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The Impact of Rotational Pasture Management for Farm-Bred Fallow Deer (*Dama dama*) on Fodder Quality in the Context of Animal Welfare

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Abstract: Extensive breeding of farmed cervids, similarly to other livestock, affects the vegetation of grasslands in different seasons. For this reason, the impact of the rotational grazing of fallow deer on the chemical and species composition of the pasture sward was assessed, along with the possibility of using these animals for grasslands conservation. The species composition of the pastures was analysed through the botanical-weight method. A quality index and mineral concentration test by inductively coupled plasma mass spectrometry were used to evaluate the feed. The highest proportion of valuable grasses, such as *Dactylis glomerata*, *Poa pratensis* and *Lolium perenne*, was recorded in the summer pens (65.7–66.1%), while the smallest proportion was recorded in the control area (46.1%). The estimated yield potential was relatively large, from 5.74 to 7.02 t ha^{-1} dry matter. The lowest total protein content occurred in the control area in the spring and autumn. The summer pens, including the sown one, had a better fodder quality, depending on the species composition. All pens were characterised by a high production potential and similar floristic composition, without the participation of undesirable plant species, which confirms the hypothesis that, under extensive grazing conditions, fallow deer can be used for grassland conservation.

Keywords: grazing; ungulates; protein; summer pen; winter pen

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Citation: Kulik, M.; Tajchman, K.; Lipiec, A.; Bąkowski, M.; Ukalska-Jaruga, A.; Ceacero, F.; Pecio, M.; Steiner-Bogdaszewska, Ż. The Impact of Rotational Pasture Management for Farm-Bred Fallow Deer (*Dama dama*) on Fodder Quality in the Context of Animal Welfare. *Agronomy* **2023**, *13*, 1155. https://doi.org/10.3390/agronomy13041155

Academic Editor: Mohamed Abdalla

Received: 2 April 2023
Revised: 16 April 2023
Accepted: 17 April 2023
Published: 19 April 2023

1. Introduction

In the temperate zone of Central and Eastern Europe, animals use the available pastures in summer, usually choosing the most palatable vegetation that meets their nutritional needs. The consumption of aboveground biomass by large herbivorous mammals has a major impact on the vegetation cover and soil [1]. Through the selective intake of plants (consuming the tastiest species), they leave other species, that increase their coverage to form a slowly decomposing plant mass [2–7].

Many investigations have been dedicated to the positive effects of livestock grazing, i.e., sheep [8–11], cattle [11] and horses [8,10], in grasslands under various forms of protection. An important element was the use of extensive grazing with low stocking densities. In the 20th century, some cervid species, especially the red deer (*Cervus elaphus*), the European fallow deer (*Dama dama*) or the sika deer (*Cervus nippon*), became quite popular farm species [12]. These animals could also preserve grasslands, including valuable natural habitats. Meadows and pastures divided into quarters in a typical deer farm and an early start of the growing season meet the nutritional needs of these animals during spring and summer when grassland vegetation is the primary component of their diet [13,14]. Richardson et al. [15] demonstrated that perennial grasses are an important nutrient in the diets of cervids when the quantity and quality of other types of food are reduced. However, some plant species are consumed mainly because they are abundant in a particular area rather than because they are highly nutritious or highly valued [15]. It has been shown that summer pastures in New Zealand do not satisfy the crude protein needs of cervids [16], which means that the plant species occurring in the sward are inadequate. Studies of the vegetation cover of pastures for cervids in different parts of the world are still insufficient, and the missing data do not allow for the effective creation of estimated nutritional balances for these animals. For both sheep and cattle, the protein concentration in their diet should be between 14 and 18% [17], while for cervids, it should be at least 15% [18,19]. Grazing animals also interact with the area where they spend 24 h a day through their urine and faeces, which change the chemical composition of the plants growing there and the cycling of minerals such as nitrogen and carbon in the soil-plant system [20–24]. The effect of grazing farm-bred wild animals on vegetation species and chemical composition is also confirmed by studies conducted on reindeer belonging to the same family [25]. Grazing animals can also have a negative impact on vegetation and soil if grazed at the wrong time or in the wrong habitat. A key element for grassland protection is the appropriate stocking of livestock [26].

Cervids are animals with particular nutritional needs due to their high demand for protein and energy, but also for macro- and micronutrients during antler growth in males and pregnancy and lactation in females [27–34]. These physiological phases largely coincide with the time of pasture grazing in commercial breeding. Males develop antlers which grow rapidly and require a significant mineral transfer from the skeleton. In this respect, Ca and P, which make up the skeleton, play an important role [33]. During the animals' growth period, there is a very high demand for these nutrients, both in males developing antlers and in females feeding their young [27–29]. The first set of antlers can grow at an average rate of 1.95 ± 0.05 cm per week, peaking in week 14 [35]. The hind gives birth to her young in June/July and feeds them with milk, but later the young consume the available vegetation. The energy and protein supplied with this food are used primarily for the growth of young animals. However, it has been shown that the first stage of cervid nutrition can affect antler size and weight. Mothers' lactation influences calves for the first two years of life. The correlation between skeleton size and antler weight is one of the animals' longest-known allometric relationships. The growth rate and size of the first antlers developed by young males in the second year of life depend on the quality of food provided by their mothers and the habitat and ecological conditions provided to the mothers [27]. The first years of life usually impact the health and fitness of the animals in the subsequent years [36].

