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# Influence of the Robotic Milking System on Milk Production and Quality: Systematic Review

Rodrigo Chaves Barcellos Grazziotin (Corresponding author)

Department of Animal Science, Universidade Federal de Pelotas, Campus Universitário 96010-610, Capão do Leão-RS, Brasil

Tel: +55 (53) 3275-7274 E-mail: r_cbg@hotmail.com

Fernando Rutz

Department of Animal Science, Universidade Federal de Pelotas, Campus Universitário 96010-610, Capão do Leão-RS, Brasil

Tel: +55 (53) 3275-7274

Daniel José Cavalli Vieira

Department of Animal Science, Universidade Federal de Pelotas, Campus Universitário 96010-610, Capão do Leão-RS, Brasil

Tel: +55 (53) 3275-7274

Vitoria Mendonça da Silva

Department of Animal Science, Universidade Federal de Pelotas, Campus Universitário 96010-610, Capão do Leão-RS, Brasil

Tel: +55 (53) 3275-7274

Rodrigo Garavaglia Chiesini

Department of Animal Science, Universidade Federal de Pelotas, Campus Universitário 96010-610, Capão do Leão-RS, Brasil

Tel: +55 (53) 3275-7274

Julio Viégas

Department of Animal Science, Universidade Federal de Santa Maria, Campus

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Universitário 1000, Camobi, Santa Maria-RS, Brasil

Tel: +55 (55) 3220-8083

Rogério Folha Bermudes

Department of Animal Science, Universidade Federal de Pelotas, Campus Universitário 96010-610, Capão do Leão-RS, Brasil

Tel: +55 (53) 3275-7274

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**Abstract**

This review aims to report the direct influence of a robotic milking system (RMS) on milk production and quality. The Scopus, SciELO, and Web of Science platforms were used as search databases. We followed the PRISMA protocol for the identification and screening of articles. Initially, 336 articles were identified. We excluded 186 articles for duplicity, 53 after screening abstracts and titles, 20 for lack of access, and 58 articles based on the exclusion criteria. Nineteen articles from 2002 to 2021 from 10 different journals were selected. We observed an increase in publications related to RMS in recent years, and the Journal of Dairy Science gained prominence among the journals whose articles were used in the present study. After lexicographic analysis of abstracts, it was clear that there were five predominant classes, and the keyword RMS was more associated with factors related to cows than milk. The study results contribute to a greater understanding of RMS research, providing farmers and readers with clarification on the actual influences on the dairy chain system and future research projects.

**Keywords**: milking, productivity, herd, health

## 1. Introduction

The robotic milking system (RMS) has represented one of the most remarkable advances in milk production techniques since the 90s, with rapid adherence by all livestock farmers in this area worldwide. By 2020, approximately 50,000 operating units were estimated to exist on the planet (Filho *et al.*, 2020), located mainly in Europe and Canada (Cogato *et al.*, 2021).

These systems have been popularized as they potentially provide more quality for workers, reducing labor and time effort compared to conventional milking systems. These systems also promise to optimize milk production rates, quality, and mammary gland health (Hovinen & Pyörälä, 2011; Rodenburg, 2017; Hogenboom *et al.*, 2019). Thus, some improvement in milk production by direct or indirect routes is unquestionable, given the growth of adherence to technology in recent decades.

The significant difference in the system is the voluntary access of cows to the milking unit during lactation, as voluntary access can generate variation in the intervals between milking. This variation is higher in animals subjected to robotic milking than in animals milked using a conventional system, which is why they can provide higher milk production (Masía *et al*., 2020). Nevertheless, a decrease in milking frequency from twice a day to once a day results in an immediate increase in the somatic cell count (SCC) (Stelwagen & Lacy-Hulbert, 1996).

In robotic milking, mechanical arms perform preliminary operations such as brushing and udder sanitation. Based on the identification of the animal, the robot adapts to the morphological characteristics of the cow (height, udder size, teat shape, and angle). However, there are criteria for excluding cows from the herd to achieve an efficient acceptance of the robot. Cows considered unsuitable for the system (Córdova *et al*., 2018b) revealed a possible failure in the system.

Considering the disagreement among several articles for the analyses of dairy production and robotic milking, and numerous conclusions suggesting premises for new research (Wagner-Storch & Palmer, 2003; Jacobs & Siegford, 2012; King & DeVries, 2018; Córdova *et al*., 2020), the authors noted the need for a systematic review on the robotic milking system, as well as the evaluation of qualitative aspects. Therefore, our intent was to represent the direction of published research in this area and outline a qualitative level of the studies which have been addressed.

## 2. Methodology

This article presents a systematic review conducted according to the recommendations of the PRISMA protocol. We selected the studies in the SciELO, Scopus, and Web of Science databases using the keywords “Robotic milking,” “Somatic cell count,” “SCC,” “Total cell count,” “TBC,” “Milk production,” and “Milk quality.” We used these keywords in both Portuguese and English. The keyword “Robotic milking” was integrated into the search with other keywords using the Boolean Operator ‘AND,’ as described in Table 1. We opted for complete articles in journals and reviews as the initial filtering method.

Two researchers independently evaluated the studies and discussed any doubts concerning the article selection until an agreement was reached. In cases of disagreement, a third evaluator was selected to decide on the article's inclusion in this review.

This systematic review aims to report on the influence of robotic milking on milk production and quality. So, we sought to answer the guiding question formulated by the Population Variable Outcome (PVO) strategy.[1]: What is the influence of robotic milking (variable) on milk production and quality (outcome) in dairy cattle (population)?

The inclusion criteria were as follows: 1) quantitative studies presented in the abstract, title, or keywords, 2) the characters “robotic milking” and the respective translation in the Portuguese language, 3) no year restrictions, and 4) publications in English, Portuguese, and Spanish. The exclusion criteria were as follows: 1) studies outside the objective, 2) qualitative studies on milk quality and production, 3) articles regarding other milking systems,

[1] PVO: P (dairy cattle) V (robotic milking) O (milk production and quality).

and 4) review articles, letters to editor/editorials, personal opinions, chapters of books, textbooks, reports, and conference summaries.

