THESIS

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INVESTIGATION OF CORRELATIONS BETWEEN AUTOMATED MILKING SYSTEMS AND PRODUCTION EFFICIENCY

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ABSTRACT OF THESIS

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The use of automatic milking systems, also known as milking robots, is increasingly popular as a technology that can reduce labor, increase milk production and maximize profit. This study ,was carried out on a private dairy farm located in West Hungary, aimed to examine the relationship between automatic milking systems (AMS) and production efficiency in lactating cows with herd sizes ranging from 267 to 322 Holstein-Friesian cows in the middle of lactation specifically 165 ± 10 days in Milk. The results of this study indicates that on average, an AMS unit milked 49 ± 3 cows daily with each cow being milked 2.7 ± 0.1 times per day and producing a daily milk yield of 32.5 ± 1.3 kg per cow. The data was statistically analyzed using Pearson correlations at a probability level of 0.95 to 0.99 and single and multiple linear regression analysis. The study found that daily milk yield was positively correlated with milking frequency ($r = 0.61$, $p < 0.01$) and negatively correlated with unsuccessful milking frequency ($r = -0.34$, $p < 0.01$) but had no correlation with refusal milking frequency ($p > 0.05$). Additionally. A positive correlation was observed between the amount of concentrate offered in AMS per cow per day and both milk yield ($r = 0.52$, $p < 0.01$) and milking frequency ($r = 0.27$, $p < 0.01$). No correlations were observed for refusal and unsuccessful frequency with the amount of concentrate offered in AMS ($p > 0.05$). Finally, the fat content was negatively correlated with daily milk yield ($p < 0.05$) and the amount of concentrate while there was no correlation observed for protein content with daily milk yield or the amount of concentrate in the AMS ($p > 0.05$). Detailed knowledge of these factors such as milking frequency and concentrate intake associated with increasing milk yield using AMS will help guide future recommendations to producers for maximizing milk yield and decrease the cost in Hungarian Dairy Farm and industries.

Keywords: Milk Yield, Milking Frequency, Automatic Milking System (AMS), Amount of concentrate.

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LIST OF ABBREVIATIONS

AFS: Automatic Feeding systems

AMR: Automatic milking rotary

AMS: Automatic milking Systems

CC: Concentrate

DMI: Days in milk

DMY: Daily milk yield

EC: electrical conductivity

FFA: free fatty acids

HC: High concentrate

LC: low concentrate

MF: Milking frequency

NC: Number of cows

PLF: Precision Livestock Farming

SCC: Somatic cell count

SPSS: Statistical Package for the Social Sciences

TMY: Total Milk yield

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I. LITERATURE REVIEW

I.1. Introduction

The EU is a significant participant in the global dairy market, with a substantial share of production for various dairy products. It contributes 22% of the world's milk production, making it the most significant producer on the global stage **(Burrell 2000).**

The increase in milk yield of dairy cattle coincides with multiple challenges imposed on the cows **(Probo et al., 2018).** During the past century, the dairy industry has embraced technological advancements to optimize their output and financial gains.

There is a strong connection between technological advancements and structural changes in agriculture. The livestock industry's fascination with automation and precision technologies is continuously growing **(Cogato et al., 2021)**. European dairy farms are presently undergoing a phase of transition to acclimate to modern dairy technology. The objective is to enhance various activities, such as management, consulting, physical labor, data collection, and analysis **(McKinsey Global Institute 2017).**

The persistent shortage of labor and the dairy farmers' aspirations to enhance their quality of life and professionalize their farms have resulted in a continuous evolution and modernization of dairy farming practices. This transformation has progressed from conventional bucket milking systems to tie-stall systems and milking parlors, and more recently, to the implementation of automatic milking systems (AMS). The adoption and proliferation of automated milking systems in European agriculture follows this trend.

As of 2020, AMS manufacturers estimated that roughly 50,000 units were operational worldwide **(Simões Filho et al., 2020)**. By 2025, it is projected that 50% of dairy farms in northwestern Europe will be equipped with AMS **(Hansen et al., 2019).** Barns that have automatic milking systems (AMS) generate significant volumes of data associated with the milking process, cow activity, concentrate feed intake, and rumination time. This data can be utilized to enhance the herd's production level and improve the welfare of the animals **(De Koning 2010).**

With the growing adoption of robotic milking, numerous studies have been conducted to investigate the impact of automated milking on various factors. These include milk yield and quality **(Lessire et al., 2020),** animal behavior, health, and welfare **(Piwczyński et al.,**

2020), herd management **(Penry et al., 2018)**, and labor efficiency **(Hansen and Stræte, 2020)**.

Schewe and Stuart (2015) observed that the implementation of AMS has altered the dairy farm's operations and organization, leading to a restructuring of the relationships between farmers, animals, technology, and the environment.

The objective of this study was to assess the impact of utilizing an Automatic Milking System on the production efficiency of dairy farms. The study examined various factors such as milk yield, milking frequency, visit time, feed intake, composition, and more.

I.2. Importance Of Dairy Farms In Europe

Precision Livestock Farming (PLF) is a novel method of animal husbandry that employs advanced technologies to collect data on every animal within a farm. This data is then utilized to optimize management practices by decreasing inputs or improving overall farm productivity.

Dairy farming is an essential industry in modern agriculture that has undergone significant technological advancements, including several smart-farming innovations. One of the most significant developments in some countries is the introduction of milking robots, or AMS, which has transformed the daily work of farmers and the relationship between farmers and animals **(Hårstad 2019)**. Presently, there are over 35,000 AMSs operating on dairy farms worldwide **(Salfer et al., 2017)**, and the utilization of AMS has gained a significant presence in family-based dairy farming.

I.3. Robotic Technologies in Animal Husbandry

Dairy farmers are increasingly evolving toward automation of their farms **(Boscaro et al., 2015)** automatic concentrate dispensers and automatic milking systems (AMS) have been utilized for years, and several manufacturers have introduced automatic feeding systems (AFS) during the past decade **(Unal et al., 2015)**

The substance of the robotic milking system to the persistent moving of livestock is guaranteed. The cows feed, milk and relax when they want according to their own needs. Robotic VMS is comprised of automated feeding, milking, analysing, reproduction, and cooling processes. The application of this system delivers lower feeding costs, improved breeding performance and healthy, productive cows **(Enikő et al., 2017).**

I.3.1. Automated Feeding System (AFS)

In recent years, the demand for reduced labor and the growth in herd sizes has driven the development of automated solutions for feeding dairy farm animals. This has resulted in the deployment of over 1,250 automatic feeding systems (AFS) worldwide. However, information regarding their energy requirements and management costs remains limited **(Tangorra and Aldo, 2018).**

Feeding a total mixed ration (TMR) diet is now a preferred practice and has affected the popularity of mechanized feeding systems, mostly represented by conventional manually operated mixer-feeder wagons.