At extensive farms, deer breeding in the spring and summer relies only on the available pastures. In addition, licks, usually intended for cattle, are sometimes used as a mineral supplement in the diet of fallow deer. Chemical analyses of soils and vegetation indicate that the greatest mineral deficiencies occur in periods with low precipitation [37–39]. It was also found that mineral concentrations in vegetation fluctuate without a predictable trend [40]. Wilson and Grace [41] emphasise that mineral deficiencies in cervids usually occur in winter or summer. The "foraging" theory proposes that animals should be able to assess the nutrient content in the consumed food and adjust their diet to meet their current needs [42,43]. Herbivores, particularly those grazing on the rangelands, also have access to the leaves, bark and fruits of trees and shrubs, which also supplement their diet with nutrients. This is the case for wild animals, but farm-bred cervids do not have the mobility to search for suitable food. The proper supplementation of the cervid diet with minerals may prove beneficial in some cases, but it is most often recommended to provide a well-balanced feed for livestock [44].

The study objective was to: (1) assess the impact of rotational pasture management for farmed fallow deer (*Dama dama*) on the chemical and species composition of pasture forage; (2) confirm the hypothesis that, under extensive grazing conditions, fallow deer can be used for grassland conservation; and (3) assess the feed value of green forage in the context of animal welfare.

2. Materials and Methods

2.1. Study Area

The study was conducted at the Research Station of the Institute of Parasitology, Polish Academy of Sciences, Kosewo Górne (the Warmia and Mazury Region; Poland; N: 53°48′; E: 21°23′). The station was established in 1984 as an experimental state-owned farm (known in Poland by the acronym PGR) dedicated to cervid breeding research [14,45]. The facility is located in an area with a large proportion of forests (30.9%), the lowest population density in Poland, and clean air. Mean annual precipitation ranges from 500 to 634 mm, the mean temperature from 7.0 to 7.7 °C, and the growing season from 190 to 200 days [46].

The deer pastures were established in an area with homogeneous habitat conditions. In 1985, the area was fenced off, and pens were designated, while grazing commenced in 1986. Numerous herds of cervids belonging to the three species inhabiting Poland are kept in near-natural conditions at the facility. Herds of the three species graze separately in separate pens in near-natural conditions.

2.2. Experimental Design

The study was conducted on pastures for fallow deer (*Dama dama*), which are grazed in a rotational system in pens whose area and animal density are consistent with the recommendations by DEFRA [47], FEDFA [48], and Mattiello [49]. The grazing is extensive, and cervid breeding is described as organic.

The study involved four sites located in a homogeneous habitat but differing in their management since 1985: (1) a summer sown pen (SS)—grazed by fallow deer from April to November, sown with a pasture grass mixture Granum—FN Granum® in 2015; (2) a summer pen, not sown (S)—grazed by fallow deer from April to November; (3) a winter pen (W)—grazed by fallow deer from December to March; and (4) a control area (C)—adjacent to the farm, with similar habitat conditions, and no grazing (Table 1). The Granum mixture had the following ingredients: *Lolium perenne* 2N 20%, *Lolium perenne* 4N 15%, *Festuca rubra* 10%, *Festulolium braunii* 10%, *Dactylis glomerata* 8%, *Trifolium repens* 8%, *Festuca pratensis* 7%, *Lolium* × *hybridum* 4N 7%, *Phleum pratense* 5%, *Lolium multiflorum var. westerwoldicum* 4N 5%, *Lolium multiflorum* 4N 5%. From April to November, fallow deer consumed biomass in the first two pens, i.e., the summer sown pen (SS) and summer pen (S), while from December to March, they grazed in the winter pen (W) and were additionally fed with farm fodder described by Tajchman et al. [50]. In the grazing pens, nitrogen fertilisation of 68 kg N ha^{-1} of ammonium nitrate (34% nitrogen) is applied.

In the early spring of 2021, representative areas were designated and fenced off so that grazing fallow deer could not take up biomass in those areas. In 2021, fertilisation was not applied in these designated areas as they were used to obtain biomass samples to assess the biomass production potential and nutritional value. Vegetation samples were obtained from 1 m^2 plots in three replicates in each pen. For yield assessment, samples were taken on three dates in 2021 (1st regrowth—May; 2nd regrowth—July; 3rd regrowth—September) from the same plots on each date. Green mass samples were weighed on site, while the absolute dry matter yield was determined by drying the samples at 105 °C. The samples for chemical analysis were collected on two dates: in the spring (May) and autumn (September).

Table 1. Characteristics of the research objects.

Feature		Summer Sown Pen (SS)			Summer Pen (S)			Winter Pen (W)			Control Area (C)
		M	**SE**	**t**	**M**	**SE**	**t**	**M**	**SE**	**t**	
Area (ha)		9.15	-	-	4.5	-	-	9.5	-	-	9.0
Animal density (pcs ha^{-1})		12	-	-	2	-	-	12	-	-	-
Body mass of fallow deer (kg)	before grazing	64.5	4.68	−4.01, $p = 0.001$ *	29.5	4.85	−3.42, $p = 0.004$ *	31	5.23	2.13, $p = 0.049$ *	-
	after grazing	93.9	3.11		48.5	3.47		42	5.63		-
Weight gain (kg)		29.5	3.18	-	19	3.40		11	3.04	-	-
Number of grazing months		8 (April–November)	-	-	8 (April–November)	-	-	4 (December–March)	-	-	-
Area with trees (ha)		3.3	-	-	1.3	-	-	0.2	-	-	0.5
Tree species		Mainly *Betula pendula*, *Malus sylvestris*, *Malus domestica*, *Prunus domestica*, *Pinus sylvestris*									

M—mean, SE—standard error, t—Student test, * statistically significant values at $p < 0.05$.

