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AVALIAÇÃO DO USO DE SISTEMAS REMOTOS DE MONITORAMENTO COMPORTAMENTAL COMO FERRAMENTA DE GESTÃO NA BOVINOCULTURA

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ALINE CARDOSO VIEIRA

A AVALIAÇÃO DO USO DE SISTEMAS REMOTOS DE MONITORAMENTO COMPORTAMENTAL COMO FERRAMENTA DE GESTÃO NA BOVINOCULTURA

Tese apresentada como requisito para obtenção do grau de Doutor em Zootecnia na Faculdade de Agronomia, da Universidade Federal do Rio Grande do Sul

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Avaliação do uso de sistemas remotos de monitoramento comportamental como ferramenta de gestão na bovinocultura[1]

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RESUMO GERAL

Ao longo dos anos a produção de leite tem se tornado mais intensiva, as vacas mais produtivas e propensas a distúrbios metabólicos. O período de transição, 21 dias antes e 21 dias após o parto, é um período crítico e de grande risco de ocorrência de doenças. Nesse período, as mudanças no manejo, na dieta, e alojamento causam estresse e as adaptações fisiológicas podem deixar a vaca mais propensa à ocorrência de doenças. Hipocalcemia, cetose e acidose ruminal são doenças metabólicas que ocorrem geralmente no final da gestação e início da lactação; e, durante esse período, as vacas também estão mais suscetíveis à ocorrência de mastite e laminite. Estudos recentes têm investigado a utilização da variação dos comportamentos para predizer a ocorrência de doenças. O desenvolvimento e validação de sistemas automáticos de monitoramento dos comportamentos por sensores tem contribuído para a evolução desses estudos. Os sistemas remotos de monitoramento comportamental registram ruminação, atividade e ócio, permitindo a análise dos padrões comportamentais e emite alertas para os produtores. Porém não é de conhecimento como os produtores estão utilizando esses sistemas e quais suas atitudes diante dos alertas. No primeiro estudo, foi realizada uma análise do perfil e motivações dos produtores para adotar um sistema remoto de monitoramento comportamental. Os produtores de leite que adotam os sistemas de monitoramento estão na faixa etária de 30 a 40 anos e o principal objetivo é a detecção do estro. No segundo estudo, foram investigadas as atitudes adotadas pelos produtores diante dos alertas de saúde e identificação de estro enviados pelos sistemas de monitoramento. Houve diferenças entre as características de fazendas que adotam e as que não adotam o sistema de monitoramento, e, após receberem os alertas, os produtores avaliam os animais sem protocolo definido. O terceiro é uma revisão sistemática sobre quais comportamentos podem ser utilizados na detecção precoce de doenças de vacas leiteiras. Os principais comportamentos avaliados são na detecção precoce de doenças: tempo de ruminação, tempo deitado e tempo de alimentação, e foi evidenciado que os tempos de ruminação e alimentação são reduzidos, enquanto o tempo deitado aumenta.

Palavras chaves: detecção precoce de doenças, monitoramento do comportamento, perspectivas dos produtores

[1]Tese de Doutorado em Zootecnia - Produção Animal, Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brasil. (105 p.) Março, 2022.

Evaluation of the use of remote behavioral monitoring systems as a management tool in livestock[2]

Over the years milk production has become more intensive, the cows more productive and prone to metabolic disorders. The transition period, 21 days before and 21 days after calving, is a critical period with a high risk of disease. In this period, changes in management, diet, and housing cause stress and physiological adaptations may make the cow more prone to disease. Hypocalcemia, ketosis and ruminal acidosis are metabolic diseases that usually occur at the end of pregnancy and beginning of lactation. During this period cows are also more susceptible to the occurrence of mastitis and laminitis. Recent studies have investigated the use of behavior variation to predict the occurrence of diseases. The development and validation of automatic systems for monitoring behaviors by sensors has contributed to the evolution of these studies. Remote behavioral monitoring systems record rumination, activity and idleness, allowing the analysis of behavioral patterns and issues alerts to producers. However, it is not known how producers are using these systems and which are their attitudes towards the alerts. In the first study, we performed an analysis of the profile and motivations of producers to adopt a remote behavioral monitoring system. The study showed that milk producers who adopt monitoring systems are between 30 and 40 years of age and the main objective is the detection of estrus. In the second study we investigated the attitudes adopted by the producers after receiving the health alerts and identification of estrus sent by monitoring systems. There were differences between the characteristics of farms that adopt and that do not adopt the monitoring system. Moreover, after receiving the alerts the producers evaluate the animals without defined protocol. In the third study we conducted a systematic review to evidence which behaviors can be used in the early detection of diseases. The main behaviors used for the early detection of diseases are: rumination time, lying time and feeding time. During the occurrence of diseases rumination and feeding times are reduced, while lying time increased.

Key words: early detection of disease, behavior monitoring, farmer’s perspective

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[2]Doctoralthesis in Animal Science, Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil. (105 p.) March, 2022.

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ABREVIATURAS

ABRS: behaviour/behavior recording analysis system

AGNE: ácido graxo não esterificado

AGV: ácido graxo volátil

AI: artificial insemination

BEN: balanço energético negativo

BHBA: beta-hidroxibutirato

CAPES: Coordenação de Aperfeiçoamento de Pessoal de Nível Superior

CMT: California mastitis test

CNPq: Conselho Nacional de Desenvolvimento Científico e Tecnológico

DMI: dry matter intake

FDN: fibra digestível em detergente neutro

Na_2EDTA: solução de sódio

NABRS: não adotantes do sistema de monitoramento comportamental

NDF: neutral detergent fiber

PICO: Population, Intervention, Comparation and Outcomes

SARA: subacute ruminal acidosis (acidose ruminal)

THI: temperature-humidity index

YABRS: adopters of behaviour recording analysis system

NABRS: Non-adopters of behaviour recording analysis system

CAPÍTULO I

1. INTRODUÇÃO

Nos últimos anos ocorreu grande evolução tecnológica no agronegócio, com o uso crescente da “zootecnia de precisão” a qual consiste em utilizar sensores eletrônicos para monitorar, de forma individual e em tempo real, a menor unidade gerenciável de produção. Abrange vários dispositivos e sistemas como a ordenha robótica e sistemas de monitoramento remoto do comportamento animal, apresentando inúmeras possibilidades de uso e futuro promissor. Os primeiros indícios dessa tecnificação datam dos anos 70 com o início da utilização de medidores eletrônicos individuais de produção de leite (Halachmi *et al*., 2019). Desde então, esses sensores estão sendo aprimorados para, além de indicar parâmetros produtivos, detectar variações no comportamento que podem ser, entre outros, sinais de doenças, desconforto ambiental ou estro (Denis-Robichaud *et al*., 2018a) e assim possibilitar que o produtor interfira no ambiente e tome atitudes promovendo melhoria no bem estar animal e na eficiência produtiva.

Na atividade leiteira, a fase mais crítica para as vacas é o período de transição, que se estende do dia 21 antes do parto até o 21º dia pós-parto, pois a vaca muda de um estado não lactante para o lactante e passa por alterações metabólicas, fisiológicas e ambientais (Sepúlveda-Varas *et al*., 2013). Nesse período, ocorre maior incidência de doenças nos animais como a cetose, acidose ruminal, hipocalcemia, metrite, retenção de placenta e deslocamento de abomaso. Essas doenças representam custos dentro da propriedade, devido aos tratamentos, perda na produção e aumento de morbidade e mortalidade (Soriani*et al*., 2012). Para minimizar os efeitos dessas doenças é necessária muita atenção durante o período de transição e monitoramento constante dos animais.

Monitorar a saúde dos animais envolve avaliações físicas e visuais dos mesmos, além da coleta de fluidos para a realização de testes comerciais, sendo inviável sua aplicação a um grande número de animais, em função do custo e limitações de mão-de-obra. Uma vez que o comportamento pode ser um indicador de dor ou período reprodutivo dos animais, várias ferramentas para monitorar o comportamento animal, automaticamente, têm sido validadas como colares e brincos, que utilizam sensores como os acelerômetros, os sensores sonoros e os medidores de bocados em conjunto com um software. O conjunto que compõe os sistemas de monitoramento remoto, sensores e softwares, do comportamento animal se utilizam de algoritmos para analisar o comportamento do animal durante um período de no mínimo sete dias, e estabelecer um padrão de comportamento individual, registrando diariamente os valores (em minutos por dia) em planilhas ou gráficos. Quando ocorre uma mudança no comportamento, detectando uma anomalia no padrão estabelecido, o sistema emite um alerta individual, indicando qual animal necessita de atenção (King *et al*., 2017).

Embora acelerômetros sejam utilizados desde os anos 80 para detectar estros em vacas, recentemente os estudos se têm voltado para a utilização dos sistemas de monitoramento remoto do comportamento para detectar e diagnosticar doenças antes da manifestação dos sintomas clínicos (Van Dixhoorn *et al*., 2018). A relação entre a mudança do comportamento com a causa só é possível após a confirmação do diagnóstico. O sistema de monitoramento automático emite um alerta indicando uma alteração no comportamento, mas sem identificar a possível causa. Em estudo retrospectivo, (González *et al*., 2008) identificaram que animais que ficaram doentes reduziam o consumo e o tempo em que permaneciam no cocho se alimentando, ocorrendo o mesmo com tempo de ruminação e atividade em geral alguns dias antes da manifestação dos sintomas clínicos (Stangaferro *et al*., 2016a). Aungier *et al*. (2012) demonstraram que os animais em estro apresentam aumento na atividade, quando comparado com o padrão comportamental do animal. No parto, o tempo de ruminação decresce acompanhando a redução no consumo de matéria seca (Liboreiro *et al*., 2015).

O Brasil está passando por um período de especialização na produção de leite, onde muitos produtores tem deixado a atividade, os quais muitas vezes representam pequenas propriedades, enquanto a produção de leite nacional vem aumentando e se concentrando em propriedades que buscam especialização na atividade (EMBRAPA, 2018). Para poder aumentar sua produção, essas propriedades adotam tecnologias de gerenciamento e monitoramento para tornar o trabalho mais eficiente e rentável.

A coleira eletrônica da Cowmed é dispositivo eletrônico, que através de um acelerômetro consegue registrar em tempo real três variáveis comportamentais das vacas: tempo de ruminação; tempo de atividade (incluindo o tempo em que caminham, montam, consomem alimentos e água, socializam com outros animais, balançam a cabeça entre outras movimentações) e o tempo de ócio em que os animais ficam parados e sem fazer nada (Martins, 2020). Através da variação desses comportamentos, os sistemas de monitoramento da Cowmed emitem alertas de saúde e reprodução.

As informações geradas pelos sistemas de monitoramento do comportamento animal deveriam auxiliar o produtor a tomar decisões, e se tornam de pouca utilidade se não forem consideradas (Halachmi *et al*., 2019). Porém, as informações sobre o perfil dos produtores que adotam sistema remoto de monitoramento comportamental das vacas são escassas, e as motivações e atitudes diante a tecnologia são pouco conhecidas. É necessário saber se os produtores estão se adaptando e conseguindo utilizar as ferramentas disponíveis nos sistemas de monitoramento de comportamento com base em acelerômetros. Sabe-se que a ocorrência de uma doença altera o comportamento das vacas, antes mesmo que a vaca apresente sinais clínicos. A variação comportamental das vacas durante a ocorrência de uma doença não é totalmente esclarecida, de forma que não se tem uma real noção de quais as variações e os melhores comportamentos para avaliar a saúde das vacas.

