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The Kielanowski Institute of Animal Physiology and Nutrition, Polish Academy of Sciences, Jabłonna

Different *Festulolium* cultivars in lamb nutrition – feed value, growth performance, and meat quality

C. Purwin[1], P. Pogorzelska-Przybyłek[1,*], B. Stefańska[2], P. Żukowski[1], A. Winiarska-Mieczan[3] and S.J. Krzebietke[4]

[1] University of Warmia and Mazury in Olsztyn, Faculty of Animal Bioengineering, Department of Animal Nutrition, Feed Science and Cattle Breeding, 10-719 Olsztyn, Poland
[2] Poznań University of Life Sciences, Faculty of Agriculture, Horticulture and Bioengineering, Department of Grassland and Natural Landscape Sciences, 60-632 Poznań, Poland
[3] University of Life Sciences in Lublin, Institute of Animal Nutrition and Bromatology, Department of Bromatology and Food Physiology, 20-950 Lublin, Poland
[4] University of Warmia and Mazury in Olsztyn, Faculty of Agriculture and Forestry, Department of Agricultural and Environmental Chemistry, 10-719 Olsztyn, Poland

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* Corresponding author:
e-mail: paulina.pogorzelska@uwm.edu.pl

ABSTRACT. The efficacy of *Festulolium* in lamb nutrition remains insufficiently investigated, and the nutritional value of different hybrids has not yet been compared. This study evaluated the feed value of three *Festulolium* cultivars (Becva, Felopa, and Paulita) in fattening Berrichon du Cher ram lambs compared to hybrid ryegrass cv. Bakus. Herbage of the grass cultivars was harvested and ensiled, and fed to 24 lambs divided into four groups depending on the type of silage in the ration. The dry matter (DM) content of experimental silages was similar and exceeded 40%. Fibre fractions were found to be lowest in silage produced from *Festulolium* cv. Felopa, and highest in hybrid ryegrass cv. Bakus. Lambs fed cv. Felopa exhibited a tendency towards increased DM intake (1046.9 g/day), and were characterised by the highest daily weight gain. They also had the highest intramuscular fat content (4.49%) in the *longissimus lumborum* muscle. The feed value of hybrid ryegrass cv. Bakus and *Festulolium* was comparable. Felopa was superior to other cultivars in terms of nutrient intake, nutrient digestibility, dry organic matter digestibility, and its effect on lamb growth performance.

Introduction

The most valuable forage grasses in ruminant nutrition include species of the genera *Lolium* L. (ryegrass) and *Festuca* L. (fescue), as well as their hybrids, *Festulolium* spp., which have been increasingly used in recent years, particularly in Europe, including Scandinavian countries, UK, Germany, Czechia, and Poland (Rzeźnik and Goliński, 2013; Humphreys et al., 2014). The *Festulolium* genome combines numerous complementary traits of the parent species, such as high yields (*Lolium*) and resistance (*Festuca*), which contributes to its growing popularity. Ryegrasses are distinguished by high dry matter (DM) yields, fast regrowth rates, and high tolerance to frequent mowing and grazing. They contain high concentrations of total protein and water-soluble carbohydrates (WSC), making them highly suitable for silage production (Rzeźnik and Goliński, 2013). Due to their low concentrations of lignins, cellulose and haemicelullose, ryegrasses have the highest digestibility and palatability of all forage grasses. On the other hand, fescues, apart from high nutritional value, have well-developed root systems, increasing their drought and frost tolerance (Kozłowski et al., 2012; Kopecky et al., 2017).

Previous studies investigating the agronomic traits and feed value of *Festulolium* demonstrated its high resistance, notable yield potential, and excellent nutritional value characterised by high content of crude protein (CP) and WSC, along with low content of crude fibre (CF) (Østrem et al., 2013; Humphreys and Zwierzykowski, 2020; Boller et al., 2022). *Festulolium* roughage can be offered to cattle and sheep fresh, ensiled, or as hay, and in Poland, fattening lambs are usually fed hay or haylage complemented with oat or barley grain (Milewski et al., 2014). It should be noted that due to their young age, lambs are particularly sensitive to insufficient quality of roughage.

The efficacy of *Festulolium* in lamb nutrition remains unexplored, and the suitability of different hybrids as ruminant feeds has yet to be evaluated. Therefore, the present study was conducted to compare the feed value of three *Festulolium* cultivars (Becva, Felopa, and Paulita) in fattening Berrichon du Cher lambs, as they are most widely grown in Europe. The selected cultivars were analysed in relation to hybrid ryegrass cv. Bakus. Additionally, the quality of lamb meat was also assessed based on the intramuscular fat (IMF) content of the *longissimus lumborum* (LL) muscle and the IMF fatty acid profile.

Material and methods

Location

The silages used in the experiment were produced at the Experimental Station in Tomaszkowo (53°43'N, 20°24'E, University of Warmia and Mazury, Olsztyn, Poland). The fields are located in a temperate transitional climate zone where the mean annual temperature in the last five years ranged from 7.5 to 8 °C, with total precipitation averaging between 550 and 650 mm. The production trial was conducted at the Animal Research Laboratory within the Department of Animal Nutrition, Feed Science and Cattle Breeding, University of Warmia and Mazury in Olsztyn.