Table 1. Search strategy for databases

| Database | Search Strategy | Results |
|---|---|---|
| SciELO http://www.scielo.org/ | (Robotic milking) AND (Milk production) OR (Ordenha Robotizada) AND (Produção de leite) | 6 |
| | (Robotic milking) AND (Milk quality) OR (Ordenha Robotizada) AND (Qualidade do leite) | 2 |
| | (Robotic milking) AND (scc) OR (Ordenha Robotizada) AND (ccs) | 2 |
| | (Robotic milking) AND (somatic cells count) OR (Ordenha Robotizada) AND (contagem de células somáticas) | 1 |
| | (Robotic milking) AND (tbc) OR (Ordenha Robotizada) AND (cbt) | 2 |
| | (Robotic milking) AND (total bacterial count) OR (Ordenha Robotizada) AND (contagem bacteriana total) | 0 |
| Scopus https://www.scopus.com/ | (Robotic milking) AND (Milk production) OR (Ordenha Robotizada) AND (Produção de leite) | 66 |
| | (Robotic milking) AND (Milk quality) OR (Ordenha Robotizada) AND (Qualidade do leite) | 39 |
| | (Robotic milking) AND (scc) OR (Ordenha Robotizada) AND (ccs) | 12 |
| | (Robotic milking) AND (somatic cells count) OR (Ordenha Robotizada) AND (contagem de células somáticas) | 21 |
| | (Robotic milking) AND (tbc) OR (Ordenha Robotizada) AND (cbt) | 2 |
| | (Robotic milking) AND (total bacteria count) OR (Ordenha Robotizada) AND (contagem bacteriana total) | 4 |
| Web of Science http://apps. webofknowledge.com/ | (Robotic milking) AND (Milk production) OR (Ordenha Robotizada) AND (Produção de leite) | 83 |
| | (Robotic milking) AND (Milk quality) OR (Ordenha Robotizada) AND (Qualidade do leite) | 48 |
| | (Robotic milking) AND (scc) OR (Ordenha Robotizada) AND (ccs) | 10 |
| | (Robotic milking) AND (somatic cells count) OR (Ordenha Robotizada) AND (contagem de células somáticas) | 33 |
| | (Robotic milking) AND (tbc) OR (Ordenha Robotizada) AND (cbt) | 1 |
| | (Robotic milking) AND (total bacteria count) OR (Ordenha Robotizada) AND (contagem bacteriana total) | 4 |
| TOTAL | | 336 |

After the including and excluding of articles, the remaining studies were subjected to risk and bias analyses. The list of criteria applied to each article is described in Board 1 based on the ideas established by Koutsos *et al*., 2019. We assumed three possible answers to the questions for each article, admitting the scale: Yes (Y) = 20 points, Inconclusive (I) = 10 points, and Not (N) = 0 points(Kitchenham *et al.* 2009). We calculated the final score by percentages of articles that resulted in 60% or more being included in the review. The bias assessment was described by Board 2. We observed that 19 of the 25 previously defined studies reached the desirable criterion of 60 %, confirming the credibility of the selected studies.

Board 1. Risk of bias criteria checklist

| Questions | Criteria |
|---|---|
| Q1 | Are the animals adapted to robotic milking? |
| Q2 | Was the research carried out with an adequate number of animals per robot? |
| Q3 | Is milk production one of the main results of the article? |
| Q4 | Does this study quantitatively describe the SCC or TBC of milk? |
| Q5 | Was the experiment conducted randomly? |

The search was conducted in September 2021. The results were exported to Mendeley Desktop v. 1.19.8, Mendeley Reference Manager v. 2.54.0, and duplicates were discarded. We organized the remaining results in Microsoft Excel 2010 (Microsoft™ Ltd, Washington, USA), in which bias criterion questions were posed. After obtaining the research articles, we listed the authors, year of publication, journal, objectives, main results linked to the systematic review, and conclusions for efficient organization of the results (Table 2).

Board 2. Bias risk assessment

| Studies | Q1 | Q2 | Q3 | Q4 | Q5 | % |
|---|---|---|---|---|---|---|
| S1 | N | Y | Y | N | Y | 60% |
| S2 | Y | Y | N | N | N | 20% |
| S3 | I | I | Y | Y | Y | 80% |
| S4 | I | I | N | N | N | 20% |
| S5 | I | I | Y | Y | Y | 80% |
| S6 | I | Y | Y | Y | I | 80% |
| S7 | Y | I | Y | N | Y | 70% |
| S8 | I | I | Y | Y | Y | 80% |
| S9 | N | I | N | Y | N | 30% |
| S10 | I | Y | Y | Y | Y | 90% |
| S11 | I | Y | N | N | Y | 50% |
| S12 | Y | N | Y | N | Y | 60% |
| S13 | Y | Y | Y | N | N | 60% |
| S14 | Y | Y | Y | N | Y | 80% |
| S15 | I | I | Y | Y | N | 60% |
| S16 | I | Y | Y | N | Y | 70% |
| S17 | N | Y | Y | Y | N | 60% |
| S18 | Y | I | N | Y | I | 60% |
| S19 | I | I | N | Y | N | 40% |
| S20 | Y | Y | Y | N | Y | 80% |
| S21 | I | N | Y | N | Y | 50% |
| S22 | I | I | Y | Y | N | 60% |
| S23 | I | I | N | Y | Y | 60% |
| S24 | N | Y | Y | N | Y | 60% |
| S25 | I | I | Y | Y | I | 70% |

The main information about the variables investigated in the selected studies was extracted for writing the results and discussion section of our review article. Therefore, the articles were analyzed specifically for the categories “milk quality” and “milk production.”

The text data were also processed and submitted for lexicographic analysis using the IRAMUTEQ 0.7 alpha2 software, aiming for qualitative analysis. Texts originally written in Portuguese or Spanish were translated into English for linguistic equalization. The keyword "Robotic Milking” was separated by “_”, becoming “Robotic_Milking”, to be read by the program as a single expression, avoiding parsing errors. Therefore, we used a descending hierarchical classification and similarity analysis

## 3. Results

Based on the combinations mentioned above, searching through keywords resulted in the initial identification of 336 studies. First, 186 articles were identified. Then, 150 articles were selected to read the titles and abstracts; 53 were excluded, resulting in 97 readable articles. We did not have access to the full text of the 20 articles. In total, 77 articles were read. After applying the exclusion criteria, 19 studies that answered the guiding question of our investigation were selected (Figure 1).

