WEIGHT GAIN OF HIGHLAND CATTLE DEPENDING ON THE SHARE OF PERENNIAL RYEGRASS (*LOLIUM PERENNE* L.) IN THE MEADOW SWARD*

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Abstract

The aim of this study was to determine the influence of the different proportion of perennial ryegrass (*Lolium perenne* L.) in the meadow sward on its fodder value and daily weight gain of Highland cattle. The research was carried out on meadow sward with natural undergrowth that was cultivated by sowing perennial ryegrass. When preparing the sward for sowing, around 40% of it was damaged with a rotary tiller. The sowing rate for perennial ryegrass seeds was varied and amounted to 5, 10 and 15 kg ha⁻¹. As a result, the following treatments of meadow sward were obtained and distinguished: semi-natural sward without sowing as the control, and three experimental treatments with approximately 18, 36 and 55% share of perennial ryegrass in the meadow sward. The animals were kept in a cowshed. In the nutritional part, the impact of feeding the obtained sward on the daily weight gain of Highland bulls and heifers was assessed. The obtained results showed higher gains in both bulls and heifers fed with sward from grasslands with a greater proportion of perennial ryegrass. The weight gain of the animals resulted from the nutrition, i.e. the quality of the feed obtained from the experimental objects. During the control fattening period, the bulls' average daily weight gain ranged from 649 g to 714 g, while for heifers 556 g to 598 g. Statistical significance ($P \leq 0.05$) in body weight gains in both bulls and heifers was shown already at 36% of perennial ryegrass in the meadow sward.

Key words: meadow sward, perennial ryegrass (*Lolium perenne*), nutritional value, daily weight gain, Highland cattle

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Grasses are the most important feeds in the nutrition of ruminants. The energy and nutrients contained in the sward of grasslands and the fodder resulting from their conservation can meet up to over 50% of demand for cattle and sheep production (Fanchone et al., 2013). One of the most valuable fodder grasses used in ruminants' nutrition is perennial ryegrass (*Lolium perenne* L.). Due to its high yield, palatability, digestibility and nutritional value, it is the most commonly used feed in cattle's nutrition in a temperate climate. However, perennial ryegrass has two significant disadvantages: unbalanced nutrient content in terms of crude protein (CP) and energy on the rumen level, and low dry matter consumption, especially by high-yielding dairy cows (Taweel et al., 2004). This grass is universally used for pastures, hay, silage, turfing and surface protection. It can be used in a wide range of soil and climatic conditions, and it is also grown in mixtures with legumes such as alfalfa and white and red clover.

Beef consumption in Poland is still relatively low, but the export of excellent quality beef is increasing. Fifteen breeds of beef cattle are in use – the largest percentage of the population is the Limousin breed, while in Europe the most popular meat breed is the Charolais breed. Recently, there has also been growing interest in the possibilities of producing high-quality beef using traditional breeds of cattle. The Highland cattle breed used for fattening in this experiment in Poland constitutes only 0.7% of the already very small beef cattle population. In Europe, this breed is kept mainly on extensive farms with difficult farming conditions. Mountain cattle are lighter, slower growing and less demanding in terms of feed than high-production beef cattle breeds (Przysucha et al., 2013 a; Pauler et al., 2019). Highland cattle's main breeding goal is to maintain good fertility, easy calving, and high vitality of the calves during the rearing period. Highland cattle are one of the smallest breeds of beef cattle, with the birth weight of calves being around 24 kg, with significant fluctuations from 17 to 45 kg. The studies also showed significant differentiation in weight at 210 d of age, ranging from 75 to 302 kg (average 161 kg) (Przysucha et al., 2013 b).

The goal in the feeding of fattening cattle is to ensure the rations provide coverage of the demand for nutrients of growing animals. The maximum of roughage fodder and relatively low concentrated feed consumption is very important. Studies show that improving the quality of feed through the appropriate plant species composition of sward can reduce the use of concentrates (Keady and Hanrahan, 2015) and balance the impact of low concentrate inputs on feed intake and digestibility (Ramos et al., 2009). The better the fodder's quality, the higher the animal intake and the less concentrated the feed intake (Keady and Hanrahan, 2015).