Experimental silages

The experimental silages were prepared from the first-harvest herbage of the following grasses (Table 1):

Table 1. Ingredients (% DM) and chemical composition of diets

Specification	Hybrid ryegrass cv. Bakus	*Festulolium*		
		cv. Becva	cv. Felopa	cv. Paulita
Ingredient				
silage from hybrid ryegrass cv. Bakus, % DM	60.0	–	–	–
silage from *Festulolium* cv. Becva, % DM	–	60.0	–	–
silage from *Festulolium* cv. Felopa, % DM	–	–	60.0	–
silage from *Festulolium* cv. Paulita, % DM	–	–	–	60.0
ground barley grain, % DM	35.0	35.0	35.0	35.0
soybean meal, % DM	5.0	5.0	5.0	5.0
premix, g/day/animal	20.0	20.0	20.0	20.0
Chemical composition				
DM, g/kg FM	596.7	598.0	600.4	596.2
g/kg DM				
OM	933.3	940.0	939.3	935.1
CP	142.0	142.6	139.6	143.8
NDF	447.3	438.9	428.1	439.5
ADF	257.9	268.7	241.1	254.4
NFC	324.0	338.4	351.6	331.8

DM – dry matter, ADF – acid detergent fibre, NDF – neutral detergent fibre, CF – crude fibre, CP – crude protein, FM – fresh matter, NFC – non-fibre carbohydrate, OM – organic matter; chemical composition of ground barley grain: DM 872 (g/kg FM), OM 956 (g/kg DM), CP 475 (g/kg DM), NDF 198 (g/kg DM), ADF 64 (g/kg DM), NFC 625 (g/kg DM); chemical composition of soybean meal: DM 886 (g/kg FM), OM 968 (g/kg DM), CP 125 (g/kg DM), NDF 86 (g/kg DM), ADF 38 (g/kg DM), NFC 375 (g/kg DM); premix contained per kg: g: calcium 200, sodium 60, total phosphorus 120, magnesium 65, ash soluble in HCl 72; mg: vit. E 1600, manganese oxide 3000, zinc oxide 2500, potassium iodide 50, sodium selenate 3, cobalt sulphate 15; IU: vit. A – 300000, vit. D_3 30000

- hybrid ryegrass cv. Bakus;
  and three *Festulolium* cultivars:
- Becva (*Festuca arudinacea* × *Lolium multiflorum*);
- Felopa (*Festuca pratensis* × *Lolium multiflorum*);
- Paulita (*Festuca pratensis* × *Lolium multiflorum*).

These grasses were in their second growing season. *Festulolium* seeds were sown in experimental plots of 544 m^2 (16 m × 34 m). The average seeding rate was 4.65 g seeds/m^2. Fertilizers (N, P and K) were applied before sowing (1.7, 4.0 and 7.2 g/m^2, respectively) and next year (2.0, 4.0 and 3.6 g/m^2, respectively). The grass was harvested using a John Deere 328A mower-conditioner (Deere & Company, Moline, IL, USA), at a height of 5 cm, between 10:00 and 14:00. After wilting for 24 h, the herbage was harvested using a Kverneland Vicon RV157 round baler (Kverneland Group, Ravenna, Italy). Six layers of plastic film were used to wrap the bales (30 µm × 750 mm) with a stationary bale wrapper (SIPMA Ltd., Białystok, Poland), with the time between baling and wrapping not exceeding 60 min. Subsequently, the experimental silages were chopped in a feed cart, transferred to 220 l polyethylene drums with ring clamps (Kaiser + Kraft Ltd., Warsaw, Poland), and compacted using a hydraulic press to a density of 250 kg DM/m^3 (Brenntag GmbH, Essen, Germany).

Animals and feeding management

The research did not require the approval of a local ethics committee. Nevertheless, throughout the study, the welfare of the animals was ensured in compliance with the Act of January 15, 2015 on the Protection of Animals Used for Scientific or Educational Purposes (2015). The experiment involved 24 young Berrichon du Cher rams, weaned at approx. 100 days of age. The lambs were divided into four groups of six animals each, and were provided with *ad libitum* access to experimental silages of hybrid ryegrass cv. Bakus, *Festulolium* cv. Becva, *Festulolium* cv. Felopa, and *Festulolium* cv. Paulita. The feed (total mixed ration, TMR) was served twice daily, at 7:00 and 17:00 (Table 3). The ration was composed (on a DM basis) of grass silage (60%), ground barley grain (35%), and soybean meal (5%) (Table 1). The animals also received a mineral-vitamin premix (Polfamix O-K; Trouw Nutrition Polska Ltd., Grodzisk Mazowiecki, Poland) at a dose of 20 g/animal/day. The ratio of roughage to concentrate was 60:40 (on a DM basis). The lambs had unrestricted access to water through automatic drinkers. The average initial body weight (BW) of animals in each group was as follows: hybrid ryegrass cv. Bakus – 33.61 kg, *Festulolium* cv. Becva – 32.46 kg, *Festulolium* cv. Felopa – 31.56 kg, *Festulolium* cv. Paulita – 32.38 kg. The lambs were reared for 50 days, including a 10-day adaptation period, in individual pens (2 × 3 m). The amount of administered and uneaten feed was recorded throughout the study. Feed intake was calculated as the difference between the weight of feed given to each animal and the weight of any feed left uneaten. The animals were housed under identical microclimatic conditions: mean temperature – 17 °C, relative humidity – 80%, natural daylight, expressed as a ratio of window area to floor area – 1:15. Following the experimental fattening, the lambs were transported to the Cattle Slaughterhouse in Biskupiec (53°86'N, 20°96'E, Zakład Uboju Bydła Biskupiec, Sp. z o. o., Biskupiec-Kolonia Trzecia, Poland) in a specialised vehicle equipped with forced ventilation, supplied by electric fans, and drinkers. The area per animal inside the vehicle exceeded 0.3 m^2 to ensure safe movement of lambs. The distance between the Animal Research Laboratory at the Department of Animal Nutrition, Feed Science and Cattle Breeding, University of Warmia and Mazury in Olsztyn, and the Slaughterhouse is 51.7 km. Before slaughter, the animals rested in lairage for 24 h, housed in individual pens with free water access. They were sacrificed in accordance with Council Regulation (EC) No. 1099/2009 of September 24, 2009 on the protection of animals at the time of slaughter (2009). After slaughter, the carcasses were divided into half-carcasses and chilled for 24 h at 4 °C. The weight of half-carcasses was measured using a linear weighing scale, to the nearest 0.5 kg, and the result was used to calculate the dressing percentage (hot carcass weight / live slaughter weight, %), and the total weight gain in BW during the experiment (initial BW, kg × dressing percentage, %).