The species composition was assessed in the spring using the botanical-weight method (fractional analysis). The names of vascular species are used according to Mirek et al. [51]. For the evaluation of the feed quality, the assessment of the grassland quality index (EGQ) proposed by Novák [52] with the forage value (FV) assigned to individual species was used. The scale of plant species' forage value ranges from −4 to 8, where −4 (death-causing), −3 (highly toxic), −1 (slightly toxic), 0 (deleterious), 1 (worthless), 2 (least valuable), 4 (less valuable), 6 (valuable), 7 (most valuable), and 8 (highly valuable).

2.3. Mineral Concentration Analysis in Plants

The concentration of minerals in the plants was determined with nitrogen acid digestion (0.5 g of sample of tissue, freeze-dried and ground in a mortar grinder) with the involvement of medium pressure (32 bars) microwave digestion system—Mars Xpress from CEM Corp., Matthews, NC, United States. The extracts were analysed by the inductively coupled plasma mass spectrometry technique (Agilent quadrupole 7500CE ICP-MS equipped with a torch, micro mist nebuliser, nickel sampler and skimmer cones, and double pass spray chamber). Argon was used as a carrier gas, and hydrogen and helium as reaction gases for the elimination of interferences. To minimise the matrix effect and ensure long-term stability, all determinations were made in the presence of an internal standard consisting of 1 mg L^{-1} of 45Sc, 89Y and 159Tb. A blank sample and certified reference material (CRM028-050) were included in the analyses for quality control. The recovery for trace elements analysed was from 90 to 97%, while the precision of the method defined as a relative standard deviation (RSD) was <3%. The LOD values were determined from 0.007 mg kg^{-1} to 0.099 mg kg^{-1}.

Chemical analyses for dry matter, crude ash, crude fat, crude protein, crude fibre, and nitrogen-free extracts (NFE) were conducted according to AOAC methods [53].

2.4. Animal Weight Measurement

Hinds (aged 3–8 years) with fawns were present within the summer pens, but only hinds at the winter pen were studied because fawns spend the first winter in a shed. For the results to be comparable, the research was carried out on all plots for one year. Therefore, the groups of animals staying on these pastures were different. For the analyses, the SS pen was selected, where animals usually achieved mean high weight gains (29.5 kg); the S pen, where fallow deer, despite lower density, achieved the smallest weight gains (19 kg); and the W pen, where animal weight gains (11 kg) were observed, depending on winter nutrition (Table 1).

The body weight of the animals was measured before summer grazing (April) and afterwards (November), i.e., before the winter period. The animals stayed in a handling box (2 m × 2 m × 0.6 m), physically immobilised, with no need of sedation. The measurement was carried out using the MP 800 sensor kit coupled with the Tru-Test DR 3000 LNB weight reader (manufacturer: Tru-Test Group, Auckland, New Zealand). According to the manufacturer's declaration, the accuracy of this kit was ±1%, with a minimum resolution of 100 g.

2.5. Statistical Analysis

The values are presented as a mean value and standard error in the case of measurable parameters and as cardinality and percentage in the case of non-measurable variables. The normality of the distribution of variables in the analysed groups was verified with the Shapiro–Wilk test. The relationship between body weight before and after grazing was calculated using the Student's *t*-test. The differences between the four pasture pens were assessed using parametric tests (and the ANOVA analysis of variance). Tukey's RIR post-hoc test checked differences between individual pairs. A significance level of $p < 0.05$ was assumed, indicating statistically significant differences or correlations. The statistical analyses were conducted using the Statistica 9.1 software (StatSoft, Cracow, Poland).

3. Results

3.1. Species Composition vs. Grassland Quality

Three different pens differing in area, fallow deer stocking rate, and duration of grazing were included in the study, as well as a control area without grazing for comparison. Within each pen, there were trees (mainly *Betula pendula*, *Malus sylvestris*, *Malus domestica*, *Prunus domestica*, and *Pinus sylvestris*) which, in addition to serving as a shelter, provided a source of minerals in the form of fruit, bark and leaves. A significant increase in the body weight of animals was demonstrated between the dates before and after the grazing period on each pen ($p < 0.05$) (Table 1).

The pens also differed in the floristic composition of the herbaceous layer. Analysing the species composition in terms of forage value according to Novák [52], it should be noted that the highest proportion was represented by valuable grasses (FV = 7–8), among which *Dactylis glomerata*, *Poa pratensis* and *Lolium perenne* occurred most frequently. The greatest number of these grasses was recorded in the summer pen (65.7%) and the summer sown pen (66.1%), while the smallest number was recorded in the control area (46.1%). *Trifolium repens*, which occurred in plots grazed by fallow deer, was sub-dominant among leguminous plants. The control area had a low proportion of leguminous plants (0.9%) and a much greater proportion of herbs (16.1%) and weeds (22.5%). The winter pen also had a high proportion of weeds (27.1%) (Table 2).

Table 2. Grouped floristic composition depending on the analysed pens and control area (%).