The main advantage of AFS is the possibility to supply a total mixed ration (TMR) with a high frequency and a low labour requirement, whilst farms that feed with conventional feeding systems (CFS) commonly supply TMR only once or twice a day and require more labour with a rigid work schedule. AFS allows for increasing the frequency of feed distribution, with a consequent optimization of dry matter ingestion by the animals, and concurrently assist to maintain a higher stability of ruminal pH with significant advantages in terms of health and production **(DeVries et al., 2005).** Another important advantage of AFS is that animals are provided with feed or forage multiple times a day, which helps to maintain the quality of the feed. When all the forage is put into the Total Mixed Ration (TMR) at once, the quality of the feed deteriorates throughout the day due to factors such as acidification. By providing the feed or forage multiple times a day, the animals have access to fresh, high-quality feed, which can improve their health and productivity.

I.3.2. Automated Milking Systems (AMS)

I.3.2.1. Conventional Milking vs Automated Milking systems

Adopting an automatic milking system (AMS) instead of a conventional milking system (CMS) requires a different management style and corresponding changes in labor tasks **(Svennersten-Sjaunja and Pettersson, 2008).**

AMS eliminates immediate milking supervision but introduces new labor tasks such as AMS control and cleaning, checking attention lists, and fetching cows that exceed maximum milking intervals. Field data on labour savings with automatic milking systems is limited, but model studies have demonstrated that physical labor can be reduced by 30 to 40% when compared to conventional milking systems **(de Koning and Rodenburg, 2004).**

A study conducted in 2003 found that dairy farms using AMS required 29% less labor compared to those using conventional milking systems **(Bijl et al., 2007).**

The following facts should be considered when deciding to implement milking systems: When considering the introduction of milking systems, several factors should be taken into account, such as the special features of the stable, the extra investment cost of the equipment compared to conventional milking, the expected life span of the system, the balance of extra costs and extra saving compared to conventional milking, the potential yield and quality improvement, higher income, indirect effects such as less herd diseases, better production parameters, and possible subsidies **(Enikő et al., 2017).**

I.3.2.2. Historical evolution of AMS

Interest in fully automated milking began in the mid-1970s, and was initially driven by the growing costs of labour in Europe. Since machine milking, and automatic detaching, and teat spraying were already in common usage, automatic cluster attachment became the focus of European work **(de Koning and Rodenburg, 2004).**

- The number of dairy farms using an automatic milking system (**AMS**) is increasing rapidly, especially in northwest Europe. Automatic milking systems (AMS) became commercially available in the early 1990s. The majority of AMS are located in northern Europe (90%) and Canada (9%), with only about 1% located in the United States **(de Koning, 2010).**
- Since the first AMS was installed in 1992, much research has been completed investigating these areas. However, as third and fourth generations of AMS become available and barn layouts and management routines have been optimized for AMS production, some of the older research may become obsolete **(de Koning 2010).**
- **IN 1992**: The first AMS were installed in the Netherlands, and by 2009, an estimated 8,000 farms worldwide had adopted AMS **(de Koning 2010; Hogeveen and Steenveld, 2013).**
- **By 2015** 16 of them were installed in neighbouring Slovakia and 170 in the Czech Republic **(Brouček and Tongel, 2015).** The first automatic system in Hungary started operating in 2009 **(Szendrei and Sós, 2010)** and further spread is expected.

Figure 1. Astronaut A3 (Mono-stall) from Lely **(Etignard and Le Gall, 2009)**

I.4. Importance and Functionality of Automated Milking Systems (AMS)

According to **Svennersten-Sjaunja and Pettersson (2008)**, the introduction of an AMS requires not only new milking technology but also a new management system that encompasses cow traffic, feeding, cow behavior, grazing, and milk quality. The use of AMS is most effective on farms with 60-260 cows **(Gustavsson 2010)**, although there are examples of both smaller and larger AMS farms.

By implementing an AMS, farmers need to shift to a new management system that considers various aspects such as cow traffic, feeding, cow behavior, grazing and milk quality, as highlighted by **Svennersten-Sjaunja and Pettersson (2008)**. The most efficient AMS usage is on farms with 60-260 cows, but there are examples of successful AMS farms with both much fewer and much more cows **(Gustavsson 2010)**. AMS not only reduces labor costs but also increases milk production per cow by allowing an increase in milking frequency without requiring additional labor.

In an AMS, in the standby position, the rear door is open and the front door remains closed. When the cows voluntarily (motivated by the supply of concentrate) enter the milking box **(de Koning and Rodenburg, 2004)** it will be detected by the infrared entry cell and then identified by its collar. The back door closes and the computer checks if the cow is ready to milk. If so, she gets her own dose of concentrate. Its mass is recorded using sensors located under the robot's cage. The system cleans the udder, milks the cow and analyses the milk in order to detect any abnormalities **(Freiss, 2009)**.

Table 1. Variation in the capacity of milking robots depending on the manufacturer **(Dussault, 2001)**

Maker	Robot capacity (cows/unit)	robot capacity (L of milk /d)
DeLaval	60	1800-2200
Lely	60-70	1900
Bou-Matic	50-60	2000
Galaxy	60-70	2100

I.5. Consequences of Using AMS For The Farmer And For The Herd

I.5.1.Pros

One advantage is the opportunity to reduce the need for hired labour and to give the farmer more time for family and recreational activities. Another advantage is the increased milk production due to more frequent milking **(Svennersten-Sjaunja and Pettersson, 2008)**

One of the main advantages of an AMS lies in the ability to control milking frequency on an individual cow basis to adjust for production level or at specific stages of lactation without incurring additional labor costs, assuming cow's milk voluntarily at the desired frequency **(Hogeveen et al., 2001; Svennersten-Sjaunja and Pettersson, 2008)**.

The adoption of AMS has significant impacts on farmers' well-being, safety, and the environment. It also affects socio-cultural factors such as household labor division and work-hour flexibility, according to research by **Drach et al. (2017)**. In a review by **Jacobs and Siegford (2012)**, a reduction in labor by up to 18% was observed, while other studies found minor differences in labor use but notable differences in task and work flexibility, as noted by **Steeneveld et al. (2012).**

According to (**Hansen 2015)**, farmers who invested in AMS emphasized the following main benefits: less time spent on milking, more interesting farming, more stable treatment of the cows, and less need for relief in the cow house.

