

**Doctoral (PhD) dissertation theses**

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**The effect of different pasture types on the meat  
production-related traits and some physiological  
characteristics of red deer**

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## **1. Background and objectives of the work**

The population of the earth has already exceeded 8 billion people and is constantly growing. This is accompanied by a change in the demand for animal products (Kurdnáková et al., 2018), and over the past 50 years, the average annual meat consumption has increased by 19 kg/person (Sans and Combris, 2015).

The average venison consumption is 0.37 kg/person in the European Union (Maggiolino et al., 2018) and 0.2 kg in Hungary (Torma et al., 2014). In recent years, several events have aimed to promote the consumption of game meat in Hungary.

In addition to the increase in consumption, new expectations have also appeared. Healthy and safe products are important for the modern consumer society, which provide a balanced diet. As a result, there is an increasing demand for low-energy and low-cholesterol foods with a favourable fatty acid composition (Hoffmann and Wiklund, 2006). In addition to all these expectations, it is becoming increasingly important that the product comes from sustainable and environmentally friendly production (Ludwiczak et al., 2016, Hoffmann and Wiklund, 2006).

Venison combines most of the expectations listed above, it is tender, low in fat and high in protein and minerals (Zomborszky et al., 1996; Roger et al., 2010), in addition, red deer can be kept with sustainable, close-to-nature farming (Kuba et al., 2015), primarily based on grazing (Volpelli et al. 2003).

In Hungary, the current legal regulation allows the keeping and breeding of game species in 3 forms in indoor conditions. Game can be kept in a hunting park for hunting purposes, in a game park for educational, research and demonstration purposes, or on a game farm for meat production.

At the Kaposvár Agricultural College, we started breeding red deer in 1985, within the framework of a research program – based on New Zealand experience. The increase in the population made it necessary to establish another deer herd in Bőszénfa in 1992, which is still in operation today.

Over the years, traditional food plots management has been replaced by intensive grassland management in our game park, which is physiologically more favourable for ruminant game species and involves the use of less input material than the cultivation of annual crops.

The conditions of the deer farm were suitable for investigating the effect of different grass mixtures on the growth of young red deer and their value measuring properties related to meat production under controlled conditions.

Deer breeding behind fences is also present in Hungary, and a number of changes (interest in alternative farming methods) may result in an increase in the number of game parks and game farms in the near future. For this reason, it is necessary to collect and analyse data on the herds kept in pasture-based systems.

During my investigations, I set the following research goals:

1. Investigation of three different planted grassland mixtures in the areas of Bőszénfa.
2. Comparative study of the body weight gain and body size of yearling hinds on three pastures with different compositions (grass, grass-legumes (papilionacea) mix, legumes).

3. Investigation of the effect of pastures with different plant compositions on the slaughter properties of yearling hinds and on the tissue composition of the carcass.
4. Examination of the meat quality and fatty acid profile of yearlings kept on pastures, with different compositions.
5. Investigation of changes in metabolic reactions characteristic of yearling hinds kept on pastures of different compositions: blood-biochemical characteristics because of.

## **2. Material and method**

### *Characterization of areas and studies of pasture mixtures*

The experiments took place on the outskirts of the village of Bőszénfa, in the Wildlife Management Landscape Centre. We are farming on 1360 hectares, of which 805 hectares are used as game parks, and 200 ha breeding block, where the experiment was carried out.

The total experimental area was 16 hectares, previously grassland cultivation, separated in three equally sized, 4-hectare paddocks, with were separated with 2,2 m high, Tornádó type deer fence.

Soil samples were collected from each of the experimental plots from a depth of 0-30 cm according to the regulations. Based on the literature data described earlier, the area is characterized by brown forest soil. Based on the data, it can be said that there is loam and clay loam soil on the study plots.

The three areas were planted with 3 different mixtures (grass, grass-legumes and legumes) in 2009. Grazing studies were carried out in 2011 and 2012.

During grazing, samples were taken 3 times in 2011 and 2 times in 2012 for chemical composition studies and yield estimation. We conducted coenological surveys in May 2010, 2011 and 2012. Meteorological factors have a significant impact on crop production, including pasture management, so it is necessary to know the local data for the given period.

The meteorological features were used from the website of the National Meteorological Service (OMSZ, 2022).