2. REVISÃO BIBLIOGRÁFICA

O bem-estar animal deveria ser uma preocupação constante para produtores, devendo os animais estarem saudáveis e bem nutridos para melhor expressar seu potencial produtivo (Von Keyserlingk *et al*., 2009). No entanto, a seleção genética, realizada por décadas para aumentar a produção leiteira, incrementou também a demanda por nutrientes e a necessidade de manter reservas corporais em níveis dificilmente atingidos, resultando em distúrbios metabólicos e menor eficiência reprodutiva (Ruprechter *et al*., 2018).

O período de transição, normalmente definido como as três semanas anteriores e as três semanas posteriores ao parto, é marcado por ajustes fisiológicos, metabólicos e físicos para acomodar o final da gestação e o início da lactação (Sepúlveda-Varas *et al*., 2013). Nesse período, a demanda energética aumenta devido ao crescimento fetal e a lactogênese, porém, o consumo de matéria seca é reduzido, resultando em balanço energético negativo (BEN) no início da lactação (Goldhawk *et al*., 2009) e em deficiência em micronutrientes (Wankhade *et al*., 2017). Vacas em BEN apresentam lipólise aumentada, produzindo uma grande quantidade de ácidos graxos não esterificados (AGNE) e liberando-os na corrente sanguínea. Essa grande quantidade de AGNE prejudica a capacidade do fígado de oxidá-los completamente, resultando no aumento de corpos cetônicos no sangue, principalmente β-hidroxibutirato (BHBA), que são produtos da oxidação parcial dos AGNE (Rodriguez-Jimenez *et al*., 2018). A adaptação ao BEN é um processo normal para vacas de alta produção, no entanto quando as vacas não se adaptam a essa condição, várias doenças de ordem metabólica ou infecciosa podem ocorrer, afetando a produção e a eficiência reprodutiva das vacas (Wankhade *et al*., 2017).

Aproximadamente 75% das doenças ocorrem no primeiro mês após o parto, afetando entre 30 e 50% de todas as vacas paridas (Sepúlveda-Varas *et al*., 2013). Essas doenças causam um aumento nos custos com veterinários e uso de drogas no tratamento, aumentam o risco de descarte precoce ou morte do animal além de causar redução na produção e afetar a reprodução das vacas (Soriani *et al*., 2012). Nesse contexto é importante monitorar a incidência de doenças no período de transição. Para isso existem muitos protocolos que incluem avaliações sistemáticas da saúde dos animais e coleta de fluidos corporais para testes laboratoriais que, no entanto, quando aplicados a um grande número de animais, tornam-se onerosos, além de demandarem tempo e mão de obra (González *et al*., 2008). Por outro lado, o comportamento dos animais é um indicador de seu estado fisiológico, podendo ser utilizado para monitorar a saúde dos animais (Rombach *et al*., 2018). Desordens do período de transição incluem mastite, metrite, distocia, cetose e retenção de placenta (Sepúlveda-Varas *et al*., 2013). O monitoramento contínuo do comportamento e parâmetros fisiológicos pode permitir a detecção de alterações sutis antes mesmo que a vaca demonstre sinais clínicos da doença (Stangaferro *et al*., 2016c). Por exemplo, o aumento na frequência de troca de posição da vaca, deitar e levantar, nas 24 horas precedentes ao parto pode ser utilizado como indicador na ocorrência de distocia em vacas (Sepúlveda-Varas *et al*., 2013). Geralmente, vacas diagnosticadas com alguma doença apresentam valores menores de tempo de ruminação e atividade do que vacas saudáveis (Stangaferro *et al*., 2016a).

Dependendo da desordem, a redução no tempo de atividade de ruminação pode ser superior a 50 min/d (King *et al*., 2017). Soriani *et al*. (2012), avaliando vacas com valores baixos, médios e altos de tempo de ruminação, observaram que, entre dez e dois dias antes do parto, os valores médios de tempo de ruminação foram 420, 491 e 556 min/dia; e que, após o parto, vacas no grupo de baixo tempo ruminação tiveram maior incidência de doenças clinicas: a cada dez animais, oito ficam doentes (onde 30% apresentam mastite, 20 % metrite, 20%laminite, 10% retenção de placenta, 10% cetose e 10% deslocamento de abomaso).

A atividade de ruminação é um indicador da condição ruminal, conforto da vaca e saúde geral, de forma que dispositivos de medição que diferenciam movimentos e sons específicos da ruminação estão disponíveis para monitoramento contínuo de bovinos (Paudyal *et al*., 2018). A ruminação tem como função facilitar a digestão, através da redução das partículas, e a subsequente passagem pelo retículo-rúmen, mantendo o consumo de alimento em níveis altos (Soriani *et al*., 2012). O tempo de ruminação está associado ao às boas condições ruminais, pois aumenta a produção de saliva que contribui para manter o pH ruminal (Moretti *et al*., 2017). A ruminação é afetada por características da dieta, como a digestibilidade do alimento, o conteúdo de fibra, principalmente fibra digestível em detergente neutro (FDN), e a qualidade da forragem, mas o tempo de ruminação é reduzido quando a vaca está em condição estressante, com ansiedade, doença ou em um grupo com alta lotação (Soriani *et al*., 2012). O tempo de ruminação e de atividade (tempo gasto com demais atividades como andar, comer e beber) estão correlacionados, podendo ser utilizados em conjunto para prever a proximidade do parto (Moretti *et al*., 2017) e ocorrência de doenças (Stangaferro *et al*., 2016a). A combinação dos dados de diferentes sensores pode aumentar a detecção de características comportamentais e assim aumentar a acurácia do sistema (Rombach *et al*., 2018). O tempo de ruminação médio é de 460 min/d para vacas primíparas e de 499 min/d para vacas pluríparas no período de dez até dois dias antes do parto, quando ocorre a redução significativa nesse comportamento, voltando a aumentar na semana seguinte ao parto até o décimo quinto dia, quando se estabiliza (Soriani; Panella; Calamari, 2013).

Muitos estudos evidenciam que esses sistemas podem indicar animais doentes, pois detectam variações no padrão de comportamento; demonstram, ainda, que para cada doença há um padrão diferente (Stangaferro *et al*., 2016a). No entanto, esses estudos foram realizados em situações experimentais, realizando regressões a partir do diagnóstico até o momento em que iniciou a alteração no comportamento, na pratica, ainda não é possível identificar a doença em curso apenas através do início das mudanças comportamentais, ou seja, para obter o diagnóstico, ainda é necessária a realização de exames clínicos e até mesmo a ocorrência dos primeiros sinais clínicos.

2.1 Sensoriamento remoto dos padrões comportamentais

Detectar doenças ainda no estágio inicial, antes do animal manifestar os sinais clínicos, pode trazer vários beneficios para o animal, alem de melhorar a resposta ao tratamento e reduzir as consequências da doença a longo prazo, sobre a saúde o desempenho da vaca (Stangaferro *et al*., 2016). Porém, registrar características comportamentais por observação direta é demorado, laborioso, consome tempo e difícil, principalmente quando não se tem prática ou conhecimento para diferenciar determinados movimentos (Rombach *et al*., 2018).

Os sistemas automatizados de monitoramento do comportamento têm ganhado popularidade pelo mundo, pois não são invasivos e o monitoramento é constante. Essa tecnologia registra dados comportamentais, como tempo de ruminação e atividade geral, produzindo alertas e sinalizando animais em risco de apresentar algum distúrbio (King *et al*., 2017; Van Dixhoorn *et al*., 2018). Esses sistemas fazem uso de sensores e algoritmos específicos que detectam anormalidades no comportamento. Um sistema de monitoramento baseado em imagens computadorizadas, por exemplo, utilizando-se de um algoritmo com alta sensibilidade (92%) para confirmar o comportamento das vacas, pode ser aplicado tanto para avaliar o comportamento alimentar quanto outras atividades, como a movimentação do animal pelo confinamento (Porto *et al*., 2015). A atividade física e o tempo de ruminação são outros atributos que podem ser utilizados para monitorar a saúde das vacas, assim, espera-se que vacas que podem apresentar alguma doença mostrem alterações nesses parâmetros em magnitudes suficientes para serem detectadas pelo algoritmo especifico ou pela inspeção visual dos dados (Stangaferro *et al*., 2016c).

Além da detecção de doenças, há evidências de que os sistemas de monitoramento remoto do comportamento animal são mais utilizados para detectar estros (Denis-Robichaud*et al*., 2018b), aumentando de 55% para 80% a sua detecção em vacas (Paudyal *et al*., 2018). O monitoramento constante reduz o risco de perder estros silenciosos, dada a importância e impacto econômico sobre o desempenho reprodutivo dos animais.

Monitorando o tempo de ruminação dos animais em períodos distintos, dia e noite, e correlacionando com o *termal humidity index* (THI) diário, utilizado como um índice de conforto térmico, sob alto THI (média de 76), 63% do tempo de ruminação ocorre durante a noite, enquanto ocorre a redução do tempo de ruminação no período diurno, indicando que os sistemas automatizados podem ser utilizados para monitorar o estresse térmico para os animais (Soriani;Panella; Calamari, 2013).

Os sensores utilizados nos equipamentos de monitoramento podem ser descritos como acelerômetros triaxiais (Rombach *et al*., 2018) combinados com um giroscópio, onde o acelerômetro é responsável por medir a aceleração do corpo enquanto que o giroscópio mede a velocidade angular do corpo (Mendes, 2014). A união e o processamento das medidas de três sensores, os acelerômetros, giroscópios e magnetômetros, possibilitam construir um medidor completo de posição, velocidade e aceleração, ajudando a melhorar a identificação de diferentes comportamentos (Turco *et al*., 2019). Os sensores capturam o movimento da vaca, registram o comportamento, enviam os dados para o multiprocessador para serem analisados por algoritmos complexos e retornam as informações, sob a forma de alertas, para os produtores (Reith *et al*., 2014).

Atualmente podemos encontrar no mercado vários sistemas remotos de monitoramento comportamental já validados, que apresentam seus sensores em uma variedade de dispositivos, melhor detalhado na tabela 1.

Tabela 1: Dispositivos de monitoramento comportamental e equipamentos disponíveis comercialmente

Dispositivos	Equipamentos[1]
Coleiras	Lely T4C Dairy Plan C21 Rumiwatch HR-TAG Afimilk HI-TAG Lely-Qwes – HR colar Cowmed[2] SenseHub[2]
Pedômetros	IceQube IceTag TinyTag Hobo Pedant G data logger Gemini data loggers
Robôs	LelyAstronaut DeLaval VMS[2]
Comedouros	Isentec B.V. Intergado[2]
Vídeos	Câmeras
Implante ruminal	SmaXtec

1Equipamentos utilizados em estudos já publicados em revistas cientificas, bem como verificada sua disponibilidade nos sites das empresas correspondentes.

2 Equipamentos disponíveis no Brasil

Os sistemas automatizados de monitoramento do comportamento são desenvolvidos para ajudar o produtor a detectar animais enfermos e assim poder interferir na progressão da doença. Ocorre, porém, que os produtores são céticos quando se trata de novas tecnologias. No desenvolvimento desses sistemas se busca alta sensibilidade e elevada especificidade no comportamento (Yazdanbakhsh *et al*.,2017). A acurácia e precisão das tecnologias de monitoramento do comportamento animal aumentam a credibilidade na ferramenta (Grinter; Campler; Costa, 2019). No entanto, há uma grande variabilidade na acurácia desses sistemas em detectar animais doentes (Rombach *et al*., 2018), devendo os produtores contribuir com o sistema para aumentar essa precisão, alimentando o banco de dados através da confirmação da causa dos alertas, os quais podem ser verdadeiros ou falsos. Cabe aos técnicos apresentar os sistemas de monitoramento remoto para os produtores, ensiná-los e auxiliá-los a utilizar a ferramenta como um suporte de decisão.