Digestibility

The apparent digestibility of DM, organic matter (OM), CP, and neutral detergent fibre (NDF) in ram lambs was determined using a balance method. Faecal samples were collected into bags that were emptied twice daily, and any remaining feed was collected before each feeding. The amount of feed offered to the animals was recorded, and leftovers, urine and faeces were collected for five consecutive days. The apparent digestibility coefficients (ADC) of nutrients (DM, OM, CP, and NDF) were calculated using the following formula:

$$\text{ADC (\%)} = (\text{nutrient ingested, g / nutrient intake, g})\ 100\%.$$

The amount of nutrient ingested was determined by subtracting the amount of nutrient excreted in the feces from the total nutrient intake. Digestible nutrient intake (kg/day) was calculated for DM, OM, CP, and NDF based on daily nutrient intake and ADC values.

Feed sampling and analysis

Feed samples were collected and subjected to chemical analyses before the experiment (herbage sampled at harvest, and silages) and twice during the experiment (silages). Samples of feed and leftovers were stored at a temperature of −25 °C.

After thawing, a portion of the samples was dried at 55 °C in Binder dryers (Binder GmbH, Tuttlingen, Germany) and ground to a particle size of 1 mm using a mill (Retsch 200, Haan, Germany). Samples of feed and leftovers were then assayed to determine the content of basic nutrients using standard AOAC International methods (2016): DM – method 934.01, CP – method 976.05, crude ash – method 942.05; NDF, acid detergent fibre (ADF). Acid detergent lignin (ADL) and WSC contents were determined according to the methods described by Purwin et al. (2022) using an ANKOM 220 fiber analyzer (Ankom Tech. Corp., New York, USA), and the anthrone method using an EPOLL 20 BIO spectrophotometer (Poll Ltd., Warsaw, Poland), respectively. Silage samples were analysed to determine the following parameters: pH, measured using a P-411 pH-meter (Elmetron GP, Zabrze, Grzybowice, Poland); N-NH_3 level in the experimental silages was measured by direct distillation using a 2100 Kjeltec distillation unit (Foss Analytical A/S, Hillerod, Denmark). The concentrations of acetic acid, propionic acid, isobutyric acid, butyric acid, isovaleric acid, and valeric acid were determined by gas chromatography using a Varian 450 gas chromatograph equipped with a Varian CP-8410 autosampler (Varian Inc., Palo Alto, CA, USA), and a flame-ionisation detector (FID). Samples (1.0 µl) were separated on CP-FFAP capillary column (length – 25 m, inner diameter – 0.53 mm, film thickness – 1.0 µm), with helium as the carrier gas (flow rate – 5.0 ml/min), detector temperature of 260 °C, and injector temperature of 200 °C. The program parameters of the gas chromatography (GC) column were set as follows: 90 °C – 1.3 min; 105 °C, 25 °C /min – 1.6 min; 190 °C, 25 °C/min – 4.1 min, 200 °C, 25 °C /min – 5.6 min. The lactic acid content was determined according to the method described by Kostulak-Zielińska and Potkański (2001) and Gąsior (2002). Briefly, the aqueous extract from 50 g of silage was deproteinised with 24% metaphosphoric acid, followed by centrifugation at 13000 rpm for 7 min. The resulting supernatant was used to determine the contents of lactic acid and ethanol by high-performance liquid chromatography (HPLC) using a SHIMADZU chromatograph (SCHIMADZU, Kyoto, Japan) in a reversed-phase system on a METACARB 67H column (Varian Inc., Palo Alto, CA, USA), applying 0.002 M sulphuric acid solution as the mobile phase. Readings were taken using a UV-VVIS detector (at 210 nm). An external standard method (Fluka, Sigma-Aldrich Chemie GmbH, Schnelldorf, Germany) was used to determine the content of individual volatile fatty acids.

