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Effect of herd management on annual cow cull rate and performance of Holstein-Friesian dairy cows

A menedzsment hatása az éves tehénselejtezési arányra és a Holstein-Fríz tejelő tehenek teljesítményére

Diploma work
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List of abbreviations

AMS = automatic milking system

BCS = body condition score

CLA = conjugated linoleic acid

DD = digital dermatitis

DIM = days in milk

DM = dry matter

MUFA = monounsaturated fatty acids

PMR = partial mixed ration

PUFA = polyunsaturated fatty acids

SA = sole abscess

SCC = somatic cell count

SFA = saturated fatty acids

SU = sole ulcer

TMR = total mixed ration

TTN = toe tip necrosis

UFA = unsaturated fatty acids

WLD = white line disease

Table of contents

1. Abstract

This study explores the impact of transitioning from a closed confinement system to indoor housing with pasture access on milk production trends and the health of dairy cows. The objective was to assess whether this change, proposed by agricultural manager Johannes EKKEL, would yield the anticipated benefits and to investigate the potential advantages of such husbandry systems. The research was conducted on a modern dairy farm in France with approximately 130 lactating cows, supported of the farmer and a team of specialized advisors.

Data on milk production, milk quality and udder health were gathered with the assistance of *LELY Industries N.V.*, a Dutch manufacturer of agricultural machinery and robotics. Information on claw pathologies was provided by the farm's farrier.

Results showed that cows with pasture access had improved milk yield, higher milk fat and protein content, and better udder health compared to the confined group. In addition, claw pathologies decreased over the examined period, and the culling rate showed similar downward trend.

Overall, statistical analysis confirmed that providing cows with access to pasture has a positive impact on claw health while maintaining economically satisfying milk production levels. These findings align with numerus existing studies, further supporting the inclusion of pasture access as a beneficial element in dairy cow husbandry systems.

2. Összefoglalás

Dolgozatomban azt vizsgáltam, milyen hatással van a tejtermelésre és a tejelő tehenek egészségére a zárt tartási rendszerből az istállós elhelyezésre – legelőhöz való hozzáféréssel – történő átállás. A cél az volt, hogy értékeljem, vajon ez a változás, meghozza-e a várt előnyöket, valamint hogy feltárjam az ilyen tartási rendszerek esetleges előnyeit. A kutatást egy modern franciaországi tehenészetben végeztem, ahol körülbelül 130 tejelő tehenet tartottak.

A tejtermelésre, tejminőségre és tőgyegészségre vonatkozó adatokat a LELY Industries N.V., egy holland mezőgazdasági gép- és robotgyártó vállalat segítségével gyűjtötték. A csülökváltozásokra vonatkozó információkat a farm patkolókovácsa szolgáltatta.

Az eredmények azt mutatták, hogy a legelőhöz hozzáféréssel jobb tejhozam, nagyobb tejzsír- és fehérjetartalom, valamint jobb tőgyegészség mutatkozott a zárt tartású csoporthoz képest. Emellett csökkentek csülökelváltozások és a selejtezési arány is mérséklődő tendenciát mutatott.

Összességében a statisztikai elemzések megerősítették, hogy a legelőhöz való hozzáférés biztosítása pozitív hatással van a tehenek csülökállapotára, miközben gazdaságos tejtermelési szintet lehet fenntartani. Ezek az eredmények összhangban állnak számos meglévő tanulmánnyal, tovább erősítve a legelőhöz való hozzáférés hasznosságát.

3. Introduction

3.1 Current trends in husbandry systems

Since industrialization of dairy cattle sector in the 1950s, most pasture-based systems have been replaced by indoor husbandry systems [1]. Nowadays, incorporating traditional grazing methods into modern animal husbandry practices of food-producing animals is an increasingly discussed topic in Europe and worldwide. This is largely driven by the growing awareness among consumers and producers about animal welfare, the environmental impact and sustainability of intensive production systems [1, 2]. Pasture access staid a common practice in beef, sheep and goat production. In the dairy sector, it is a time-honoured approach that is still applied to heifers and dry cows, while slowly regaining popularity for lactating cows as producers recognize its potential benefits for animal welfare, milk quality and biodiversity. While many dairy farmers are not yet confidant to change their management system because of concerns about the potential risks, such as reduced milk yield, or the challenges of adapting to new practices, some farmers are exploring strategies to meet consumer demands while maintaining an economic efficiency and productive performance of their animals.

Each management system comes with its own set of advantages and disadvantages, and pasturing is no exception. In this study, focus was put on the grazing systems as this is the newly adopted management practice of the later analysed dairy farm.

3.2 Constraints of grazing

First, due to climatic and geographic factors (temperature, rainfalls, soil type), grazing dairy cattle is more feasible in certain regions compared to others [2, 3]. A comprehensive overview about the geographical distribution of grazing systems was presented in a study [2]. In Europe, extensive production systems are more commonly practiced in the northern countries like Norway, Sweden and Finland, as well as in western countries such as Ireland and UK. In contrast, these systems are much less prevalent in southern countries like Portugal, Spain, Greece and Italy, as well as eastern countries like Poland, Estonia, Lithuania, Czech Republic, Bosnia Herzegovina, Slovenia, Hungary and Bulgaria. Central countries, including Netherlands, Belgium, Luxembourg, France, Switzerland, Denmark, Germany and Austria, fall in between with a decreasing percentage of grazing cows over the last decades [2]. In addition, traditions, cultures,

government policy and market prices play a role in the husbandry systems adopted [2, 3]. In general, pasture-based feeding systems tend to be successful in temperate regions with moderate temperatures and adequate rainfall patterns throughout the year [4]. This review focused on the changes induced by pasture access in a dairy cattle herd in the centre of France. The temperate climate in this region makes grazing possible, enabling farmers to meet consumer demands for improved cattle welfare.

Then, on farm level many other factors must be considered, such as the infrastructure and grazing area available compared to the herd size [2, 3]. In addition, modern cow genetics pose a problem mainly regarding robustness and adaptability, as these animals have been selected first for high production qualities and later reproductive parameters have been considered (fertility and calving ease) [1–3]. In temperate regions, where grazing is possible, other constraints appear: constant quantity and quality of pasture is difficult to achieve and feed intake difficult to monitor [5]. The assessment of grass growth is the next complication [5]. Herbage growth is influenced by many factors, such as grazing management, stocking density, sward renewal and fertiliser management but also weather, soil type, season and year dependent and thus highly variable [3].

Last, the farmers themselves are important factors to think about. Depending on their knowledge, education, attitude, social environment and management capacities, including grazing in their management system can be challenging [2, 3].