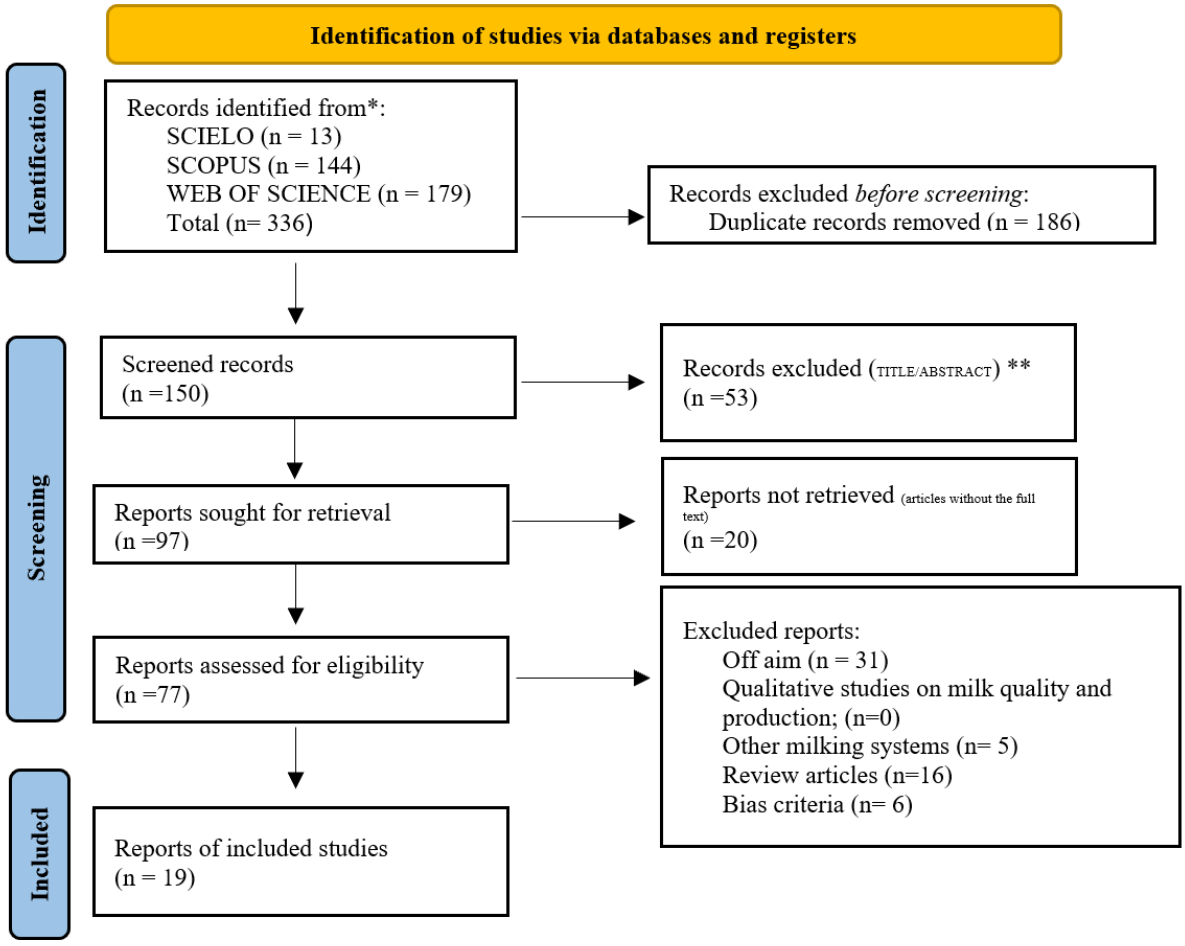


Figure 1. Identification flowchart

Source: Adapted from PRISMA 2020 statement.

The selected studies were published in 10 journals over 12 years. The main characteristics of the studies and a summary of the results are presented in Table 2. It is important to note that the main conclusions and results described here always correlate with the variables studied in our review, thus increasing the reliability and highlighting the aim of the study

Table 2. Selected articles

| NUMBER | Title | Author | Year | Journal | Objective | Main results | Conclusion |
|---|---|---|---|---|---|---|---|
| 1 | Adaptation strategy of different cow genotypes to the voluntary milking system | O.O. Borshch et. al. | 2020 | Ukrainian Journal of Ecology | The aim was of this study was to discover the adaptation indicators of different breeds first-calving cows to voluntary (robotic) milking system during the first month of lactation. | The groups of French Holstein breed and Brown Swiss breed, had lower daily average milk yields of these cows' groups during the adaptation period, compared to the German Holstein breed | It was established that the German Holstein breed was distinguished by greater adaptation features as compared to the French breed and the Brown Swiss breed. During the adaptation period, the German Holstein breed was differed by higher milk yield, milking multiplicity, and the amount of consumed concentrate feed in comparison with the French Holstein breed and Swiss breed. The German Holstein breed had lower electrical milk conductivity and the somatic cells amount in milk during the adaptation period in comparison with the French Holstein breed and Brown Swiss breed. So we suggested that the German Holstein breed had more higher stress resistance and thus less time-consuming adaptation to the keeping. |
| 2 | Behavior, health, and productivity of early-lactation dairy cows supplemented with molasses in automated milking systems | S. M. Moore et. al., | 2020 | Journal of dairy science | The objective of this study was to determine the effect of molasses-based liquid feed (LF) supplementation within automated milking systems (AMS) on the behavior, health, and production of early-lactation dairy cows. | No differences were detected between treatments for milk yield (average milk yield = 37.4 ± 1.98 kg/d) and milking frequency (average milking frequency = 3.2 ± 0.01 times/d). | Supplementing a molasses-based liquid feed to early-lactation dairy cows milked in AMS demonstrated positive benefits for cow metabolic health, but did not affect production outcomes or rumination behavior as hypothesized. Cows receiving this extra energy supple-mentation across the first 60 DIM displayed lower blood BHB levels by ~15 DIM and had fewer repeat positive tests for SCK. Additionally, LF cows lost less body condition over the first 60 DIM compared with CON cows. Therefore, supplementing a molasses-based liquid feed to fresh cows milked in AMS may be an effective way to supply additional energy to cows during a period of NEB |
| 3 | Benchmarking of farms with automated milking systems in Canada and associations with milk production and quality | R. D. Matson et. al., | 2021 | Journal of dairy science | The objective of this study was to benchmark the herd-level housing and management strategies of auto-mated milking system (AMS) farms across Canada and assess the associations of these herd-level housing | Greater lying alley width (cm) was associated with lower SCC; each 30 cm increase in lying al-ley width tended to be associated with 10,414 cells/mL decrease in SCC. Greater alley-cleaning frequency (no./d) was associated with lower SCC; each 5 additional alley cleanings per day was associated with | Specifically, when controlling for breed differences, AMS herds with greater feed push-up frequency, greater feed bunk space per cow, and ventilation systems |