However, rational cattle nutrition based on grazing brings many challenges due to the seasonal availability of feed and the changing quality and nutritional value of the sward with the growth phase (Guyader et al., 2016). Poland, due to the fact that it has a large amount of grassland and the need to use it rationally, has significant opportunities in the traditional breeding of beef cattle (Jankowska-Huflejt, 2016). One of the breeds of beef cattle that is very resistant and undemanding to the conditions of maintenance in terms of housing, care and nutrition is the Highland cattle breed. Due to low nutritional requirements, the cattle of this breed are often used for grazing the so-called difficult areas and landscape maintenance on ecological and agri-

tourism farms. Although Highland cattle are low-productive, they have the potential to sustain and promote ecosystem services on species-rich, semi-natural grasslands (Pauler et al., 2019).

The aim of this study was to determine the influence of the differentiated share of perennial ryegrass (*Lolium perenne* L.) in the meadow sward on its fodder value and daily weight gain of Highland cattle.

Material and methods

Study site

The research was carried out on a farm (50°36'N, 19°54' E) located in the Śląskie Voivodeship, Jędrzejów district, Słupia commune. The experiment was established on a permanent meadow on brown rendzina soil (pH_{KCl} was 5.9), classified as class IIIa in terms of valuation. The soil's chemical properties were as follows: absorbable P – 2.3 mg, K – 7.1 mg and Mg – 3.8 mg 100⁻¹ g of soil.

Study design

The experiment was carried out in a permanent meadow dominated by cocksfoot (*Dactylis glomerata*) and red fescue (*Festuca rubra*). In smaller amounts were also found timothy (*Phleum pratense*) and common crest (*Cynosurus cristatus*). There were also 12 species of dicotyledons in the meadow sward, constituting 23% of the area coverage. The species composition of the meadow sward was determined by the Klapp method (Klapp, 1965).

In a part of the permanent meadow in the third decade of August 2018, the perennial ryegrass cultivar 'Gagat' was sown. This variety has been added to the National Register of Varieties since 12 March, 2007, and bred by DANKO Hodowla Roślin Sp. z o.o. (Choryń 27, PL-64-000 Kościan). The sown seeds' weight was varied in the sowing process and was equal to 5, 10 and 15 kg ha⁻¹. As a result, four treatments of meadow sward were obtained (A – control, without sowing and with undersowing, with a varied share of perennial ryegrass; B – sward managed by undersowing of perennial ryegrass with around 18% of perennial ryegrass; C – with around 36% of perennial ryegrass; and D – with around 55% share of perennial ryegrass). Each treatment had an area of 2 ha.

Nitrogen fertilisation (in the form of ammonium nitrate) was as follows: 50 kg ha⁻¹ for the first regrowth and 40 kg ha⁻¹ for subsequent regrowth. In all treatments, phosphorus fertilisation (in the form of enriched superphosphate) was applied once in spring in the amount of P, 52.8 kg ha⁻¹, and potassium (57% potassium salt) in two doses – for the first and third regrowth in the amount of K, 49.8 kg ha⁻¹.

During the study, the sward was mown and the forage was delivered to the cowshed, where the animals were kept in group pens. The vegetation samples for determining the content of basic components by the Weenden method (AOAC, 2005) were cut from an area of 1 m² before each grazing in four replications from each object (treatment of meadow sward). The samples were selected diagonally for each treatment of meadow sward. The following ingredients were labelled: dry matter,

crude ash, crude protein, crude fat, crude fibre, neutral detergent fibre (NDF), acid detergent fibre (ADF) and water-soluble carbohydrate (WSC).