Os sistemas inteligentes de monitoramento geram vários alertas, sinalizando animais que necessitam maior atenção, seja por um desconforto, gerando um alerta de saúde, estro ou proximidade do parto (Grinter, Campler, Costa, 2019). Para (Halachmi *et al*., 2019) as informações dos sistemas automatizados de monitoramento do comportamento animal ajudam os produtores na tomada de decisões, porém devem ser utilizadas em conjunto com a experiência e técnica dos mesmos para que as ações sejam eficientes. Para melhor monitorar a saúde dos animais, amostras de urina, leite ou sangue podem ser coletadas para a realização de testes (Von Keyserlingk *et al*., 2009). Os produtores podem fazer avaliações simples e de baixo custo, como observar a aparência do animal e analisar sua postura, medir a temperatura, verificar se há secreções anormais e avaliar as fezes (escore de fezes).

No ano de 2020, o Brasil já possuía 218.150.298 cabeças de gado monitoradas, das quais 16.167.625 são vacas em ordenha (IBGE, 2022). Essa informação é uma amostra da disponibilidade de mercado para os sistemas remotos de monitoramento comportamental. No entanto, muitas destas tecnologias disponíveis no mercado brasileiro são importadas de países desenvolvidos, sendo de custos elevados e ainda estão sendo adaptadas para os nossos sistemas de produção (Turco *et al*., 2019). Desde 2016, startups, EMBRAPA, empresas privadas e universidades tem trabalhado para transformar o setor leiteiro, através de ferramentas e sistemas que permitem gerenciar e monitorar digitalmente os animais e geram dados que podem ser usados com Big Data, Data Science, Internet of things (IoT), Inteligência Artificial (IA), análises preditivas, Block Chain, entre outros (Azevedo, 2019).

As informações prestadas pelos sistemas remotos de monitoramento comportamental dos animais abrem novas possibilidades para o diagnóstico de doenças nas vacas. Identificar animais em desafio através do seu comportamento alterado já é uma realidade que nos permite dedicar mais atenção a determinado animal. Assim, podemos avaliar suas condições físicas, seus parâmetros fisiológicos e acompanhar sua evolução ao longo dos dias. Entender o que está afetando o comportamento da vaca e identificar precocemente quando uma doença está em curso, iniciando o tratamento ainda nos estágios iniciais da enfermidade são possibilidades para uma realidade próxima, facilitada pelos sistemas remotos de monitoramento comportamental.

2.2 Relação entre doenças e comportamentos detectados

A cetose é uma das doenças mais frequentes em vacas recém paridas. Aproximadamente 43% das vacas apresentam cetose subclínica quando testadas três vezes por semana do terceiro ao décimo sexto dia de lactação (Kaufman *et al*., 2016). Os primeiros sintomas da cetose são apetite reduzido, baixo consumo de alimento e também menor atividade (Steensels *et al*., 2017). Rodriguez-Jimenez *et al*. (2018) observaram que vacas diagnosticadas com cetose no pós-parto permanecerem menos tempo em atividade durante o pré-parto, assim como no pós-parto tenderam a permanecer mais tempo em ócio. Vacas diagnosticadas com cetose subclínica visitam o cocho com menor frequência e gastam menos tempo se alimentando, consumindo menos durante a semana anterior ao parto e nas duas semanas seguintes (Sepúlveda-Varas *et al*., 2013), o que se reflete, também, em menor tempo de ruminação durante o período (Kaufman *et al*., 2016). Stangaferro *et al*., (2016b) relataram que vacas cetóticas apresentam menor tempo de ruminação (275 min/d) e atividade (380 unidade arbitrária/d), medida em unidade arbitraria (un) por dia, um índice de movimento da cabeça utilizado por um equipamento comercial, quando comparadas a vacas saudáveis (502 min/d e 546,82 un/d, respectivamente), e que após o diagnóstico e tratamento os valores aumentam. Os principais indicadores metabólicos de cetose são os ácidos graxos não esterificados (AGNE) e o beta-hidroxibutirato (BHBA), assim sua concentração sanguínea pode ser utilizada para monitorar a ocorrência dessa doença. Em vários estudos são utilizados como valores de referência a concentração sérica de ≥0,3 até 0,5 mEq/L para o AGNE e de ≥0,6 até 0,8 mmol/L para o BHBA durante o pré parto; no pós parto, valores entre 1,2 e 1,4 mmol/L de BHBA são utilizados para diagnosticar cetose subclínica e acima de 1,4 mmol/L de BHBA para a cetose clínica (Wankhade *et al*., 2017).

Metrite é uma doença comum em vacas no início da lactação, podendo afetar até 40% das vacas (Stangaferro *et al*., 2016c). É necessário identificar vacas em risco de desenvolver metrite, pois a doença apresenta grande incidência e efeitos negativos sobre a eficiência reprodutiva das vacas (Von Keyserlingk *et al*., 2009). A metrite é evidenciada pelo descarte uterino de muco castanho-rosado e fétido, além do útero se encontrar em tamanho aumentado. Outros sintomas da doença são anorexia, febre, depressão e desidratação quando em estado severo da doença (Stangaferro *et al*., 2016c). Vacas diagnosticadas com metrite aguda no pós-parto apresentaram menor permanência no alimentador, iniciando doze dias antes do parto, também apresentando baixo consumo de matéria seca duas semanas antes do parto e três semanas antes de demonstrar sinais clínicos da doença (Sepúlveda-Varas *et al*., 2013). Segundo (Von Keyserlingk *et al*., 2009), a redução de 10 minutos no tempo que o animal gasta consumindo o alimento, no pré-parto, aumenta em 2 vezes as chances desse animal apresentar metrite após o parto. Stangaferro *et al*. (2016c) observaram que vacas com metrite, diagnosticadas sete dias após o parto, apresentaram menor tempo de ruminação do que vacas saudáveis, diferindo em 131 min/d; também menor atividade, cujo menor valor atingido foi de 434 un/d. A metánalise realizada revelou que há pouca heterogeneidade entre os estudos que avaliam o tempo de ruminação como preditor de metrite: vacas metriticas apresentam menor tempo de ruminação tanto no pré- quanto no pós-parto, quando comparadas com vacas saudáveis (Cocco; Canozzi; Fischer., 2019).

A laminite, normalmente, não é considerada uma doença do periodo de transição, pois seus sintomas surgem meses após o parto, porém o inicio das lesões no casco podem ter início no período em torno do parto (Sepúlveda-Varas *et al*., 2013). Essa doença é um dos maiores problemas para o bem-estar de vacas leiteiras, podendo ser resultado de infecções ou rupturas no casco, mas está frequentemente associada com o confinamento dos animais, onde o piso de concreto e cama inadequada são importantes fatores de risco (Von Keyserlingk *et al*., 2009). Segundo Sepúlveda-Varas *et al*. (2013), vacas sadias durante à lactação consomem mais alimento durante as semanas anteriores ao parto, e, em média, um consumo de 5kg a mais de matéria seca durante as 24 horas seguintes ao parto, quando comparado com vacas diagnosticadas com laminite. Identificar e tratar a laminite é importante para o bem-estar animal, pois animais com claudicação no casco tendem a permanecer mais tempo deitados (≥ 14 h/d) e trocarem de posição menos vezes (≤ 5 vezes/d), com longo tempo de duração para cada posição (≥110 min/posição) (Solano *et al*., 2016).

A hipocalcemia é um distúrbio metabólico comum em vacas leiteiras de transição que é considerada uma doença de porta de entrada, aumentando o risco de outros distúrbios de saúde e reduzindo o desempenho da vaca (Hendriks *et al*., 2020). Para produzir leite, no inicio da lactação, mudanças no mecanismo de homeostase do cálcio faz com que ocorra aumento no reabsorção de cálcio dos ossos e reduza a taxa de deposição de cálcio no osso e perdas fecais, porem essas mudanças não são rápidas o suficiente e quase todas as vacas apresentam algum grau de hipocalcemia durante os primeiros dias após o parto, mas a concentração plasmática de cálcio retorna ao normal (1,6 até 2,6 mmol/L) dentro de 2 a 3 dias (Jawor *et al*., 2012). A hipocalcemia grave ocorre quando as vacas são incapazes de manter as concentrações de cálcio no sangue e apresentam sinais clínicos como letargia, excitabilidade, decúbito prolongado e, se não tratada, morte (Barraclough *et al*., 2020).Sepúlveda-Varas *et al*. (2013) comentam que vacas com hipocalcemia subclínica visitam o bebedouro e o comedouro menos vezes do que vacas sadias durante as semanas seguintes ao parto. O diagnóstico de hipocalcemia em vacas parturientes pode ser realizado testando o cálcio sérico, utilizando como valores de referência 2,0 mmol/L de cálcio sérico total ou 1,0 mmol/L de cálcio ionizado; vacas com valores inferiores encontram-se hipocalcêmicas. A acidificação da dieta é um manejo preventivo à hipocalcemia cliínica e subclínica, podendo sua eficiência ser mensurada pelo pH urinário, o qual deve estar entre 6,0 e 7,0 com o consumode dieta anionica (Oetzel, 2004).

Na produção leiteira, a mastite é um grande problema que afeta o bem-estar animal, a produtividade e a economia (Herskin *et al*., 2020). A mastite bovina é uma inflamação da glândula mamária, tipicamente causada por bactérias pertencentes às famílias Enterobacteriaceae, Staphylococcaceae ou Streptococcaceae (Khatun *et al*., 2020). Durante a mastite, ocorre uma inflamação concomitante do úbere, aumento da pressão intramamária e aumento da pressão externa (dês Roches *et al*., 2017). O diagnóstico precoce de casos clínicos pode melhorar o bem-estar das vacas e reduzir os custos associados à doença, permitindo o tratamento oportuno (Sepúlveda-Varas*et al*., 2016). Mudanças comportamentais como atividade e ruminação, monitoradas automática e continuamente por sensores localizados em coleiras e outros acessórios de identificação, podem contribuir para a previsão de mastite clínica (Khatun *et al*., 2020). Para detectar vacas com mastite clínica, os programas de monitoramento da saúde incluem a avaliação das características do leite, sinais de inflamação do úbere e sinais sistêmicos de doença (Stangaferro *et al*., 2016a).

Vacas leiteiras no início da lactação são particularmente suscetíveis à acidose ruminal (SARA) devido à transição abrupta de uma dieta de vaca seca, composta principalmente de forragens e grãos mínimos, para uma dieta de lactação de alta energia contendo uma maior proporção de componentes concentrados prontamente digeríveis (Coon *et al*.,2019). Geralmente a SARA ocorre quando o pH ruminal permanece dentro da faixa de 5,2-6,0 por um período prolongado (Antanaitis *et al*., 2019a). Uma das consequências da diminuição do pH ruminal é uma mudança na composição de ácidos graxos voláteis (AGV) no rúmen, que pode ser afetada pela microbiota ruminal; nesse caso as bactérias reduzem a síntese de ácido acético e aumentam os ácidos propiônico e butírico (Antanaitis *et al*.,2019b). Essa doença pode reduzir a ingestão de alimentos, a digestão de fibras e a produção de gordura do leite, afetar os microrganismos do rúmen e causar diarreia, danos à mucosa ruminal, laminite, inflamação e abscessos hepáticos (Li *et al*., 2011). Coon *et al*. (2019) avaliando animais com risco de desenvolverem acidose ruminal (pH < 5,8) demonstram que animais com maior risco de desenvolverem a doença, principalmente quando a dieta é composta por fibras longas (5,08 cm), apresentam menor tempo de ruminação do que vacas sob baixo risco (432,3 *vs* 493,2 min/d, respectivamente). DeVries *et al*. (2009) induziram a ocorrência de acidose ruminal em vacas através da alteração da dieta, suas observações relatam que, no primeiro dia após a indução, as vacas aumentam o tempo de alimentação, embora ocorra redução na taxa de consumo e no tempo de ruminação.