Faecal samples represented 10% of the daily faecal output of each animal. These samples were frozen, and upon completion of the experiment, thawed and mixed to prepare two bulk samples. Fresh samples were analysed for nitrogen content using the Kjeldahl method, AOAC International (2016) method 984.13. The remaining samples were dried at 135 °C for 2 h following initial drying at 60 °C for 24 h, then ground to pass through a 1 mm screen. The dried samples were analysed to determine the content of basic nutrients by standard AOAC International methods (2016): DM – method 934.01, CP – method 976.05, and NDF using a method described by Van Soest et al. (1991). The OM content was calculated as the difference between the DM content and crude ash after ash content determination using AOAC International (2016) method 923.03.

Meat sampling and analysis

Samples of the LL muscle were collected from the right side of each carcass (at the last rib) after chilling. Muscle tissue samples were transferred to polyethylene bags, and transported to the Animal Research Laboratory at the Department of Animal Nutrition, Feed Science and Cattle Breeding, University of Warmia and Mazury in Olsztyn, in isothermal containers on ice, and subsequently frozen until analysis (approx. 7 days). The proximate chemical composition of meat was determined using standard methods (AOAC International, 2016). Fat was extracted from meat samples using the Soxhlet method (PN-ISO 6492, 2005). To determine fatty acid composition, fatty acid methyl esters were prepared using a modified Peisker method (methanol, chloroform, concentrated and sulphuric acid mixture, 100:100:1 v/v/v). Fatty acids were separated and identified by gas chromatography using a Varian CP-3800 gas chromatograph (Varian Inc, Palo Alto, CA, USA) and FID. Samples (1 µl) were injected into a Select ™ FAME Varian capillary column (length – 100 m, inner diameter – 0.25 mm) with a Hamilton syringe and a CP-8410 autosampler (Varian Inc, Palo Alto, CA, USA). Helium was used as the carrier gas (flow rate – 1.2 ml/min), and injector temperature was 260 °C. The total time of a single analysis was 68 min. Fatty acids were divided into the following groups: saturated fatty acids (SFAs), unsaturated fatty acids (UFAs) including monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs), as well as n-3 PUFAs and n-6 PUFAs. The following ratios were calculated: MUFA/SFA, PUFA/SFA and n-6/n-3 PUFA.

The values of the index of atherogenicity (IA) and the index of thrombogenicity (IT) were calculated using the formulas proposed by Ulbricht and Soutgate (1991):

$$IA = (C12:0 + 4*C14:0 + C16:0) / (n\text{-}3\ PUFA + n\text{-}6\ PUFA + MUFA),$$

$$IT = (C14:0 + C16:0 + C18:0) / (0.5*MUFA + 0.5*n\text{-}6\ PUFA + 3*n\text{-}3\ PUFA + n\text{-}3\ PUFA/n\text{-}6\ PUFA).$$

Statistical analysis

The results were statistically processed by analysis of variance (ANOVA) for factorial designs. The significance of differences between group means was determined by Duncan's test. All calculations were performed using Statistica 9.0 software (StatSoft).

Results

Chemical feed composition

The chemical composition of herbage is presented in Table 2. No significant differences were found in the chemical composition of the grasses, except for the ADL content. *Festulolium* herbage was characterised by a lower lignin content than ryegrass herbage, and cv. Felopa contained even less lignin than the other *Festulolium* hybrids. Despite the absence of significant differences, the herbage of all *Festulolium* hybrids displayed lower content of NDF and ADF, along with considerably higher WSC content compared to ryegrass herbage. The content of NDF, ADF and WSC was similar in *Festulolium* cv. Felopa and *Festulolium* cv. Paulita. The content of CP and WSC was low in all herbage samples, especially in comparison to ryegrass herbage.

The DM content of experimental silages was similar and exceeded 40% (Table 3). The experimental silages differed in the content of NDF, ADF, WSC ($P < 0.01$), and ADL ($P < 0.05$). NDF, ADF, and ADL contents were lowest in silage from *Festulolium* cv. Felopa, while silage from hybrid ryegrass cv. Bakus the highest. Each silage had a different WSC content ($P \leq 0.01$). Fermentation parameters indicated rapid but varied rates of fermentation in the samples analysed. Differences were observed in pH and concentrations of lactic and butyric acids between silages prepared from individual grass cultivars ($P \leq 0.01$). N-NH_3 level, expressed as a percentage of total nitrogen, was lowest in silage from *Festulolium* cv. Felopa ($P \leq 0.01$).

Table 2. Chemical composition of herbage

Specification	Hybrid ryegrass cv.Bakus	*Festulolium*			SEM	*P*-value
		cv. Becva	cv. Felopa	cv. Paulita		
DM, g/kg FM	220.0	201.3	213.2	235.3	5.83	ns
Chemical composition, g/kg DM						
OM	922.8	930.3	922.7	929.7	4.16	ns
crude ash	77.2	69.7	77.3	70.3	4.16	ns
CP	125.9	119.7	121.3	117.2	6.5	ns
crude fat	17.6	18.4	24.6	22.5	1.42	ns
CF	250.3	231.7	227.4	229.3	6.37	ns
NDF	584.5	548.4	528.5	531.7	18.28	ns
ADF	374.1	362.6	325.4	308.0	13.89	ns
ADL	51.0^{A}	25.4^{B}	17.8^{B}	25.7^{B}	5.68	≤0.01
WSC	86.6	152.5	170.3	181.1	25.11	ns