From the point of view of grassland management, the climatic conditions of 2011 were more favourable, because more precipitation fell during the growing season, coupled with slightly lower temperatures, which resulted in a balanced humidity. On the other hand, in 2012, the low amount of precipitation coupled with higher temperatures induced aride-like conditions, which had a negative effect on the development of vegetation.

#### *Livestock*

The red deer population included in the study, came from the breeding area - belonging to the game park of the Wildlife Management Landscape Centre.

In each grazing area (grass, grass-legumes and legumes mixture), 11-month-old red deer hinds were placed in groups of 22-22-22 individuals in both experimental years (2011, 2012), so a total of 132 (66+66) yearling hinds participated in the study.

From a methodological point of view, it was a particularly important requirement that the individual experimental pasture plots should have a population of the same weight (body size) and age as much as possible every year. In order to ensure that the genetic effects are unbiased, we placed a similar proportion of offspring of different sires

on the 3 different pasture mix. Ear tags (Zee Tag) were used for the calves for animal identification.

During our investigations, the following characteristics were measured:

- bodyweight: the measurement was carried out in the handling system with a Trutest type digital scale, with an accuracy of 0.5 kg, which was specially designed for weighing red deer,
- chest circumference: taking the tape under the chest, guiding it around the chest behind the shoulder, reading it on exhalation,
- hip width: measured with a calliper (40 cm) at the outer hip angles of standing red deer,
- head length: with a tape, guided from the nape of the neck through the forehead and bridge of the nose to the nose tip,
- head width: the measurements were taken on the forehead, behind the eyes, in the narrowest place, with a calliper.

Body weight, and body size data were measured at the start of the experiments in April, followed by June, and at the end of the experiment in November.

#### *Computer tomography examination of the composition of the carcasses*

At the end of the grazing period, 10-10 randomly selected individuals were shot from the experimental groups, with a hunting weapon and then bled out. At this time, blood samples were also collected. The bodies were taken to the cooler of our processing plant (4-6°C), the internal organs (lungs, heart, digestive tract and genitals) were removed, and various tissue and organ samples (liver, kidney, perirenal fat) were collected. The kidney fat index (weight of the kidneys

on both sides + the weight of peri-renal fat/weight of the kidneys) was calculated based on Sugár (1983), which was recorded for the purpose of determining the condition. We calculated the slaughter loss (November live mass – carcass mass). By carcass, we mean a eviscerated body covered with skin, without heads and bottom part of the legs (at *articulation carpi* and *articulation tarsi*). The dismantling of different body parts and the collection of meat samples also took place in the processing plant.

In both experimental years, the carcasses were subjected to volumetric CT examination (60 individuals). 24 hours after slaughter, at the Health Center of the University of Kaposvár. The carcasses were inspected with a Siemens Somatom Sensation Cardiac multi-slice scanner (Siemens AG Erlangen, Germany) with full coverage. The results were given in unit volume (cm<sup>3</sup>), the layer thickness of the images was 10 mm. The images were taken from the atlas to the hock joint.

#### *Meat quality tests*

The pH values of the sirloin (*Musculus Longissimus lumborum*) and haunch (*Musculus vastus lateralis*) samples were measured 24 hours after slaughtering with a built-in temperature-controlled electrode (Testo Cat., No. 0650 2051) Testo 205 precision handheld pH meter (Testo SE & Co. LGa, Lenzkirch, Germany).

The colour of meat was measured by Minolta ChromaMeter 300 (Minolta Corp., Tokyo, Japan) (aperture diameter: 11 mm; observer: 10°; angle: 90°; light: D65) 45 minutes after cutting. The results were interpreted in the CIELAB coordinate system (Commission International DE L' Eclairage, 1976).

The dripping loss of meat was determined by the Honikel (1998)

method. To determine the cooking loss, samples (100 g) were individually placed in polyethylene bag and cooked according to Lawrie (2006). Subsequently, the cooking loss was determined: the amount of liquid left in the bag after cooking was expressed as a percentage of the weight of the baseline sample. These tests took place in 2011.

#### *Examination of the fatty acid profile of organs and feed*

Meat and liver samples of the slaughtered individuals and from pasture vegetation were extracted according to the method of Folch et al. (1957). Fatty acid methyl esters were extracted with 300 µL of ultrapure n-hexane for gas chromatography and analysed as described by Szabó et al. (2007) The fatty acid profile results were expressed as a percentage by mass of total fatty acid methyl esters. The analysis was carried out in the pilot year 2011.