3.3 Advantages of grazing

Beside constraints, grazing also has a lot of opportunities. The first benefit that likely comes to mind is animal welfare, as the natural habitat for herbivores is grassland. Pasture-based systems bring a lot of improvement regarding animal health. This will be discussed in more details later in this review.

From an economical point of view, grass is the most cost-effective feedstuff when available [3]. Furthermore, grass is not usable by humans directly and is therefore an important source of feed that should be exploited as ruminants are able to transform it to human edible food [2]. In addition, grassland are often found in areas that are unsuitable for cultivating crops intended for human consumption [3]. This excludes them from the food versus feed debate, where the use of human-edible foods in total mixed ration (TMR) diets for ruminants is a point of criticism [5].

Regarding the final product, grazing improves milk quality by increasing the proportions of beneficial milk fats, total protein concentrations, and fat-soluble vitamin levels [3, 5].

The value of grazing goes beyond the farm. Environmental advantages include landscape appearance, soil carbon sequestration, biodiversity and conservation of soil quality [2]. Additionally, reduced need for feed purchase reduces associated transport emissions [3].

3.4 Solutions to the constraints of grazing

In regions where the meteorological conditions are not favourable year-round, pasture can still be utilized during periods when conditions are ideal for herbage growth [3], so called part-time grazing systems. Furthermore, pasture use can be optimized through the right management [4]. Several management systems that incorporate grazing exist, tailored to the local environment and possibilities [5]: 1) free grazing from spring to autumn on whole pasture area where spare areas are added bit by bit, 2) rotational grazing, whereby the pasture is fragmented in paddocks enabling recovery time to the sward, 3) multi-species pasture enabling the full utilization of the grassland's resources due to the different grazing behaviours and dietary preferences of diverse species, and 4) guarded grazing in the mountains [4]. To maximize the potential of each method, grazing time, sward recovery duration, stocking rate and grazing intensity must be managed appropriately [4].

On site, potential solutions are grounded in technological advancements including virtual fencing, automatic gates, drones, automatic regulation of supplementary feeding, non-destructive grass quality analysers, robotic herbage mass analysers, advisor systems, satellite imagery, and automatic milking systems (AMS) [2–5].

To improve understanding of the management of pasture-based systems, existing knowledge must be put into practice with the aim of convincing farmers who need evidence of success. Young farmers, who represent the next generation, and particularly teachers, should be targeted for education on various husbandry possibilities and their connection to new technologies. To motivate farmers who remain uncertain, providing rewards framed as a service to society could be an effective incentive. Advisors also need additional training to provide site-specific management recommendations effectively [2].

3.5 Aim of the investigation

The objective of this investigation was to assess whether the part-time-grazing management system offers better production performance, health outcomes, and so reduced cow cull rates compared to the full confinement system on a dairy farm located in central France.

4. Literature review

This study focused on comparing production and health parameters between two distinct management systems: 1) full confinement and 2) part-time pasturing. The annual cow cull rate, referring to the number of cows removed from the herd each year, is influenced by many factors including their production and reproduction capacities, both of which are closely linked to the animals' health status. The aim of the literature review is to explore existing research on the impact of different housing systems on dairy cow welfare, health, and productivity, helping to understand the factors behind these differences.

4.1 Welfare and behaviour

Animal welfare refers to the quality of care and treatment animals receive in terms of housing, feeding, health and mental state [6]. It can be evaluated by factors such as lifespan, disease prevalence, behaviour and reproductive success, which together indicate the overall well-being of an animal. Diseases such as lameness and mastitis, as well as reproductive performance will be discussed in the subsequent sections. Here, we will focus on physical indicators of health and behavioural parameters.

A study [6] evaluated physical indicators such as body condition score (BCS), skin lesions and dirtiness on cows with pasture access and cows housed only indoors. It came out that BCS did not differ significantly, even though other authors [7–10] noticed that grazing worsens BCS, probably due to decreased feed quality and nutrient intake caused by non-proper pasture management. It was found [6] that skin lesions and hairless patches were significantly less present in cattle with pasture access. This can be explained by the bigger space available, softer ground and less objects susceptible to cause injuries. Similarly, in the same study, cows kept in barns were dirtier than those on pasture, indicating inadequate environmental hygiene [6]. This, in turn, can increase the risk of mastitis and lameness disorders. It is important to remember that hygiene on pasture can also be poor, depending on factors such as weather conditions [11] and stocking density.

The most straightforward behavioural patterns to analyse include resting, movement and feed intake. The activities that shape the day of a cow are important indicators of their general health status and well-being. According to another investigation [12] cattle kept on pasture lie for shorter time than cattle kept inside. These were confirmed by another

experiment as well [10]. This can be explained by the increased time needed for feed intake when grazing, changing the daily time budget of the animals. Cows housed indoors take longer to lie down and stand up due to the limited space in cubicles [6]. The resting posture is also affected by housing system, with grazing cows adopting more outstretched positions, thanks to the greater space available to them [13, 14]. It is no surprise that pasture access encourages exercise, which is beneficial for cattle health as long as the distances aren't excessively long [6]. Feed intake timing and durations are greatly differing when cows are pasturing or not. Following their natural diurnal rhythm cows on pasture ingest most feed two hours before sunrise and two hours before sunset [13]. In comparison, this is not possible for cattle kept in barns as their feed intake is dependent on feed delivery. In addition, cows in both husbandry system types are feeding straight after milking. Furthermore, the time spent on feeding is longer in cows kept on pasture, because of different feed intake methods. During grazing, cows must grab and pull-out grass tufts, whereas TMR intake does not need that effort [13]. Feed structure and dry matter content also plays a role in feed intake duration.

Another behavioural aspect that is worth mentioning is social interactions based on hierarchical structure. In pasture-based systems with sufficient space, submissive animals can more easily avoid conflicts with dominant ones compared to those in confinement [6]. This reduces competition for feed, water and resting areas, which in turn lowers stress levels. Additionally, it benefits claw health, as submissive cows don't need to make sharp turns on concrete floors to avoid dominant individuals when kept on pasture.

It is worth noting that a study mentioned above [6] focused on the local Romanian Spotted cattle, a dual-purpose breed more adapted to grazing than Holstein-Friesians. Similarly, another investigation [13] compared the behaviour of Brown Swiss on pasture to that of Holstein-Friesians, with the latter being less robust and genetically selected for intensive indoor management.