DM – dry matter, FM – fresh matter, OM – organic matter, CP – crude protein, CF – crude fibre, NDF – neutral detergent fibre, ADF – acid detergent fibre, ADL – acid detergent lignin, WSC – water-soluble carbohydrates, SEM – standard error of the mean; ^{AB} – means with different superscripts in the same row are significantly different at $P \leq 0.01$, ns – not significant

Table 3. Chemical composition and fermentation products of experimental silages

Specification	Hybrid ryegrass cv. Bakus	*Festulolium*			SEM	*P*-value
		cv. Becva	cv. Felopa	cv. Paulita		
DM, g/kg FM	405.2	407.2	410.8	403.8	9.89	ns
Chemical composition, g/kg DM						
OM	910.8	921.8	921.2	914.3	9.80	ns
CP	130.0	131.2	125.6	133.1	1.77	ns
NDF	620.6^{A}	607.1^{a}	588.5^{Bb}	607.7^{a}	4.02	≤0.01
ADF	389.1^{a}	406.9^{Ab}	360.9^{B}	382.6^{A}	5.22	≤0.01
ADL	53.4^{a}	36.2^{ab}	29.4^{b}	37.6^{ab}	3.71	≤0.05
WSC	16.4^{B}	15.2^{B}	48.7^{Aa}	27.8^{b}	3.09	≤0.01
Fermentation products						
pH	4.63^{A}	4.38^{B}	4.41^{B}	4.40^{B}	0.03	≤0.01
lactic acid, g/kg DM	55.5^{b}	33.3^{Aab}	71.5^{ab}	108.8^{Ba}	10.23	≤0.01
acetic acid[1], g/kg DM	12.9	14.9	12.8	12.7	0.41	ns
butyric acid[2], g/kg DM	0.13^{Bb}	0.42^{A}	0.28^{Ba}	0.22^{Ba}	0.16	≤0.01
VFA[3], g/kg DM	0.23^{Ab}	0.52^{B}	0.36^{Aa}	0.33^{A}	0.16	≤0.01
N-NH_3, %/kg N	8.5^{A}	9.4^{A}	4.5^{BC}	7.6^{AC}	0.57	≤0.01

DM – dry matter, FM – fresh matter, OM – organic matter, CP – crude protein, NDF – neutral detergent fibre, ADF – acid detergent fibre, ADL – acid detergent lignin, WSC – water-soluble carbohydrates, N-NH_3 – ammonia nitrogen, SEM – standard error of the mean; [1] acetic acid and propionic acid; [2] butyric acid and isobutyric acid; [3] total volatile fatty acids: butyric acid, isobutyric acid, valeric acid, and isovaleric acid; ^{ab,ABC} – means with different superscripts in the same row are significantly different at $P \leq 0.05$ and $P \leq 0.01$, respectively, ns – not significant

Nutrient intake and silage digestibility

The average daily nutrient intake and the apparent digestibility of silages made from three *Festulolium* cultivars and hybrid ryegrass are presented in Table 4. The type of grass silage, offered with ground barley grain and soybean meal at a ratio of 60:35:5, had no significant effect on digestible nutrient intake. The latter parameter (g per kg DM feed), including digestible organic matter (DOM), CP, NDF, and net energy was highest in ram lambs fed cv. Felopa silage, albeit without significant differences compared to silages from the other grass cultivars. Additionally, a trend towards increased DM intake was also observed in lambs fed cv. Felopa silage (1046.9 g/day). This diet also had the highest ADC of DM, OM, CP, and NDF ($P \leq 0.01$). The ADC values of silage from *Festulolium* cv. Paulita were nearly as high, and considerably lower in silages from the other two grass cultivars. Consequently, the ADC values varied depending on the type of silage.

Table 4. Nutrient intake and apparent digestibility of diets containing silages made from hybrid ryegrass cv. Bakus and three *Festulolium* cultivars in growing lambs

Specification	Hybrid ryegrass cv. Bakus	*Festulolium*			SEM	*P*-value
		cv. Becva	cv. Felopa	cv. Paulita		
Intake, g/day						
DM	1001.2	959.2	1046.9	953.6	35.07	ns
OM	934.4	901.6	983.3	891.7	31.89	ns
CP	142.2	136.8	146.1	137.1	5.30	ns
NDF	447.8	421.0	448.2	419.1	15.59	ns
Apparent digestibility coefficient, %						
DM	67.57^{A}	69.52^{A}	80.29^{B}	76.64^{B}	1.37	≤0.01
OM	70.60^{A}	72.41^{A}	82.18^{B}	79.41^{B}	1.26	≤0.01
CP	87.85^{Aa}	87.37^{A}	91.87^{B}	90.47^{b}	0.54	≤0.01
NDF	63.19^{Aa}	66.56^{ab}	74.44^{aBb}	69.03^{b}	2.33	≤0.01
Digestible nutrient intake, g/day						
DOM	659.69	652.85	808.08	708.10	23.37	ns
digestible CP	124.92	119.52	134.22	124.03	4.80	ns
digestible NDF	282.96	280.22	333.64	289.30	12.63	ns

DM – dry matter, OM – organic matter, CP – crude protein, NDF – neutral detergent fibre, DOM – digestible organic matter, SEM – standard error of the mean; ^{ab,AB} – means with different superscripts in the same row are significantly different at $P \leq 0.05$ and $P \leq 0.01$, ns – not significant

Growth performance of ram lambs and intramuscular fat characteristics

The effect of silage-based diets on the growth performance of rams is presented in Table 5. During the 50-day experimental fattening period, lambs had a similar initial BW of 31.56–32.61 kg. Daily weight gain was highest in lambs fed silage from *Festulolium* cv. Felopa, and lowest in lambs fed cv. Becva silage ($P \leq 0.05$). Carcass dressing percentage was comparable in all groups (42.90–43.60%), and was not affected by live weight at slaughter.