Existem vários sensores para monitorar o comportamento dos animais, bem como softwares validados, fornecendo diariamente inúmeras informações para os produtores. Atualmente os produtores podem acompanhar seus rebanhos por aplicativos no celular, ondem recebem as informações em tempo real como a produção individual de cada animal, alertas de saúde ou reprodução, variações meteorológicas, ou seja, dados que podem ser usados para mensurar o conforto dos animais e utilizados para melhorar seu bem-estar. Porém, não há publicações que demonstrem o uso dessas informações, recebidas várias vezes ao dia pelos produtores em suas fazendas. Diante da grande possibilidade de uso dos sistemas de monitoramento automatizado do comportamento animal, é necessário que se evidencie como essas informações estão sendo utilizadas e se estão beneficiando os produtores e bem-estar aos animais.

3. HIPÓTESES E OBJETIVOS

3.1. Hipóteses

As informações fornecidas pelo sistema remoto de monitoramento comportamental permitem a identificação precoce de animais que necessitam de atenção, para a saúde ou reprodução.

Os produtores usam essas informações para a adoção de práticas e cuidados com os animais.

Existem padrões comportamentais para as vacas que se alteram com a ocorrência de uma doença, mesmo antes do aparecimento de sinais clínicos.

3.2 Objetivos

3.2.1 *Objetivos Geral:*

Identificar comportamentos que se alteram com a ocorrência de doenças nas vacas e verificar se os produtores utilizam as informações fornecidas pelo sistema remoto de monitoramento comportamental, identificando e monitorando os animais, para adotar práticas e cuidados com os mesmos.

3.2.2 *Objetivos secundários:*

- Atualizar a literatura sobre o uso de sistemas de monitoramento remoto do comportamento animal;
- Avaliar a motivação dos produtores para utilizar esses sistemas;
- Avaliar a conduta dos produtores após receberem as informações;
- Identificar os comportamentos que relacionados com aspectos da saúde e reprodução;
- Verificar se os alertas de saúde e reprodução são confirmados pelo produtor e são utilizados para gerar uma ação;
- Verificar se o produtor consegue intervir na evolução do quadro de saúde do animal, antes dos sinais clínicos de uma doença.

CAPÍTULO II

MOTIVATIONS AND ATTITUDES OF BRAZILIAN DAIRY FARMERS REGARDING THE USE OF AUTOMATED BEHAVIOUR RECORDING AND ANALYSIS SYSTEMS[3]

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Motivations and attitudes of Brazilian dairy farmers regarding the use of automated behaviour recording and analysis systems

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Short title: **Attitudes and perspectives of dairy farmers about use of ABRS**

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Summary

In this Research Communication we investigate the motivations of Brazilian dairy farmers to adopt automated behaviour recording and analysis systems (ABRS) and their attitudes towards the alerts that are issued. Thirty-eight farmers participated in the study distributed in to two groups, ABRS users (USERS, n = 16) and non-users (NON-USERS, n = 22). In the USERS group 16 farmers accepted being interviewed, answering a semi-structured interview conducted by telephone, and the answers were transcribed and codified. In the NON-USERS group, 22 farmers answered an online questionnaire. Descriptive analysis was applied to coded answers. Most farmers were young individuals under 40 years of age, with undergraduate or graduate degrees and having recently started their productive activities, after a family succession process. Herd size varied with an overall average of approximately 100 cows. Oestrus detection and cow's health monitoring were the main reasons given to invest in this technology, and cost was the most important factor that prevented farmers from purchasing ABRS. All farmers in USERS affirmed that they observed the target cows after receiving a health or an oestrus alert. Farmers believed that they were able to intervene in the evolution of the animals' health status, as the alerts gave a window of three to four days before the onset of clinical signs of diseases, anticipating the start of the treatment. The alerts issued by the monitoring systems helped farmers to reduce the number of cows to be observed and to identify pre-clinically sick and oestrous animals more easily. Difficulties in illness detection and lack of definite protocols impaired the decision making process and early treatment, albeit farmers believed ABRS improved the farm's routine and reproductive rates.

Many technologies are being developed to decrease farmer's time and labour, without losing reliable information about crucial aspects of a dairy farm's management (Grinter et al., 2019; Maltz, 2020). The precision tools are usually related to milking process (automatic milking systems and recoding of milk yield and composition) and animal behaviour (monitoring of activity, rumination time, the position and location of the animals) to detect diseases or reproductive events (Gargiulo et al., 2018). Several portable remote behaviour monitoring systems have been validated over the last few years, identifying animals out of the normal behavior range and assisting the farmers in the decision-making process (Norton and Berckmans, 2017). Remote monitoring technologies were initially used for oestrus detection (Benaissa et al., 2020), and recently for disease detection (Eckelkamp and Bewley, 2020). However, many dairy farmers still have difficulties and uncertainties about the use and the efficiency of these technologies, their cost–benefit relation, affecting negatively the adoption of these systems (Borchers and Bewley, 2015).

Previous studies have focused on the development and validation of algorithms (Nortonand Berckmans, 2017), combining behaviours for better identification of disease and oestrus (Stangaferro et al., 2016a, b; Mayo et al., 2019; Michie et al., 2020). Some studies have addressed factors affecting the equipment's adoption (Eastwood et al., 2017; Gargiulo et al., 2018), but there is currently rather inadequate information about the attitudes of farmers and managers to the alerts sent by the remote behavioural monitoring system as well as their perspectives towards this technology. In Brazil, the use of remote monitoring systems is recent, increasing fast but still limited to some hundreds of dairy producers (for example, organic farms supplying the Nestlé dairy industry, within the project named cow sense (Schimidt, 2020), as well as some individual dairy farmers). Information about how producers are adapting and using these technologies, as well as what their motivators to use them is still lacking. Thus, the aim of this study was investigate the motivations of Brazilian dairy farmers to adopt the automated behaviour recording and analysis systems (ABRS) and their attitudes towards the issued alerts.

Material & Methods

This study was approved by the ethics committee of the Federal University of Rio Grande do Sul, n°. 25671819.3.0000.5347.Dairy farmers who participated in this study were informed of the procedures, and they signed an informed consent form authorizing the use of the provided information.

Data collection

From 150 farmers using ABRS by Chip Inside Tecnologia S.A., 27were randomly selected (USERS). Farmers were contacted by telephone by the same interviewer from September 2019 to March2020. Sixteen farmers accepted and answered the entire semi structured questionnaire about how they were introduced to the system, what motivated them to use it, time using the system, their actions towards the alerts, and if they managed to intervene in the evolution of the disease status. Data were transcribed and the answers were coded (online Supplementary Table S1). Dairy farmers who did not use ABRS (NON-USERS) received an online questionnaire about their interest and motivations in ABRS acquisition, and reasons that prevented them from purchasing an
ABRS. Twenty-two farmers replied to the online questionnaire and the answers were coded (online Supplementary Table S2).The online questionnaire was generated on the Google platform, disseminated through social networks and partners (technicians and universities) and farmers were able to freely and anonymously answer the questionnaire from 06/2020 to 12/2020.

Thirty-eight Brazilian dairy farmers effectively participated in the study, 22 and 16 in the NON-USERS and the USERS groups, respectively. In NON-USERS and USERS 81.8% and 75% of farmers were less than 40 years old. Education level was categorized as high-school, technical, undergraduate, graduate. In NON-USERS and USERS 77.3% and 56.3% of farmers had undergraduate or graduate degrees, mainly in the agricultural area; 36.3% of the farmers in NON-USERS were in the dairy activity for more than20 years compared with 68.7% of the farmers in the USERS group. In NON-USERS group, 77.2% of the farms were pasture based systems, while 100% in the USERS group confined cows in feedlots, mostly (68.7%) in compost barns. In both groups of farmers, Holstein was the prevalent breed (54.55 and 93.75% for NON-USERS and USERS, respectively). Farms in NON-USERS and USERS groups had herd size of (mean ± SD) 50.6 ± 41.6 and165.5 ± 139.7 cows, respectively (online Supplementary Table S3).In USERS group, for 50% of farmers dairy production was the farm’s only income, while for the remaining 50%, the income was made up of dairy production plus other activities, mainly cereal grain production. The NON-USERS group was not asked about the composition of income on the farm.

The ABRS sensors used were Cowmed Collars (C-tech/Chip Inside Engineering and Technology, Santa Maria, Brazil), which measure daily time spent in rumination, activity and rest. Data were transferred to a central data processing facility and returned to the farmer in the form of health and oestrus alerts.

Data analysis

The data were analyzed descriptively using SAS Studio (SAS Institute, version 3.8, 2016). The FREQ procedure was used to calculate the frequency of the responses regarding motivations for using or not the ABRS, and actions of the farmers users of the system.

Results and Discussion

Aspects such as age and education level are recognized as factors affecting the decision to adopt a new technology (Isgin et al., 2008), besides herd and farm sizes (Michels et al., 2020). Drewry et al. (2019) reported that ease and reliability of access to the internet facilitates the adoption of digital technologies on farms when managers are young and with high education. Usually farms with large herd size are more likely to adopt precision technology due to the need to work more efficiently, reduce costs and implement protocols to better monitor and register as well as manage large-scale operations (Gargiulo et al., 2018).

The majority (81.82%) of the farmers in the NON-USERS group (Table 1) were interested in using a monitoring system to improve reproductive rates (25%) and monitor production efficiency (25%). Farmers showed interest in health, calving, thermal comfort and especially oestrus alerts, but factors such as cost (47.6%), low-quality of internet services (33.3%) and concerns about contact with equipment and service's suppliers (19.0%) prevented ABRS acquisition by farmers.

Frequently technologies are developed by public or private companies without the participation of farmers and thus their needs, requests and limitations are not fully considered, resulting in failures to demonstrate the system's usability, the benefits of its correct use, training and adaptation (Borchers and Bewley, 2015). Farmers and companies should recognize that the complexity of precision technologies requires changes in the farmer's way of working, altering from decision making through experience to decision making through data-driven processes, otherwise uncertainty about the costs and benefits of the technology will not decrease (Eastwood et al., 2017). The availability of the internet services and the ease of monitoring production remotely by smartphone's apps make the system more attractive to the farmers (Drewry et al., 2019).

Farmers became aware of the ABRS by company representatives (43.7%), and oestrus detection and cow's health monitoring were their main reasons to acquire the system, in agreement with Gargiulo et al. (2018). Timely and accurate detection of oestrus and calving events are of paramount importance for dairy farmers, explaining the increased adoption of automated systems using sensors (Benaissa et al., 2020). Adoption of ABRS is recent as 56.3%

of USERS were using it since 2019, and only 12.5% had used it for more than 3 years (Table 2).

All respondents of USERS group informed they observed the target cows after a health alert (Table 2). The interviewees cited an average of 7.3 ± 3.8 aspects they observed in a health target cow, totaling 117 responses. Changes in feeding behaviour (27.3%) or in milk production (6.8%), observation of unspecific health indicators such as dehydration, mucous membrane colour and body temperature (22.2%), results of mastitis tests (13.7%), thermal comfort (6.0%), or specifics tests with or without commercial kits (5.2%) were the most cited. All farmers in the USERS group believed they could intervene in the evolution of the disease in the cow.