The nutritional value of pasture sward was estimated in the INRA system using the WinRAR program, ver. 1.6. by DJG. For the valuation of green forage protein digested in the small intestine supplied by rumen-undegraded dietary protein, plus protein digested in the small intestine provided by microbial protein from rumen-fermented organic matter (PDIE) and rumen-degraded protein (PDIN), tabular coefficients of intestinal protein degradation were used. The meat production unit was also calculated (1820 kcal). The content of available phosphorus in the soil was determined by the colorimetric method according to PN-R-04023:1996, the available potassium content by the flame photometry method according to PN-R-04022:1996 + Az1:2002, and the available magnesium content by the flame atomic absorption method according to PN-R-04020:1994 + Az1:2004.

Animals

The feeding experiment was performed on 20 Highland bulls and 20 Highland heifers. At the beginning of this study, the bull calves weighed 182–204 kg, and the heifers: 158–163 kg. The animals were divided by the method of analogs according to the initial body weight into four groups. The fodder was meadow sward fed *ad libitum*. The housed cattle had water and a salt lick at their disposal. After two weeks of pre-feeding, the observations and weighing of the animals commenced. The animals were weighed every three weeks. The duration of the experiment was 90 days.

Statistical analysis

The normality of the distributions of dry matter, crude ash, crude protein, crude fat, crude fibre, NDF, ADF, WSC, UVF, PDIE and PDIN were tested using the Shapiro-Wilk normality test (Shapiro and Wilk, 1965). One-way analysis of variance (ANOVA) was carried out to determine the effects of the share of perennial ryegrass (*Lolium perenne* L.) in meadow sward on the variability of dry matter, crude ash, crude protein, crude fat, crude fibre, NDF, ADF, WSC, UVF, PDIN and PDIE as well as daily weight gain of the bulls and heifers. The mean values, standard deviations and coefficient of variation (V) of traits were calculated. Fisher's least significant difference (LSD) was calculated for individual traits and, on this basis, homogeneous groups were determined. The relationships between the observed traits were assessed based on Pearson's correlation. The effect of crude fat, ADF, WSC, UVF and PDIE values on daily weight gain of the Highland bulls and heifers was assessed by multiple regression analysis. All the analyses were conducted using the GenStat® 18th Edition statistical software package.

Results

The share of perennial ryegrass differed among the treatments. In the sward sown with 5 kg, ryegrass accounted for 18%, 10 kg – 36% and 15 kg – 55% of the yield. The analysis of variance for the 13 quantitative traits [dry matter ($F_{3,8} = 21.90$,

$P < 0.001$), crude ash ($F_{3,8} = 25.88$, $P < 0.001$), crude protein ($F_{3,8} = 31.00$, $P < 0.001$), crude fat ($F_{3,8} = 157.18$, $P < 0.001$), crude fibre ($F_{3,8} = 12.99$, $P = 0.002$), NDF ($F_{3,8} = 11.10$, $P = 0.003$), ADF ($F_{3,8} = 38.10$, $P < 0.001$), WSC ($F_{3,8} = 106.11$, $P < 0.001$), UVF ($F_{3,8} = 68.16$, $P < 0.001$), PDIN ($F_{3,8} = 39.53$, $P < 0.001$), PDIE ($F_{3,8} = 251.64$, $P < 0.001$), as well as daily weight gain of bulls ($F_{3,8} = 33.88$, $P < 0.001$) and heifers ($F_{3,8} = 15.96$, $P < 0.001$) confirmed the variability of the tested perennial ryegrass shares in meadow sward at a significance level $\alpha = 0.05$. Data of the determined nutrients in the meadow sward are presented in Table 1.

Table 1. Forage quality parameters (mean values and standard deviations) of the investigated meadow sward (N = 12)