Several studies imply that the main motivation for farmers to invest in AMS is not economic, but rather to improve their quality of life and achieve a more flexible working day **(Hansen, 2015; Hårstad, 2019).**

I.5.2. Cons

Although the improvement in milking technology via the use of multiple sensors and data analysis programs in AMS can be beneficial to the manager and cow alike, certain disadvantages are also present

- The cost of implementing AMS is a major concern as it is estimated that each single-stall AMS could cost between $150,000 to $200,000, depending on the desired number of milking events per day for each cow, and can serve approximately 60 cows. In contrast, a new conventional parlor could cost between $4,000 and $15,000 per milking stall, depending on the type of parlor and the possibility of reusing an existing shell (e.g., concrete and plumbing), according to **Bijl et al. (2007).**
- The disadvantages include the large investment cost and the risk of a decrease in milk quality. It is often found that the milk quality decreases after the introduction of an AMS, but there are also findings of no differences and even improved milk quality **(Andersson 2012).**
- Certain cows may not be suitable for milking in an AMS due to behavioral or conformational issues. For example, if a cow has an unfavorable teat position or variations in udder quarter size, cluster attachment may be challenging if teat cup attachment fails. This can lead to lower milk production by the affected quarter during the next milking, even after adjusting for the interval length **(Bach and Busto, 2005).**
- One major difference for the farmer who installs an AMS is that even if the milking process in a conventional system is very time consuming and ties the farmer to the milking process at specific times, an automatic milking system means the farmer has to be on call 24 hours a day in order to handle possible alarms from the system **(de Koning 2010, Gustavsson 2010).**
- A further disadvantage of implementing AMS is that dairy managers must be prepared to invest time in training their entire herd, as well as individual cows, to use the AMS. Transitioning from a conventional parlor to an AMS requires approximately 3 to 4 weeks of intensive labor to achieve a success rate of 80 to 90% cows voluntarily using the system **(Jacobs and Siegford, 2012)**.

I.6. Effect Of Using AMS On Cow Behaviour

To ensure regular milking, various cow traffic systems are implemented to control cow movement within the barn for feeding, resting, and milking. The farmer can control cow movement by dividing the barn into different sections using gate systems. The primary motivation for cows to visit the milking unit is to receive concentrate feed, making it the most common approach in AMS. However, roughage feeding and resting needs are also utilized to encourage cows to pass through the milking unit.

There are two types of cow traffic systems used to guide cows to the milking unit: free traffic and forced traffic. In a free traffic system, cows can move freely between the roughage and cubicle areas and are motivated to visit the milking unit for concentrate feed. There may or may not be a waiting area in front of the milking unit, and no selection gates are used in this system. In a forced traffic system, cows must pass through the milking unit to access the feeding area again. If a cow has permission to be milked, she will receive concentrate and be milked. If not, the exit gate will open and no concentrate will be delivered **(Bach et al., 2009).**

I.7. Effect Of AMS On Feed Intake

The authors of a study concluded that based on a choice test between milking and feeding, the cow's motivation to be milked was weaker compared to the motivation to feed **(Prescott et al., 1998)**. However, another study found no significant difference in the amount of concentrate offered, the frequency of voluntary milking, and the need to fetch cows to the AMS **(Jago et al., 2007).** Yet, a study by **Madsen et al. (2010)** found that the composition of the concentrate offered in the AMS affected the number of visits achieved. Thus, it may not be enough to rely solely on cows' motivation to milk, and providing palatable feed or access to fresh pasture in the AMS may be necessary to encourage cows to enter the milking unit.

The amount of concentrate is not the main factor in increasing motivation **(Bach et al., 2007; Jago et al., 2007)**, but rather its composition and palatability **(Madsen et al., 2010)**. High yield cows require a significant amount of concentrate, but it is not possible to ingest the total amount in the robot due to health issues (ruminal acidosis) and time constraints. Determining the specific amount to be offered in the robot is a difficult task, because if there is only a small proportion of the daily ration in the robot, it will not have the desired appealing effect **(Armstrong and Daugherty, 1997)**, while it is also advisable to avoid feeding too much. Ideally the automatic concentrate feeders are placed in the milking and selecting area, but care must be taken to avoid situations when cows are not able to eat the full ration because they don't spend enough time in these areas.

According to **Tranel (2013),** typical amounts of concentrate consumed by cows in partially mixed ration (PMR) feeding systems at the AMS range from 1 to 8 kg per day, and the feed offered at the robot should be palatable and pelleted. However, the rest of the PMR ration should still be provided multiple times a day, and care should be taken to ensure its quality and appropriate hygiene of the feed bunk.

AMS manufacturers usually offer solutions for future generation feeding systems also. With automatic systems gaining ground manual labour is decreased as much as possible. The system only requires manual labour for loading every day and all further phases of feeding are fully automatic: from the precise load and mixing of feed components to distribution of feed, even pushing up feed in the bunks. Not only feeding but also the removal of manure can be fully automatic in a modern barn, which may increase hygiene and cow comfort.

A challenge with high-concentrate allocation in the AMS is that increasing the concentrate delivered in the AMS results in a substitution effect, where the increased concentrate consumed is offset by a reduction for the intake of the partial mixed ration (PMR) **(Bach et al., 2007)**. Only one study known to the authors has considered the impact of how AMS concentrate provision strategies affect PMR intake. However, the substitution of PMR for AMS concentrate can have a large impact on the nature of the diet consumed as **(Bach et al., 2007)** reported that for every 1 kg d^{-1} increase in AMS concentrate consumed, cows decreased PMR intake by 1.14 kg d^{-1} .

I.8. Effect of AMS on Milk production

The efficiency of the milking unit is dependent on many factors, e.g. milk yield, milking frequency, milking intervals, success of teat cup attachment and duration of milking procedure **(Gygax et al., 2007)**

The time cows spend in the milking unit without being milked (i.e. non-milking visits, entering and exiting) should be as short as possible to maximize the efficiency of the robot. (Gygax et al., 2007) reported a mean milking time of 7.6 minutes during a normal milking. When milking failed (i.e. one or more teat could not be found by the robotic arm or the teat cup were kicked off early in the milking), the median time to pass the milking unit was 6.3 and 7.8 minutes for free and milk first traffic respectively**. (Stefanowska et al., 1999a)** showed that cows that had to stop outside the milking unit, because it was occupied, had a slower walking speed when entering the milking unit**. (Stefanowska et al., 1999b)** observed that cows hesitated more before entering the milking unit if the previous visit was a non-milking visit (i.e. the cows were not milked and did not receive concentrate).

I.8.1. Milk Yield

Automatic milking systems have the potential to increase milk production by up to 12%, decrease labor by as much as 18%, and simultaneously improve dairy cow welfare by allowing cows to choose when to be milked **(Jacobs et al., 2012).**

- **Milking frequency**

Studies have shown that increased milking frequency can increase milk production by up to 10.4 % when milking cows three times per day compared to two **(Melin et al., 2005)**. Milking frequency is dependent of the cows' willingness to voluntary visit the milking unit continuously during the day **(Melin et al., 2005)**. However, cows own motivation to be milked is low **(Prescott et al., 1998),** which makes management strategies and barn layout important in AMS. Several researchers have reported an increase in milking production of 2 to 12% in cows milking 2+ times per day in AMS compared with cows milking twice per day in conventional parlors **(Wade et al., 2004)**. For example, milk yield was found to be 9% higher in cows milked 3.2 ± 0.1 compared with 2.1 ± 0.1 (means ± SD) times per day in AMS **(Melin et al., 2005).** However, other researchers have reported no increase in milk production related to increasing frequency of milking by AMS **(Gygax et al., 2007)**.