Dairy farmers still have difficulties in disease diagnosis, as they do not have access to cheap and fast tests, except for mastitis and clinical ketosis (Stangaferro et al., 2016a, b). Nor do they typically have clear protocols of treatment, and there is not a specific pattern of changes in the behaviour that allows illness identification (Sumner et al., 2018). Many alerts did not generate actions by farmers, evidencing absence of a clear follow-up action or actual health problem (Eckelkamp and Bewley, 2020). Despite the disease diagnose challenges, health alerts draw the attention of the farmer to a smaller number of animals than it would be the case without ABRS, reducing labour and cost of tests (Gargiulo et al., 2018).

Following an oestrus alert, all interviewees inspected the target cows for oestrus confirmation; 55.1% of famers looked for standing behaviour, 27.6% sought the presence of hyaline mucus in the cow's vulva, and in the absence of visual signs, 17.3% of farmers performed a gynacological palpation exam accessing the consistency and contractility of the uterine horns. After oestrus confirmation,87.5% of farmers inseminated cows following the recommendations of the system. Cows change behaviour during oestrus, decreasing rumination time, while increasing activity time (steps taken: Mayoet al., 2019). Farmers monitored cows during the far-off period(50% of farmers), keeping the ABRS on the cow until the pregnancy confirmation (43.7% of farmers) or until the end of lactation (43.8%of farmers). The highest incidence of health problems at the beginning of lactation (Stangaferro et al., 2016a) and the reproductive management such as oestrus identification and AI services (Benaissa et al., 2020) are the main reasons for this prioritization.

In conclusion, remote monitoring systems of animals draw great interest from farmers, but their acquisition cost is an important factorthat prevents the widespread adoption of the system. Profile of adopters and those deeply interested in ABRS are young entrepreneurs, highly educated, concerned with their own life quality with personal and material facility to access mobile apps and internet. The main motivation to adopt the ABRS is still to detect oestrus

more easily, followed by early detection of health problems and heat stress monitoring. The alerts issued by the monitoring system reduce the number of animals to be checked and help farmers to identify pre-clinically sick and oestrous animals more easily. Difficulties in illness detection and lack of specific protocols impair
the decision-making process and early treatment, albeit farmers believe ABRS is improving the farm's routine and quality of their lives as well as reproductive rates.

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Table 1: Interests and motives of farmers who do not use a behaviour remote monitoring system.

Variable	%
Would you use an ABRS? (n=22)	
No	18.2
Yes	81.8
Alerts that would be of interest (n=22)	
Health (nº of farmers)	12
Oestrous (nº of farmers)	17
Calving (nº of farmers)	12
Thermal comfort (nº of farmers)	9
Reasons for using an ABRS (n=22)	
Facilitate management with animals	15.0
Reduce the occurrence of diseases	15.0
Improve animal comfort and well-being	20.0
Improve reproductive rates of farm	25.0
Track production efficiency	25.0
What prevents you from using an ABRS? (n=22)	
Not knowing where to find the service	19.1
Low-quality of internet services[1]	33.3
Cost	47.6

[1]Speed and amount of data transfer, consistency of internet services

Table 2: Motivations and attitudes of dairy farmers about use of a behaviour remote monitoring system.

Variable	%
How did you hear about the system? (n=16)	
Other producers	12.5
Events and fairs	12.5
Agreement between companies[1]	12.5
Internet	18.8
Enterprise representatives	43.7
Reasons that led to the acquisition of the system (n=15)	
Agreement between companies[1]	6.3
Monitor cow health	43.7
Monitor cow oestrus	50.0
How long do you use collars? (n=16)	
< 12 months	56.3
From 13 to 24 months	12.5
From 25 to 36 months	18.7
More of 36 months	12.5
Attitude when receiving a health alert (n=16)	
No action	0
Observe the animal	100
Actions related to the targeted animal [2] (n=117)	
Observation if the cow is approaching the trough and eating	12.8
Observation whether the cow keeps close to herd mates or away from others	9.4
Observation of change in milk production	6.8
Check if the cow is dehydrated	6.8
Visual check on mucous staining, especially at the vulva	5.1
Observation of clots or blood in forestripping milk	8.6
Perform CMT test	5.1
Attribute rumen fill score	7.7
Attribute faecal score	7.7
Attribute locomotion score	6.8
Measurement of body temperature	10.3
Attribute panting score	6.0
Blood clotting test	1.7
Ketone bodies test	2.6
Measurement of urinary pH	0.9
Measurement of heart rate	1.7
Does the system allow intervention in the evolution of health status? (n=16)	
No	0
Yes	100

[1]It refers to the collaboration between the collar's provider and other companies such as feed suppliers and even dairy cooperatives, providing producers with the acquisition of equipment at a reduced cost.

[2] Farmers could choose multiple options of actions. Further details in *supplementary material*.

Supplementary File

Materials and Methods

After the accomplishment of the interviews, data was transcribed (Fischer et al., 2019; Cachia and Millward, 2011) and the answers were coded. Briefly when the answer was one-choice, numbers were assigned and when answers allowed multiple-choice, letters were assigned, following the grammatical coding methodology described by Saldana (2013), where magnitudes are assigned to the response classes (Supplementary Table S1 and S2).

Supplementary table S1: Questions asked to interviewed dairy farmersthat already use the automated behaviour recording system (YABRS), and codes of the answers.

Questions	Response options
1. Characterization of the farmer	
1.1 Age	declared value
1.2 Education	1. Complete High School 2. Technical Education 3. Undergraduate 4. Graduate
1.3 Training area	declared value
2. Characterization of the farm	
2.1. City	declared value
2.2 State (County)	declared value
2.3 Time spent in the dairy business	declared value
2.4 Production system	1. Pasture system 2. Semi-confined 3. Confined – Free stall 4. Confined – Tie stall 5. Confined – Compost barn
2.5 Predominant breeds on the farm	1. Holstein cow 2. Jersey 3. Gyr 4. Holstein cow x Gyr crossbreed 5. Others
2.6 Number of lactating cows	declared value
3. Reasons to purchase the system	
3.1 How did you know about the remote monitoring system?	1. Other farmers 2. Events and markets 3. Enterprise representatives 4. Agreement between companies[1] 5. Internet search
3.2 Reasons that led to the acquisition of the system	1. Monitor cow oestrus 2. Monitor cow health 3. Others
4. Use of the animal’s remote monitoring system	
4.1 For how long the remote monitoring system has been used?	1. Up to one year 2. From one to two years 3. From two to three years 4. More than three years
4.2 Monitored cows (% of herd)	1. Up to 25% 2. From 26 to 50% 3. From 51 to 75% 4. From 76 to 100%
5. Attitudes towards a health alert	
5.1 What do you do when you receive a health alert?	1. Nothing 2. Leave the cow under observation
5.2 What you look for in the cow?	a. Observe if the cow is approaching the trough and eating b. Observes whether the cow keeps close to herd mates or stay away from others c. Changes in milk production d. Mucous staining e. Perform milk forestripping

	f.	Perform CMT test
	g.	Rumen fill score
	h.	Faecal score
	i.	Locomotion score
	j.	Body temperature
	k.	Panting frequency
	l.	Heart rate
	m.	Blood clotting test
	n.	Ketone bodies
	o.	Urinary Ph
5.3 Can intervene in the evolution of the health situation of cows	1.	No
	2.	Yes
6. Attitudes after receiving an oestrus alert		
7.1 Actions taken an oestrus alert is received?	1.	Evaluate the cow
	2.	Inseminate the cow
7.2 What do you evaluated in the cow?	a.	Mounting behaviour
	b.	Existence of hyaline mucus
	c.	Gynaecological palpation exam
7.3 Do you inseminate at the time recommended by the system	1.	No
	2.	Yes

Answers with numbers in the options: Questions with unique answers

Letter answers in options: Multiple answer questions

[1]It refers to the collaboration between the collar's provider and other companies such as feed suppliers and even dairy cooperatives, providing producers with the acquisition of equipment at a reduced cost.

Supplementary table S2: Questions asked to farmers that still do not use automated behaviour recording system (NABRS) in an online questionnaire about a remote monitoring system of the dairy cow' behaviour, and codes of the answers.

Questions	Response options
4. Characterization of the farmer	
1.1 Age	declared value
1.2 Education	5. Complete High School
	6. Technical Education
	7. Undergraduate
	8. Graduate
1.3 Training area	declared value
5. Characterization of the farm	
2.1. City	declared value
2.2 State (County)	declared value
2.3 Time spent in the dairy business	declared value
2.4 Production system	6. Pasture system
	7. Semi-confined
	8. Confined – Free stall
	9. Confined – Tie stall
	10. Confined – Compost barn
2.5 Predominant breeds on the farm	6. Holstein cow
	7. Jersey
	8. Gyr
	9. Holstein cow x Gyr crossbreed
	10. Others
2.6 Number of lactating cows	declared value
3. Interest in systems to monitor cows	
3.1 Would you use an ABRS	1. No
	2. Yes
3.2 Alerts that would be interesting	a. Health
	b. Oestrous
	c. Calving
	d. Thermal comfort
3.2 Reasons for using a monitoring system	1. Facilitate management with animals
	2. Reduce the occurrence of diseases
	3. Improve animal comfort and well-being
	4. Improve reproductive rates of farm
	5. Track production efficiency
4. Impediment to the acquisition of a monitoring system	
What prevents you from using an ABRS?	1. Not knowing where to find the service
	2. Difficulty in accessing the system
	3. Cost

Results and discussion

Supplementary table S3: Characteristics of dairy farms where the remote monitoring system of the animals' behaviour are used, and profiles of dairy farmers interviewed about this technology (values in each column and variable are the relative frequency of observations).

Class	NABRS (n = 22)	YABRS (n = 16)	P>ChiSq	
Age (years)			0.002	
Less than 30 years	59.09	31.25		
Between 30 and 39 years	22.73	43.75		
Between 40 and 49 years	9.09	18.75		
Between 50 and 59 years	9.09	6.25		
Education			0.001	
High school	22.73	18.75		
Technical	0	25.00		
Undergraduate	54.55	50.00		
Graduate	22.73	6.25		
Dairy activity time (years)			<0.001	
Less than 5 years	13.64	0		
From 6 to 10 years	18.18	6.25		
From 11 to 15 years	22.73	18.75		
From 16 to 20 years	9.09	6.25		
More than 20 years	36.36	68.75		
Production system			0.003	
Pasture	77.27	0		
Semi-confined	13.64	0		
Free-stall	0	31.25		
Compost barn	9.09	68.75		
Breeds			<0.001	
Holstein	54.55	93.75		
Jersey	18.18	0		
crossbred cattle *	13.64	6.25		
Others	13.64	0		
Number of cows in the herd (Means ± SD)			S.E.M	P-value
	50.68 (±41.62)	165.56 (±139.74)	110.47	0,008*

*Crossbred cattle (*Bos Taurus* x *Bos indicus*).