As outlined in a review [6], even if grazing is restricted to specific times of the day and does not occur year-round, the benefits of allowing animals access to pasture are clearly noticeable. Overall, from a welfare point of view, it is not debatable that pasture access significantly enhances animal welfare by allowing animals to express natural behaviours, experiencing better physical health, and reduce stress compared to confinement systems.

4.2 Claw health and lameness

Lameness, being one of the most significant challenges and an animal welfare concern in the intensive dairy industry, it is a crucial parameter to consider when evaluating husbandry systems. Several studies [6, 10, 15–17] proved that pasture is beneficial to claw health and helps in lameness recovery. For example, a publication [15] demonstrated that allowing lame cows an outdoor access for only seven weeks, already shows amelioration in their pathologies: 55,6% of cows on pasture during the experience had a sound period over at least two successive weeks, versus 26,9% for the indoor group. This was also reported some years ago in an experiment [10] with four week access to pasture. Interestingly, another study [18] found that pasture access did not have any significant positive impact on claw lesions, such as sole haemorrhages, sole ulcers and deep with-line fissures. The different outcomes between studies highlight the complexity of managing lameness in dairy cows, where not only outdoor access but also indoor environmental factors play a crucial role in influencing claw health. Factors within a barn that contribute to the risk of lameness include hard, slippery walking surfaces, overall barn hygiene, as well as stall design and stocking density [19–21]. Stocking density causing increased lameness risk is associated with ranking and competition for lying areas.

As mentioned in a publication [15], pasture access can be incorporated into husbandry systems to improve claw health by using exercise paddocks, without necessarily using it as a feeding area. This approach may make it more practical and attractive to a wider range of farmer.

4.3 Udder health and mastitis

Although mastitis is one of the major concerns for dairy cattle, studies comparing udder health in pasture-based systems and confined systems are limited and give inconsistent results. One study reports that mastitis is less prevalent in pasture-based systems [6], while another suggests confinement is more favourable, with a lower need for antimicrobial treatments [22]. It is important to note that the types of pathogens varied by management system in this study [22]. Yet another study found no significant difference in somatic cell count (SCC) and mastitis prevalence between the two husbandry systems [11]. These conflicting results indicate that udder health is influenced by multiple factors, requiring a holistic approach.

As for claw health, hygiene is of great importance regarding udder health. That's why weather condition is an important factor that can increase the risk of mastitis on pasture [23]. Cows on pasture are found dirtier than indoor housed cows in a study due to heavy rainfall [11]. This underscores the importance of carful management in pasture-based systems, to ensure an optimal environment that reduces health risks for the animals.

4.4 Reproductive performance

Reproduction plays a crucial role in the economic success of a dairy farm. Issues ranging from oestrus detection difficulties over fertility problems to dystocia cause financial losses and an increase in the annual cow cull rate.

Outdoor access can improve heat detection by observation thanks to increased oestrus behaviour, such as standing to be mounted and mounting [24, 25]. This can help in reproduction programs where observation is the main detection method used. The higher incidence of mounting behaviour in pasture-based systems compared to confinement systems can be attributed to the difference in flooring. Concrete flooring in the barns being slippery, cattle seem less confident to express such behaviours. This hypothesis was also mentioned in another review [24] where cows from the housed group were observed attempting some mounts without success due to slipping and falling. Furthermore, stress from confined spaces, hierarchic dominance, or lameness, all of which are more prevalent in housed systems as previously mentioned, may also contribute to the decrease in sexual behaviours. Reduced oestrus behaviour in confinement is likely one of the factors that prompted the development of newer techniques and technologies for oestrus detection. Additionally, in an experiment [25] it was observed that oestrus duration is longer in cows with pasture access than cows in confined systems. In addition to potentially facilitate the oestrus detection through visual observation, this factor may also increase the chance of a successful pregnancy.

In pasture-based systems, seasonal calving is commonly practiced to simplify management by aligning energy demand with the quality and availability of pasture [3, 26]. For this approach to succeed, reproductive management must be highly efficient and well-timed to ensure optimal fertility and calving outcomes.

4.5 Milk production

One of the main factors likely holding farmers back from offering pasture access to their lactating dairy cows is the fear of reduced production. This concern is valid, as several studies [3, 5, 27, 28] have shown that grazing cows have a lower milk yield and feed efficiency than full confined cows fed with TMR. The reduced performance may be linked to the lower nutritional value of pasture compared to TMR, combined with higher energy requirements due to increased efforts needed for grazing [27]. Furthermore, a paper [28] concluded that nighttime pasture access does not benefit milk yield, as cows tend not to graze after sunset. Based on this, farmers who want to graze their cattle should do so during the day or, ideally, provide full-time access, allowing the cows to choose when to graze freely. Another study found that when cattle were given the choice between pasture and ad libitum indoor partial mixed ration (PMR), they preferred to feed indoor but still chose to graze afterward, showing that they like to be outside grazing [29]. In the same study, no difference was found between daytime and nighttime grazing systems.

According to a report [30], with only grass-diet, a cow can meet its maintenance requirements and produce 22 to 26 kg milk per day. This quantity of milk being lower than what farmers usually want nowadays, cows that are kept on pastures must be supplemented with concentrates. In summary, as mentioned in a study [4], a cow's diet composed of grass only is not sufficient to support very high milk yields. Interestingly, another study [31] showed that cows having free access to pasture during dry period produce more milk in the following lactation than cows kept in confinement.

To optimise output per cow in grazing systems, precise pasture management and strategic supplementation is needed [5]. As mentioned in the introduction, new technologies may be necessary to evaluate pasture quality, as well as dry matter and nutrient intake per cow to do so.

Along with differences in milk quantity, variations in milk quality are observed between animals that are grazing and animals fed conserved forages. However, in this case, grazing systems offer an advantage over confined systems. Lipids are the components that consistently show similar changes across studies, making them the most interesting aspect from a nutritional perspective. In milk of cows from pasture-based dairying systems, lower levels of saturated fatty acids (SFA) and higher levels of unsaturated fatty acids (UFA) with a higher fraction of polyunsaturated fatty acids (PUFA) are more increased compared to monounsaturated fatty acids (MUFA) are

reported [3, 4, 32–34]. Among PUFA, conjugated linoleic acid (CLA) has the most significant health benefits [4]. The n-6:n-3 ratio recommended by nutritionists is maintained in grazing-cow's milk [33]. In summary, milk from grazed cows has an improved fatty acid profile, which makes it attractive for consumers. Nevertheless, another investigation [35] revealed slightly different results, with higher SFA and PUFA in grazing system and higher MUFA in confined system. This difference may be due to variations in diet composition in each study and system. Regarding grazing systems, fatty acid profile also varies depending on season, with higher fat concentration in autumn than spring and summer [32]. Dairy farms that aim to minimize external inputs, particularly concentrate feeds, can benefit from grazing, when possible, all while preserving or even improving the fatty acid profile of milk [35].