- **Milking intervals**

Shorter milking intervals have been shown to increase milk production and reduce somatic cell count (SCC) in dairy cows **(Wright et al., 2013)**.

(Sitkowska et al., 2015) found the optimal number of milkings per cow and day to be 2.6-2.8 with a milk flow rate of 2.6 kg/min. **(de Koning and Ouwektjes., 2000)** evaluated the relationship between number of milkings per day and milk yield per milking unit and day. They found that short milking interval results in lower milk yield per milking and increased number of milkings per day. Increased milk yield per milking resulted in less milkings per day but a higher milk production per milking unit and day.

"Changes in milking frequency when milking systems operate with different numbers of cows with varying milk yields can affect the capacity limits of the AMS. A decrease in the number of milkings occurred when more than 45 high-performance cows were milked per AMS **(Artmann, 2004)**. On the other hand, milking interval has a significant effect on milk yield and milk flow rate (Hogeveen et al., 2001), and a milk yield increase resulting from increased milking frequency has been reported **(De Koning and Rodenburg, 2004; Speroni et al.,**

2006)."

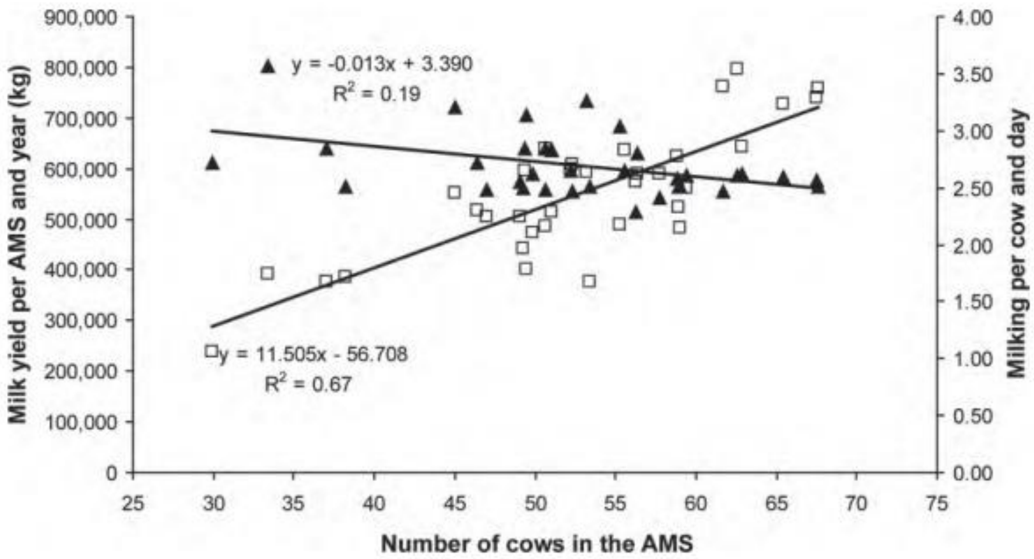

Figure 2. Effect of cow number per automatic milking system (AMS) on the milk yield per AMS and year (□) and the effect of cow number per AMS on number of milkings per cow and day (Δ) **(Castro et al., 2012).**

I.8.2. Milk quality

- **Compositional Aspects**

According to a study by **Abeni et al. (2005),** the type of milking system does not appear to have an impact on the protein and fat content in milk, nor does it affect the levels of lactose and urea in milk as found by **Hopster et al. (2002).** Instead, research suggests that the interval length between milkings and variation in milk yield per milking have more of an impact on fat content, as noted by **Friggens and Rasmussen (2001).** Some evidence exists indicating that levels of FFA are increased in milk collected from farms that milk cows with AMS **(de Koning et al., 2004).** High FFA content in milk is considered undesirable because it confers a rancid taste to the products produced from such milk. The increased milking frequency and shorter milking intervals found in AMS systems have been found to cause increased FFA content in milk **(Hamann et al., 2004).** In part, increased FFA may be due to low milk yields resulting from short milking intervals **(Rasmussen et al., 2006).** However, technical differences in handling milk between AMS farms and parlor farms, such as greater air intake during milking, may also cause some of the observed increase in FFA in AMS milk **(Rasmussen et al., 2006).**

- **Hygienic Aspects**

Automatic milking units are fitted with sensors that measure milk quality, for instance somatic cell count (SCC) and electrical conductivity **(Jacobs and Siegford, 2012).**

A healthy cow has a SCC level of about 100 000 cells/ml, while an infected udder can have a SCC level of above 1 000 000 cells/ml. However, a SCC level of 200 000 cells/ml on udder quarter and a whole udder SCC level of 400 000 cells/ml is an indication of mastitis **(Sharma et al., 2011)**.

In one study, **(Helgren and Reinemann, 2006)** followed the changes in SCC and total bacterial counts on 12 US farms for 3 yr after they transitioned from parlors to AMS. No initial increases in SCC or total bacterial count were found to be associated with AMS use; in fact, SCC and total bacterial counts decreased the longer the farms used AMS **(Helgren and Reinemann, 2006).**

Epidemiological studies have commonly shown that the implementation of Automatic Milking Systems (AMS) leads to an increase in somatic cell count (SCC) and a decrease in milk quality. However, experimental studies have found no negative impact on udder health, according to **Hovinen and Pyörälä (2011**). The introduction of an AMS usually involves other alterations to the barn, such as modifications in teat cleaning, cow grouping, stall type, manure handling, and overall herd management. This could result in a higher dependence on automatically collected data.

The milk's electrical conductivity (EC) is a measure of its concentration of anions and cations. Cows that are suffering from mastitis have an increased level of Na+ and Cl concentration in the milk, which increases the EC **(Hovinen and Pyörälä., 2011).**

I.9. Effect of AMS on Animal Health And Welfare

Milk quality is a crucial factor for breeders, farmers, and the dairy industry, regardless of the milking system being used. Milk quality is directly influenced by the somatic cell count (SCC). To assess SCC, it is log-transformed into somatic cell score (SCS) to achieve normality and facilitate statistical analysis. The method of genetic evaluation of SCS varies depending on the country and breed of cows, as stated in the **Interbull report of 2019**. Martin and colleagues (2018) found that the genetic correlation between clinical mastitis and SCS was positive and very high, reaching up to 0.85.

Rapid detection of mastitis and limitation of over-milking, since the robot allows milking on the scale of the district and not of the animal **(Freiss, 2009)**

Poor liner and teat hygiene, as around 60 cows per day can be milked with the same milking cluster **(Klungel et al., 2000).** In addition to the poor disinfection of the cleaning brushes, and the low efficiency of the rinses that the robot can perform after the passage of an infected animal **(Labbé, 2008).** A US study has shown that the number of cows culled because of low milk flow or abnormal or sub-optimal teat placement increased by 4.1–6.5% after the installation of an AMS, but culling for udder health reasons dropped by 5% (**Tranel, 2013).**

I.10.Effect of AMS on Reproduction

Reproductive performance has a major effect on profitability of dairy farms **(Overton and Cabrera, 2017)**. In many European countries, milk production per cow has more than doubled in the last 40 years. The increase in production has been accompanied by declining ability to reproduce, increasing incidence of health problems, and declining longevity in modern dairy cows.