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|---|---|---|---|---|---|---|---|
| | | | | | fac-tors and management practices with milk production and quality. | 7,012 cells/mL lower SCC. Lesser stocking density at the feed bunk (cm/cow) was positively associated with milk yield; each 10-cm increase in feed bunk space per cow was associated with +0.3 kg/d greater milk production This is the first time that feed push-up frequency has been associated with greater milk yield in herds with AMS. Each of these models controlled for the effect of breed, with Holstein herds having 9.3 kg/d greater milk yield than non-Holstein herds. Each additional 5 feed push-ups per day was associated with 0.35 kg/d greater milk yield, | other than natural ventilation alone had greater milk yield, FCM, and ECM per cow. Greater milk yield per cow and lower herd-average SCC were also reported for those herds using sand bedding as compared with those bedding with organic substrates. Additionally, greater lying alley width and alley-cleaning frequency were associated with lower herd-average SCC. |
| 4 | Comparison of the conventional and robotic milking system for the parameters of composition and quality of milk, in grazing system | J. P. Avilez et. al., | 2021 | ITEA-Información Técnica Económica Agraria | El objetivo de este estudio fue comparar el impacto productivo (kg día–1de leche por vaca), calidad nutricional (cantidad de grasa y proteína) y microbiológica (RCS) de la leche, en un rebaño lechero que pasó de una ordeña convencional a una robotizada, con sistemas de alimentación en base a pradera. | En producción de leche, % de grasa y en recuento de RCS se observó diferencia estadística significativa ($p < 0,05$), se logró un aumento de un6,4 % en la producción de leche. | El sistema robotizado presentó significativa-mente ($p> 0,05$) una mayor producción de le-che (24,18 ± 2,76 L) y de grasa (4,12 ± 0,34 %) en relación a la ordeña convencional (22,62 ± 4,16 Ly 4,03 ± 0,39 % de grasa). Por otro lado el RCS fue significativamente mayor ($p> 0,05$) en la ordeña robotizada (221,56 ± 62,96× 103cel. ml–1) en relación a la convencional (213,56 ± 94,88 × 103). |
| 5 | Cow-level associations of lameness, behavior, and milk yield of cows milked in automated systems | King M. T. M. | 2017 | Journal of dairy science | Compare the behavior and productivity of lame and nonlame cows while accounting for body condition, parity, DIM, and other environmental factors in a robotic milking system. | Lame cows produced 1.6 kg/d less milk during the 6-d data collection period in this study. As the number of cows per AMS unit in-creased, cows were milked less often. It may also be that refusal frequencies were influenced by milking permission settings and, thus, milk production. the reduced milking frequency we observed in lame cows was disproportionately attributable to fewer milkings at night | Through a comparison of individual lame and non-lame cows in AMS, this cross-sectional study provides detailed estimates of the differences in behavior and productivity associated with lameness. When accounting for other cow-level factors, lame cows produced less milk in fewer milkings each day, were more likely to be fetched, and spent more time lying down in bouts that were longer compared with non-lame cows. Cow-level risk factors identified for lameness in AMS were lower body condition, higher parity, and lower environmental temperature. Although not directly associated with lameness in this study, greater stocking densities (at the AMS and relative to lying stalls) were associated with reduced lying time, increased daily activity, and an increased need to fetch cows for milking |
| 6 | Effect of feeding intensity and | Stergiadis, S. et. al., | 2012 | journal of agricultural and food chemistry | Quantify the effect of milking system (by | robotic milking resulted in a slight (5%) numerical decrease in milk yield per | Robotic milking was shown to increase the |

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| | milking system on nutritionally relevant milk components in dairy farming systems in the north east of England | | | | comparing farms using standard and robotic milking systems but similar feeding regimens) on animal health and nutritionally relevant milk composition parameters (protein, FA, and antioxidant profiles). identify associations between specific production system components (e.g., dietary components, housing, milking system/frequency, proportion of Holstein-Friesian cows) and milk composition by redundancy analysis | cow even though it is known to increase milking frequency and would therefore have been expected to increase milk yield. SCC in milk (an indicator of subclinical mastitis) were not significantly different between seasons and farms using contrasting milking systems. | incidence of clinical mastitis and veterinary antibiotic use. |
| 7 | Effects of concentrate location on the behavior and production of dairy cows milked in a free-traffic automated milking system | A. J. Schwanke | 2019 | Journal of dairy science | The objective of this study was to determine whether the amount of concentrate allowance in an automated milking system (AMS) affects partial mixed ration (PMR) sorting behavior, milking activity, and production of lactating dairy cows fed isocaloric diets. | No differences were detected between treatments in the frequency of rejected milkings per day, daily yield, yield per milking, box time per visit, milk fat or protein, MUN, or SCC | For primiparous cows in early to peak lactation and milked in a free-traffic AMS with low stocking density, allocating a greater quantity of concentrate to the AMS and altering the PMR to maintain total dietary nutrient density decreased the extent of PMR sorting and increased total DMI, despite lower PMR intake. Further, allocating a greater proportion of dietary concentrate to the AMS also increased voluntary AMS visits and milkings and reduced the frequency of fetching to the AMS. Despite greater day-to-day variation in AMS concentrate intake, allocating a greater amount of concentrate to the AMS resulted in decreased sorting of the PMR, with no difference in day-to-day variation of PMR intake and total DMI. Therefore, offering a greater proportion of total dietary concentrate at the AMS in free-traffic systems with low stocking density may promote greater milking activity while maintaining consistency in total amount of DM consumed |
| 8 | Effects on milk yield of milking interval regularity and teat cup attachment failures with robotic milking systems | Bach et. al., | 2005 | Journal of Dairy Research | Assess the impact of teat cup attachment failures and milking interval regularity on milk production with an AMS using a retrospective database | Average milk production throughout the monitored period was 14.1±5.4 l/milking, with an average milking interval of 12.06±4.07 h. Milk production from the front quarters was 60% of the production from the rear quarters (5.3v.8.8 kg/milking). Average somatic cell count throughout the period of the study was 262000±15.4 cells/ml. | Apparently, a milking failure seems to affect the ability of the mammary gland to eject milk resulting in low milk flowrates. However, these three negative consequences of milking failures are transient, as milk production should return to the levels prior to the failure within seven milkings. On the other hand, irregular milking |