#### *Blood serum analysis*

After sampling, the blood was immediately cooled on ice in Falcon 13 ml tubes, centrifuged after coagulation (1500 g/10 min), and then the serum was stored at a temperature of -70 °C until the analysis was performed. The chemical analysis was carried out with automatic equipment (Hitachi 917, Tokyo, Japan). Reagent kits for triglyceride, total cholesterol, HDL (high density lipoprotein) and LDL (low density lipoprotein) cholesterol, albumin, total protein (TP), creatine kinase (CK), aspartate aminotransferase (AST) and alanine aminotransferase (ALT), urea, and uric acid were purchased from Human Ltd. (Wiesbaden, Germany). Creatinine and calcium reagents were purchased from Roche Diagnostics (Qebec, Canada), gamma glutamyltransferase (GGT), lipase, alkaline phosphatase and

magnesium reagents were purchased from Diagnosticum Ltd. (Budapest). Na and K were determined using ion-selective electrodes. The total lipid content was determined by the sulphophosphovanillin method, spectrophotometrically (Johnson et al., 1977). The analyses were carried out during the 2011 experimental period.

#### *Statistical methods used*

For each statistical analysis, we have performed a check of the normal distribution. The statistical reliability of the differences caused by different effects (pasture, year) on body weight and body sizes was performed by one or more factor analysis of variance (Proc ANOVA, Proc GLM). Pasture types, years and, in some cases, seasons were taken into account as fixed factors. The correlations between body parameters were investigated by correlation calculations (Pearson) (Proc CORR).

In the studies aimed at meat quality characteristics, multifactor variance analysis (GLM) was performed, the pasture types were used as a fixed factor, and the body weight at the time of killing was used as a covariate in the model. SPSS 20 for Windows (2012) software was used for the analysis.

The analysis of the parameters that were practical and professional to specify as a percentage was evaluated after arcsin transformation during the statistical tests.

The fatty acid composition of the samples of red deer herds kept on different pastures was compared by a one-factor analysis of variance by tissue type (Tukey "post-hoc" test).

During the examination of blood serum parameters, the experimental groups were compared by analysis of variance (GLM procedure). The experimental groups were treated as a fixed effect, in the model the

body weight at the time of killing was covariant. In order to be able to distinguish the individual groups on the basis of blood biochemistry data, a discriminant factor analysis (DFA) was used. The analyses were performed using SPSS 20 for Windows (2012) and AlphaSoft 12.3 (2009).

### **3. Results and discussion of them**

#### *Grassland management*

Meteorological data were used from the website of the Hungarian Meteorological Service. Of the two full years of the study, the distribution of precipitation in 2011 was favourable for pasture management, while 2012 was extremely dry in summer and early autumn. In the two experimental years, the temperature values in the grazing period were very similar.

During the examinations, the botanical survey was always carried out in May, when the vegetation showed the most complete picture of the pastures.

In 2010, the cover of sown plants were below 40% in all three pasture mix, against other plants, like ragweed (*Ambrosia artemisifolia*). In 2011, the cover of sown plants exceeded 80% in all three pasture. In 2012, this ratio decreased to around 70% for the grasses, to around 60% for the legumes, while it remained above 80% for the grass-legume mix.

Changes occurred in the composition of pastures during the years, where it is important to emphasize that in 2011, in the case of all three pasture mix, fresh and moderately moist plants with a water balance dominated. In 2012, plants with moderate and wet water balance completely disappeared from grass, and legume mixtures, and in the

case of grass mixture, the cover of moderately dry plant species increased. In the case of the grass-legumes mixture, the cover of plants in the moderately fresh, fresh and moderately moist categories remained high in 2012, but this mixture provided the lowest yield this year. Based on the composition studies, the quality of the pasture mixtures deteriorated by the summer months, and then in the autumn there was an improvement in quality in both years. In 2012, lower yields were also coupled with lower quality based on the evaluation of fibre fractions.

The fatty acid profile of pastures with different botanical compositions was examined at the beginning of the experiment in 2011 (April). The grass-legume pasture showed a relatively high proportion of capric acid (C10:0), while the grass-legume mixture showed a higher proportion of palmitoleic acid (C16:1 n7) and slightly lower eicosatrienoic acid (C20:3 n3). The proportion of monounsaturated fatty acids (MUFA) was highest in the pasture planted with grass-legumes mix. The n6 PUFA ratio was highest in the legume pasture, compared to the grass, and grass-legume mixtures, while the n3 PUFA ratio was quite high for all pasture types.