Faster and more effective detection of heat **(Pomiès, 2006)** and therefore better management of reproduction thanks to an estimation of the progesterone level **(Eradus et al., 1992)** adopted by several brands of milking robot such as DeLaval Herd Navigator **(DeLaval, 2009)**, which therefore makes it possible to reduce the cost of reproduction **(Bisson, 2017)**. In addition, the calving interval is more limited: 399 days in the case of the AMS vs. 404 days for the milking parlor, the data collected by the AMS helps to keep the animal healthier which is good for fertility. Other point of view, AMS searches the repeat-heatings more efficient by measure the activity and progesteron level which is necessary for the good reproduction management **(Bisson, 2017).**

Increase in the frequency of milkings and therefore in the relative exhaustion of the reproductive potential of energy-deficient cows **(Kruip et al., 2017).**

I.11. Effect of AMS on Environment

Since the creation of milking robots, sensors and sensor systems have been developed to touch the environmental aspect today. Indeed, recently, robotic milking systems allow estimation of methane emissions using towers equipped with fast-response methane sensors and wind speed/direction sensors, combined with atmospheric transport modelling. More specifically, it is the use of signal processing to detect burping peaks of methane (CH_4) released by dairy cows during robotic milking**.** It reduces environmental pressure by using of resources more efficient. By keeping the animal healthier, less will be out, which will need to be replaced by fewer heifers, thus reducing the ecological footprint **(Van Breukelen., 2021)**

I.12.Economic Considerations of Feeding Practices (Point Of View)

Dairy farming is a business, just like any other business in life. It is a human activity whose basic purpose is to satisfy consumer needs while making a profit. The owner expects a return on the money invested. If this does not happen for several consecutive years, he will consider continuing the activity and invest the capital in another area. This is why, in the face of climate change, the absurdities of fodder production and the hectic and rapidly changing macro- and microeconomic environment, it is very important to use all the reserves in farming to ensure profitability. We have no control over the price at which we receive the milk, which is the main determinant of income, but we do have control over the quantity of milk produced and the cost of production (figure 3).

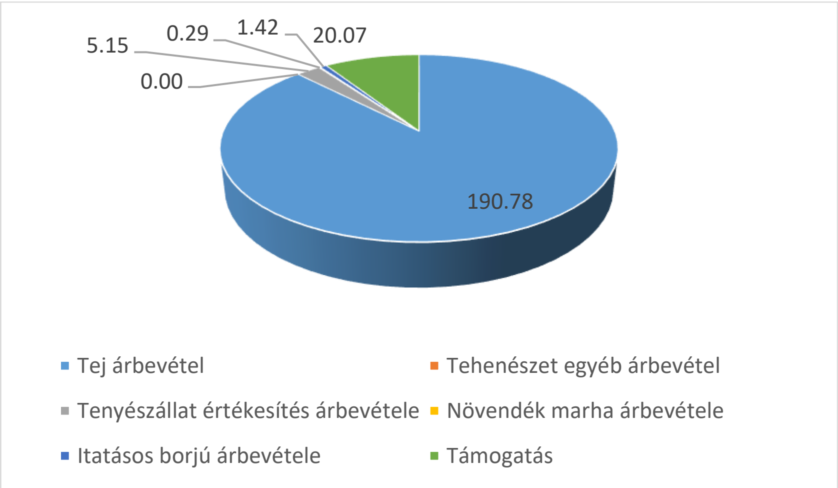

Figure 3.Distribution of income

- Tej árbevétel: milk revenue, tenyészállat ért árbevétele: slaughter cow revenue, itatásos borjú árbevétele : drinking calves (bulls) revenue, tehenészet egyéb árbevétel : other revenue of dairy, novendékmarha árbevétele : growing cattle (heifers) revenue, támogatás : subsidies.

The sale of milk accounts for a majority of the income, specifically 87.63%. There is also a notable contribution from subsidies. When considering the different costs involved, feed is the largest component by a considerable margin, as shown in figure 4.

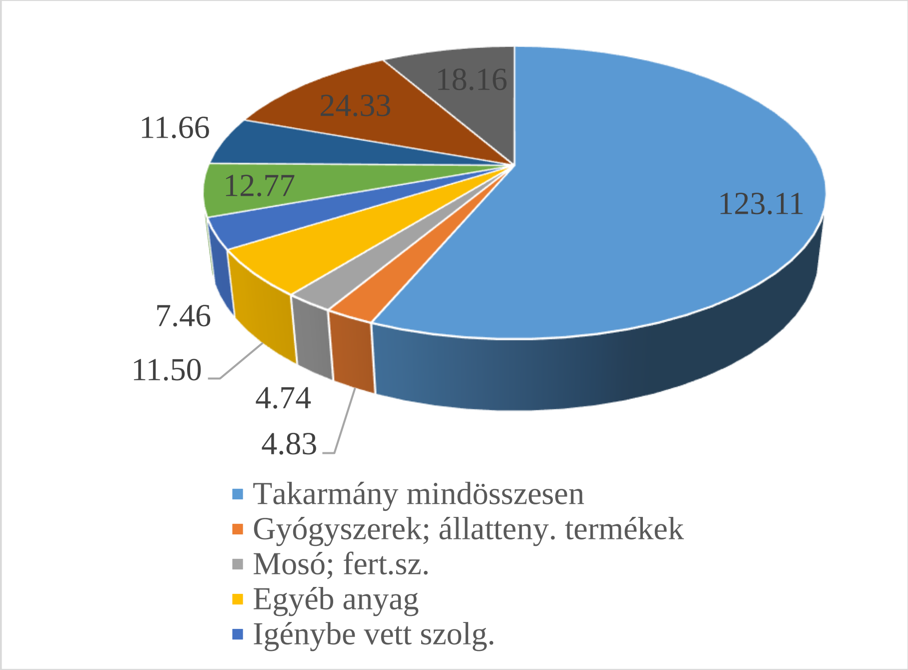

Figure 4.Proportion of costs incurred in production

Takarmány: nutrition cost, gyógyszerek: medicine and other breeding products cost, móso fert szer : detergent disinfectant cost, egyéb anyag : other cost, igénybe vet szolgáltatás : service cost.

The cost of milk production is dominated by feed, accounting for 56% of the total cost, which translates to 123 Ft/kg in practice. As a result, it is crucial to produce milk in the most efficient manner possible from the feed that is being consumed. Precision technologies can be immensely beneficial in achieving this goal.

II. MATERIALS & METHODS

II.1. Dairy Farm

The study was carried out on a private dairy farm located in West Hungary. The farm was characterized by a free-stall system housing 294 lactating cows with concrete floor and surface scrapers for a frequent removal of manure equipped with a ventilation system. Installed in the housing there are 6 singles AMS. The milking robots were purchased from their own resources. The prevailing breed was Holstein-Friesian. The original data were collected over a period of 3 months per AMS from October 2022 to January 2023. In total, 49 Holstein cows were milked daily per AMS unit. The days in milk was 165 (mid-lactation) with a total of 9542.3 kg Milk production per herd per day.