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| | | | | | | | intervals represent a potential problem with AMS, especially when the weekly CV for milking intervals is >27%. Above this variation, milk synthesis appears to be compromised. It is, therefore, important to implement management practices that reduce the irregularity of milking intervals with AMS. |
| 9 | Feeding behavior, milking behavior, and milk yields of cows milked in a parlor versus an automatic milking system | Wagner-Storch A. M. et. al., | 2003 | Journal of dairy science | Determine the effect on milk yield of cows milked with a conventional herring bone milking parlor 2×and cows milked in a robotic milking system; | Robot system had lower parity (1.6 vs. 2.4±0.1), higher milking frequency (2.4±0.02 vs. 2.0±0.0), and slightly higher milk production (58.1 vs. 56.7±0.5 lb, or 26.4vs. 25.8±0.2 kg) than parlor cows. Lower average parity of cows in the robot group was partially the result of the animal selection process, where cows with uneven udders were assigned to the parlor side to avoid robot unit attachment problems. | Because human intervention increased milking and feeding activity for cows milked with a robot, studying effects on milking frequency, feeding activity, and milk production of additional human intervention during the night would be of interest |
| 10 | Feeding soyhulls to high-yielding dairy cows increased milk production, but not milking frequency, in an automatic milking system | Halachmi, I. et. al., | 2009 | Journal of dairy science | Quantify the effects of replacing starchy grain pellets with pellets high in digestible NDF (6 to 14 kg/d per cow) on the AMS behavior of high-yielding cows and on their milk-ing performance. | The milk yield of the experimental group (42.7 ± 0.76;44.5 ± 0.43;39.1 ± 0.33) was higher than that of the control group (39.7 ± 0.68;42.4 ± 0.45;37.5 ± 0.40) throughout the lactation. | The inclusion of SH pellets high in digestible NDF in place of starchy grains fed to high-yielding dairy cows milked in an AMS 1) led to more milk, but not to a greater frequency of milking in the AMS; and 2) led to an increase in daily milk yields from 39.7 to 42.7 kg at 10 to 60 DIM, from 42.4 to 44.4 kg at 61 to 120 DIM, and from 37.54 to 39.09 kg at 120 to 180 DIM. This study adds evidence showing that what is fed in the AMS has no impact on milking frequency. |
| 11 | Impact of automatic milking systems on dairy cattle producers' reports of milking labour management, milk production and milk quality | Tse, C. et. al,. | 2018 | Animal | Determine producers' reports of change in milking labour management (milking-related activities), milk production, milk quality, and use of DHI programmes after transition to AMS. | Median milking frequency was 3.0 milkings/cow day, with Lely owners reporting higher milking frequency than DeLaval owners. After adopting AMS, most producers (81%) reported that milk yield had increased. Overall, milk yield on AMS farms was 32.6 kg/cow per day, with no differences between AMS brands. Based on reported averages over the past year, geometric mean BTSCC was 180 000 cells/ml, with no differences between the two predominant brands. At AMS Milk yield and herd size were not associated (P=0.43), whereas milk yield tended to decrease with increasing number of cows/robot (P=0.06). | farms using an AMS reported increased milk yield with little effect on milk quality. The number of employees and time devoted to milking-related activities decreased after the transition to AMS. Half of the producers who were not DHI participants had stopped participation after transitioning to AMS. Findings from this study can actas a benchmark for future dairy producers who decide to switch to AMS and improve transitions by providing information on what to expect |
| 12 | Impact of the factors of animal production and welfare on robotic milking frequency | Córdova, A. H. et. al,. | 2018 | Pesquisa Agropecuaria Brasileira | Evaluate the impact of production factors on milking frequency and the latter's effect on animal welfare in robotic milking | The average milk yield per milking varied from 13.32 kg at the beginning of lactation to 15.48 kg at its peak, reaching 13.36 kg at the end of lactation. The curves for milk yield per milking, ECM and protein production, and milking frequency decreased | The increase in milking frequency observed in the automatic milking system (AMS) is affected by factors such as concentrate |

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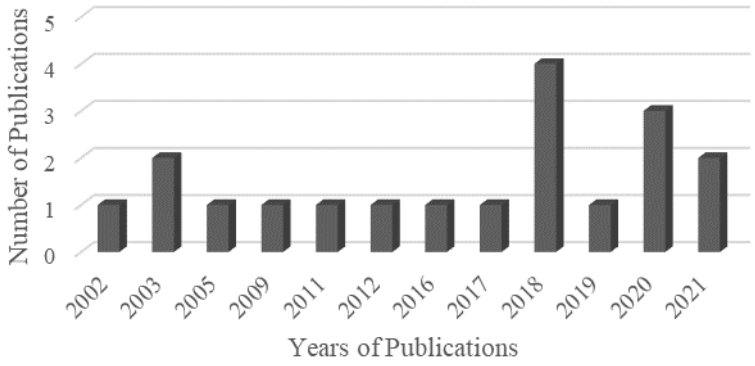
| | | | | | | throughout lactation. The peak milk yield observed at 105 days of lactation may have been caused by the higher concentrate intake at this lactation stage and the higher number of daily milkings at the beginning of lactation. | intake, days in milk, milk yield, and locomotion problems. Milking frequency impacts milk yield and protein content and, to a lesser degree, fat content. Milking frequency does not affect mammary gland health or animal welfare. The AMS allows the management of the evaluated data in real time, facilitating decision making to improve management, milk yield, and animal welfare. |
| 13 | Influence of udder depth on cleaning teats and health of the mammary gland in robotic milking | Córdova, A. H. et. al,. | 2018 | Arquivo Brasileiro de Medicina Veterinária e Zootecnia | Relate udder depth to teat cleaning and contamination and the health of the mammary gland in the robotic milking system. | The most productive cows present more daily milkings and have a deeper udder and less effective teat cleaning. | Farms intending to introduce RMS should first select and standardize the udder shape using cows with udder depth just above the hock. The impact of RMS on teat TBC is related to pre-milking teats cleaning condition, in which the cows' environment condition is essential to obtain milk with low microbiological contamination. |
| 14 | Quality of raw milk from a farm with automatic milking systemin the Czech republic / Kvalita mléka z farmy v České Republice s automatizovaným systémem dojení | Janštová, B. et. al., | 2011 | Acta Veterinaria Brno | Assess the quality of raw cow's milk from an automatic milking system. | The mean somatic cell count (SCC) was 221 ± 46·$10^3$·$ml^{-1}$ (range from 171 to 237·$10^3$·$ml^{-1}$). Somatic cell count decreases with the increasing level of zoohygienic conditions, dairy cow health and welfare and milking conditions | None of the determined results would pose a risk to the quality of milk. The automated milking system thus seems to be excellent in terms of milking and milk hygiene. Robotic milking also has the advantages of promoting good general health of animals and animal welfare and removing the labour |
| 15 | Milk yield relative to supplement intake and rumination time differs by health status for fresh cows milked with automated systems | King, M. T. M. et. al., | 2018 | Journal of dairy science | Examine associations of milk yield (per day and relative to supplement consumed), AMS supplement intake, and rumination time with blood BHB and SCK status of dairy cows in early lactation | Milk yield of multiparous cows varied by health status (P < 0.001), such that cows in SCK (subclinical ketosis) produced the most milk and OTH (BHB always <1.2 mmol/L, with a health disorder) cows were the least productive. There were differences in milk yield-to-supplement intake by health status (P< 0.001). With no difference in supplement intake between groups, SCK cows, therefore, had the highest ratio of milk production to supplement intake. | Milk production relative to supplement intake and rumination time were positively associated with blood BHB and differed by health status for cows milked in automated systems, but we found no such associations with supplement intake. These results suggest that AMS settings need to account for milk production of cows during their first 3 wk of lactation when determining supplemental pellet allowance |
| 16 | Robotic milking and its effect on fertility and cell counts | Kruip, T. A. M. et. al., | 2002 | Journal of dairy science | Analyze the effect of robotic milking (RM) on fertility and somatic cell counts (SCC) among dairy herds participating in the national Dutch milk recording system. | Significant increase in milk yield is observed when a change in milking frequency from 2×to 3×occurred (from 26.2 to 31.5 kg/d;P<0.001) and when a change in milking frequency occurred from 2×to RM (from 25to 27.2 kg/d;P<0.001) .Farms with 3×milking had an average test-day yield higher than farms with RM and 2× . The mean SCC was always higher (P<0.05) in the RM group than when those same herds had been previously milked either at | It is clear that direct comparisons of effects of RM and conventional milking are difficult because the systems differ in more ways than milking frequency alone. However, there are enough data to expect that with more experience and |