5. Material and Methods

5.1 Selection and description of the farm

To evaluate the effect of herd management on annual cow cull rate and performance of Holstein-Friesian dairy cows, the dairy farm *EARL du Domaine de la Maison du Bois* located in France and managed by Johannes EKKEL made its database available to us. The obtained data was analysed to assess the impact of the husbandry system on the herd's performance, health status and longevity.

The analysed farm counts approximately 130 lactating Holstein-Friesian cows and 30 heifers to this day. All lactating cows are kept together in a modern 2.000 m^2 free-stall barn, providing cubicles for rest. Johannes manages his lactating cows in a single large group, without sorting them by lactation phase. This approach is made possible thanks to the advanced technology used at the farm. Cows in the dry period and heifers aged 16 months and above are housed together, with access to a 9-hectare outdoor paddock that serves primarily as an exercise area rather than a feeding space.

The farm is equipped with four robots from the Dutch manufacturer LELY: 1) one of them is pushing the feeding ration regularly during the day so that the feed is always within reach of the cows, improving overall heath and production capacity, 2) another one is scraping the manure from the barn's floor, helping in the prevention of hoof problems and keeping udders clean, 3) and two automatic milking robots allowing a calm and stress-free atmosphere in the barn as cows can follow their natural rhythm. To encourage the cows to pass through the milking robots, they are positioned at one end of the barn, serving as gates that the cows must go through to access the free-range pasture area.

On average, cows visit the milking robot 2.6 times per day during the grazing season, and slightly more, around 3 times daily, during the winter months. The robots are connected to a farm management platform, namely Lely Horizon, allowing the collection of a vast amount of data from each cow at every milking. This technology provides the farmer a detailed overview of his animal's production and health, aiding in decision-making to optimize farm management.

Since March 2019, Johannes changed the management of lactating cows on his dairy farm from full-time indoor loose housing system to a part-time outdoor grazing system. The pasture is freely accessible day and night from March till November approximately,

in accordance with weather conditions. The cows can freely decide when and how long to graze, and typically, as soon as temperatures exceed 25°C, they prefer to graze in the evening and night rather than during the day.

The farmer possesses a total of 280 hectares of arable land, divided in 20 plots where various types of cereals are cultivated in a rotational system. Alfalfa is grown on 1 plot, meadow on 2, rapeseed on 3, wheat on 3, barley on 2 and corn on the remaining 9 plots. In addition, 24 hectares of pasture are available to the cows, located directly adjacent to the stable. Instead of relying on naturally growing grass, a specially selected meadow seed mix is used to ensure high-quality forage for the animals (Table 1). To maintain good soil quality of the pasture area, each year 4 hectares from the 24 are sown with corn and not accessible for grazing. Prior to the change to grazing in 2019, the 24 hectares were part of the rotational system for cereal culture and meadow, which was used to compose the TMR provided to the cows.

Table 1: Composition of sown grass

Type of plant	Seed amount (%)	Population (%)
RGH 2N CADOR	10.0	5.1
Purple clover 2N SUEZ/RESPECT	10.0	7.2
DAWN Hybrid clover	10.0	20.1
Timothy ½-early ALMA	5.0	16.8
RGA 2N 2-late BOVINI	15.0	10.3
RGA-late 4N PRODIGE/TAPPIANA	15.0	7.1
Tall fescue TOWER/NEOSO	25.0	14.1
Intermediate white clover CHIEFTAIN/DUBLIN	5.0	10.8
Ladino white clover FANTASTICO/APIS	5.0	8.4

Regarding the feeding management, until 2019 the dairy cows were fed on TMR ad libitum containing 25kg corn silage, 18kg meadow silage, 6kg alfalfa, 4kg corn grains, 1.5kg soja, 200g minerals and 100g salt. The cereals in this mixture are cultivated on the farm, ensuring a direct connection between feed production and feed distribution. Since 2019, the animals receive the same TMR ad libitum, with the only variation being the quantity of meadow silage included. As grass becomes more abundant in the pasture,

typically from March to June and from September to October, the amount of meadow silage in the TMR is adjusted accordingly. The meadow silage can range from 5 to 18kg in the TMR, depending on the availability of grass on pasture. Additionally, the cows receive concentrates during milking that provide essential minerals and vitamins. This supplementary feed is dispensed directly by the milking robot, scanning each cow's identification number to adjust the dose according to the cows' individual needs, based on the amount of milk given and considering their age, lactation number, and lactation stage.

The farm does not conduct direct quality assessments of its grasslands due to a lack of specialized technological equipment. Instead, the soil quality of the pasture is analysed every 3 years. Furthermore, feed quality is evaluated by a laboratory using samples collected from the silos prior to the feed being utilized. Specifically, the dry matter content (DM) is evaluated since the TMR is formulated based on this parameter. If the DM content of the meadow silage is too high, extra water must be added to reach the desired 38-40% DM content in the TMR. Given that cows require 25kg of DM per day, a higher dry matter percentage could lead to inadequate nutrient intake.

As discussed in the literature review, there appears to be a trend of combining grazing with seasonal calving. However, this is not the case on the farm being analysed here. Johannes explains that, because he uses milking robots, he must maintain a constant level of production throughout the year from an economic perspective. He also notes that, in his opinion, it is easier to manage a dairy farm with a relatively consistent number of calves year-round, rather than handling a large influx of calves all at once.

The farmer's goal with this change is to accomplish several long-term objectives: 1) increase longevity by enhancing the cows' lifespan, 2) decrease the number of heifers needed for replacement, and 3) reduce yearly cow cull rate by minimizing removals from the herd. In numbers this means that he would like each cow to produce 40 000L of milk over its productive lifespan at the farm, requiring 3 to 4 lactations at least. Johannes emphasizes that the primary motivation for him in providing a pasture area for his cows is to promote their well-being.

5.2 Data collection and analysis

The data concerning milk yield, milk protein, milk fat and somatic cell count (SCC) utilized in this study was collected with the support of the LELY company, which has access to the farm's database since 2014. The numbers were then organized using the Microsoft Excel XP Professional computer program and finally analysed. The LELY advisor collected the following data for individual cows: lactation number, calving date, dry-off date, days in milk (DIM), milk yield, milk protein, milk fat and SCC. For each lactation number the mean value, standard deviation and significance of milk yield, milk protein, milk fat and milk SCC was calculated using the Microsoft Excel XP Professional computer program. The milk yield, milk protein and milk fat values were corrected to reflect an average of 305 DIM to facilitate comparison.