Figure 5. Dairy farm

II.2.Data Collection

The data were collected from six Lely Astronaut A5 milking robots using PMR (partial mixed ration) on the feed fence with additional robot concentrate. Each time a cow was milked by an AMS during the 24 h. the AMS management system recorded identification numbers of the AMS unit. The cow being milking, date and time of the milking, milk yield (kg) as measured by the milk meters installed on each AMS unit, Milk quality and type of visit per visit.

The AMS automatically collected all data and saved it as "log files". These log files included classifications for three types of cow visits: milkings, Refusals and failures. Milkings indicated that the cow was milked normally, Refusals indicated that the cow was not permitted to be milked and failures indicated that the milking was not successful. The log files were processed using MS-Excel to calculate various metrics such as mean milk yield (kg/d/cow), milking frequency (n/d), refusal frequency (n/d) and visit frequency (n/d), amount of concentrate offered (kg/cow/day) and milk fat and protein content (% of milk volume) for each day of each feed delivery treatment.

Figure 6.Lely Astronaut A5

II.3. Statistics Analysis

A statistical analysis was carried out using SPSS (**Statistical Package for the Social Sciences**). Descriptive statistics were calculated for almost all the variables. Mean milk yield, milk composition, concentrate offered and Type of visit presented in table 2. Results were analyzed statistically by Pearson linear correlations at 0.95 and 0.99 probability level (table 3)**.** A single-trait model was used to measure the effect of increasing milk yield per AMS per day. Multiple linear regression data analysis was used to model the linear relationship between the dependent or criterion variable (Milk yield and the independent or predictor variables). The model expressed the value of the dependent variable as a linear function of the predictor variables and an error term (Table 4 and table 5).

III. ESULTS AND DISCUSSION

III.1 Descriptive Statistics of the Production

Mean milk yield, milk composition, concentrate offered and type of visit presented in Table 2.

The results of the study showed that Daily Milk Yield (DMY) on this AMS farm was 32.5 ± 1.3 kg/cow/day**.** The reported in milk yield on AMS was similar to direct measurements of other studies (32.6 kg/cow per day) **(Tse et al., 2018)** where used the same brand of AMS Lely. The average milk yield was higher than other studies at 28 kg/d M. **(Nixon et al., 2009).**

Table 2. Descriptive statistics of the production and operation variables for the automatic milking system (AMS) in West Hungary (n =100)

Variable	Mean	Minimum	Maximum	SD [1]
Days in Milk (DIM)	165	149	181	10
Total Cows milked (no[2].)	294	267	322	16
Cows per milking unit (AMS) (no.)	49	45	54	3
Total Milk Yield (kg/per herd / day)	9542.3	8463.1	11050.7	535
Daily Milk yield per cow per day (kg)	32.5	28.9	36.0	1.3
Milking frequency per cow per day (no.)	2.7	2.3	3.0	0.1
Refusals frequency per cow per day (no.)	2	0.9	3.4	0.5
Unsuccessful frequency per cow per day (no)	0.1	0	0.2	0
Separated Milk per herd per day (kg)	251.6	81.8	602.3	110.9
Fat content (%)	3.4	3.1	3.7	0.2
Protein content (%)	3.3	3.2	3.5	0.1
Total intake of cc per herd per day (kg)	1601.9	1412.0	1767.0	72.9
Concentrate offered per cow per day (kg)	6.0	5.8	6.4	0.1
Rest of cc per AMS (kg)	0.6	0.4	1.1	0.1

[1] (Standard deviation). [2]: (Number)

The observed average number of milking or Milkings frequency (MF) per cow per day was 2.7± 0.1 above the interval of mean values reported by **Gygax et al. (2007)** which ranged from 2.38 to 2.56 milkings per cow per day. Moreover, the observed number of milkings per cow per day was greater than that reported by **Bach et al. (2009)** or free (1.7 to 2.2) and forced (2.4 to 2.5) cow traffic to the AMS. Nevertheless. **Madsen et al. (2010)** reported 2.96 milkings per cow per day indicating that a greater cow throughput through the AMS is still possible. This high MF (2.7 ± 0.1) was the consequence of the small herd size milked by AMS which would allow more milkings.

According to **Dussault (2001),** the optimal range of cows per AMS is between 60 to 70. However, the average number of cows per AMS in this case study was 49 ± 3 which is lower than the optimal range. Since the Lely robot has the capacity to handle more cows. It would be possible to increase the number of cows per AMS on this farm. This should only be done under ideal conditions such as having enough space in the barn, maintaining the average visit time for every milking and avoiding an increase in herd size that would cause more competition between the cows. The mean amount of concentrate offered per cow per day in an automatic milking systems (AMS) was 6 ± 0.1 kg/cow/day based on survey data dairy producers utilizing automated milking systems (AMSs) typically feed between 1.8 and 7.7 kg of concentrate daily to entice cows to visit the milking unit **(Rodenburg 2011).**

The average frequency of unsuccessful or failed milkings (0.1 ± 0) was much lower than the frequency of refusal or rejection (2 ± 0.5) accounting for only 3.7% of the total milkings. However, a different study reported that the average attachment failure in the AMS was 7.6% of total milkings. When the milking interval was extended. **Bach and Busto (2005)** observed a 26% decrease in milk production in the affected udder quarter compared to regular milk yields. According to **Hermans et al. (2003) and Munksgaard et al. (2011)**. Cows in a forced-traffic situation experienced more milking failure visits with an average of 1.2 visits per cow per day compared to 0.6 visits per cow per day for cows who entered the AMS but were not milked due to the minimum interval between milkings not yet being reached. The average Days in Milk for the herd was 165 ± 10 days indicating that the cows were in mid-lactation. This phase typically occurs between days 100 and 200 after calving with cows achieving peak production around 8-10 weeks after calving which is the beginning of this phase according to some studies.

The fat and protein content on the AMS farm were measured at 3.4 ± 0.2% and 3.3 ± 0.1%. respectively. **Bach et al. (2007)** reported that the protein percentage level was similar to our study at 3.26 ± 0.03% while milk fat content was slightly higher at 3.63 ± 0.04%. In contrast. Salovuo et al. (2005) found that milk fat content increased after the introduction of AMS from 3.9% to 4.2%.

III.2 Correlation between Milkings, Unsuccessfull, Failure Frequency and Milk Production

The result of the study clearly showed the Daily Milk yield (DMY) was strongly and positively correlated with Milking frequency **($r = 0.61$, $p \leq 0.01$)** (table 3). Values obtained with a single-trait model (model 1) provide some information (Table 4) as evidenced by the R^2 values obtained. The R^2 value obtained for the model that calculated the DMY as a function of Milking Frequency was **0.37**. On the other hand. The R^2 value obtained (**0.72**) with multivariate linear model (model 7) using the forward stepwise method showed that variables number of milkings per day per cow, average concentrate per cow per day, total feed intake, number of unsuccessful milkings and rejections, fat and chewing were significant predictors of the daily milk yield per cow (table 4) .