Groups of Plant Species		Pens Summer (S)	Winter (W)	Summer Sown (SS)	Control Area (C)
Valuable grasses FV = 7–8	Mean	65.7	47.4	66.1	46.1
	Species *	*Poa pratensis, Dactylis glomerata, Alopecurus pratensis, Lolium perenne*	*Poa pratensis, Dactylis glomerata, Lolium perenne*	*Poa pratensis, Dactylis glomerata, Alopecurus pratensis, Lolium perenne, Festuca pratensis, Phleum pratense*	*Dactylis glomerata, Arrhenatherum elatius*
Other grasses FV ≤ 6	Mean	7.1	7.3	16.3	14.4
	Species *	*Festuca rubra*	*Festuca rubra*	*Avenula pubescens, Festuca rubra*	*Elymus repens, Festuca rubra*
Legumes FV = 7–8	Mean	8.1	11.2	8.3	0.9
	Species *	*Trifolium repens*	*Trifolium repens*	*Trifolium repens*	-
Sedges FV = 2	Mean	0.1	0	0.3	0
	Species *	-	-	-	-
Herbs FV = 4–6	Mean	9.6	7	4.7	16.1
	Species *	*Taraxacum officinale*	*Taraxacum officinale*	-	*Achillea millefolium*
Weeds FV ≤ 3	Mean	9.4	27.1	4.3	22.5
	Species *	*Urtica dioica*	*Geranium pusillum, Polygonum aviculare, Urtica dioica*	-	*Artemisia vulgaris, Chaerophyllum aromaticum*

* Species—subdominants with a share ≥5%.

The forage value of grasslands for fallow deer was assessed based on the forage numbers proposed by Novák [52]. Calculations showed that the forage value of the grazed pastures ranged between valuable and highly valuable (summer, winter and summer sown pens). In contrast, in the case of the control area, it ranged between less valuable and valuable. Significantly, the best fodder value was in the summer pens (S and SS), while the worst was found in the control area (C). The estimated yield potential was relatively large, ranging from 5.74 t ha^{-1} DM (winter pen) to 7.02 t ha^{-1} DM (control area), but it was not significantly different (Figure 1).

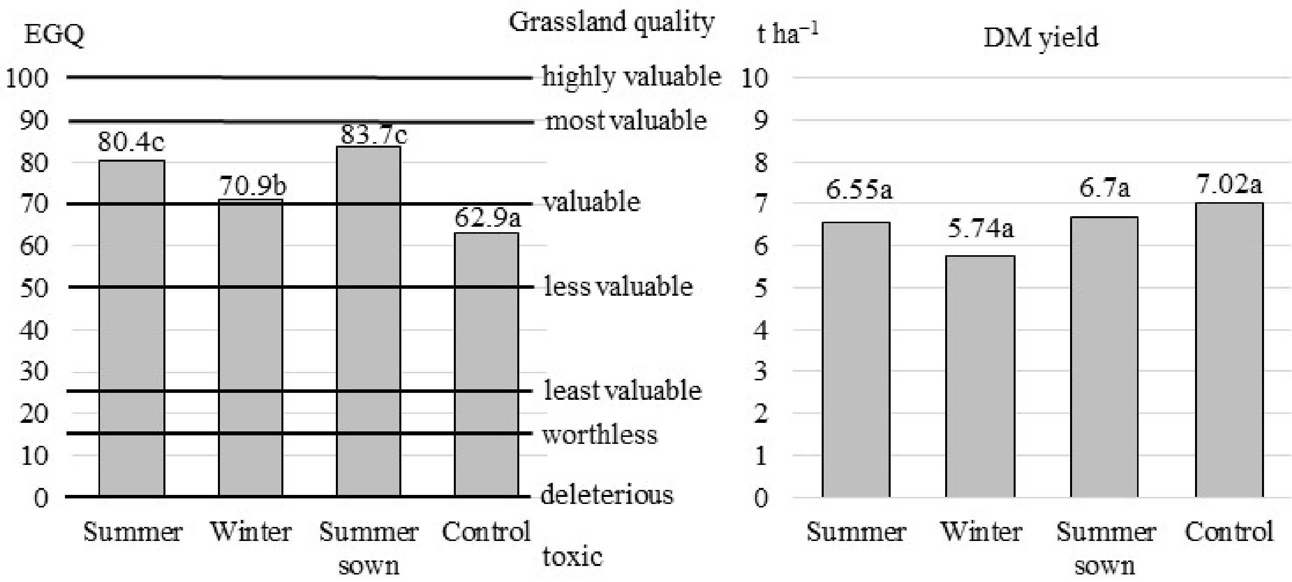

Figure 1. Evaluation of the grassland quality acc. to Novák [52] and yield potential (DM—dry matter). Different letters indicate statistically significant differences ($p < 0.05$). The similar values for species composition and forage value, particularly for the yield potential, not only in the pastures but also in the control area, indicate similar habitat conditions within the study area analysed, allowing for valuable and representative results.

3.2. The Nutritional Value of Green Fodder

Changes in the chemical composition of the green fodder in the pens and, consequently, in the nutritional value of the forage were mainly related to the growing season of the plants (Table 3). The spring months were conducive to intensive biomass growth, translating into a higher concentration of organic components in dry matter, primarily crude protein. The content of this nutrient in the spring green fodder regrowth (S1, W1, SS1) exceeded 200 g of crude protein per kg of dry matter and was significantly higher than its concentration in the autumn green fodder. The lowest protein content, both in spring and autumn, occurred in the green fodder in the control area (C).