Table 5. Effect of diets on lamb growth performance

Specification	Hybrid ryegrass cv. Bakus	*Festulolium*			SEM	*P*-value
		cv. Becva	cv. Felopa	cv. Paulita		
Initial BW, kg	33.61	32.46	31.56	32.38	1.14	ns
Final BW, kg	42.68^{a}	41.15^{b}	42.27^{ab}	41.70^{ab}	1.21	≤0.05
Daily weight gain, g	227^{ab}	217^{b}	268^{a}	233^{ab}	0.01	≤0.05
BW gain, kg	9.09^{b}	8.67^{b}	10.71^{a}	9.33^{ab}	0.17	≤0.05
Carcass weight, kg	18.59	17.73	18.29	18.19	0.47	ns
Carcass dressing percentage, %	43.48	42.90	43.22	43.60	0.39	ns
FCR, kg DM/kg BW	4.411	4.420	3.910	4.090	0.20	ns

BW – body weight, FCR – feed conversion ratio, DM – dry matter, SEM – standard error of the mean; ^{ab} – means with different superscripts in the same row are significantly different at $P \leq 0.01$, ns – not significant

Analysis of the IMF content of the LL muscle in lambs from different feeding groups (Table 6) revealed a difference of 1.39% between the highest and lowest values of this parameter. The IMF content in the LL muscle was higher in the group fed silage from *Festulolium* cv. Felopa (4.49%), while it was lower in the group receiving cv. Paulita silage ($P \leq 0.05$). The IMF content of the LL muscle was similar in lambs fed silages prepared from hybrid ryegrass cv. Bakus and *Festulolium* cv. Becva.

The analysis of fatty acid concentrations revealed that the content of arachidic acid ($C_{20:0}$) was the only parameter that differed between the groups of lambs fed silages from hybrid ryegrass cv. Bakus vs. *Festulolium* cvs. Becva and Paulita ($P \leq 0.05$).

Fatty acid groups and ratios that can be utilised to evaluate the nutritional value of lipids and health benefits of lamb meat are presented in Table 7. In all feeding groups, the proportion of SFAs in total fatty acids exceeded 50%. The percentage of SFAs was significantly higher in the IMF of lambs fed *Festulolium* cv. Felopa silage compared to those administered silage from *Festulolium* cv. Becva. The opposite trend was recorded for UFAs ($P \leq 0.05$). This distinction was further reflected in the variation in the UFA:SFA ratio between the aforementioned groups of animals

Table 6. Intramuscular fat content (%) and fatty acid composition of intramuscular fat in the *longissimus lumborum* muscle of young Berrichon du Cher rams, g/100 g fatty acids

Specification		Hybrid ryegrass cv. Bakus	*Festulolium*			SEM	*P*-value
			cv. Becva	cv. Felopa	cv. Paulita		
Intramuscular fat content		4.09	4.03	4.49[a]	3.10[b]	0.25	≤0.05
Saturated fatty acids	capric acid ($C_{10:0}$)	0.22	0.16	0.21	0.22	0.01	ns
	lauric acid ($C_{12:0}$)	0.35	0.30	0.33	0.40	0.02	ns
	myristic acid ($C_{14:0}$)	4.17	4.22	4.30	4.41	0.21	ns
	pentadecanoic acid ($C_{15:0}$)	0.65	0.57	0.63	0.59	0.02	ns
	palmitic acid ($C_{16:0}$)	25.99	26.71	27.07	26.92	0.28	ns
	margaric acid ($C_{17:0}$)	1.72	1.50	1.70	1.56	0.04	ns
	stearic acid ($C_{18:0}$)	19.44	17.86	20.03	19.41	0.45	ns
	arachidic acid ($C_{20:0}$)	0.19[a]	0.16[b]	0.17[ab]	0.16[b]	0.01	≤0.05
	behenic acid ($C_{22:0}$)	0.07	0.07	0.06	0.08	0.01	ns
Monounsaturated fatty acids	myristoleic acid ($C_{14:1}$)	0.18	0.17	0.15	0.15	0.01	ns
	palmitoleic acid ($C_{16:1}$)	2.10	2.16	2.05	2.05	0.05	ns
	margoleic acid ($C_{17:1}$)	1.18	1.12	1.14	1.10	0.03	ns
	oleic acid ($C_{18:1}$)	38.83	40.37	37.96	37.85	0.46	ns
	gadoleic acid ($C_{20:1}$)	0.12	0.11	0.11	0.11	0.00	ns
Polyunsaturated fatty acids	linoleic acid ($C_{18:2}$)	2.99	2.78	2.54	2.92	0.11	ns
	conjugated linoleic acid (CLA)	0.18	0.22	0.21	0.16	0.01	ns
	α-linolenic acid ($C_{18:3}$)	0.59	0.46	0.47	0.59	0.02	ns
	eicosadienoic acid ($C_{20:2}$)	0.03	0.04	0.03	0.04	0.00	ns
	arachidonic acid ($C_{20:4}$)	1.00	1.05	0.84	1.28	0.08	ns

