4	–	–	–	–
Butyric acid	2	0.5	–	–	–	–
Total VFA[2]	12	1.2	–	–	–	–
pH	4.70	0.05	–	–	–	–
Nitrogen fractions, g kg^{-1} N-total						
Ammonia-N	60	5.5	–	–	–	–
Protein-N	557	13.4	–	–	–	–
Buffer-soluble-N	268	11.5	–	–	–	–
Acid detergent-insoluble-N	100	5.3	–	–	–	–
Net energy, UFV kg^{-1} DM	0.71	0.006	1.21	1.01	1.17	0.02

[1]Digestible organic matter in DM.
[2]Sum of formic acid, acetic acid, propionic "acid", butyric acid, isobutyric acid, and valeric acid.
SEM: Standard error of the mean, VFA: volatile fatty acids, UFV: from the French "unité fourragère viande" = feed unit for meat.

Table 2. Effect of sire breed and category on the fattening performance of crossbred bulls and steers.

	PHF × HH		PHF × LM		PHF × CH					
Specification	Bulls	Steers	Bulls	Steers	Bulls	Steers	SEM	B	C	I
Initial live weight, kg	305	300	297	297	291	300	2.1			
Final live weight, kg	597	580	569	543	554	554	6.5			
Daily intake										
Grass silage, kg DM	5.1	5.6	4.8	5.4	4.9	5.1	0.13			
Total, kg DM	8.5	8.9	8.0	8.7	8.1	8.3	0.14			
Net energy, UFV	8.0	8.3	7.5	8.1	7.6	7.8	0.12			
Crude protein, g	1324	1381	1248	1351	1261	1295	21.8			
Grass silage intake, g DM kg^{-1} W$^{0.75}$	51.7	58.1	50.5	58.2	52.2	53.9	1.32		*	
Total intake, g DM kg^{-1} W$^{0.75}$	87.0	92.8	84.6	94.1	87.0	88.6	1.30		*	
Live weight gain, kg	293	280	272	245	263	254	5.4			
Daily live weight gain, g	1170	1121	1087	982	1052	1015	21.7			
Carcass dressing percentage, %	60.0	56.4	60.2	58.9	60.2	56.6	0.41		**	
Carcass weight gain, g	700	631	654	579	633	574	12.8		**	

PHF × HH: Crossbred calves sired by Hereford bulls, PHF × LM: crossbred calves sired by Limousin bulls, PHF × CH: crossbred calves sired by Charolais bulls, SEM: standard error of the mean, B: sire breed, C: category, I: interaction, UFV: From the French “unité fourragère viande” = feed unit for meat.
*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

Table 3. Effect of sire breed and category on feed conversion in crossbred bulls and steers.

	PHF × HH		PHF × LM		PHF × CH					
Specification	Bulls	Steers	Bulls	Steers	Bulls	Steers	SEM	B	C	I
Feed conversion/kg live weight gain										
Silage, kg DM	4.3	5.0	4.4	5.6	4.6	5.0	0.12		**	
Concentrate, kg DM	3.0	3.0	3.0	3.4	3.1	3.3	0.06			
Total, kg DM	7.3	8.0	7.4	9.0	7.7	8.2	0.16		**	
Net energy, UFV	6.9	7.4	7.0	8.4	7.2	7.7	0.14		**	
Crude protein, g	1136	1244	1154	1397	1198	1278	24.6		**	
Feed conversion/kg carcass weight gain										
Silage, kg DM	7.3	8.9	7.4	9.5	7.7	8.8	0.23		**	
Concentrate, kg DM	5.0	5.3	5.0	5.8	5.1	5.7	0.10		**	
Total, kg DM	12.2	14.2	12.3	15.3	12.8	14.6	0.30		**	
Net energy, UFV	11.4	13.2	12.6	13.0	12.0	13.6	0.22		**	
Crude protein, g	1898	2204	1915	2374	1993	2260	45.5		**	

PHF × HH: Crossbred calves sired by Hereford bulls, PHF × LM: crossbred calves sired by Limousin bulls, PHF × CH: crossbred calves sired by Charolais bulls, SEM: standard error of the mean, B: sire breed, C: category, I: interaction, UFV: From the French “unité fourragère viande” = feed unit for meat.
*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

no impact on the growth rate of PHF × CH or PHF × HH crosses, and PHF × HH bulls and steers had numerically higher daily live weight and carcass weight gains than their continental counterparts.