Farmer Johannes provided us access to the data available on his work computer through the Lely Horizon platform. This platform acts as a digital extension of the automatic milking robot, collecting a large amount of data. All cows are included in the automatically generated calculations without exception, ensuring the reliability of the results. From this platform, we extracted information related to annual cow cull rate and the causes of culling.

Claw health data was provided, with the farmer's consent, by the farrier overseeing the care of the farmer's cows. The farrier comes approximately twice a year to examine lame cows selected by the farmer; in addition, some cows close to dry-off period are also assessed. At each visit, the farrier records his findings and observations in a table, which we collected for the relevant time period, noting that the data for 2014 was missing. From the claw pathologies presented in the mentioned table, we selected the most frequent and relevant hoof lesions including white line disease (WLD), sole ulcer (SU), digital dermatitis (DD), sole abscess (SA) and toe tip necrosis (TTN). The data was then organized for analysis using the Microsoft Excel XP Professional computer program. The prevalence rate for each claw pathology was determined by calculating the percentage of cows with that specific condition relative to the total number of cows examined each year.

Data on both milk quantity and quality were collected and used in this study from cows with at least 2 lactations, ranging from their 1st to 3rd lactation. The requirement for at least 2 lactations was imposed due to the well-known variability in both quality and quantity of milk produced by primiparous cows. The analysis is limited to 1st, 2nd and 3rd lactations, as the new husbandry system has not been in place long enough to generate

sufficient data for the subsequent lactations. To avoid potential bias in the results, cows that experienced both management systems throughout their first 3 lactations were excluded from the study.

The animals were organized in 2 groups: 1) the control group, containing animals kept only in the indoor husbandry system from 2014 to 2018, 2) and the experimental group, consisting of animals kept only in the part-time outdoor system from 2019 to 2024. The distribution of lactation number in both test groups can be seen in Figure 1.

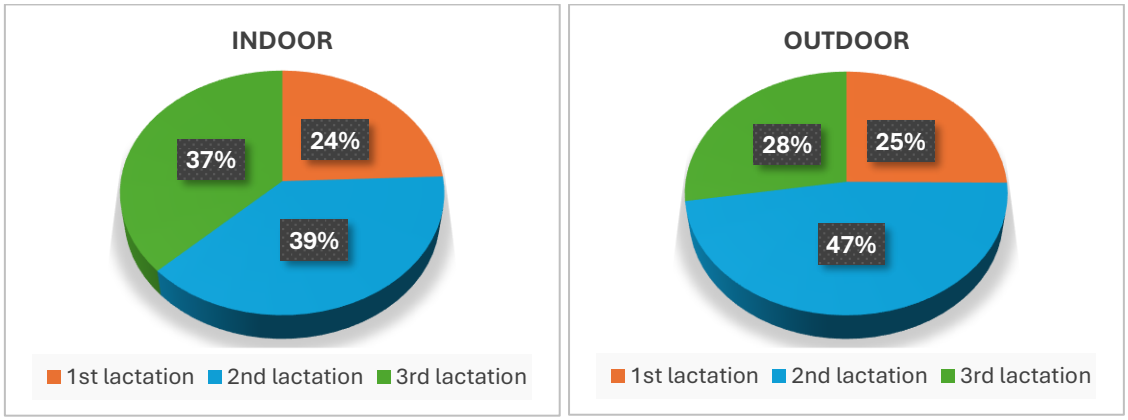

Figure 1. Distribution of lactation number in the indoor versus outdoor group

The data was not as complete and bulky as expected, the LELY advisor could not recall the data for each cow and every lactation since 2014. Especially from 2014 to 2018 the data available was limited, probably because the farmer did not record calving dates and dry-off dates as meticulously as he does since 2019. This led to a quite unequal number of cows in the control group compared to the experimental group, illustrated in Figure 2.

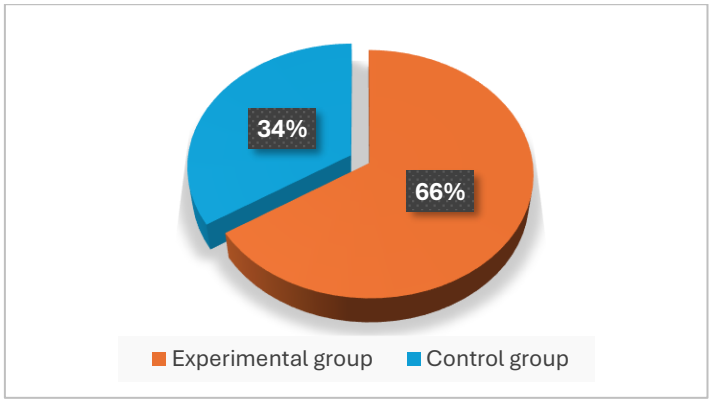

Figure 2: Distribution of animals in the two examined groups

6. Results

6.1 Production parameters

The analysis of milk yield per cow per lactation cycle, measured in kg/lactation/cow, revealed that cows in the experimental group with access to pasture consistently outperformed their indoor counterparts across all lactation numbers. In the 1st lactation, the difference in milk yield between the outdoor group (7 891.1 kg) and the indoor group (7 448.6 kg) was not statistically significant. In the 2nd lactation, outdoor cows showed a notably higher milk yield (9 822.4 kg) compared to the indoor kept cows (7 586.2 kg), with a highly significant difference confirmed by statistical testing ($P < 0.001$). In the 3rd lactation this trend continued, where the outdoor group again produced significantly ($P < 0.001$) more milk (10 730.3 kg) than the indoor group (7 932.2 kg).

The standard deviations for each lactation number revealed greater variability among the cows of the indoor group, while outdoor cows had more consistent milk yields. The results are detailed in Table 2.

Table 2: Comparison of milk yield between indoor and outdoor groups across lactations
Mean Milk Yield (Mean MY), Standard Deviation (SD), and Statistical Significance (P-value)

Lactation	Group	Mean MY (kg)	SD (kg)	P-value
1st	Indoor	7 448.6	2 133.4	0.29
	Outdoor	7 891.1	1 114.5	
2nd	Indoor	7 586.2	2 646.6	< 0.001
	Outdoor	9 822.4	1 478.6	
3rd	Indoor	7 932.2	1 817.3	< 0.001
	Outdoor	10 730.3	1 212.7	

Data from the Lely Horizon platform further emphasized this trend, indicating that the average lifetime milk production for culled animals increased notably, from 17 567 kg in 2014 to 42 548 kg in 2023, surpassing the farmers' established goals.