Crude protein content in dry matter was significantly negatively correlated with crude fibre content ($r = -0.84$). In contrast to the spring period, the increase in crude fibre content in autumn was thus associated with a decrease in crude protein content in the green fodder. This characteristic relationship, resulting from the slowing down of pasture plant growth during late summer, significantly impacted the nutritional value of the green fodder (Table 4). The increase in difficult-to-digest polysaccharides and lignin (crude fibre) reduced the energy value of the green fodder (S2, W2, SS2) but also the amount of available protein (protein digested in the small intestine). The amount of the latter depends not only on the supply of crude protein but also on the amount of available energy required for its fermentation.

Similar changes to those in the protein and nutritional values were observed in mineral elements. In general, green fodder in the spring had a higher concentration of both macro and micro mineral elements, although it was not statistically confirmed (Table 5). This results from the fact that the content of elements, particularly microelements, in the plant materials is quite variable in a short time due to the physiological processes of plants and the availability of nutrients in the soil, which can often affect the variability of the internal statistical estimation error.

Table 3. Chemical composition of green fodder.

Study Objects	Season	Dry Matter %	Crude Ash g kg^{-1} DM	Crude Protein g kg^{-1} DM	Crude Fat g kg^{-1} DM	Crude Fibre g kg^{-1} DM	NFE g kg^{-1} DM
Summer pen (S)	Spring	16.52 ± 2.83 a	94.37 a ± 9.52	223.36 b ± 38.93	28.53 a ± 2.78	249.26 a ± 33.36	404.48 a ± 54.30
	Autumn	30.07 b ± 5.66	87.54 a ± 7.64	116.94 a ± 31.91	27.79 a ± 3.10	281.66 a ± 23.17	486.08 b ± 19.15
	Total	23.30 ± 8.43	90.95 ± 8.58	170.15 ± 66.41	28.16 ± 2.66	265.46 ± 31.22	445.28 ± 57.65
Winter pen (W)	Spring	28.91 a ± 0.01	111.78 a ± 1.69	274.08 b ± 0.49	24.76 a ± 0.18	197.64 a ± 0.04	391.75 a ± 1.05
	Autumn	24.84 a ± 6.30	93.36 a ± 14.31	167.65 a ± 41.31	26.53 a ± 3.91	288.12 a ± 43.96	424.35 a ± 15.08
	Total	26.46 ± 4.98	100.73 ± 14.31	210.22 ± 65.20	25.82 ± 2.93	251.92 ± 58.50	411.31 ± 20.81
Summer sown pen (SS)	Spring	18.79 a ± 1.42	91.67 a ± 4.38	208.57 b ± 17.55	28.59 a ± 8.68	233.73 a ± 13.60	437.45 a ± 2.45
	Autumn	30.08 b ± 2.32	85.63 a ± 3.82	126.21 a ± 10.24	25.98 a ± 6.29	296.65 ± 15.87	465.53 a ± 4.69
	Total	24.43 ± 6.42	88.65 ± 4.94	167.39 ± 46.91	27.28 ± 6.93	265.18 ± 36.91	451.49 ± 15.74
Control area (C)	Spring	21.43 a ± 0.56	99.92 a ± 1.20	176.69 a ± 11.71	27.64 a ± 11.08	240.50 a ± 7.21	455.24 a ± 1.27
	Autumn	20.39 a ± 3.53	99.77 a ± 11.98	118.23 a ± 19.87	25.11 a ± 2.32	314.24 a ± 33.79	442.64 a ± 18.66
	Total	20.91 ± 2.33	99.85 ± 7.61	147.46 ± 35.19	26.38 ± 7.29	277.37 ± 45.92	448.94 ± 13.69

Different letters indicate statistically significant differences according to Tukey's test ($p < 0.05$); NFE—nitrogen-free extracts, DM—dry matter.

Table 4. Nutritional value of green fodder (in 1 kg of DM).

Study Objects	Season	ME (MJ)	UFL	dCP (g)	PDI (g)
Summer pen (S)	Spring	11.05 b ± 0.40	0.83 b ± 0.04	125.08 b ± 21.80	77.82 b ± 4.25
	Autumn	9.81 a ± 0.35	0.72 a ± 0.03	65.49 a ± 17.87	63.77 a ± 5.00
	Total	10.43 ± 0.76	0.77 ± 0.07	95.28 ± 37.19	70.80 ± 8.74
Winter pen (W)	Spring	11.53 b ± 0.02	0.88 b ± 0.00	153.48 b ± 0.27	83.65 b ± 0.14
	Autumn	10.34 a ± 0.43	0.77 a ± 0.04	93.88 a ± 23.13	71.07 a ± 4.18
	Total	10.82 ± 0.72	0.81 ± 0.07	117.72 ± 36.51	76.10 ± 7.50
Summer sown pen (SS)	Spring	10.92 b ± 0.17	0.82 b ± 0.02	116.80 b ± 9.83	76.18 b ± 3.01
	Autumn	9.91 a ± 0.14	0.73 a ± 0.01	70.68 a ± 5.73	66.41 a ± 0.40
	Total	10.41 ± 0.57	0.77 ± 0.05	93.74 ± 26.27	71.30 ± 5.68
Control area (C)	Spring	10.45 a ± 0.10	0.78 a ± 0.01	98.95 a ± 6.56	71.81 a ± 2.57
	Autumn	9.66 a ± 0.22	0.71 a ± 0.02	66.21 a ± 11.12	64.14 a ± 2.65
	Total	10.05 ± 0.46	0.74 ± 0.04	82.58 ± 19.70	67.98 ± 4.80

Different letters indicate statistically significant differences according to Tukey's test ($p < 0.05$); calculations were based on digestibility coefficients from domestic cattle [18]; ME—metabolisable energy; UFL—energy units for milk in forage; dCP—digestible crude protein; PDI—true digestible protein in the small intestine [53].