*Change in body weight and different body sizes depending on the botanical composition of pastures in 2011 and 2012*

There was no significant difference ( $P < 0.05$ ) between the populations assigned to different grazing areas and between the years measured.

In 2011, the body weight and all body size parameters were significantly higher ( $P < 0.05$ ) of the group kept on legume pastures

compared to the groups grazed on the other pasture types, except for the head width.

In November measurements - at the end of the grazing season - the herds kept on legume-type pasture significantly ( $P<0.05$ ) outperformed the other groups in terms of body weight and all body dimensions, with the exception of head width.

In 2012, the study started similarly, and in June, the data of the measurement showed a significant ( $P<0.05$ ) superiority in body weight and hip width of the population kept on the legumes-dominated pasture. Chest circumference, head length, and head width did not differ significantly ( $P<0.05$ ) between the experimental groups at this time. In November, at the last measurement, the population reared on legumes pasture was significantly higher ( $P<0.05$ ) in all body parameters, except for the head width, that of the other two pasture mixtures.

In 2011, there was also a much greater increase in body weight and the correlated body sizes compared to the performance in 2012. At the same time, in 2012, the proportion of legumes in the pasture had a relatively much greater impact on the increase in body parameters than in 2011.

During the grazing period, in both years, we measured the yearling hinds in June, so we were able to divide the grazing season into two phases, from the beginning of the grazing till June, and then from June till the end of the grazing season: spring and summer-autumn period. In the case of body weight, there were significant ( $P<0.05$ ) differences in the spring and summer-autumn grazing seasons. In both years, the average daily weight gain was significantly higher during the spring period than in the autumn. The differences in 2011 and 2012 are

striking. In both years, the superiority of the group kept on legumes pastures was clear, which was particularly high in 2012.

The live weight gain of yearling hinds kept on pastures sown with grasses decreased to a greater extent in the summer-autumn (June-November) period compared to the spring (April-June) period, than the herds kept on the two other pasture types

#### *Phenotypic relationships between body parameters*

At the beginning and at the end of the experiment, there was a weak correlation between head width and other body sizes. In all cases, a strong positive significant ( $P < 0.05$ ) relationship was found between body weight and other body sizes. At both measurement times, body weight showed the closest correlation with chest circumference and hip width.

#### *Experimental slaughtering*

At the end of the grazing periods, 10 individuals randomly selected from each experimental group, and slaughtered in both years.

During the examinations in 2011, there were significant differences in all the examined parameters depending on the composition of the pasture. The exceptions to this were the sirloin weight and the kidney fat index. The carcass weight, the tenderloin, the haunch, the shoulder, the heart, the liver and the kidney weight increased from the grass mixture through the grass-legumes mix to the legumes. The slaughter loss was significantly higher ( $P < 0.05$ ) in the group, grazed on grass.

The results of the 2012 test slaughter showed a similar trend to the previous year, but this year the carcass weight, tenderloin, sirloin,

haunch and shoulder was significantly lighter than in 2011. The differences differed significantly ( $P<0.05$ ) depending on the pasture type. At the same time, the weight of the heart, liver and kidneys was almost the same as that, of animals slaughtered in 2011. The kidney fat index showed a lower value in 2012 than in 2011 for the groups kept on a grass and grass-legumes mixture.

In terms of slaughter losses, there was a marked difference between 2011 and 2012. Significantly higher slaughter losses were observed in all experimental groups in 2012.

#### *Correlation studies between body parameters and butchering results*

Correlation calculations were made between the body parameters measured in November (pre-slaughter) and the results of the slaughtering.

The live weight before slaughter showed a close correlation with the carcass weight, the weight of the shoulder, the sirloin and the haunch, as the most important prime cuts. Chest circumference and hip width were also strongly correlated with the former measurements. The length of the head was only moderately tight but showed a significant ( $P<0.05$ ) correlation with the above parameters, while the head width showed no significant ( $P<0.05$ ) correlation with the examined parameters.

#### *Volumetric computed tomography examination of the carcasses and determination of tissue composition*

During the volumetric CT examination, the total muscle volume, the total fat volume and the volume of the bones of carcasses were measured. A separate radiodensity analysis of the sternum was also performed.