The increase in milking frequency is a consequence of a greater increase of milk production. Our results were consistent with the findings of **Melin et al. (2005)** who reported that increasing milking frequency from two to three times a day can result in a milk yield increase ranging from 2% to 12%. Conversely, a study that increased milking frequency of AMS cows by adding flavoured and appetizing substances to feed delivered at the milking unit determined that milk yield was not affected by increased milking frequency **(Gygax et al., 2007)**. The main advantage of automated milking is to establish the frequency of milking depending on the physiological state and milk production. There is abundant evidence that the rate of milk secretion is directly correlated with milking frequency as a result of the mechanisms related to the local control of milk secretion **(knight et al., 1998).**

In contrast, negative correlation was observed between DMY and unsuccessful milking frequency **($r = -0.34$, $p < 0.01$)** (table 3). Unsuccessful milking can reduce milk yield and increase the risk of udder health issues leading to a negative impact on milk production. The most common reason for unsuccessful milking was failed teat cup attachments (72.4%). If a cow is not directed to a new milking after an unsuccessful milking it can lead to production losses and problems in cow wellbeing.

Table 3. Linear correlations between production variables of lactating cows on Automated Milking Systems (Pearson correlation, n=100).

	DIM	Nc	TMY	DMY	MF	Refusals	Unsuccess-ful	Badmilk	Total cc intake	Cc in AMS	Rest of cc	Fat	Protein	Chewing
Days in milk	1	-0.29**	-0.37**	-0.13	- 0.1	0.31**	-0.06	0.16	-0.32**	-0.1	0.09	-0.59**	-0.37**	-0.01
Number of cows		1	0.61**	-0.32**	-0.39**	-0.49**	0.24*	-0.11	0.45**	-0.58**	0.20*	0.70**	0.25*	0.014
TMY (kg/herd/d)			1	0.55**	0.16	-0.29**	-0.08	-0.01	0.81**	-0.07	-0.16	0.46**	0.30**	0.11
DMY (kg/cow/d)				1	0.61**	0.18	-0.34**	-0.004	0.45**	0.52**	-0.43**	-0.20*	0.09	0.12
Milking freqency (n/d)					1	0.67**	-0.23*	-0.07	0.49**	0.27**	-0.81**	-0.25*	-0.13	-0.01
Refusals (n/d)						1	-0.22*	0.02	0.04	0.16	-0.53**	-0.45**	-0.27**	-0.03
Unsuccessful (n/d)							1	-0.24*	-0.06	-0.14	0.13	0.04	-0.1	0.13
Badmilk (kg/d)								1	-0.22*	-0.05	0.20*	-0.12	0.17	-0.22*
Total cc intake (kg/herd/d)									1	-0.135	-.514**	0.38**	0.19	0.01
CC offered in AMS (kg /cow/d)										1	-0.014	-0.34**	0.07	0.105
Rest of cc (kg)											1	0.174	0.14	0.135
Fat (%)												1	0.25*	0.04
Protein (%)													1	-0.35**
Chewing (min)														1

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

DMI: Days in Milk, NC: Number of cows, TMY: Total Milk yield, DMY : Daily Milk yield , MF : Milking frequency, CC : Concentrate, n : number , d: day.

Table 4. Single-trait model and multiple regression analysis output using the forward stepwise method (dependent variable: Daily milk yield)

Model Summary[h]

					Change Statistics					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	.61[a]	.37	.37	.91615	.374	58.636	1	98	.000	
2	.72[b]	.51	.50	.81371	.137	27.229	1	97	.000	
3	.78[c]	.60	.59	.73615	.093	22.517	1	96	.000	
4	.80[d]	.64	.63	.70445	.037	9.833	1	95	.002	
5	.82[e]	.67	.66	.67472	.033	9.557	1	94	.003	
6	.84[f]	.71	.69	.63902	.037	11.795	1	93	.001	
7	.85[g]	.72	.70	.62830	.013	4.203	1	92	.043	1.394

a. Predictors: (Constant). Milking frequency;

b. Predictors: (Constant). Milking freqency. av.cc;

c. Predictors: (Constant). Milking freqency. av.cc. total cc intake

d. Predictors: (Constant). Milking freqency. av.cc. total cc intake. Unsuccessfull;

e. Predictors: (Constant). Milking freqency. av.cc. total cc intake. unsuccessfull. Refusals;

f. Predictors: (Constant). Milking freqency. av.cc. total cc intake. unsuccessfull. Refusals. Fat;

g. Predictors: (Constant). Milking freqency. av.cc. total cc intake. unsuccessfull. Refusals. Fat. Chewing;

h. Dependent Variable: av.daily milk yield

Table 5. Single-trait model and multiple regression analysis output using the forward stepwise method (dependent variable: Total milk yield)

Model Summary[e]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.81[a]	.66	.66	235	.660	190.044	1	98	.000	
2	.87[b]	.76	.75	199	.099	40.021	1	97	.000	
3	.88[c]	.78	.77	192	.018	7.922	1	96	.006	
4	.89[d]	.79	.78	189	.010	4.608	1	95	.034	1.275

a. Predictors: (Constant). Total cc intake (robot);

b. Predictors: (Constant). total.cc intake (robot). Failures ;

c. Predictors: (Constant). Total cc intake (robot). Failures..rest of cc ;

d. Predictors: (Constant). total.cc intake (robot).Failures. rest of cc. unsuccessfull;

e. Dependent Variable: total milk yield.

Daily Milk yield was not correlated with refusal milking frequency **($p > 0.05$)**. In contrast negatively correlation was showed between total milk yield and refusal frequency **($r = -0.29$, $p < 0.01$)** (table 3). An increase in refusal frequency lead to decrease milk production per AMS per herd per day. Whereas strong and positive correlation between milking and refusal frequency was founded **($r = 0.67$, $p<0.01$)** (table 2). Our research confirm that higher milking frequency induces an increase in refusal frequency. However, it could be envisaged that higher milk yield (kg/cow per day) induced higher milking frequency.