SEM – standard error of the mean; [ab] – means with different superscripts in the same row are significantly different at $P \leq 0.05$, ns – not significant

Table 7. Fatty acid groups and ratios in intramuscular fat in the *longissimus lumborum* muscle of young Berrichon du Cher rams

Specification	Hybrid ryegrass cv. Bakus	*Festulolium*			SEM	*P*-value
		cv. Becva	cv. Felopa	cv. Paulita		
SFAs	52.80[ab]	51.55[b]	54.50[a]	53.75[ab]	0.64	≤0.05
UFAs	47.20[ab]	48.45[a]	45.50[b]	46.25[ab]	0.58	≤0.05
MUFAs	42.41	43.93	41.41	41.26	0.61	ns
PUFAs	4.79	4.52	4.09	4.99	0.19	ns
n-3 PUFAs	0.62	0.50	0.50	0.63	0.03	ns
n-6 PUFAs	4.18	4.05	3.59	4.36	0.18	ns
n-6/n-3 PUFA	6.96	8.17	7.10	6.96	0.25	ns
UFA:SFA	0.89[ab]	0.94[a]	0.83[b]	0.86[ab]	0.02	≤0.05
MUFA:SFA	0.80	0.85	0.76	0.77	0.02	ns
PUFA:SFA	0.09	0.09	0.07	0.09	0.01	ns
DFAs	65.44	66.32	65.52	65.66	0.48	ns
OFAs	33.36	33.69	34.48	34.34	0.46	ns
DFA:OFA	2.02	1.97	1.90	1.92	0.04	ns
IT	1.96[ab]	1.91[b]	2.13[a]	2.05[ab]	0.04	≤0.05
IA	0.91	0.91	0.98	0.97	0.03	ns

SFAs – saturated fatty acids, UFAs – unsaturated fatty acids (MUFAs + PUFAs), MUFAs – monounsaturated fatty acids, PUFAs – polyunsaturated fatty acids, DFAs – hypocholesterolaemic fatty acids, OFAs – hypercholesterolaemic fatty acids, IT – index of thrombogenicity, IA – index of atherogenicity, SEM – standard error of the mean; [ab] – means with different superscripts in the same row are significantly different at $P \leq 0.05$, ns – not significant

($P \leq 0.05$). In the present study, the PUFA/SFA ratio ranged from 0.07 to 0.09. The levels of hypocholesterolemic fatty acids (DFAs) and hypercholesterolemic fatty acids (OFAs) did not differ significantly between the groups. IA and IT analyses demonstrated a significant difference ($P \leq 0.05$) in the IT values between lambs fed silages made from *Festulolium* cv. Becva (1.91) and cv. Felopa (2.13). However, no significant differences in the IA values were observed between the groups of lambs fed silages prepared from the grass cultivars tested.

Discussion

Chemical feed composition

Delayed harvest due to adverse weather conditions could have negatively affected the chemical composition of all forages. This was evident in the high content of fibre fractions (528.5–584.5 g/kg DM), corresponding to maturity stages 3 (heading, 50% of inflorescences emerged) and 4 (anthesis, peduncle node visible) according to Østrem et al. (2014). The cited study has demonstrated that the maturity stage at harvest exerts a strong effect on

NDF content, which varies widely both intra- and inter-species. Another reason for the low WSC content could be the high dose of nitrogen fertiliser, which reduced the use of carbon chains for protein synthesis and the energy production required for nitrate reduction preceding protein synthesis.

The study grass cultivars were grown under identical weather conditions, they were cut and harvested at the same time, and received identical fertiliser rates. Therefore, it was possible to determine the influence of grass cultivar on the rate of herbage wilting. Ensiling induced an increase in the fractions of structural carbohydrates and CP compared to fresh herbage, potentially due to fermentation losses in WSC. According to Weiberg and Ashbel (2003), the WSC content of silage is determined by their content in herbage and the concentration of sugar used for fermentation, which in turn depends on the buffering capacity of the ensiled raw material, DM content, degree of crop compaction, and the addition of fermentation inhibitors or stimulants. In the present study, additives were not used, and all grasses were harvested using the same baler, therefore, the observed differences in WSC concentrations in experimental silages with similar DM content can be attributed to differences in the buffering capacity of the herbage (Purwin et al., 2015). The fermentation profile was optimal in all silages (Weissbach and Honig, 1992), but *Festulolium* silages were characterised by higher acidity compared to ryegrass silage. While butyric acid concentrations displayed significant differences, they were not indicative of secondary fermentation. The lowest N-NH_3 values as a percentage of total nitrogen in cv. Felopa silage ($P \leq 0.01$) indicated a low degree of amino acid degradation during fermentation.