Details of aspects observed in the animal for health assessment

a) Forestripping is used to identify clinical mastitis and California Mastitis Test is used to identify subclinical mastitis;
b) Rumen fill score and Faecal score: Scores used to assess food consumption and quality (1 = the cow eats little or nothing and 3 = well fed) , and feces consistency (1 = consistent and 3= watery, indicating severe diarrhea), respectively;
c) Locomotion score: Score to identify animals with hoof problems (1 = healthy to 5 = severely lame);
d) Body temperature: physiological indicator of infections, the animal is considered to have a fever when the rectal temperature is above 39.4ºC;
e) Panting score: score used to identify animals in thermal stress, or with respiratory complications (0 = normal to 3 = panting, open mouth, tongue protruded and huge salivation) ;
f) Blood clotting test: practical test to identify animals with tick fever or *bovine babesiosis* and *anaplasmosis*, where the blood of the animal with the disease does not clot. Farmers use a syringe to collect an animal blood sample, leaving it at room temperature and observe whether blood clotting occurs, but there is no description of the technique in the literature;
g) Ketone bodies and urinary pH: tests performed using commercial kits, which use tapes with reagents to measure the concentration of ketone bodies in the blood or urinary pH to access efficiency of anionic salts in the prepartum period;
h) Heart rate: performed by the veterinarian.

CAPÍTULO II

FARMERS ATTITUDES TOWARDS AUTOMATED BEHAVIOUR SYSTEM IN DAIRY COWS[4]

[4] Artigo formatado para envio a revista Journal of Rural Studies

Farmers' attitudes towards automated behaviour systems for dairy cows

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Abstract

The aim of this study was to characterize the profile of Brazilian dairy farmers and farms that adopt or do not a commercial remote behavior monitoring systems (Cowmed® collars), verify the attitudes of adopters related to alerts, and identify possible motivations and limitations to not users to adopt the behavior remote monitoring system. Forty-two farmers that are users (USERS) of an automated behavior recording and analysis systems (ABRS) were interviewed by telephone and 40 farmers currently non-users (NON-USERS) of ABRS answered a digital questionnaire about ABRS use. The interview included 40 open questions, while the digital questionnaire had 18 multiple choice questions. The answers were coded according to the grammatical coding methodology. For statistical analysis, frequencies and nonparametric analyses (test Kruskal-Wallis) were performed on categorical variables, while variance analysis was performed to compare the number of cows. The characteristics of the farms differed significantly between USER and NON-USERS. For USERS, the number of monitored cows and the moment of placement the collars are affected by the motivation to acquire the ABRS. Attitudes related to mastitis and locomotion's diseases are affected by acquisition type and motivation to acquire the ABRS. For NON-USERS, the main impediment to adopt the ABRS was the cost of investment. Usually, farms that adopt ABRS are more intensively managed than those that do not. However, both groups have in common the objective of improving the reproductive indices.

Keywords: automated behavior monitoring dairy farms; estrus monitoring; farmer's profile; health monitoring.

1. Introduction

With the increase in the size of dairy herds and the lack of labor time for routine tasks at the farm, the identification of sick animals by human direct observation is becoming increasingly difficult (Brassel et al., 2019). Quantifying the time animals' spend in a specific behavior is essential to monitor their health status; however, direct observation requires time, is expensive and the interpretation is subjective. An alternative is the use of sensors attached to the cows, allowing the continuous record of their behavior, as well as the data interpretation (Cangar et al., 2008). These automatic behavior monitoring systems can decrease the losses, i.e., economic and productive, associated with illnesses (Huybrechts et al., 2014) and improve individual cow management (Eckelkamp& Bewley, 2020).

Sensor-based monitoring systems that measure physiological and behavioral parameters and milk yield are in use on commercial dairy farms allowing the detection of specific events, such as oestrus and health disorders (Paudyal et al., 2018a). The early detection of a disease may prevent its progression and improves response to treatment (Antanaitis et al., 2020b). However, technologies are usually developed by public or private companies, mostly without farmers participation (the end users). Therefore, their needs and limitations are frequently not considered, resulting in a lack of demonstration of the system's applicability, the benefits of its correct use, training and adaptation (Borchers and Bewley, 2015; Eastwood et al., 2017). As a consequence, farmers might be overwhelmed by the amount of information provided by the systems, while they need a simple technology, as well as effective training during the implementation (Eckelkamp & Bewley 2020).

In the literature, there are few studies reporting factors affecting the adoption of technologies in the farm (Gargiulo et al., 2018; Eastwood et al., 2017; Khanal et al., 2010). In addition, the attitudes of farmers and farm staff in relation to the alerts send by the behavior monitoring system and their perspectives are scarce (Vieira et al., 2021). Since 2018, there are 35 enterprises delivering digital solutions specifically for dairy farmers (Azevedo, 2019). Currently, in Brazil, there are two companies that provide the service of remote behavior monitoring of cows, using collars reaching increasing number of dairy farmers. The aim of this study was to know the profile of Brazilian dairy farmers and farms that adopt or do not a commercial remote behavior monitoring systems (Cowmed® collars), verify the attitudes of adopters related to alerts, and identify possible motivations and limitations to not users to adopting the behavior remote monitoring system.

2. Material and Method

This study was approved by the ethics committee of the Federal University of Rio Grande do Sul (n°25671819.3.0000.5347). Dairy farmers who participated in this study were informed about the procedures, and they signed a consent form authorizing the use of the provided information. This study is an extension of a study published work by Vieira et al. (2021).

2.1. Survey protocol

2.1.1. Automated behavior recording and analysis systems (ABRS)

In the present study, the interviewed dairy farmers using automated behavior monitoring system (USERS) are users of the Cowmed® collars (Chip Inside Technology S. A., Santa Maria, RS, Brazil). This equipment consists of a control panel, collars equipped with sensor and software. The sensors used in behavioral monitoring equipment are triaxial accelerometers (Rombach et al., 2018), responsible for measuring the acceleration of the body, combined with a gyroscope, which measures the angular velocity of the body (Mendes et al., 2014). The accelerometer, positioned along the left side of the collar, continuously records the activities of the animal. All data are downloaded from collars to antennas installed in the shed and sent to a server, where an algorithm classifies the data into the following behaviors: rumination time, general activity (as walking, feeding and mating behaviors) and rest behavior (time in which the cow remains without chewing and displacement). Automatically, and in real time, the information is transferred to the farm's computer in two formats: data lists and graphs.

Previously, Cowmed® collars were experimentally validated by Facco et al. (2017), Matos et al. (2017) and Martins (2019). Briefly, the system of Cowmed® collars establishes an individual behavior standard based on 7-days mobile average, an algorithm compares the daily behavior with this standard and sends alerts if the animal behavioral values vary more than this standard established. The system sends two different alerts: i. health alert if an individual cow reduces both daily rumination and activity times or if a group of cows shows very low rumination time (Facco et al., 2017; Matos et al., 2017); or ii. estrus alert if an individual cow reduces the daily rumination time and increases the activity time (Martins, 2019).

2.1.2. Data collection

Data were collected between August 2019 and May 2021. To collect data from USERS and Non-USERS, two different methodologies were used. Chip Inside Tecnologia S.A. selected 87 farmers to participate in the survey, who further were contacted by phone by a single interviewer. Of the 87 farmers contacted, 42 agreed to participate in the survey by answering the questionnaire by telephone. Due to the greater difficulty in contacting Non-USERS farmers directly, a digital questionnaire was developed and distributed via social networks and emails supplied by breed associations. Forty farmers answered the digital questionnaire.

2.2. Survey design

The questionnaire consisted of 40 open questions split into eight sections: characterization of dairy farmer (age and education), characterization of dairy farm (location, herd, time in dairy activity), motivation for acquiring the remote behavior monitoring system, how the herd was monitored before the adoption of the ABRS, how the information provided by the system is used by farmers, attitudes of farmers towards the alerts issued (health and estrus), feedback from dairy farmers to the company and how the farmer perceive the system. After the accomplishment of the interviews, data were transcribed (Cachia & Millward, 2011; Fischer et al., 2019).

The 40 Non-USERS of ABRS answered a digital questionnaire with 18 multiple choice questions in three sections: characterization of dairy farmer (age and education), characteristics of dairy farm (location, herd, time in dairy activity) and motivation for acquiring or not the automated behavior monitoring system.

All answers, both interviews and the digital questionnaire, were coded, following the grammatical coding methodology described by Saldaña (2013), where magnitudes are assigned to the response classes. Briefly, when the answer was one-choice, numbers were assigned and when answers allowed multiple-choice, letters were assigned. A complete copy of the questionnaire is available on request from the corresponding author.

2.2.1. Data analysis

The data were analyzed using the statistical software SAS Studio (SAS Institute Inc.). The data were analyzed with frequencies test by PROC FREQ, and to verify the difference between groups, a nonparametric procedure (PROC NPAR1WAY) was applied with Kruskal-Wallis test.

The profile of Non-USERS and USERS was analyzed considering the localization of farm, farmer’s age, scholar degree and time in the dairy activity. For farm characterization, the production system and dairy cattle bread were compared using PROC FREQ and PROC NPAR1WAY, while the number of cows in lactation was tested using the variance analysis by PROC GLM and Tukey test with $P = 0.05$.

During the interviews we identified three ways of acquiring ABRS by farmers, and the enthusiasm in the USERS responses was different according to the way the technology was acquired. Initial analyzes of USERS responses revealed that there were two main motivations for adoption. In this way, both the forms of acquisition and the motivations could influence the use of ABRS and the farmers' attitudes towards the alerts.

For analysis of use ABRS tools, Cowmed® collars application and attitudes to alerts sent by ABRS, the USERS were classified based on their statements during the interview I); by the type of acquisition of the system as 1) invitation, when the paying farmer was invited to test the ABRS and finally acquired the system; 2) agreement, when the acquiring occur through other companies or cooperatives, at no direct cost charged to the farmer; 3) direct search, when the farmer tried to solve a problem and voluntarily contacted the company and pay for the system acquisition. II) by their main motivation to acquire the system (easy estrus detection or illnesses early detection).

To Non-USERS group the PROC FREQ was used to measure the possibility of adopt the ABRS, the interests in alerts and information that the ABRS can provide and the limitation to adopt the ABRS.

The significant differences were declared when $P \leq 0.05$ and a trend considered to exist if $0.05 < P < 0.10$.

3. Results

The profile of USERS and NON-USERS affected the adoption of the system (Table 1). The profile of ABRS USERS and NON-USERS farmers differ according to the region of farm's location ($P = 0.038$), time in dairy activity ($P = 0.013$) and tends to differ for the age of farmer ($P = 0.060$), but there is no statistical difference in relation to the farmers' schooling. The characteristics of the farms differ significantly between USERS and NON-USERS for production system ($P<0.001$), dairy cattle breed ($P<0.001$) and number of cows in the lactation ($P<0.001$). Most USERS (92.86%) have confined production systems, 97.50% of the cows were Holstein and the average number of lactating cows was 137 ± 110 cows, while in the farms belonging to NON USERS, 72.5% used pasture production system, 57.50% of cows were Holstein and the average number of lactating cows was 49 ± 37 cows.

Table 2 shows the results of the use of tools in ABRS, actions to cows monitoring, and attitudes of USERS relationship to health and estrus alerts. The ABRS tools used by farmers were not affected by acquisition type or motivation for ABRS acquisition. Generally, the graphics (83.33%) and reports (66.67%) were the ABRS tools more used by USERS.

The farmers' actions related to cows monitoring showed differed according to their motivation to acquire the equipment for the moment the collar is placer on the cow (P = 0.025). USERS motivated by early disease detection placed the collars on *prepartum* (60.0%) or immediate *postpartum* (40.0%), while only 33.3% of USERS motivated by easy estrus detection place the equipment at the *prepartum*. The number of cows with collars tends to be different (0.092) according to the motivation for ABRS acquisition. The majority of USERS (73.3%) motivated by early disease detection monitored 70 to 100% of the lactating cows compared with only 47.8% of the USERS motivated by easy estrus detection. The moment of removing the collar was not affected by acquisition type or motivation to acquire the ABRS. In general, 35.7% of USERS don't remove the collar of the cows, but 33.33% of those who take off the equipment remove it on the pregnancy confirmation and 21.43% on the dry off.