Average daily gains recorded in PHF × LM bulls and steers in our study were lower than those reported by other Polish authors for cattle fed maize silage (Bilik et al., 2009). Average daily gains noted in PHF × CH bulls and steers in our experiment were comparable with that reported by Simcic et al. (2009) for Charolais crosses (1032 g d^{-1}). Purebred ‘Charolais’ bulls and steers were characterized by higher average daily gains of 1321 to 1557 g (Pesonen et al., 2013a). In presented study PHF × HH bulls and steers had the numerically highest average daily gains in all analyzed categories, which could suggest that ‘Hereford’ cattle are well adapted to fattening system based on grass silage and that under extensive feeding systems beef cattle can achieve high weight gains also when fed diets with a higher proportion of concentrates. High growth potential of ‘Hereford’ cattle was also demonstrated by Manninen et al. (2011) in whose study finishing ‘Hereford’ bulls fed grass silage with a high moisture content and D-value of 750 g kg^{-1}, supplemented with concentrate at 3.2 kg DM d^{-1}, were characterized by average daily gain of 1588 to 1808 g. However, carcass dressing percentage reported in the above study was 4 percentage points lower than in our experiment. In a study by Pesonen et al. (2013a), higher average daily gain was noted in purebred ‘Charolais’ bulls than in purebred ‘Hereford’ bulls (1476 g *vs*. 1300 g), but the D-value of the analyzed silage was 667 g kg^{-1} DM.

Nutrient intake per unit of metabolic body weight was lower in our study than in experiments performed by other authors (Keady et al., 2008; Manninen et al., 2011). Silage intake was limited by decreased digestibility and because excessive heating in the silo reduced the palatability and nutrient availability of silage (Krizsan and Randby, 2007).

The average daily live weight gains achieved by PHF × LM and PHF × CH crosses in our study were unsatisfactory, which suggests that the genetic potential of animals could not be fully realized in the applied dietary treatments. There is evidence that cattle of late maturing breeds are more responsive to protein level in the diet than early maturing breeds (Huuskonen, 2008). Pesonen et al. (2013b) reported crude protein intake of 1282 to 1491 g in young ‘Charolais’ bulls. In our experiment, crude protein intake by PHF × CH bulls and steers was 21 to 230 g lower, which resulted from relatively low silage intake and its low protein content. Additionally in our study, the BSN content of silage was nearly twofold lower than that noted in typical silages with a DM content lower than 300 g kg^{-1} (Huuskonen et al., 2007; Pesonen et al., 2013a; 2013b). Such proportions of N fractions in experimental grass silage point to lower availability of N compounds for the synthesis of bacterial proteins, and to lower digestibility of protein flowing into the intestine (Purwin et al., 2014b).

Crossbred bulls and steers were characterized by similar feed efficiency, which could result from similar DM intake and average daily gains. Nutrient intake per kilogram live weight gain was lower in PHF × HH crosses than in late-maturing breeds, which was probably affected by the low D-value of silage (Keady et al., 2008). Feed conversion per kilogram carcass weight noted in PHF × HH bulls was comparable with that reported for purebred HH bulls by Pesonen et al. (2013b), whereas feed conversion for 'Charolais' crosses was 20% higher. Protein intake from silage accounted for 56% to 60% of total protein intake. It appears that high protein conversion was due to the low quality of protein from high-wilted grass silage.

In comparison with steers, bulls were characterized by significantly higher final body weights, daily carcass weight gains and carcass dressing percentage, and significantly lower feed intake, which resulted from significantly higher feed efficiency. Bulls produce more muscle and deposit less fat than steers (Nogalski et al., 2014). The above differences were observed despite the fact that all animals were housed together in free-stalls, which probably led to greater energy losses in bulls due to mounting each other. The average daily live gains of bulls were lower than expected and lower than those reported by other researchers (Pesonen et al., 2013a), who analyzed feed rations with nutrient concentrations higher than in our study. Higher silage intake on a DM basis was observed in steers, particularly in PHF × LM and PHF × HH crosses, leading to higher energy and protein intake. In steers, higher energy and protein intake accompanied by a lower ability to synthesize protein contributed to a higher feed conversion ratio (FCR), and due a lower carcass dressing percentage, the differences per kilogram carcass weight gain increased to 16%, 24%, and 14% in PHF × HH, PHF × LM and PHF × CH crosses, respectively.

CONCLUSIONS

The results of this study indicate that sire breed had nonsignificant effect on the fattening performance of crossbred bulls and steers fed high-wilted grass silage produced in bunker silos. PHF × HH crosses had the highest productivity parameters. Bulls were characterized by better fattening performance than steers, and the greatest differences were found between PHF × LM crosses. Fattening based on high-wilted grass silage limited the growth potential of PHF × LM and PHF × CH crosses, which have high nutrient requirements.

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