Table 5. Mineral content in dry matter.

Study Objects	Season	Ca (g)	P (g)	Mg (g)	Na (g)	K (g)	Cu (mg)	Zn (mg)	Fe (mg)
Summer pen (S)	Spring	5.35 ± 1.31	4.83 ± 0.61	2.18 ± 0.38	0.36 ± 0.10	36.12 ± 4.51	7.6 ± 1.7	25.5 ± 5.0	143.1 ± 72.2
	Autumn	5.16 ± 0.43	3.20 ± 0.44	2.03 ± 0.14	0.25 ± 0.07	24.14 ± 5.04	6.9 ± 1.4	47.9 ± 4.3	83.1 ± 15.6
	Total	5.26 ± 0.88	4.01 ± 1.01	2.11 ± 0.26	0.31 ± 0.10	30.14 ± 7.83	7.2 ± 1.5	36.7 ± 13.0	113.1 ± 57.1
Winter pen (W)	Spring	8.13 ± 0.05	4.81 ± 0.20	2.45 ± 0.01	0.59 ± 0.24	32.47 ± 0.72	5.8 ± 0.1	34.7 ± 0.2	357.8 ± 22.7
	Autumn	6.95 ± 1.52	3.61 ± 0.34	2.34 ± 0.17	0.64 ± 0.37	31.15 ± 6.10	6.1 ± 0.4	30.9 ± 4.4	106.2 ± 2.2
	Total	7.42 ± 1.26	4.10 ± 0.71	2.38 ± 0.14	0.62 ± 0.29	31.69 ± 4.39	6.0 ± 0.4	32.4 ± 3.7	206.8 ± 138.3
Summer sown pen (SS)	Spring	7.03 ± 1.20	4.87 ± 0.32	2.28 ± 0.38	0.41 ± 0.18	33.68 ± 1.58	9.0 ± 0.7	28.8 ± 2.6	127.8 ± 23.2
	Autumn	6.14 ± 0.75	3.14 ± 0.49	2.17 0.06	0.32 ± 0.11	19.53 ± 2.34	7.3 ± 2.0	87.3 ± 69.5	149.5 ± 44.2
	Total	6.58 ± 1.02	4.01 ± 1.02	2.22 ± 0.24	0.36 ± 0.14	26.61 ± 7.95	8.2 ± 1.6	58.0 ± 54.4	138.6 ± 33.7
Control area (C)	Spring	7.64 ± 0.40	4.40 ± 0.46	2.40 ± 0.10	0.33 ± 0.11	34.24 ± 2.76	3.1 ± 2.6	37.4 ± 4.3	159.0 ± 52.1
	Autumn	11.81 ± 0.86	3.72 ± 0.64	2.91 ± 0.12	0.58 ± 0.35	22.12 ± 4.37	5.4 ± 0.3	47.2 ± 14.7	128.3 ± 57.0
	Total	9.72 ± 2.37	4.06 ± 0.62	2.65 ± 0.29	0.45 ± 0.27	28.18 ± 7.40	4.4 ± 1.8	42.3 ± 11.1	143.6 ± 51.2

Ca—calcium; P—phosphorus; Mg—magnesium; Na—sodium; K—potassium; Cu—copper; Zn—zinc; Fe—iron.

In spring, significant differences were noted in the content of crude ash, crude protein, crude fibre, and elements such as Ca, Zn, and Fe. The spring fodder was characterised by a significantly higher content of crude ash, crude protein, and Ca and Fe in the winter pen ($p < 0.05$). In the summer pen, the spring fodder was characterised by a significantly higher crude fibre content ($p < 0.05$). Spring fodder in the control area (C) had the significantly highest Zn content.

Significant differences were noted in the nitrogen-free extracts (NFE) and calcium (Ca) and magnesium (Mg) content in autumn. The autumn fodder was characterised by a significantly higher NFE content in the summer pen than in the winter and control areas ($p < 0.05$). The autumn biomass in the control area (C) had a significantly higher magnesium content than the pasture pens (Table 6).

Table 6. Comparison of the chemical composition of green fodder in different pens and control areas in spring and autumn.

Analysed Variable	Spring			Autumn		
	F	*p*	Differences between Pens	F	*p*	Differences between Pens
Crude ash (g kg^{-1} DM)	8.475	0.007 *	W > S (p = 0.016); W > SS (p = 0.007)	1.159	0.383	-
Crude protein (g kg^{-1} DM)	10.077	0.004 *	W > S (p = 0.027); W > C (p = 0.003)	2.134	0.174	-
Crude fat (g kg^{-1} DM)	0.188	0.901	-	0.215	0.883	-
Crude fibre (g kg^{-1} DM)	4.570	0.038 *	S > W (p = 0.035)	0.619	0.622	-
NFE (g kg^{-1} DM)	3.471	0.070	-	8.993	0.006 *	S > W (p = 0.005); S > C (p = 0.036); SS > W (p = 0.047)