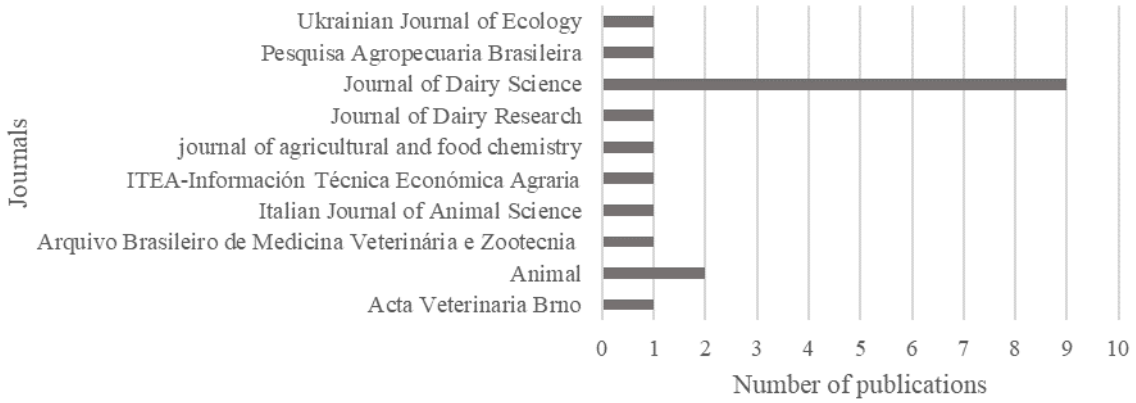
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | frequencies of 2×or 3×. Changing from 2×to 3×or vice versa did not significantly affect SCC. | attention to detail with all aspects of RM and by further improvements in teat cleaning that effects of RM on increasing SCC can be attenuated |
| 17 | Robotic milking and milk quality: effects on bacterial counts, somatic cell counts, freezing point and free fatty acids | De Koning, K. et. al., | 2003 | Italian Journal of Animal Science | Identify possible risk factors that affect milk quality on farms with AM-systems. | For all three countries and for most milk quality parameters (TPC, BMSCC, FP, FFA) the milk quality was slightly negatively affected after introduction of the AM-system in comparison to the period before. Differences between the AM-brands explained 32% percent of the variation in TPC, 30% was explained by installation period and 22% by farm effect. Regarding BMSCC, 56% of the variation could be explained by the farm differences. | The highest levels for TPC and BMSCC (bulk milk somatic cell count) are found in the first six months after introduction. After this period the milk quality slightly improves and all farms more or less stabilize their levels. However, the stable level is still a little above the average of conventional farms. |
| 18 | The effect of concentrate allocation on traffic and milk production of pasture-based cows milked by an automatic milking system | Lessire, F. et. al,. | 2017 | Animal | Determine the effect of concentrate allocation on voluntary cow traffic from pasture to the robot during the grazing period, to highlight the interactions between grazed pasture and concentrate allocation in terms of substitution rate and the subsequent effect on average milk yield and composition. | On average, HC-group (high concentrate) produced 1.07 kg milk/cow and per day more over the season, representing 0.56 kg of milk/kg concentrate | This experiment demonstrates a response to concentrate offered to grazing cows milked by a mobile AMS at numerous level. Finally, in the specific conditions of the present study, allocating higher amounts of concentrates might be questioned regarding the low MR. Thus, concentrate supply should be adapted with regards to pasture quality and availability to maximise economic impact on milk yield and on traffic. |
| 19 | Trends in somatic cell count deteriorations in Dutch dairy herds transitioning to an automatic milking system | B.H.P. Van den Borne, et. al., | 2020 | Journal of dairy science | Analyze national trends in SCC deteriorations of Dutch dairy herds transitioning from a CMS to an AMS. | A clear downward trend was observed. The average monthly BMSCC was 230,000 cells/mL in 2007 and decreased to 174,000 cells/mL in 2019. An obvious seasonal pattern was also visible, with BMSCC levels being higher in the summer period compared with the winter period. | Using census data from the Dutch test day recording, this study identified that SCC deteriorations were common in herds that transitioned from a CMS to an AMS. In the context of decreasing SCC levels nation-ally, less strong SCC deteriorations were observed during the 13-yr study period. Farmers and mas-titis workers should therefore continue to pay attention to udder health when herds transition to an AMS. A continued monitoring of trends in SCC deteriorations when herds transition to an AMS is recommended to allow a prompt intervention if needed |

Articles that considered milk production and quality essential characteristics in their study were presented between 2002 and 2021 (Graph 1). However, we observed that the theme of our investigation was still little explored, especially from 2002 to 2012, when the RMS was not yet popular and underwent some adaptations (Jacobs & Siegford, 2012).




Graph 1. Distribution of publications by years of selected articles

The journals of the selected articles were compared to the number of publications related to the review variables. The Journal of Dairy Science (Graph 2) shows the numerical superiority of articles, representing 47% of the articles chosen for data extraction. However, this data was not surprising because of the journal's reputation and its purpose of dealing directly with dairy chain issues




Graph 2. Distribution of journals by publications of selected article

The Descending Hierarchical Classification (DHC) method identified five classes of segments in the vocabularies (Figure 2). The corpus was divided into two sub-corpuses and partitioned to obtain Class 2. In the third stage, there were more partitions, which resulted in other classes. We observed a relationship between metabolic diseases and milk production and animal feeding in the system and the importance of milk management and quality in Classes 3 and 4.