Similar trends were observed in the analysis of milk protein production per cow per lactation cycle, expressed in kg/lactation/cow, where the outdoor group again

demonstrated superior results across all lactations. In the 1st lactation, the difference in milk protein production between the outdoor group (254.8 kg) and the indoor counterpart (250.6 kg) was not significant. In the 2nd lactation, however, outdoor cows demonstrated a significantly ($P < 0.001$) higher protein yield (318.6 kg) than the indoor cows (241.1 kg). This pattern persisted in the 3rd lactation, where the outdoor group again produced more protein (351.7 kg) than the indoor group (267.1 kg) with a statistically significant margin ($P < 0.001$).

The standard deviations for each lactation number showed greater variability in the indoor group's values, whereas the outdoor group had more consistent production values. The exact results are summarised in Table 3.

Table 3: Comparison of milk protein between indoor and outdoor groups across lactations
Mean Milk Protein (Mean MP), Standard Deviation (SD), and Statistical Significance (P-value)

Lactation	Group	Mean MP (kg)	SD (kg)	P-value
1st	Indoor	250.6	70.5	0.75
	Outdoor	254.8	32.0	
2nd	Indoor	241.1	88.1	< 0.001
	Outdoor	318.6	44.7	
3rd	Indoor	267.1	66.6	< 0.001
	Outdoor	351.7	37.4	

The analysis of milk fat production per cow per lactation cycle, quantified in kg/lactation/cow, also showed higher values for cows with outdoor access compared to those housed indoor, with the only exception observed in the 1st lactation. In this initial cycle, the difference in milk fat production between both groups was not significant (indoor: 341.1 kg vs outdoor: 329.5 kg). In the 2nd lactation, the outdoor group yielded a remarkably higher milk fat content (427.0 kg) compared to the indoor group (319.2 kg), with this difference being highly significant ($P < 0.001$). This trend continued in the 3rd lactation, where the outdoor cows produced again significantly ($P < 0.001$) more fat (467.1 kg) than their indoor counterparts (366.0 kg).

The standard deviations suggest greater variability in milk fat yields among the indoor group, while the outdoor group maintained more consistent levels across lactations. Detailed results can be found in Table 4.

Table 4: Comparison of milk fat between indoor and outdoor groups across lactations
Mean Milk Fat (Mean MF), Standard Deviation (SD), and Statistical Significance (P-value)

Lactation	Group	Mean MF (kg)	SD (kg)	P-value
1st	Indoor	341.1	111.5	0.56
	Outdoor	329.5	44.6	
2nd	Indoor	319.2	116.0	< 0.001
	Outdoor	427.0	66.6	
3rd	Indoor	366.0	102.1	< 0.001
	Outdoor	467.1	56.9	

6.2 Udder health

The evaluation of udder health, based on SCC data, expressed in (10^3 C/ml)/lactation/cow, collected by the milking robots during each milking session, revealed notable differences between the indoor control group and the outdoor experimental group across all lactations. In the 1st lactation, outdoor cows showed a significantly ($P < 0.001$) lower SCC average (103.1) compared to the indoor cows (272.5). During the 2nd lactation, the difference in SCC between the outdoor group (201.5) and the indoor group (269.9) was not statistically significant; however, the likelihood that other factors influenced this outcome remained relatively low ($P < 0.09$). In the 3rd lactation, the difference between both groups difference did not reach statistical significance (outdoor: 262.0 vs indoor: 326.6).

The standard deviations indicated variability in the outdoor groups' values and more consistent results in the indoor group. The specific values are summarised in Table 5.

Table 5: Comparison of Somatic Cell Count between indoor and outdoor groups across lactations

Mean Somatic Cell Count (Mean SCC), Standard Deviation (SD), and Statistical Significance (P-value)

Lactation	Group	Mean SCC (C/ml)	SD (C/ml)	P-value
1st	Indoor	272 500	208 000	< 0.001
	Outdoor	103 100	791 000	
2nd	Indoor	269 900	179 500	0.09
	Outdoor	201 500	190 800	
3rd	Indoor	326 600	205 200	0.32
	Outdoor	262 000	302 600	

6.3 Claw health

The evaluation of claw health revealed a gradual decrease over the years in the number of cows the farmer selected for examination by the farrier. This decrease led to a higher number of cows examined by the farrier in the indoor husbandry system (331) compared to the lame cows selected in the outdoor husbandry system (320). It is worth noting that the data available for the control group spans a shorter period (4 years) than the data for the experimental group (6 years), further underscoring the reduction in lameness on the farm. From 2015 to 2018, an average of 85% of the cow herd was examined by the farrier, whereas from 2019 to 2024, this average dropped to 43%.

WLD was more prevalent in the outdoor group (46.15%) than in the indoor group (31.59%), with a remarkable decrease between 2023 and 2024. Similarly, SU were diagnosed more frequently in cows kept outdoors (36.81%) than in those kept indoors (25.36%), with a notable decline also between 2023 and 2024. DD results revealed that outdoor cows had lower exposure to this condition (53.26%) compared to indoor cows (64.82%), with reductions observed since 2020. SA were found slightly more often in the control group (10.73%) than in the experimental group (10.58%). This trend extended to TTN, which showed a higher percentage in the indoor group (5.47%) than in the outdoor group (3.53%). These results are detailed in Table 6 and Figure 3.

Table 6: Prevalence rate of claw diseases in cows from 2015 to 2024
WLD: white line disease, SU: sole ulcer, DD: digital dermatitis, SA: sole abscess, TTM: toe tip necrosis

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
WLD	30.77	38.64	22.81	34.15	38.89	37.50	43.64	53.66	62.69	40.54
SU	30.77	40.91	17.54	12.20	11.11	25.00	27.27	24.39	43.28	16.22
DD	41.76	65.91	83.33	68.29	59.72	75.00	45.45	41.46	49.25	48.65
SA	13.19	13.64	8.77	7.32	8.33	14.58	9.09	19.51	11.94	0.00
TTN	7.69	6.82	6.14	1.22	5.56	4.17	1.82	0.00	1.49	8.11