CT scans from 2011 clearly confirm a significantly higher ( $P < 0.05$ ) volume of total muscle content in the carcasses in the group consuming legumes. The total fat content of the whole body increased from the grass mixture through the grass-legumes mixture to the legumes mixture. Significantly ( $P < 0.05$ ) lower total fat content was typical for yearling hinds kept on grass.

The significantly higher volume ( $P < 0.05$ ) of the bone content of the whole carcass in the case of the group grazing legumes compared to the stock kept on other pasture types is remarkable. In addition, the sternum density values also indicate a significantly more favourable bone quality status, which also indicates the superiority of the herds grazing on legumes.

In 2012, volumetric CT scans followed a similar trend as in 2011. The superiority of the stands kept on legumes pastures was significantly greater compared to the populations kept on other pasture types. Compared to 2011, in line with the total volume of the carcass, the volume of muscle tissue was lower, the fat content of the carcass was significantly reduced in all populations, and the bone content was reduced to a lesser extent.

*Meat quality and tissue fatty acid profile of red deer yearling hinds depending on the botanical composition of the pastures*

The meat quality tests were carried out on red deer yearling hinds raised and slaughtered in 2011.

Grass and groups of legumes for sirloin muscle *post mortem* its 24-hour pH was the same and significantly ( $P < 0.05$ ) lower than the grass-legumes result. In contrast, the drip loss of the grass legumes groups

significantly exceeded the value of the group kept on the grass, while the cooking loss showed no difference between the groups. In the colour components, the brightness ( $L^*$ ) and yellow tint ( $b^*$ ) were significantly higher in the legumes group, while the red shade ( $a^*$ ) was the same in all groups.

The colour of the sirloin (*M. longissimus thoracis et lumborum*) showed higher conjugated linoleic acid (CLA9c11t) ratios in both high density of grass species pasture groups (grass mix and grass-legumes mix) and significantly lower ( $P<0.05$ ) conjugated linoleic acid ratios were found than in pure legume pasture consumers. In the saturated fatty acid group, arachidic acid (C20:0) was found in a lower ratio in the group kept on a grass-legumes mixture compared to both other groups (grass and butterfly). Docosahexaenoic acid (DHA, C22:6 n3) showed the lowest proportion in the legumes group, the highest in the grass group, while the grass-legumes mix group did not differ significantly from either. The ratios of n6 polyunsaturated fatty acids did not differ between the groups (only small differences were found in eicosadienoic acid (C20:2 n6). In contrast, the n6/n3 fatty acid ratio was significantly ( $P<0.05$ ) highest in the legumes group, probably due to the relatively high ratio of n6 polyunsaturated fatty acids.

In the thigh, we found basically similar results as in the sirloin muscle, in terms of CLA9c11t, DHA ratios and n6/n3 ratios. Although the effect of the ratio of  $\alpha$ -linolenic acid (ALA, C18:3 n3) (high presence in feed) was not reflected in the total muscle n3 ratio, it was highest in the group consuming the grass-legumes mixture (about 7%), showing a significant ( $P<0.05$ ) difference from the legumes group.

In the liver, the grass group showed the highest proportion of oleic acid (C18:1 n9), which ultimately resulted in the outstanding

monounsaturations of this group. Conjugated linoleic acid (CLA) also showed the distribution pattern described above, analogous to muscle distribution in the liver (grass and grass-legumes mixture > legumes). In the n6 polyunsaturated group, the ratio of linoleic acid (C18:2 n6) in the animals of the legumes group exceeded the values of the grass and grass-legumes mix groups, and the legumes group exceeded the value of those who consumed the grass mixture in the ratio of arachidonic acid (C20:4 n6), which eventually led to the dominance of n6 PUFAs in the legumes group, shifting the n6:n3 ratio towards the n6 PUFAs.

*Changes in metabolic reactions characteristic of red deer reared on pastures with different composition based on blood biochemical parameters*

Blood biochemical testing of metabolic reactions was carried out in the herds reared and slaughtered in 2011.

Due to the nature of the topic, it seemed most expedient to compare the blood biochemical parameters of the herds kept on the two types of pasture that are the most different from the point of view of nutrient supply (grass and legume pasture).