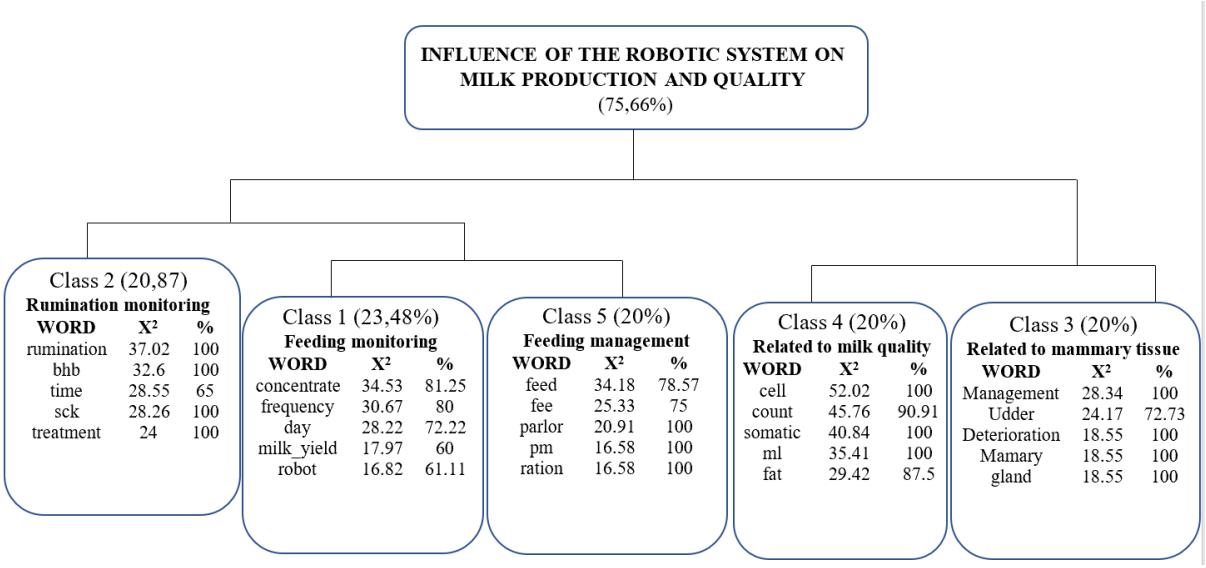



Figure 2. Descending Hierarchical Classification

A direct relationship between the five classes stood out in the similarity analysis. Classes with the terms “milk” and “cow” are entirely related. Still, some subclasses correlate with the class “cow.” For example, the words “AMS” (entirely related to “robotic milking”) and “farm” farm.” On the other hand, we observed the words “health” and “udder” establishing a link with the class “cow,” indicating that health is more related to cow and not milk in the selected articles. In the “milk” class, there is a coalition with the milk quality words “somatic,” “count,” “total” and “cells,” indicating a result of a cohesive search in the articles.

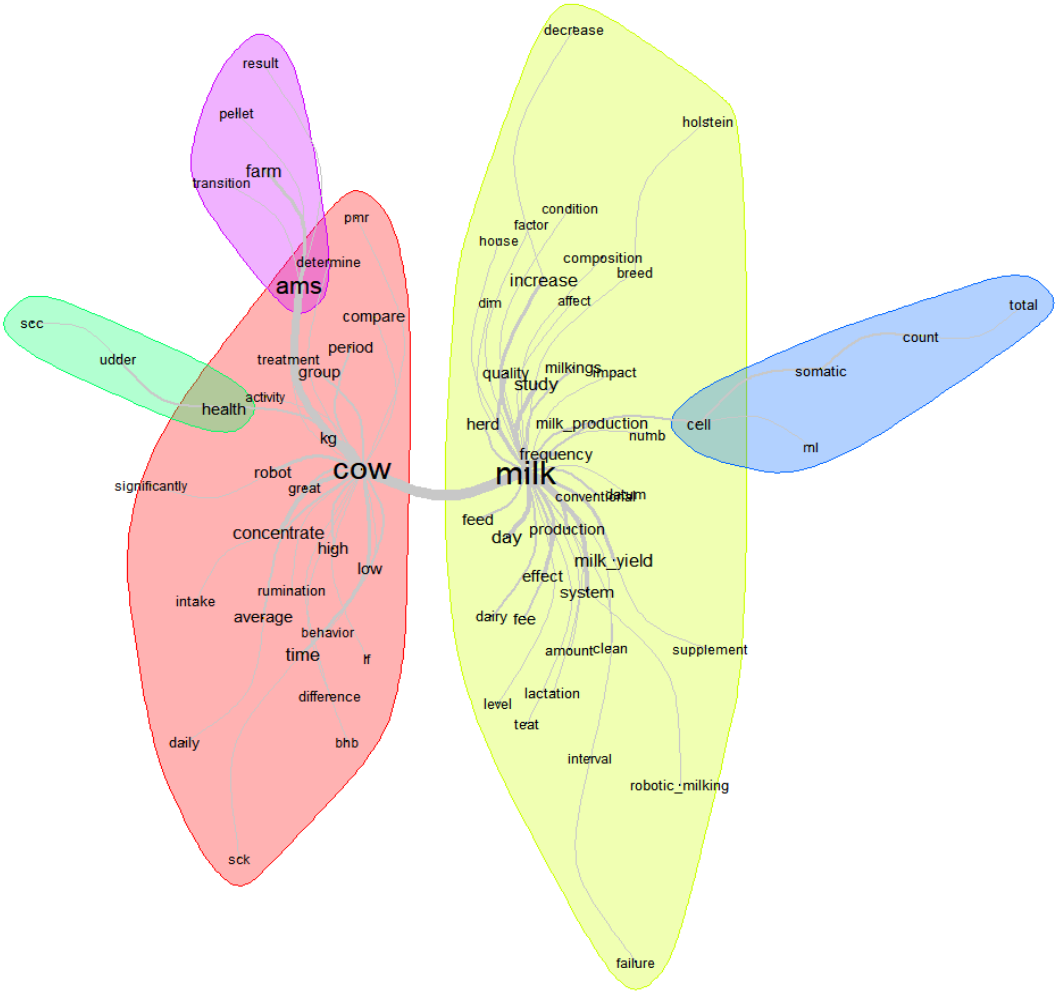



Figure 3. Similarity Analysis Tree

## 4. Discussion

Based on the results of the 19 selected articles, we observed an interaction between the passage of years and an increase in studies on robotic milking. This interaction has been expected since the first commercial RMS was installed on a dairy farm in 1992 (Svennersten-Sjaunja & Pettersson, 2008). Despite being an innovative technology, the uncertainties of farmers and the low supply of representatives meant that, in the 2000s, the system was accepted in the USA and most European countries (De Koning, 2010).

At that time, research projects observed an increase in somatic cell count and a decrease in quality resulting from the new milking system (Klungel *et al.*, 2000; Vorst, Y. Van der Hogeveen, 2000). This event triggered a warning in farmers that it was a new technology and a different method of conducting the business. Furthermore, this method depends on external factors, such as facility conditions, animal management, and staff rosters (Rossing & Hogewerf, 1997; Rossing *et al.*, 1997). A new wave of research on RMS began (Jacobs & Siegford, 2012) from these first complaints and the new challenges in the first decades of the

2000s, corroborating with the data.

As shown in Graph 2, the Journal of Dairy Science stood out in the number of publications selected by the authors. These data converge because the journal is in the top 10 of the Scopus database in "Animal Science and Zoology" and is based on the CiteScore index, reaching a value of 6.2 (Scopus, 2021).

Considering the h-index by Scimago Journal & Country Rank, the journal becomes even more relevant in "Animal Science and Zoology" and stands out in the first place of the ranking (Table 3). Using the SRJ index as a reference unit, the Journal of Dairy Science remains in the top 10 rankings (Scimago Journal & Country Rank, 2021). There was a significant difference compared with the other selected journals. These were not even in the top 20 rankings.