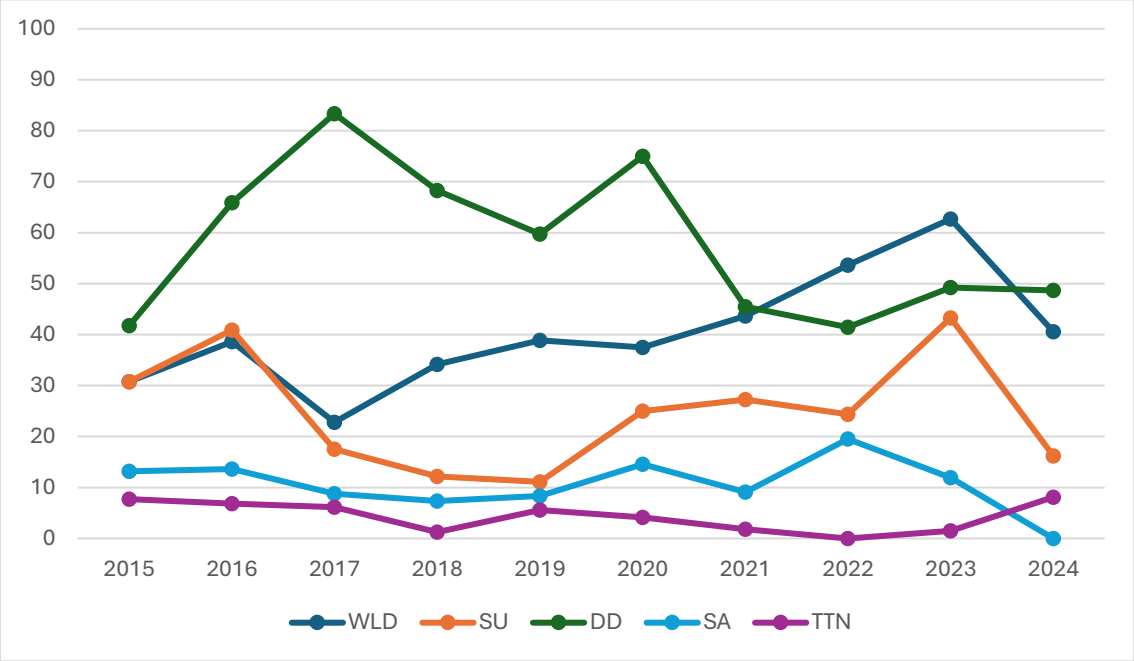

Figure 3: Evolution of claw diseases over 10 years
WLD: white line disease, SU: sole ulcer, DD: digital dermatitis, SA: sole abscess, TTM: toe tip necrosis

6.4 Cow cull rate

The average cow cull rate during the 5 years of the indoor husbandry system from 2014 to 2018 was 36,46%. This rate decreased by 7%, reaching a cull rate of 29,46% during the subsequent 5 years of part-time grazing husbandry system from 2019 to 2023. The year 2024 is excluded in this part, as the study was performed prior the end of that year. The detailed cow cull rates and culling ages are summarised in Table 7.

Table 7: Culling rate and average culling age per year

Husbandry system	Year	Culling rate (%)	Average culling age (years)
INDOOR	2014	30.6	4.07
	2015	36.4	4.03
	2016	35.9	5.00
	2017	26.0	5.06
	2018	53.4	5.07
OUTDOOR	2019	31.4	5.00
	2020	26.6	5.00
	2021	31.2	5.06
	2022	29.2	5.01
	2023	28.9	6.01

Unfortunately, culling causes were only recorded since 2019. According to the farmer, from 2014 to 2018, the primary reasons for culling were high SCC and claw disorders. Since 2019, the registered reasons of culling show udder diseases as the leading cause at 23.60%, followed by fertility problems at 16.30%, low production as third cause at 12.72% and claw disorders being the last reason at 7.34%. It is important to note that 40.04% of cow cull rate reasons are registered under “other causes”, which complicates the interpretation of the data, as this lack of detailed classification obscures the specific factors behind individual animal departures. Nevertheless, considering the mentioned results, a marked improvement in the herd management can be observed, particularly with the reduction in cull rate under the part-time grazing system.

Johannes notes that in the grazing system, more cows are culled due to age-related declines in production compared to the earlier full-time indoor system, suggesting a longer production lifetime on the farm. This observation is supported by the data from Lely Horizon, where the average age of culling is recorded annually. In 2014, the average culling age was 4.07 years, and by 2023, it had increased by nearly 2 years, reaching 6.01 years of age. In addition, the average number of lactations per cow has risen over the past decade, starting at 2.1 in 2014 and reaching 2.6 in 2023.

7. Discussion

In this study, milk production results, including milk yield, milk protein, and milk fat content, indicated a clear advantage for dairy cows in the experimental group with pasture access. In contrary, most studies comparing grazing to confinement systems report that indoor husbandry tends to be more profitable from a milk production point of view, particularly in terms of quantity [3, 5, 27, 28]. This difference may come from key distinctions in study designs: unlike most studies, which compare fulltime grazing systems to fulltime indoor systems, this study examined a farm that offered pasture access in addition to barn housing. Several factors help explain these contrasting results. Milk production is primarily influenced by genetics and feeding regime. In general, cows in closed confinement receive a highly controlled, balanced, and energy-rich diet designed to maximize milk yields, a level of control that is challenging to achieve in pure pasture-based systems. Other essential factors influencing milk production include health status, environmental conditions and cow comfort. Pasture access often improves cow health, mostly due to fewer cases of lameness commonly seen in confinement. Environmental conditions also play a role; while a barn provides consistent climate control, cows with pasture access can benefit from choosing between indoor and outdoor environments. However, cows limited to pasture alone may be exposed to extreme weather conditions, which can increase stress and reduce milk production. Cow comfort and stress levels are significant as well. Cows with pasture access experience more freedom to express natural behaviours, with fewer confinement-related stressors, while confined cows face stress due to limited space and potential hierarchical conflicts.

It is important to note that on the farm where this study was conducted, cows were fed TMR with pasture as an additional feed source, which may explain why milk production did not decrease in the outdoor group. Factors such as improved health, favourable environmental conditions, and greater cow comfort, likely contributed to the higher milk production observed in the pasture-access group compared to cows housed fully indoor. Additionally, this farm's setup further reduces stress through several features: 1) milking robots that minimize long waiting periods in confined spaces and allow flexible milking schedules, 2) pasture access that allows cows the freedom to choose their preferred environment, and 3) a flexible feeding system that enables cows to choose between TMR and grazing.

On the other hand, literature demonstrates that milk quality may be enhanced by pasture management, especially the milk fat components show notable improvements [3, 4, 32–35]. This trend is in accordance with the results of the present study.