Our study found a positive correlation between total milk yield and herd size (number of cows) ($r = 0.61$, $P < 0.01$) indicating that an increase in cow numbers is associated with a greater increase in milk production. We also found that the number of cows per AMS was negatively correlated with daily milk yield and milking frequency ($r = -0.32$, $r = -0.39$) respectively. As the number of cows per robot increased milking frequency and daily milk yield tended to decrease ($p < 0.05$). These findings are consistent with those of **Castro et al. (2012).**

III.3. Effect of the Concentrate Supply in the AMS on Production efficiency

Total milk yield per herd per day were strongly and positively correlated ($r = 0.81$**,** P **< 0.01)** more with the total feed intake of concentrate (table 3). Value obtained with a single-trait model (models 1) provide some information (Tables 5) as evidenced by the R^2 values obtained. The R^2 value obtained for the model that calculated the TMY as a function of Total feed intake was **0.66.**

Our study found that the amount of concentrate offered in the AMS per cow per day was positively correlated with both daily milk yield (DMY) per cow per day and milking frequency (MF) ($r = 0.52$, $r = 0.27$. $p \leq 0.01$) as shown in table 3. While the amount of remaining concentrate in the robot was negatively correlated with both DMY and MF ($r = -0.43$, $r = -0.81$. $p \leq 0.01$) all these results are presented in table 3. It could be concluded that high concentrate offering did increase Daily milk yield and milking frequency of those cows that did not need to be fetched to the AMS but offering a large amount of concentrate in the AMS did not reduce the need to fetch the cows that would not visit the AMS otherwise. **Henriksen et al. (2018)** reported increased milk yield with increased concentrate allocation and **Menajovsky et al. (2018)** reported a tendency for increased milk yield.

Our results are in agreement with previous studies that have reported that cows that were not fetched and received a Low Concentrate treatment were milked 2.4 ± 0.1 times per day. On the other hand, cows that received a High Concentrate treatment and were not fetched were milked 2.7 ± 0.1 times per day, which is consistent with the results reported by Bach et al. (2007) **(Bach et al., 2007).** IN contrast to other authors that found no differences in milking attendance to an AMS when comparing a daily concentrate allowance at the AMS of 1.5 vs. 7 kg/d. **(Halachmi et al., 2005).**

Despite the commercial practice to feed large quantities of concentrate in the AMS most controlled studies evaluating concentrate provision in the AMS have not supported the suggestion that increasing the quantity of concentrate in the AMS will improve voluntary visits or milk and milk component yield **(Bach et al.. 2007; Hare et al.. 2018).** Conversely the increase in MF and MY can be achieved when high CS (reaching 6.56 kg/cow per day) is associated with complementation with dry or ensiled forages or PMR provided at barn (table 3).

No correlations were founded for refusal and unsuccessful frequency with the amount of concentrate offered in automated milking system **(p > 0.05)** (Table 3) similar result with **(Bach et al., 2007)** (table 3).

Negative correlations were observed for total milk yield and total concentrate intake with the days in milk (r= - 0.37; r =-0.32. p<0.01) respectively. It is demonstrated that the increase in DIM induced a decrease in Milk production and concentrate intake. In contrast DIM was positively correlated with refusal frequency (r=0.31. p<0.01) (table 3)

III.4. Correlations between Milk composition, Milk yield and feed intake

Considering the relationship between milk production and the productive qualities of cows (Table 2) we noted a reliable correlation. The correlation was negative between fat content and DMY (**r = –0.2, p< 0.05)** as well as between Fat content and Milking Frequency (**r = –25**, **p< 0.05)**. As milk yield declines milk fat percentage increases. The changes are probably related more to the utilization of energy for maintenance of body temperature leading to reduced energy available for milk synthesis.

Negative correlation was observed for fat content and amount of cc **(r = -0.34, p <0.01).** Milk fat tended to decrease as the quantity of AMS concentrate increased. On the other hand no correlation were observed for protein content with DMY and milking frequency as well as with the amount of concentrate in the AMS **($p > 0.05$)** (Table 3).

Milk composition was not affected by the level of concentrate offered at the AMS. Cows receiving the LC treatment had 3.63 and 3.26 % milk fat and protein contents respectively and HC cows had 3.60 and 3.27 % milk fat and protein contents respectively **(Bach et al., 2007).**

Fat and protein content were negatively correlated with DIM ($r=-0.59$; $r= -0.37$, $p<0.01$) respectively. Separated or bad milk was negatively correlated with unsuccessful milking ($r = -0.23$, $p<0.05$).

IV. CONCLUSION

The AMS currently used in west Hungary milked an average of 49 cows per AMS with 2.7 milking frequency per cow per day, a daily milk yield of 32.5 kg/Cow/day and. The predictor variables Milking frequency and feed intake had a greater level of influence on the milk yield per AMS.

At the end of this work, it can be deduced that:

1/ Milkings frequency was usually considered as an indicator of robot performance and researchers focused on ways to optimize it. It showed wide variability and positive correlation **($p < 0.01$)** with Daily Milk yield. Consequently, with this increase in milking frequency the average milk yield per cow per day would increase. In contrast negative correlation was observed between DMY and unsuccessful milking frequency **($p < 0.01$).**

2/ Daily milk yield per cow and milking frequency were positively correlated with the amount of concentrate offered in AMS per cow per day **($p \leq 0.01$)**.

3/ Fat content did negatively correlated with daily milk yield. Milking Frequency and amount of concentrate offered in automated milking systems (**$p< 0.05$).**

4/ For protein content no correlations were observed with daily milk yield, milking frequency as well as with the amount of concentrate in the AMS **($p > 0.05$**).

Detailed knowledge of these factors such as milking frequency and concentrate intake associated with increasing milk yield using AMS will help guide future recommendations to producers for maximizing milk yield and decrease the cost in Hungarian Dairy Farm and industries.

SUMMARY

The use of automatic milking systems, also known as milking robots, is increasingly popular as a technology that can reduce labor, increase milk production and maximize profit. This study ,was carried out on a private dairy farm located in West Hungary, aimed to examine the relationship between automatic milking systems (AMS) and production efficiency in lactating cows with herd sizes ranging from 267 to 322 Holstein-Friesian cows in the middle of lactation specifically 165 ± 10 days in Milk. The results of this study indicates that on average, an AMS unit milked 49 ± 3 cows daily with each cow being milked 2.7 ± 0.1 times per day and producing a daily milk yield of 32.5 ± 1.3 kg per cow. The data was statistically analyzed using Pearson correlations at a probability level of 0.95 to 0.99 and single and multiple linear regression analysis. The study found that daily milk yield was positively correlated with milking frequency ($r = 0.61$, $p < 0.01$) and negatively correlated with unsuccessful milking frequency ($r = -0.34$, $p < 0.01$) but had no correlation with refusal milking frequency ($p > 0.05$). Additionally. A positive correlation was observed between the amount of concentrate offered in AMS per cow per day and both milk yield ($r = 0.52$, $p < 0.01$) and milking frequency ($r = 0.27$, $p < 0.01$). No correlations were observed for refusal and unsuccessful frequency with the amount of concentrate offered in AMS ($p > 0.05$). Finally, the fat content was negatively correlated with daily milk yield ($p < 0.05$) and the amount of concentrate while there was no correlation observed for protein content with daily milk yield or the amount of concentrate in the AMS ($p > 0.05$). Detailed knowledge of these factors such as milking frequency and concentrate intake associated with increasing milk yield using AMS will help guide future recommendations to producers for maximizing milk yield and decrease the cost in Hungarian Dairy Farm and industries.

Keywords: Milk Yield, Milking Frequency, Automatic Milking System (AMS), Amount of concentrate.

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