This difference between rankings occurs in the way the indices are calculated. The calculation of CiteScore considers citations from many files such as articles, book chapters, reviews, and data articles. The journal performs the count over four years, dividing by the number of the duplicate files indexed in Scopus and published during the same period (James *et al*., 2019). The h-index is the reference that indicates the minimum citations referring to the total publications in a certain period, quantifying productivity and scientific impact (Bornmann & Daniel, 2007).

Table 2. Top 10 h-index journals

| Rank | Title | SJR | *h*-index | Total Docs. (2020) | Total Docs. (3years) | Total Refs. | Total Cites (3years) | Country | Publisher |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Journal of Dairy Science | 1,483 | 191 | 1042 | 2955 | 47550 | 12522 | United States | Elsevier Ltd. |
| 2 | Journal of Experimental Biology | 1,367 | 185 | 608 | 1978 | 17162 | 4857 | United Kingdom | Company of Biologists Ltd |
| 3 | Agriculture, Ecosystems and Environment | 1,844 | 174 | 316 | 1016 | 20756 | 5842 | Netherlands | Elsevier |
| 4 | Animal Behaviour | 1,261 | 166 | 237 | 845 | 16019 | 2235 | United States | Academic Press Inc. |
| 5 | Journal of Animal Ecology | 2,134 | 157 | 253 | 464 | 18722 | 2098 | United Kingdom | Wiley-Blackwell Publishing Ltd |
| 6 | Journal of Animal Science | 0,928 | 156 | 416 | 1468 | 18451 | 3707 | United States | American Society of Animal Science |
| 7 | Poultry Science | 1,072 | 141 | 773 | 1804 | 33681 | 6073 | United States | Elsevier Inc. |
| 8 | Theriogenology | 0,816 | 133 | 570 | 1378 | 30541 | 3693 | United States | Elsevier Inc. |
| 9 | Integrative and Comparative Biology | 1,328 | 123 | 122 | 380 | 9160 | 1114 | United Kingdom | Oxford University Press |
| 10 | Behavioral Ecology and Sociobiology | 1,203 | 120 | 152 | 538 | 10919 | 1373 | Germany | Springer Verlag |

Within the DHC (Figure 2), the sub-corpus refers to classes 1, 2, and 5 instead of classes 3 and 4, representing 64.35% of the total textual corpus, whereas classes 3 and 4 represented 35.65% of the results. The first set of data signaled the importance of the studied variables. This aspect can be observed through an analysis of the selected terms.

Through the analysis of Class 2, the relationship between metabolic diseases and animal rumination became clear. Milk production and rumination time are responsive variables to a cow's health status. However, cows with subclinical ketosis achieved low rumination rates in an RMS, although they produced the highest rumination rates (King *et al*., 2018). This may be related to the high production rates of the herd, indicating the need for energy supplementation in animals fed partial mixed rations (PMR). Regarding this class, the variations in beta-hydroxybutyrate (BHB) in the system did not vary significantly in the evaluated studies.

Classes 1 and 5 complement each other. Animal feeding has attracted the attention of researchers. The system's users know the use of the concentrate to acquire higher visitation rates for the robot. However, some studies have reported that the gains in production by using this technique are limited despite maintaining a constant dry matter intake (Lessire *et al*., 2017; Schwanke *et al*., 2019). Some researchers even suggest using pellets with neutral detergent fibers and high degradability rates in the robot to increase visits without affecting production and milk composition (Halachmi *et al*., 2009). However, these results may be controversial with respect to milk production. We observed more occurrences of animals with mastitis in the robotic system than in conventional milking, leading to decreased production rates (Stergiadis *et al*., 2012)

Another essential factor in Classes 1 and 5 is the passage rate. It is essential to adapt a herd to voluntary milking, and this indicator is usually related to animal productivity (Borshch *et al*., 2020). Although voluntary milking can benefit animals, a higher visit rate was observed between 8 a.m. and 11 a.m. and between 3 p.m. and 6 p.m. This can be explained using the forced milking technique (Wagner-Storch & Palmer, 2003). Forcing animals to go through milking and increasing their frequency may decrease milk flow and increase milking time, milk production, and milk composition. Locomotion problems, lactation stage, and the production rate of each cow are also factors that influence visit rates (King *et al*., 2017; Córdova *et al*., 2018a).

In the second sub-corpus, Classes 3 and 4, the selected words were correlated with milk quality. Many studies have correlated the increase in somatic cell counts with the entry of animals into RMSs (Kruip *et al*., 2002; Avilez Ruiz *et al*., 2021; Van den Borne *et al*., 2021). However, some researchers have suggested that this high counting rate decreases after six months of herd adaptation (De Koning *et al*., 2003). The increase in SCC may be caused by failures in the fixation of teats, which can reach up to 7% of all milkings (Bach & Busto, 2005). Although there is an increase in SCC, there is also an increase in the milk fat of animals in RMS (Janštová *et al*., 2011; Avilez Ruiz *et al*., 2021; Matson *et al*., 2021).

An increase in SCC may also result from inadequate teat sanitation (Van den Borne *et al*., 2021). Cows with shallow and small udders are not recommended for robotic milking. Therefore, farms installing the system should select animals with greater udder depth to achieve better mammary gland health in this system (Córdova *et al*., 2018b; Tse *et al*., 2018).

Nevertheless, RMS is highly effective in terms of milk hygiene. Samples from cooled tanks were collected from facilities with an automated milking system, and the total bacterial count

was below the minimum evaluation value (Janštová *et al*., 2011).

The similarity analysis unifies the terms “cow” and “milk,” organizing a perception of the system. The term “AMS” (automatic milking system) is not directly associated with the word “milk.” This indicates that milk production and quality are not related to the milking system but the animal. Thus, the system directly influences animal health and feeding (Figure 3). Milk production and somatic cell count are directly associated with “milk” and “cow.” Thus, we can observe a link between animal welfare and better sanitary conditions in the final product.

## 5. Conclusion

This study demonstrated the influence of a robotic system on milk production and quality. Analyzing the articles lexicographically, we can observe the similarity of their terms and glimpse at a new vision of the system and its variables for future decision making. SCC has significant similarities with “milk” and “cow.” Therefore, farmers should act directly on the herd's health to modify the rates of somatic cells in milk, rather than modifying the milking system. As RMS is directly related to feeding, before deciding to change the property system, farmers should consider the nutritional supply of the herd

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**List of abbreviations and acronyms**

| Abbreviation | Explanation |
|---|---|
| RMS | Robotic Milking System |
| SCC | Somatic Cell Count |
| TBC | Total Bacterial Count |
| DHC | Descending Hierarchical Classification |
| SCK | Subclinical Ketosis |
| BHB | Beta-hydroxybutyrate |
| PVO | Population Variable Outcome |
| PMR | Partial Mixed Ration |