The total protein (TP) content of the blood serum was higher in the group that consumed legumes. At the same time, the concentrations of albumin, uric acid and creatinine did not differ between the groups that consumed the grass and the legumes mixture. Serum urea concentrations were slightly higher in the herd kept on legume-rich pasture, but the difference was not significant ( $P < 0.05$ ).

Total lipid concentrations, high-density lipoprotein (HDL) and low-density lipoprotein (LDL) cholesterol levels in the serum were higher in the legumes-grazing group, but a statistically significant ( $P < 0.05$ )

difference was only observed in triglyceride concentrations, where higher values were shown in animals kept on legume-rich pastures.

There were no differences between the groups in terms of serum sodium, total and ionic calcium, chloride and magnesium concentrations. In contrast, higher potassium concentrations were typical in animals kept on pastures rich in legumes. In the case of the experimental group that consumed grasses, higher concentrations of inorganic phosphate were characteristic.

Lactate dehydrogenase (LDH) and alkaline phosphatase (ALP) activity were significantly higher ( $P < 0.05$ ) in the legumes pasture group, while aspartate aminotransferase (AST) activity was lower compared to the grass grazing group. There was no difference in the activity of alanine aminotransferase (ALT), gamma-glutamyl aminotransferase (gamma-GT), lipase and creatine kinase (CK) between the experimental groups.

#### **4. Conclusions and recommendations**

Our results clearly support the importance of planting and maintaining legumes mixtures - although it is a costly and time-consuming, but profitable investment in big game areas. Under fenced conditions, the daily weight gain of red deer calves exceeded that of individuals grazing on grass by 60-80 g.

The food supply of species-poor, poor-medium pastures often found in game parks and game farms can be supplemented with legume plants with lower fibre content, richer in protein and calcium, and better digestibility indicators, which are better suited to the species characteristics of red deer.

The main component of the legume mixture in my studies was the "Szentesi Róna" creeping alfalfa (60%), which showed coverage between 5.1-25% and 25.1-50% in the two years examined. In the case of closed deer breeding and open-area game management, it would be expedient to include this alfalfa variety for grazing, but neglected in the last decade, in seed mixtures, which is suitable even for monoculture cultivation.

The weight ratio of red clover seeds was 30% in the legumes mixture. In the first year of planting, we could not count on significant yields in areas heavily infested with ragweed, so the utilization of red clover, which forms a stand for two or three years, was further shortened. In our studies, it gave a substantial yield only in the second year after planting with a cover of 5.1-25%, so it should be considered to maximize the proportion of red clover seeds around 10-15%, and instead to include other species (such as chicory and plantain) in the mixture.

In our investigations, white clover was also a decisive and significant pasture mixture, which represented the third largest proportion in the seed mixture with 10% and retained its 5.1-25% cover ratio in the legumes mixture in both experimental years. It tolerates trampling and total grazing, and provides almost continuous pasture except for long, dry and persistently cold periods. A great advantage may be that its yield does not show a significant surplus during the spring, so there is no need to clean the pastures, the game "maintains" the area with their grazing.

The composition of the three planted pasture mix changed during the examined years, which also showed a correlation with the weather conditions. In 2011, the grass mixture and the grass-legumes mixture

were dominated by plants with humid and moderately moist water balance, while the legumes mixture was dominated by plant species in the moderately humid, humid and moderately moist categories. In 2012, plant species with moderately aqueous and moist water balance disappeared from the grass and legume mixtures, and in the case of the former, the cover of plant species with moderately dry water balance increased.

The yield of pasture mixtures was significantly lower in 2012 in the case of grass and grass-legume mixtures, which was coupled with a lower quality yield in terms of the value of fibre tailings. In the years under review, the quality of feeds deteriorated by the summer months, which can be explained by the aging and fibrous character of the vegetation and the resulting decrease in digestibility.

The growth of the yearling hinds placed in the pasture followed these trends, so they grew more intensively in the spring periods and the changes in their body sizes were similar. For the entire growing season, the body weight and body dimensions of the yearling hinds kept on the legumes mix were the highest in both years of the study.

The slaughter rates of yearling hinds grazing legumes mixtures were also more favourable in both years. The weight of valuable meat parts was the highest and their slaughter losses were the lowest in these cases.

The results of the CT scans also showed the superiority of the individuals grazing on the legumes mixture, where they had the largest muscle and bone volume and the highest bone density.