Traits	Treatments of meadow sward				Coefficient of variation – V (%)
	A	B	C	D	
Chemical composition					
Dry matter (g·kg ⁻¹)	211.5 a ±5.19	198.7 b ±4.12	183.7 c ±4.30	182.9 c ±6.29	6.73
Crude ash on DM (g·kg ⁻¹)	91.59 c ±1.72	97.8 b ±1.92	101.9 a ±0.96	102.55 a ±2.05	4.86
Crude protein on DM (g·kg ⁻¹)	165.8 c ±3.12	172.5 c ±2.73	188.3 b ±6.38	198 a ±5.09	7.65
Crude fat on DM (g·kg ⁻¹)	25.17 c ±0.47	27.87 b ±0.52	28.18 b ±0.53	34.53 a ±0.65	12.50
Crude fibre on DM (g·kg ⁻¹)	264.4 a ±5.53	249.1 b ±5.65	247.8b c ±4.64	238.8 c ±4.49	4.22
NDF on DM (g·kg ⁻¹)	590.3 a ±11.10	580.6 a ±10.91	557.8 b ±10.49	546 b ±9.71	3.60
ADF on DM (g·kg ⁻¹)	344.1 a ±5.91	317.8 b ±5.97	308.6 b ±5.80	295 c ±5.55	6.13
WSC on DM (g·kg ⁻¹)	88.88 d ±1.44	92.64 c ±1.14	101.26 b ±0.80	103.93 a ±1.29	6.72
Nutritional value (in kg of DM)					
UVF	0.80 c ±0.01	0.84 b ±0.01	0.87 a ±0.01	0.88 a ±0.01	4.00
PDIN (g)	85.74 c ±0.85	94.5 b ±1.24	96.18 b ±1.64	100.18 a ±2.52	6.05
PDIE (g)	73.88 d ±0.98	79.39 c ±0.60	86.07 b ±0.65	88.91 a ±0.67	7.49

a, b – values with different letters in a row are significantly different ($P < 0.05$). A – control object with undergrowth without undersowing, sward developed by: sowing perennial ryegrass with around 18% (B), undersowing of perennial ryegrass with around 36% (C), and 55% (D) share of perennial ryegrass.

In the sward of treatment A (control, without undersowing of perennial ryegrass), a lower content of the basic components was observed. The total protein content ranged from 165.8 to 198.0 $\text{g} \cdot \text{kg}^{-1}$ dry matter (DM). In treatments with undersowing, the total protein content in green forage increased by 4, 14 and 19%, respectively. The content of crude fat in green forage ranged from 25.17 $\text{g} \cdot \text{kg}^{-1}$ DM (treatment A – control, without undersowing of perennial ryegrass) to 34.53 $\text{g} \cdot \text{kg}^{-1}$ DM (treatment D – with around 55% share of perennial ryegrass) – with 55% share of perennial ryegrass. The content of crude fibre in individual treatments of meadow sward ranged from 238.8 to 264.4 $\text{g} \cdot \text{kg}^{-1}$ DM, and it was the highest in the control treatment. With the increase in the share of perennial ryegrass in the forage fed, its content (crude fibre) decreased.

Table 2. Daily weight gain (g) ($\pm$ standard deviations) in a period of fattening of Highland bulls and heifers (N = 12)

Parameters	Groups		V (%)
	bulls	heifers	
Initial body weight (g)	193 $\pm$ 7.20	161 $\pm$ 6.40	12.78
Daily weight gain (g)			
A – control object with undergrowth without undersowing	648.8 c $\pm$ 8.80	555.9 c $\pm$ 7.78	10.90
B – sward developed by sowing perennial ryegrass with around 18% share of perennial ryegrass	672.1 b $\pm$ 9.17	571.2 b $\pm$ 7.57	11.47
C – sward developed by undersowing of perennial ryegrass with around 36% share of perennial ryegrass	702.3 a $\pm$ 7.16	584.0 ab $\pm$ 8.16	13.01
D – sward developed by undersowing of perennial ryegrass with around 55% share of perennial ryegrass	714.3 a $\pm$ 9.90	597.6 a $\pm$ 8.86	12.59
Average	684.4 $\pm$ 27.83	577.2 $\pm$ 18.27	12.02
V (%)	3.75	2.67	–

a, b – values with different letters in columns are significantly different ($P \leq 0.05$); V – coefficient of variation.