Few aspects used to evaluate animal health differed between the USERS classified by types of acquisition or motivation to acquire the ABRS. During the interviews, the farmers stated that they checked the cows after receiving the health or estrus alerts and cited fourteen aspects for health verification and five aspects for estrus confirmation. The aspects towards health that differed according to acquisition type of ABRS were forestripping use (P = 0.039), CMT test (P = 0.040) and veterinary assistance request (P = 0.035), as well a trend for locomotion score (P = 0.093). In group of USERS that acquire the ABRS by active search a higher percentage of farmers declared that, after being warned with a health alert, they performed forestripping milk, CMT test, and locomotion score. All USERS that acquire the ABRS by agreement requested veterinary assistance, while USERS that acquire by the active search and by invitation this percentage fall to 95.6 and 88.9, respectively. Concerning mastitis detection, 53.3% of USERS motivated by the early disease detection and 20.8% of the USERS motives by easy estrus detection affirmed to perform CMT test.

The attitudes towards the estrus alert were not affected by the acquisition type or motivation to acquire the ABRS. In general, to confirm the estrus, USERS claimed to use visual mating behavior (88.1%), check for presence of mucus in the vulva (42.9%), and gynecological touch exam (28.6%). The insemination was performed at the schedule time recommended by ABRS by 78.6% of USERS.

Between Non-USERS, 77.5% were interested in adopt an ABRS. The main motivations were estrus alert (82.5%) and calving alerts (70.0%). About the information that Non-USERS would like received of ABRS, 52.5% would like the ABRS inform the estrus behavior, 45.50% thermal comfort for cows and 37.50% physiological parameters (as temperature, respiratory and cardiac frequencies). The major limitation for Non-USERS adopt de ABRS is the cost (60.0%).

4. Discussion

It is important to mention that our study amplified the sample size of the survey previously done by Vieira et al. (2021), who interviewed 37 producers (16 using monitoring technology for animal behavior and 22 not using it), as 26 farmer users of behavior monitoring technology and 18 non users were included, totaling 42 USERS and 40 NON-USERS farmers, respectively.

In our methodology, bias may have occurred in our data collection. Although Cowmed randomly selected its customers (USERS) to provide us with their contacts, those with a tendency to collaborate accepted to participate in the survey, the same occurs for the answer of Non-USERS, who answered the digital questionnaire, were farmers with access to internet and with a possible interest in behavioral monitoring technologies.

In the present study, it is noted that the evaluated farms were very contrasting: USERS represented larger and intensive farms specialized in milk production, while NON-USERS were smaller and less technological. In many cases, the adoption of monitoring technologies is associated with larger farms and larger herds, in an attempt to address labor-related problems, such as availability of labor, cost, training and efficiency, while implementing routines and protocols to better manage the farm (Gargiulo et al., 2018). The present study is in agreement with the Silvi et al. (2021), in Brazil, 42% of the farms that have adopted the precision technologies are in the south of the country and that Holstein is the most used breed in more technological systems, while in pasture systems the most used breed is the Holstein x Gyr crossbred (Girolando), due to its higher adaptation to tropical pastures and climate compared with *Bos taurus* breeds. Similar to the results found by Borchers & Bewley (2015), the age of most USERS is between 30 and 40 years. Education is not a significant factor for technology adoption, but it is a facilitator in its use (Isgin et al., 2008).

In the present study the use of ABRS tools was not affected by acquisition type or motivations to acquire de ABRS, and graphics were used by more than 80% of USERS farmers. The ABRS developed by public and private companies tend to facilitate on farm-routine, reducing costs and labor, but the farmers need to adapt to use this technology (Adriaens et al., 2020; Gargiulo et al., 2018). Farmers and the companies should recognize that the complexity of precision technologies requires changes in the farmer's way of working, altering from decision making through experience to decision making through data-driven processes, otherwise uncertainty about the costs and benefits of the technology wont decrease (Eastwood et al., 2017).

About the number of cows monitored by Cowmed® collar, USERS farmers motivated to acquire the ABRS by early disease detection tended to monitor a higher percentage of lactating cows and started the monitoring at the close-up period or beginning of lactation. The transition period, correspondent to 21 days before calving to 21 days postpartum, is a critical period where the cows pass by changes in the diet, daily activity routine, which can generate stress and fall in immunity, increasing the risks of metabolic disorders and infectious diseases (Steensels et al., 2017).

The USERS farmers don’t have a specific follow-up protocol to check the cows after receiving a health alert, but some attitudes/actions towards the health alerts were affected by acquisition type and motivations to acquire the ABRS. Attitudes/actions that showed significant differences were associated to mastitis detection (affected by acquisition type and motivations to acquire the ABRS) and laminitis (tended to be affected by acquisition type of ABRS). Laminitis and mastitis are very common diseases in dairy herds, generating both economic and cow welfare costs (Miekley et al., 2012). Nevertheless, the assessment of cow health was based on subjective and non-specific observations, commonly making use of observations of general health, alertness, appetite, milk yield, temperature assessment and rectal palpation, to try to identify signs of disease or the intensity of these signals (Paudyal et al., 2018).

The attitudes towards estrus alerts were not affected by acquisition type or motivation to acquire the ABRS. The selection of cows for higher milk yields resulted in reduced estrus duration, less pronounced intensity of estrus signs, and more estrus activity at night (Reith et al., 2014). According to Denis-Robichaud et al. (2018) the main reason for farmers to adopt an ABMS is dissatisfaction with reproductive indices and they can use the technology to improve estrus detection.

Systems are available for monitoring animal activity, rumination, resting time, temperature, and many other events associated with animal well-being (Borchers and Bewley, 2015). In addition to the detection of health problems and fertility events, many of these sensor systems also have the potential to provide targeted information about other traits (Adriaens et al., 2020). The adoption of technologies is subjective, because the needs and preferences and financial constraints of farmers are variable, and thus, farmers will make their choices according to their specific needs and conditions (Isgin et al., 2008). The decision to purchase and implement a precision technology in the farm represents a significant investment for the farmer, who is often challenged to choose a technology that will meet his needs for several years (Borchers and Bewley, 2015). The technologies considered most useful by farmers are also those with which farmers are most familiar, while technologies that require skilled labor and changes in farm management activities may be negatively evaluated (Silvi et al., 2021). Computer use on the farm by farmers for commercial purposes has a significant positive impact on the likelihood of adoption of precision technologies (Isgin et al., 2008). The availability of the internet and the ease of monitoring production remotely by smartphone's apps make the system more attractive to the farmers and the access to the internet facilitates the adoption of digital technologies on farms (Drewry et al., 2019). The main reasons for Dutch dairy farmers not investing in monitoring technologies were: have other investment priorities in the farm; uncertainty about investment profitability; expected poor integration of sensors with other agricultural systems and software; and waiting for improved sensor versions (Rutten et al., 2018).

4. Conclusion

ABRS USERS and Non-USERS farms have distinct characteristics. Generally, farms that adopt ABRS have been specializing in milk production for some years and are seeking intensification and greater productivity. Non-adopting farmers are smallholders based on grazing system, small production scale and family labor and less time in the activity. Regarding the attitudes towards alerts and use of systems, farmers do not have specific follow-up protocols to assess the health of animals, basically testing for mastitis and locomotion problems. Many Non-USERS farmers show interest in some information that systems could provide such as health and reproductive alerts. However, cost is still the main reason for not using an ABRS.

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CRediT authorship contribution statement

Aline Cardoso Vieira: the conception and design of the study, acquisition of data, data analysis and interpretation of data, drafting the article and revising it critically for important intellectual content; Vivian Fischer: the conception and design of the study and critical revision of the article for important intellectual content; Maria Eugênia A. Canozzi: the critical revision of the article for important intellectual content; Arthur Bettencourt: acquisition of data; Juliany Ardegui Guimarães: acquisition of data.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Table 1: Farmer's profiles and farm's characteristics of Non-USERS and USERS of Remote behavior monitor system.

Variables	Non-USERS N=40	USERS N=42	P>ChiSq	
Region of localization of farm (% of N)			0.0385	
Midwest	NA[1]	4.76		
North East	5.00	NA		
South	87.50	66.67		
Southeast	7.50	28.57		
Age o farmer (% of N)			0.0600	
To 30 years	55.00	26.19		
From 30 to 39 years	17.50	42.86		
From 40 to 49 years	12.50	11.90		
From 50 to 59 year	15.50	16.67		
From 60 to 70 years	2.50	2.38		
Farmer scholar degree(% of N)			0.2767	
Incomplete primary education	5.00	2.38		
Complete primary education	2.50	NA		
Incomplete high school	10.00	4.76		
Complete high school	22.50	11.90		
Technical education	NA	11.90		
Undergraduate	47.50	57.14		
Postgraduate	12.50	11.90		
Dairy activity time(% of N)			0.0136	
Less than 10 years	15.00	2.63		
From 10 to 20 years	15.00	7.89		
From 21 to 30 years	22.50	21.05		
From 31 to 40 years	12.50	7.89		
More than 40 years	35.00	60.53		
Production System(% of N)			<0.001	
Pasture	72.50	4.76		
Semi-confined	22.50	2.38		
Confined in Free stall	NA	28.57		
Confined in Compost barn	5.00	64.29		
Dairy cattle breed(% of N)			<0.001	
Holstein	57.50	97.50		
Jersey	27.50	NA		
Cross breed	15.00	2.50		
Number of cows in lactation (Mean ± SD)			S.E.M	*P*-value
	49.17 ± 37.01	137.12 ± 110.17	82.18	<0.001

[1]Not has answer

Table 2: use of remote cow behavior monitoring system by farmers and their attitudes towards alerts