Udder health is a parameter that has not been extensively studied in relation to husbandry practices, and the limited research available shows highly inconsistent results [6, 11, 22, 23]. This inconsistency likely arises from the multifactorial nature of udder diseases like mastitis, which are influenced by complex factors beyond a simple comparison of indoor versus outdoor systems. In the present study, changes in SCC were not highly significant; however, the experimental group with outdoor access consistently demonstrated better SCC results than the control group, suggesting a potential positive impact of outdoor access on udder health. Since udder hygiene is of great importance in this disease, based on the present study it can be hypothesized that, unlike the findings of other studies [11, 23], outdoor access offers a cleaner environment than indoor housing. Nevertheless, it is important to recognize that mastitis is influenced by multiple factors, and the observed reduction in SCC over the years could also be attributed to improvements in genetic selection or adjustments in milking and management practices.

Claw health is a well-researched area, with consistent findings showing that, thanks to the soft walking surface and the increased space available, cows on pasture experience significantly less claw issues than those kept in closed confinement [6, 10, 15–17]. The present study adds further evidence on this, as it observed a decrease in lameness among cows following a change in herd management. However, it is important to note that certain claw diseases, namely WLD and SU, were more prevalent in the outdoor system. A similar finding was reported in an investigation [18], where pasture access did not affect these particular claw issues. These conditions are often a consequence of laminitis, a disease primarily associated with energy-rich feeding regimes. Given that, in this work, feed remained consistent in both systems, and improvements in these claw conditions only began to show about four years after the switch in housing system, it can be assumed that the transition to a softer flooring surface requires time to positively impact WLD and SU. In contrast, the outdoor environment had an immediate positive effect on DD, a disease of infectious origin that is favoured by dirty, humid and abrasive flooring. This result suggests again that pasture provides a cleaner environment. As for udder health, it must be considered that claw health is of multifactorial nature, and the observed

improvements may not be solely due to the shift from indoor to outdoor system, especially given the time lag.

No literature was found specifically about the influence of herd management on cow cull rate. Therefore, this study adds new insights on this area. Cow cull rate being a consequence of the above-mentioned topics, the lower cow cull rate in the experimental group suggests that the change in husbandry practices positively impacted cow health and longevity, even though udder disease continued to be a persistent issue on the farm. It is noteworthy, however, that claw diseases are much less of a problem in pasture-based systems compared to closed husbandry systems, highlighting one of the clear benefits of outdoor access. The trend towards an increased age at culling indicates that the shift to a part-time grazing system has extended the overall herd longevity and productivity on the farm, suggesting a better health status and improved welfare of the cows.

Reproduction is also of high significance in relation to culling and dairy farm profitability. Unfortunately, very few research has been conducted on this subject in relation to dairy cow housing systems, and the present study did not focus on this aspect due to time and resource restrictions. The only reported advantage of pasture concerning reproductive performance is improved heat detection through visual observation [24, 25]. This was confirmed by farmer Johannes, who also uses visual observation for heat detection. Further research on the impact of pasture on fertility and dystocia would be valuable.

One limitation of this study is the lack of consistent data registration on milk production and cow culling reasons particularly from 2014 to 2018, which led to insufficient data, especially for the control group. This gap in data availability may have impacted the significance of the results. Additionally, the absence of thorough records on cow cull reasons during this period makes it difficult to draw precise conclusions about the relationship between housing systems and culling decisions. However, a key advantage of this study is that it was conducted on a single farm, which allowed for a more controlled evaluation of the impact of husbandry management on dairy cow health and productivity. Unlike studies that compare grazing and confinement systems across multiple farms with varying environmental conditions, cattle breeds, and management practices, this study focused on one farm where only one parameter, namely the husbandry management, was changed between the two periods examined. In addition, here the pasture was used primarily as an exercise area, rather than a primary feeding

source, with feed remaining largely consistent across both periods. The farm's consistent location, climate, and breed of cows further minimized external variables, providing a clearer picture of the specific effects of the husbandry system change.

There are several other important areas that could help us better understand how pasture access affects cow health and productivity. For instance, it would be useful to study how pasture access as an exercise area impacts the occurrence of metabolic disease like ketosis, milk fever, and abomasum displacements.

8. Conclusion

There is no universal solution for optimal cattle management; rather, the optimal approach would be a combination of several management practices tailored to the specific farm context. Grazing systems are without a doubt preferable in terms of cow welfare and claw health. However, when it comes to milk production, confinement systems are typically preferred, as they allow for more precise control over feeding, which is the most significant factor influencing milk yield. Udder health, on the other hand, does not appear to be significantly affected by the housing system, making it difficult to determine if pasture or confinement is more beneficial in that regard.

This study highlights that combining barn management with pasture access can be an effective strategy, making use of the benefits of both systems. Feeding is more effectively managed indoors with a TMR system, while pasture access offers significant advantages for cow health and welfare, particularly through increased exercise and improved comfort. This combined approach provides a balanced solution that enhances both productivity and cow-well-being.

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Thesis progress report for veterinary students

Name of student: **Anna Hering**

Neptun code of the student**: DNFDPL**

Name and title of the supervisor: **Dr. István HULLÁR assoc. prof.**

Department: **Animal Nutrition and Clinical Dietetics**

Thesis title: **Effect of herd management on annual cow cull rate and performance of Holstein-Friesian dairy cows**

Consultation – 1st semester

Timing				Topic / Remarks of the supervisor	Signature of the supervisor
	year	month	day		
1.	2024.	02.	12.	Review of literature.	
2.	2024.	03.	26.	Structure of the thesis.	
3.	2024.	04.	19.	Citation of the authors.	
4.	2024.	05.	24.	Research questions.	
5.	2024.	06.	19.	Food safety concerns.	

Grade achieved at the end of the first semester: 5 (very good)

Consultation – 2nd semester

Timing				Topic / Remarks of the supervisor	Signature of the supervisor
	year	month	day		
1.	2024.	07.	31.	Advantages and limitations of different feeding methods.	
2.	2024.	08.	27.	Conclusions.	
3.	2024.	09.	12.	Discussion about the first version.	
4.	2024.	10.	17.	Corrections.	
5.	2024.	11.	08.	Development of the final version.	

Grade achieved at the end of the second semester: 5 (very good)

The thesis meets the requirements of the Study and Examination Rules of the University and the Guide to Thesis Writing.

I accept the thesis and it is found suitable to defence,

.....
signature of the supervisor

Signature of the student: .....

Signature of the secretary of the department: .....

Date of handing the thesis in: 17. 11. 2024