In terms of energy value expressed in UVF units, the tested feeds were not very diverse (coefficient of variation: $V = 4.0\%$) and contained from 0.80 (for treatment A – control, without undersowing of perennial ryegrass) to 0.88 UVF kg^{-1} DM (for treatment D – with around 55% share of perennial ryegrass). On the other hand, the mean protein value was significantly diversified and ranged from 85.74 (for treatment A – control, without undersowing of perennial ryegrass) to 100.18 (for treatment D – with around 55% share of perennial ryegrass) for PDIE ($V = 6.05\%$), as well as from 73.88 (for treatment A – control, without undersowing of perennial ryegrass) to 88.91 g kg^{-1} DM (for treatment D – with around 55% share of perennial ryegrass) for PDIN ($V = 7.49\%$). Compared with the control object, the protein value increased in green fodder in mixtures with around 18, 36 and 55% of perennial ryegrass by 10, 12 and 17% of PDIE and by 7, 16 and 20% of PDIN, respectively.

The average results from three months of the nutritional experiment concerning changes in daily weight gain in the period of fattening of the Highlander bulls and heifers are presented in Table 2. The bulls' gains varied and ranged from 649 to 714 g; the heifers had lower daily gains of 556–598 g. Also, in this group, a smaller differentiation between the nutritional treatments was shown (2.67%). When analysing the daily gains between bulls and heifers, a greater differentiation was found in the treatment where green forage was used with approximately 36% share of perennial ryegrass ($V = 13.01\%$). The obtained results showed significantly higher ($P \leq 0.05$) increments in young bulls grazed with sward with a higher share of perennial ryegrass.

The relationships between all pairs of the observed traits were statistically significant (Table 3). The content of fat, ADF and UVF had a directly proportional effect on the daily weight gain of the Highlander bulls and heifers, while the content of carbohydrates and PDIE was inversely proportional (Table 4). These five independent traits accounted for 98.3% and 98.8% of daily weight gain of the Highlander bulls and heifers variability, respectively (Table 4).

Table 3. Correlation coefficients between all pairs of 11 observed traits estimated on the basis of animals means for each of the treatments and each of the replications (N = 12) and tested by *t*-test

Trait	Dry matter	Crude ash	Crude protein	Crude fat	Crude fibre	NDF	ADF	WSC	UVF	PDIE
Crude ash	-0.84***									
Crude protein	-0.83***	0.86***								
Crude fat	-0.72**	0.77**	0.84***							
Crude fibre	0.82**	-0.71*	-0.79**	-0.77**						
NDF	0.85***	-0.68*	-0.87***	-0.73**	0.91***					
ADF	0.89***	-0.83***	-0.87***	-0.82**	0.98***	0.93***				
WSC	-0.94***	0.90***	0.93***	0.83***	-0.79**	-0.87***	-0.89***			
UVF	-0.94***	0.88***	0.89***	0.78**	-0.92***	-0.92***	-0.98***	0.94***		
PDIE	-0.82**	0.90***	0.82**	0.84***	-0.89***	-0.80**	-0.94***	0.85***	0.93***	
PDIN	-0.94***	0.90***	0.94***	0.83***	-0.88***	-0.92***	-0.96***	0.98***	0.99***	0.92***

p*<0.05; *p*<0.01; ****p*<0.001.

Table 4. Results of the multiple regression model: characteristics significantly affecting the daily weight gain (g) of Highland bulls and heifers, independently

Gender	Bulls		Heifers	
Source of variation	d.f.	mean squares	d.f.	mean squares
Model	5	1688.54***	5	729.771***
Residual	6	12.87	6	4.067
Total	11	774.54	11	333.933
Variate	Estimate of partial regression coefficients (Standardised estimation of partial regression coefficients)			
Constant		-2517**		-2292***
Crude fat		6.43**		7.55***
ADF		3.16**		3.004***
WSC		-2.84*		-4.534***
UVF		2752***		2667***
PDIE		-1.573*		-2.078**
Percentage variance accounted for		98.3		98.8
Standard error of observations		3.59		2.02

*P<0.05; **P<0.01; ***P<0.001.