Nutrient intake and silage digestibility

Silage intake is largely affected by the level of concentrate in the ration. In the current study, the level of concentrate was identical in all diets, making silage quality the primary determinant of feed intake by ram lambs. In lambs fed silage-based diets, DM intake (953.6–1046.9 g/day) was comparable to the high intake reported by Sobiech et al. (2015) (957.3 g/day), which was considered high. According to the latter authors, high nutrient digestibility was responsible for elevated feed intake on a DM basis. A similar DM intake (889–1019 g/day) was found in another study where sheep were fed diets based on high-moisture maize and triticale grain (Purwin et al., 2022). The ADC values varied depending on the type of silage. Diets based on *Festulolium* cv. Felopa silage contained the highest levels of ADC dry matter, OM, CP, and NDF ($P \leq 0.01$). The lignin content in cv. Felopa silage contributed to higher digestibility and intake. The amount of lignin content affects the digestibility and properties of NDF and OM. The ratio of lignin to NDF (L/NDF) in silage from *Festulolium* cv. Felopa was 4.9% compared to 6.0% in cv. Becva, 8.6% in cv. Bakus, and 6.2% in cv. Paulita. All values obtained in this study were highly satisfactory, with the parameters of cv. Felopa silage being most optimal. A lower NDF content in silage contributes to higher DM intake, higher dry OM digestibility, and lower energy losses due to chewing and digestion. These three factors collectively affect the supply of net energy (Mertens and Huhtanen, 2007). The diets fed to lambs can be arranged in the following descending order based on the ADC of nutrients: silage made from *Festulolium* cv. Felopa, silage made from *Festulolium* cv. Paulita, silage made from *Festulolium* cv. Becva, and silage made from hybrid ryegrass cv. Bakus.

The growth performance of ram lambs and intramuscular fat characteristics

The type of silage may significantly influence fattening performance and meat quality in lambs. The very high BW gain in the group of lambs receiving silage made from *Festulolium* cv. Felopa was due to its high nutrient digestibility (Table 4). This led to differences in body weight gain and final body weight. The carcass dressing percentages recorded in the current study were lower than those reported by Purwin et al. (2022) (46.11–49.43%) and Borowiec et al. (2011) (46.15–46.62%). A high dressing percentage was achieved in animals raised in intensive production systems fed high-moisture maize and triticale grain at 50 or 75% DM of the diet (Purwin et al., 2022) and dried or ensiled maize grain supplemented with concentrate and meadow hay (Borowiec et al., 2011). Despite the indicated trends, there were no statistically confirmed differences for FCR, but the values recorded were more desirable than those reported by Sobiech et al. (2015), i.e., 6.36 kg DM/kg BW. In the present study, the growth performance of lambs was highly satisfactory, which can be attributed to the proportion of concentrate (40%) in the diet.

The type of grass silage used in the current study had a significant effect on the IMF content of lamb meat, with the same level of concentrate in all diets.

The IMF content in meat was previously shown to be considerably lower in extensively fattened lambs (2.12–2.69%) (Zapletal et al., 2010), and in lambs fed red fescue silage (2.32%) (Milewski et al., 2014). Studies have demonstrated that the IMF content of meat is determined primarily by the feeding system and the roughage to concentrate ratio (Aurousseau et al., 2004; Diaz et al., 2005). In a production system, factors such as breed, BW, sex, and age of animals, as well as diet, housing and management affect the fatty acid profile of meat, which can also vary depending on the type of muscle and its fat content (Diaz et al., 2005). Higher IMF content is correlated with a quantitatively higher conjugated linoleic acid content as the latter is primarily deposited in triacylglycerols (Raes et al., 2004). This relationship was not confirmed by the results of the current study. De Smet et al. (2004) demonstrated that the concentrations of SFAs and MUFAs increased faster with increasing fat levels than the PUFA content. In the conducted studies carcass fat content was not negatively correlated with the proportion of PUFAs in lambs. Diaz et al. (2005) observed a high positive correlation between the IMF content and SFA levels, which could be attributed to the relatively stable phospholipid content in lamb muscles. Phospholipids primarily contain PUFAs, whereas the proportion of neutral lipids composed mainly of SFAs and MUFAs increases with raising IMF content. Excessive intake of n-6 PUFAs may be associated with adverse health effects, therefore, the n-6/n-3 PUFA ratio should be lower than 4 (Wood et al., 2008). In the current study, the n-6/n-3 PUFA ratio was closest to the recommended value in the IMF of lambs fed silages prepared from *Festulolium* cv. Paulita and hybrid ryegrass cv. Bakus (6.96), which was due to the slightly higher proportion of n-3 PUFAs in total fatty acids in these groups. The values obtained in this experiment were considerably higher than those reported by Margetín et al. (2019) (2.94) in a study on the same breed of sheep (Berrichon du Cher). Previous research has shown that meat from pasture-raised lambs had significantly higher levels of n-3 PUFAs than meat from lambs fed a concentrate diet. Stall-feeding on grass silage and concentrate was shown to induce undesirable changes in the fatty acid composition of lamb meat (Elaffifi et al., 2016). The n-6:n-3 PUFA ratio of lamb meat can be reduced by supplementing the diet with oil products rich in omega-3 fatty acids (Margetín et al., 2019).

Conclusions

The *Festulolium* cultivars and hybrid ryegrass evaluated in this study exerted a similar influence on the growth performance of lambs. *Festulolium* cv. Felopa was superior to other cultivars, and diets based on silage prepared from this cultivar were characterised by the highest intake, digestibility, and dry organic matter digestibility.

The intramuscular fat (IMF) content of the *longissimus lumborum* muscle in Berrichon du Cher ram lambs was affected by the cultivar of forage grass fed as silage; however, it exerted no significant effect on the fatty acid profile of IMF.

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Conflict of interest

The Authors declare that there is no conflict of interest.

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