Table 6. *Cont.*

Analysed Variable	Spring			Autumn		
	F	*p*	Differences between Pens	F	*p*	Differences between Pens
Ca (g)	5.312	0.026 *	W > S ($p = 0.040$)	24.957	<0.001 *	C > S ($p < 0.001$); C > W ($p = 0.002$); C > SS ($p < 0.001$)
P (g)	1.405	0.310	-	1.089	0.407	-
Mg (g)	0.819	0.518	-	22.771	<0.001 *	C > S ($p < 0.001$); C > W ($p = 0.005$); C > SS ($p = 0.001$)
Na (g)	3.987	0.052	-	1.647	0.254	-
K (g)	0.946	0.462	-	3.759	0.059	-
Cu (mg)	2.447	0.138	-	1.395	0.313	-
Zn (mg)	6.641	0.014 *	C > S ($p = 0.015$)	1.334	0.329	-
Fe (mg)	15.533	0.001 *	W > S ($p = 0.002$); W > SS ($p = 0.001$); W > C ($p = 0.004$)	1.807	0.223	-

* Statistically significant values at $p < 0.05$; F: analysis of variance (ANOVA); Study objects: S—summer pen, W—winter pen, SS—summer sown pen, C—control area; NFE—nitrogen-free extracts.

4. Discussion

The conducted research is the first assessment of the impact of rotational pasture management of fallow deer (*Dama dama*) on the chemical and species composition of the pasture sward. Seasonal differences in the nutritional quality of pastures are a key factor to consider when managing pastures and feeding the animals grazing there. The decline in pasture quality is correlated with pasture species and grazing management, strongly impacting dry residues' quality in early summer [54,55]. Ru and Fortune [56] also found a large variation in the nutritional value of subterranean clover cultivars. Therefore, fallow deer breeders should select not only the right species but also cultivars of grasses and leguminous plants for over-drilling the pastures. According to Karpowicz [57], the plant species that are valuable to fallow deer include legumes (*Lotus corniculatus*, *Trifolium repens*, *T. pratense*, *T. hybridum*), grasses (*Phleum pratense*, *Arrhenatherum elatius*, *Festuca pratensis*), and herbs (particularly *Plantago lanceolata*). In the pastures analysed, the predominant plants were valuable grasses such as *Dactylis glomerata*, *Poa pratensis*, and *Lolium perenne*, as well as legumes: mainly *Trifolium repens* (Table 3), with the less numerous *Lotus corniculatus*. Based on the species composition and forage value, according to Novák [52], the best forage quality was observed in the summer pens (S—80.4 and SS—83.7), while a slightly lower quality occurred in the winter pen (W—70.9). Despite significant differences, these values were within the range of valuable and highly valuable. This means that keeping fallow deer in winter pens guarantees the preservation of a good floristic composition, which is a key element of fodder quality. The grazing of fallow deer in the summer pens ensures a better species composition of the sward, particularly when over-drilled. All the pens had a high production potential, meaning the habitat conditions were similar. Even the control area (outside of the grazing area) had a high potential and could be used as a pasture in the future. However, it should be emphasised that secondary metabolites in plants also determine the palatability of feed taken by grazing fallow deer and can act as pest repellents. Moreover, plants' chemical defence substances affect litter decomposition [58].

Apart from the floristic composition, fodder quality is also influenced by habitat, maintenance measures, grazing period, and appropriate animal density. Grazing the pastures at an optimum stocking rate will maintain pasture quality by slowing the accumulation of fibre in the plant materials and reducing the dead material in the swards [59]. Providing shelter is an essential part of the welfare of grazing animals. Wooden sheds are often built for livestock, but in natural pastures (rangelands), trees and shrubs perform this role. In the study area, fallow deer used the dominant trees' fruit, leaves and small twigs to supplement mineral deficiencies. Fallow deer also like mushrooms, berries and ferns. The bark and twigs of the trees contain tannins, which naturally regulate digestive processes in wild ruminants, support their immune system, and have a deworming function, particularly regarding intestinal nematodes. Furthermore, the leaves of trees and shrubs are rich in micronutrients such as selenium, copper and molybdenum. Young walnut twigs, in addition to their deworming effect, lend a shiny appearance to the coat of fallow deer [57,60,61].

Analyses of forage nutritional value showed variation depending on the season and pen. The mineral content of pasture plants is variable and largely depends on the season and climate. Animals are also affected by nutrient deficiencies in plants caused by drought or frost in late winter. Studies by Landete-Castillejos et al. [62] showed that late winter frosts increased Si content and decreased Na content in plants. This resulted in, among other things, lower Mn and P content and higher Na and B content in the animals' antlers which increased the antlers' fragility. Such an effect was not found in farm-bred cervids, where supplementary feeding with feed concentrate was used [50]. Attention is drawn to the unfavourable ratio of calcium to phosphorus in the dry matter of green fodder, which should be at least 2:1 given the demand of fallow deer for these elements [62]. In this respect, the most favourable Ca:P ratio occurred in the control area. In addition, the relatively low sodium content in all examined plots indicates the need for year-round supplementation with mineral mixtures or licks. The antlers are built with calcium phosphate from their skeleton. Hence, fractures can be caused by reduced Mn content with a reduced Ca/P ratio. Even small changes in the proportions of bone trace elements can affect the mechanical properties of the bones of cervids [62]. Ca content in the biomass from the winter pen was similar to that shown by the authors above, but it was lower in the summer pens. In contrast, the control area had the highest Ca content, similar to the feed results obtained in the late winter game estate. The average P and Zn content in the pens under study was similar to the concentration shown in the farm fodder on which the animals exclusively fed in Spain. In contrast, Mg, Cu, and Fe levels in the pasture plants were similar, while Na and K levels were significantly higher compared to plants taken up after late winter in the study by Landete-Castillejos et al. [62]. High K concentrations and low Zn concentrations in the vegetation are available to fallow deer. This explains the concentration of these minerals in the examined antlers of the population bred in the area [50].