One of the surprising results of our investigations is the development of the total bone content ( $\text{dm}^3$ ) of the carcass of individuals

slaughtered at the end of the grazing period. The bone volume and sternum density of the deer grazing on the legumes mixture also significantly exceeded the results of the other two groups. Although the present studies did not cover the study of male growth and one of the most controversial areas - antler growth, the bone volume and bone density data provide a good basis for the conclusion that the grazing of legumes can have a similarly beneficial, positive effect on the weight of stags' antlers.

These results are also supported by blood biochemistry studies, where the metabolic metabolites and enzymes for the more intensive growth of the yearling hinds kept on the legumes mixture were higher.

Based on the above, it would be expedient to plant and maintain 30-40% of the arable areas with perennial legume mixtures in game parks and game farms, taking into account the local conditions. The planting of such mixtures may also be justified in an open hunting area, but it is essential to know the characteristics of the game population and the habitat in order to plan it.

## 5. New scientific results

1. The body weight gain of red deer (*Cervus elaphus*) yearling hinds reared on deer farms, grass and grass-legumes mixtures was highest on the legumes mixture. In 2011, the year with a more favourable pasture management, the growth of individuals reared on a legume mixture exceeded that of individuals reared on a pure-sown grass mixture by 57.7 g/day, while in 2012, in a year with a less favourable precipitation distribution, the increase of individuals reared on a

formázott: angol (Egyesült Királyság)

legume mixture exceeded that of individuals reared on a pure-sown grass mixture, taking into account the entire grazing period.

2. The variance of body weight gain and the increase of different body sizes (except head width) in red deer yearling hinds between the ages of 11 and 18 months was significantly influenced by the type of pasture and the annual effect to almost the same extent.

3. Based on the analysis of the spring and summer-autumn grazing periods, it could be concluded that in the spring (April-June) period of the year with more favourable weather conditions for pasture management (2011), the legumes mixture had a significant positive effect on the body weight of the yearling hinds and their closely correlated body sizes, while in the case of less favourable weather conditions (2012) the favourable effect of the legumes mixture increased significantly, the favourable effect of the grass mixture and the grass-legumes mixture.

4. The slaughter loss (%) of red deer yearling hinds kept on a legumes mix was lower in my studies in both years compared to the other two groups. In the more favourable year (2011) from the point of view of grazing, their slaughter losses were proportionally 2.2% lower, while in the less favourable year (2012) they had a 5.5% lower slaughter loss than those consuming grass mixtures.

5. The pasture mixtures of different composition and the effect of the year had only a slight effect on the proportion of valuable meat parts (primal cuts) in relation to the live weight before slaughter and the weight of the carcass.

6. Based on volumetric analysis with computed tomography (CT) scans, it was found that the total muscle tissue and adipose tissue content of the total carcass of red deer yearling hinds was significantly higher in the case of the group kept/reared on the legumes mixture, compared to those reared on grass at the age of 18 months.

7. Legumes pasture significantly increased the amount of bone tissue in the carcass (CT scan) and also the density of the sternum. The effect of the year did not affect the correlations.

8. The meat of red deer yearling hinds kept on pastures planted with grasses had the most favourable dripping loss and the most advantageous docosahexaenoic acid (C22:6 n3) proportion.

9. The colour of the sirloin (*musculus longissimus thoracis et lumborum*) of red deer yearling hinds kept on pastures planted with legumes has changed towards a lighter shade (higher L\* value) compared to that of the other groups.

10. The fatty acid profile of red deer yearling hinds in the sirloin muscle and the thigh muscle was significantly influenced by the composition of the pasture.

11. The red deer yearling hinds with greater body weight gain in grazing legumes with higher crude protein content was associated with higher blood serum total protein content, K concentration, and aspartate aminotransferase (AST) activity, but remaining within the physiological reference range.

12. The increased ossification activity of hinds kept on a mixture of legumes was well characterized by higher alkaline phosphatase (ALP) activity compared to animals kept on grass pastures.

## **6. Publications related to the topic of the dissertation**

### *Journal articles*

In English:

1. Bokor, J. Nagy, J. Donkó, T. Horn, P. Bokor, Á. (2023): The effect of age and sex on carcass traits and body composition of Hungarian yearling farmed red deer (*Cervus elaphus hippelaphus*). *Meat Science* 204, 109209.
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