Discussion

Due to its rapid response to nitrogen (N) fertilisation and its relatively high nutritional value, perennial ryegrass (*Lolium perenne* L.) is one of the main forages used in intensive dairy cattle farming in Northwest Europe. For many years, breeding work has been carried out to obtain new perennial ryegrass varieties and lines which are tested for the appropriate content of nutrients adapted to ruminants' needs (Hannaway et al., 1997; McDonald et al., 1995; Van Vuuren et al., 1991). Perennial ryegrass is an essential source of nutrients for ruminants; due to its high digestibility and palatability, it is the most frequently used grazing species (Delagarde et al., 2000).

The appropriate content of water-soluble protein and carbohydrate is very important in assessing the nutritional value of a feed. Protein is an essential nutrient and carbohydrates are a vital source of energy. Often, especially in sward at an early stage of maturity, the protein content may exceed the animal's requirements. The low carbohydrate content cannot compensate for the highly degradable protein. This imbalance causes large N losses in the rumen and low N utilisation by grazing animals (Rearte, 2005). The protein and carbohydrate content can be regulated to some extent by the appropriate regrowth time and date of the sward harvest, the amount of nitrogen fertilisation applied, and even the height of mowing (Hoekstra et al., 2007). Breeding works are also carried out to develop varieties of ryegrass with higher carbohydrate content. The use of these varieties as feed for ruminants has resulted in

an increase in animal production (Lee et al., 2001; Miller et al., 2001) and – which is very important from an environmental point of view – a reduction in urinary N excretion (Miller et al., 2001).

The mean initial body weight of the animals in the present experiment at 210 d of age was 193 kg for bulls and 161 kg for heifers. It was therefore in line with the reports of weight in this rearing period. According to the research by Przysucha et al. (2013 b), the average birth weight of calves has remained at a similar level in recent years, while the decrease in daily weight gain of calves (calves and bulls) during the rearing period with mothers, i.e. up to the age of 210 d, is alarming. In 2007, calves' average body weight at this age was 204 kg, and of bulls – 208 kg. In 2010, a decrease in daily weight gain was observed on d 210, which was probably caused by a decrease in the mother's milk production that could have a genetic basis (Przysucha et al., 2013 b).

The gains obtained in this experiment are consistent with the literature data, according to which the daily gains in the first year of life are 550 g for heifers and 650 g for bulls (Borys and Rozwadowska, 2010). Such values were obtained in the control treatment. On the other hand, in the experimental treatments of meadow sward, the highest gains – for both bulls and heifers – were obtained using sward with a 55% share of perennial ryegrass in the feed.

In a study by Berry et al. (2002), during pasturage of cattle on two alpine pastures lasting 77 and 127 days, the calf growth rate was similar, amounting to 0.69 kg day⁻¹. Only at the end of the season, between day 77 and day 127, was a slightly decreased weight gain of around 0.06 kg day⁻¹ found. In the second year of study, the average gain amounted to 0.73 kg day⁻¹. The calves' growth rates in the groups were practically linear with time, and the calves did not respond to differences in nutrient intake. These results confirm the breed's ability to gain weight even when the NDF feed's digestibility has dropped to 0.50 and when the N content has fallen to just 16.5 g kg⁻¹ DM mid-season. Thus, the Highland cattle breed's nutrient requirements can be covered all season long, regardless of how the pasturage is managed. The authors state that Highland cattle make poorer use of improved Alpine pasture than dairy cows. However, they utilise pastures of low nutritive quality under extensive management without loss of productivity.

Conclusions

Based on the analysis of the results of the research, it was found that the use of sowing seeds of ryegrass on permanent meadow sward improved the nutritional value of this sward. The animals fed with green fodder from undersowing sward were characterised by higher body weight gains. The obtained results showed higher gains in both bulls and heifers fed with undergrowth from plots with sward with a higher proportion of perennial ryegrass. During the control fattening period, the mean daily weight gain of bulls ranged from 649 g to 714 g, while for heifers, 556 g and 598.0 g, respectively. Statistical significance ($P < 0.05$) in weight gain in both bulls and heifers was demonstrated with a 36% share of perennial ryegrass in meadow sward.

Due to the potential benefits of sowing natural meadow sward with perennial ryegrass in the nutrition of Highland cattle, it would also be advisable to extend and update the research on the quality of the obtained livestock.

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