Estevez et al. [6] assessed seasonal differences in the mineral content in plants frequently consumed by wild deer (*Cervus elaphus hispanicus*) in south-eastern Spain. The investigation revealed that K, Mg, Mn, Na, P, Cu and Zn concentrations in these plants were generally low. Furthermore, no clear differences in the growing season were observed. In our study, differences were recorded between spring and autumn, which can be explained by the differences in climatic and habitat conditions between Spain and Poland. Chemical analyses of soils and vegetation indicate that the greatest mineral deficiencies occur in the dry season, similar to the above-described deficiencies occurring after frosts in late winter, which causes herbivores to migrate [37,38,63]. Wild deer often traverse large areas in search of food, using both forested areas and cropland, thus causing damage [64]. This phenomenon does not occur in the case of farm-bred deer, but these animals can then seek other ingredients found, for example, in fruit, leaves or tree bark.

The crude protein content is a key nutrient for ruminants. For cervids in the reproductive period, crude protein content in the dry matter of a feed ration should range from 5% to 25% [65]. According to many studies, green fodder for cervids usually contains between 5 and 15% of crude protein in a dry matter [66–68]. Such content indicates the need to provide animals with feed concentrate during their increased demand for protein. Other authors state that to ensure proper rumen function, deer feed should contain at least 6–7% of crude protein and between 13–16% for adequate antler development [69]. In our study, the crude protein content was high (Table 4) despite a significant reduction in the amount of available protein (protein digested in the small intestine) in each pen during the growing season (spring to autumn). All pens had a lower forage value in autumn than in spring. This was especially true for the lower concentration of energy and protein in dry matter, the use of which in ruminants is related to the demand for energy required for rumen metabolism. This is evidenced by the lower values of most of the evaluated parameters in autumn compared to spring (Table 5). Spring biomass in the winter pen had higher crude ash, crude protein, Ca and Fe content, which is a well-known phenomenon. Often this can be caused by urine and faeces left by animals in random places, which also affects the results obtained by individual authors. The nutritional value of forage taken up by cervids in pastures shows significant variation depending on the growing season, habitat, and agrotechnical factors [70].

Regarding macro- and micronutrient content, according to Tajchman et al. [44], the daily demand for Ca and P in feed should be 0.09–0.64% and 0.14–0.56%, respectively. The present study confirms that the content of these minerals in the analysed feed was appropriate for fallow deer. However, young males require relatively high amounts of protein, up to 22%, and lower levels of calcium (0.45%) and phosphorus (0.28%) [69]. Pregnant and lactating females have different nutritional requirements. The mineral demand of hinds during this period is similar to that observed in bucks during antler development, and the required amount of protein can be even higher, i.e., 22–24% of dry matter [71]. Perkins [69], on the other hand, showed that the optimal mineral composition should be about 0.64% of Ca and 0.56% of P. The most optimal calcium/phosphorus ratio should be 0.2. In the analysed fallow deer pastures, the Ca:P ratio was not stable in three pens (W, SS and C); a higher Ca content was accompanied by a lower P content, except for the summer plot (S), where the biomass had a similar content of these elements [69]. No significant deviations were observed in the development of antlers by fallow deer bred on that farm [50]. Larger weight gains of fallow deer grazing on pastures were recorded in the spring–summer period compared to the autumn–winter period. Similar correlations were observed by Shin et al. [72] in red deer.

The nutrient content, except for sodium, was within normal limits in the context of the requirements of pasture-fed ruminants. Considering the gains and mineral content, it can be assumed that the feed quality was satisfactory as an element of animal welfare.

5. Conclusions

The study found that pasture sward's chemical and species composition for fallow deer (*Dama dama*) varied depending on rotational pasture management (winter and summer pens). The summer pens, including the sown one, had a better fodder quality, depending on the species composition. Still, the fodder in the winter pen was also in the range between valuable and highly valuable. This means that keeping fallow deer in winter pens guarantees a good floristic composition, which is a key element of feed quality.

All the grazed pens were characterised by a high production potential and similar floristic composition, without the participation of undesirable plant species and seedlings of trees and shrubs (except for large trees), which confirms the hypothesis that, under extensive grazing conditions, fallow deer can be used for grassland conservation.

Intensive spring biomass growth translated into a higher concentration of organic components in dry matter, a primarily crude protein content of 176.69–274.08 of crude protein per kg of dry matter. It was significantly higher than its concentration in the autumn green fodder.

Nutrient levels were within normal limits for grazing ruminants. However, when analysing changes in the content of minerals, it should be noted that for animal welfare reasons, access to mineral mixtures (licks) should be allowed, as the supply of minerals changes significantly during the growing season.

The presented study covers only selected aspects of a comprehensive assessment of mid-forest pastures as feeding grounds for fallow deer. To identify the best ways to manage such pastures, it is necessary to conduct observations in subsequent years of research.

Author Contributions: M.K. and K.T. conceived the idea and designed the methodology; K.T. and Ż.S.-B. collected data; M.B., A.U.-J. and M.P. performed laboratory analyses; M.K., K.T., A.L. and F.C. analysed the data and wrote the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: Publication co-financed by the Ministry of Science and Higher Education under agreement No. DKN/SP/546699/2022.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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