Variables	% (N=42)	Acquisition type				Motivation		
		Invitation N=9	Agreement N=10	Active Search N=23	P>ChiSq	Estrus N=24	Health N=15	P>ChiSq
Use of ABRS tools								
Graphics (% of N)	83.33	100.0	66.67	84.21	0.1905	85.00	78.57	0.6335
Reports (% of N)	66.67	87.50	66.67	57.89	0.3398	65.00	64.29	0.9833
To do lists (% of N)	44.44	25.00	55.56	47.37	0.4290	40.00	42.86	0.8867
THI[1] (% of N)	11.43	25.00	NA[3]	11.11	0.2803	10.53	14.29	0.7474
Actions to cows monitoring								
Number of cows with collars(% of N)					0.2471			0.0923
To 25 % of lactation cows	2.44	NA	NA	4.55				
Of 26 to 50% of lactation cows	21.95	22.22	40.00	13.64		26.09	6.67	
Of 51 to 75% of lactation cows	21.95	11.11	30.00	22.73		26.09	20.00	
Of 76 to 100% of lactation cows	53.66	66.67	30.00	59.09		47.83	73.33	
The moment the collar is put in(% of N)					0.5585			0.0259
In the prepartum	47.62	33.33	50.00	52.17		33.33	60.00	
Right postpartum	33.33	33.33	40.00	30.43		33.33	40.00	
To 30 days postpartum	9.52	22.22	NA	8.70		16.67	NA	
Not specific period	9.52	11.11	10.00	8.70		16.67	NA	
The moment the collar is removed(% of N)					0.7580			0.2544
In the pregnant confirmation	33.33	22.22	40.00	34.78		37.50	20.00	
In the dry of lactation	21.43	11.11	30.00	21.74		16.67	33.33	
Don't remove	35.71	44.44	30.00	34.78		33.33	46.67	
Not specific period	9.52	22.22	NA	8.70		12.50	NA	
Check the cows after received health alert[2]								
Observe if the cow is approaching to the trough and eating(% of N)	78.57	77.78	80.00	78.26	0.9918	83.33	73.33	0.5813
Observe whether the cow is walking in a group or away from others(% of N)	59.52	55.56	60.00	60.87	0.9631	58.33	53.33	0.7623
Changes in milk production(% of N)	57.14	55.56	30.00	69.57	0.1130	62.50	60.00	0.8775
Check if the cow is dehydrated(% of N)	23.81	22.22	30.00	21.74	0.8731	25.00	26.67	0.9089
Mucous staining, especially vulva(% of N)	26.19	33.33	30.00	21.74	0.7652	29.17	20.00	0.5290
Forestripping[a](% of N)	45.24	11.11	40.00	60.87	0.0397	37.50	60.00	0.1759
CMT test [a](% of N)	35.71	NA	40.00	47.83	0.0409	20.83	53.33	0.0387
Rumen fill score [b](% of N)	21.43	22.22	20.00	21.74	0.9918	20.83	26.67	0.6780
Fecal score [b](% of N)	23.81	11.11	30.00	26.09	0.5912	29.17	20.00	0.5290
Locomotion score [c](% of N)	28.57	NA	30.00	39.13	0.0930	25.00	40.00	0.3297
Body temperature [d](% of N)	66.67	77.78	80.00	56.52	0.3152	66.67	66.67	1.0000
Panting score [e](% of N)	23.81	11.11	30.00	26.09	0.5912	25.00	26.67	0.9089
Request veterinary assistance	95.24	88.89	100.0	95.65	0.0358	95.83	93.34	0.6699
Check the cows after received estrus alerts								
View the historical(% of N)	14.29	NA	20.00	17.39	0.3865	12.50	20.00	0.5330
Behavior mating view(% of N)	88.10	100.0	80.00	86.96	0.4015	91.67	80.00	0.2953
Presence of mucus(% of N)	42.86	66.67	30.00	39.13	0.2441	33.33	46.67	0.4111
Gynecological touch exam(% of N)	28.57	44.44	30.00	21.74	0.4475	20.83	40.00	0.2015
Insemination at the time recommended by ABMS(% of N)	78.57	88.89	80.00	73.91	0.6516	79.17	86.67	0.5578

[1]Termal Humidity Index

[2]Actions that producers claim to perform: a) Forestripping is used to identify clinical mastitis and California Mastitis Test is used to identify subclinical mastitis; b) Scores used to assess food consumption and quality; c) Score to identify animals with hoof problems; d) Physiological indicator of infections, the animal is considered to have a fever when the rectal temperature is above 39.4ºC; e) Score used to identify animals in thermal stress, or with respiratory complications

[3]Not has answer

Table 3: Farmer's profiles and farm's characteristics of Non-USERS and USERS of Remote behavior monitor system

Variables	Non-USERS N=40	USERS N=42	P>ChiSq	
Region of localization of farm (% of N)			0.0385	
Midwest	NA[1]	4.76		
North East	5.00	NA		
South	87.50	66.67		
Southeast	7.50	28.57		
Age o farmer (% of N)			0.0600	
To 30 years	55.00	26.19		
From 30 to 39 years	17.50	42.86		
From 40 to 49 years	12.50	11.90		
From 50 to 59 year	15.50	16.67		
From 60 to 70 years	2.50	2.38		
Farmer scholar degree(% of N)			0.2767	
Incomplete primary education	5.00	2.38		
Complete primary education	2.50	NA		
Incomplete high school	10.00	4.76		
Complete high school	22.50	11.90		
Technical education	NA	11.90		
Undergraduate	47.50	57.14		
Postgraduate	12.50	11.90		
Dairy activity time(% of N)			0.0136	
Less than 10 years	15.00	2.63		
From 10 to 20 years	15.00	7.89		
From 21 to 30 years	22.50	21.05		
From 31 to 40 years	12.50	7.89		
More than 40 years	35.00	60.53		
Production System(% of N)			<0.001	
Pasture	72.50	4.76		
Semi-confined	22.50	2.38		
Confined in Free stall	NA	28.57		
Confined in Compost barn	5.00	64.29		
Dairy cattle breed(% of N)			<0.001	
Holstein	57.50	97.50		
Jersey	27.50	NA		
Cross breed	15.00	2.50		
Number of cows in lactation (Mean ± SD)			S.E.M	*P*-value
	49.17 ± 37.01	137.12 ± 110.17	82.18	<0.001

[1]Not has answer

CAPÍTULO IV

BEHAVIORS USED TO EARLY DISEASE DETECTION: A SYSTEMATIC REVIEW[5]

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Behaviors used to early disease detection: a systematic review

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Abstract

The aim of this systematic review was to answer the question "Which are the main behaviors used to predict metabolic and infectious diseases in dairy cows?". The search strategy was applied in four databases (PubMed, Science Direct, Scopus and Web of Science) to find articles evaluating the use of behaviors (activity, feeding, lying, rumination and standing) to early predict diseases in dairy cattle. The diseases evaluated were hypocalcemia, ketosis, laminitis, mastitis and subacute ruminal acidosis (SARA). The search resulted in 37 articles. Several articles evaluated more than one disease and more than one behavior. Five articles were related to hypocalcemia, 19 to ketosis, 11 to laminitis, five to mastitis, and three to SARA. Feeding time was mentioned in five articles, lying time in 13 articles, rumination time in 11, activity time in four and standing time in two articles. The behaviors most frequently used for predicting diseases in dairy cattle were feeding time, lying time and rumination time. Changes in cows' behavior might begin days before the diagnosis, with reduction in rumination and feeding time while increasing lying time. Time spent ruminating, feeding and lying presented clear changes with the occurrences of diseases, so are promising behaviors to be used as

predictive variables in models to early detection of metabolic and infectious diseases, but we still need to better evaluate how long before the disease the behavior begins to change.

Keywords: Dairy cows; Early diseases detection; Predictive behaviors; Monitoring cows; Health cows; Animal welfare

1. Introduction

During the transition period, i.e., 21 days before and 21 days after calving, high-yielding dairy cows undergo several challenges, partially related to changes in the diet, daily activity routine, which can generate stress and impair immunity, increasing the risks of metabolic disorders and infectious diseases (Steensels et al., 2017).

Hypocalcemia, ketosis and rumen acidosis are the most common diseases in the transition period. The negative energy balance faced by cows at the end of gestation and beginning of lactation can result in the manifestation of ketosis, while the sudden increase in calcium demand due to copious milk secretion in this period may result in hypocalcemia. (Rodriguez-Jimenez et al., 2018b; Jawor et al., 2012). In order to supply the nutrients needed by cows at the beginning of lactation, farmers offer diets with larger amounts of grains to the cows, which can be rapidly fermented in the rumen, resulting in increased production of lactic acid, reducing the ruminal pH and, consequently, causing rumen acidosis (Coon et al., 2019; Moore et al., 2020). Although laminitis and mastitis occur at all lactation, they are may happen together with the previous listed diseases and contribute to raise the challenges faced by the transition cow (Miekley et al., 2012).

Diseases decrease welfare, productivity, reproductive efficiency, lifetime in the herd and change milk composition, needing attention and animal care (King et al., 2018a).

Costs increase due to medical treatments or even early disposal or death of the cow (Kaufman et al., 2016a).

Changes in behavior associated with illnesses' clinical symptoms are well described and recognized (González et al., 2008b). Dairy cows exhibit different behavior patterns, such as feeding and idleness, and deviations of a pattern (within the same animal) can be measured and used to identify cows at risk of developing a disease. The response of animals to an infection or metabolic or digestive disturb is the change in behaviors frequently called as sick behavior, that is associated with depression, loss of appetite, weight loss, discomfort and pain (Dittrich et al., 2019). However, cattle show little emotion reaction, so physical and behavioral changes associated or not with diseases and pain can be subtle, making their identification difficult (Barragan et al., 2018). Over the past few decades, several researchers have studied the change in animal behavior as a way to predict the occurrence of diseases (King et al., 2018a). More recently, studies highlighted that monitoring technologies could enable and facilitate the observation of these behaviors (Antanaitis et al., 2020a), with the development of sensors that identify changes in the behavior of cows before the onset of clinical symptoms. This technology is becoming an useful tool to identify animals at a high risk and may promote early treatment, shortening illness duration and/or severity (Calamari et al., 2014).

Unfortunately, a consensus on how much a behavior varies before or during each disease, or which behaviors are best suited to predict the occurrence of a specific disease is still not settled (Siivonen et al., 2011). The objective of this systematic review was to answer the question "Which behaviors can be used to predict metabolic and infectious diseases in dairy cows?".

2. Materials and Methods

2.1. Research question

The literature search strategy was defined based on the PICO (P=population, I=intervention, C= comparator and O=outcome). The population studies in this systematic review was dairy cows. No restrictions were applied regarding breed, parity, milk yield and system production. The intervention was five diseases that are frequently reported during the transition period: hypocalcemia, ketosis, laminitis, mastitis and ruminal acidosis. We sought to identify behaviors used to predict the occurrence of diseases, i.e., eating (feeding time and feed intake), rumination, position (lying and standing) and activity.

We only consider observational studies that provided mean and some dispersion measure for the evaluated behaviors. A *priori* protocol was developed, and each screening tool for this study was adapted from previously available forms (Sargeant et al., 2005) and pre-tested before implementation.

2.2. Search method for selecting studies

The literature search was performed between January and February 2021 and used the same list of final search terms in all four databases - PubMed (3120 citations to February of 2021), Science Direct (915 citations to February of 2021), Scopus (2979 citations to February of 2021) and Web of Science (3486 citations to February of 2021). The search strategy included the following keywords: “("cow" OR "dairy cattle") AND (behavi* OR activity OR feed* OR eat* OR ruminat* OR lying OR standing) AND ("disease detection" OR hypocalcemia OR "ruminal acidosis" OR SARA OR mastitis

OR laminitis OR ketosis OR posture)". The citations were imported to the Mendeley software and those duplicated were manually excluded.

2.3. Selection of studies

Before the selection of studies, the articles were selected based on the titles, excluding citations that were not related to population, outcomes or intervention of interest.

The relevance of the screening process was performed by two previously trained and independent reviewers, evaluating all identified citations using the titles and abstracts (when available). The screening questions applied in each citation were: 1) Does this abstract reported a primary research? 2) Does this abstract investigate strategies to predict disease in dairy cow? 3) Does this abstract investigate one of the following behaviors (activity, feeding, rumination, lying or standing) in dairy cow? 4) Does this abstract investigate one of the following diseases (ketosis, hypocalcemia, laminitis, mastitis or subacute ruminal acidosis) in dairy cow?

Data conflicts in the screening process were solved through discussion, and an expert opinion was requested when consensus was not attained. Answers were registered in Microsoft Excel. The full text manuscript of the chosen citations, who received positive answer (yes) in all screening questions, was accessed for more detailed evaluation and data extraction.

+2.4. Data extraction process

Data extraction was performed using a model form for data collection (Sargeant et al., 2005). An Excel sheet was built with the extracted data. The purpose of this form was to extract all information regarding the population, methods of diagnosis of diseases and measurements of behaviors. The articles excluded were those related only to the risk of developing a disease, without the true event, and articles in which the disease was induced in cows through sudden changes in diet or infusions (e.g., *E. coli* to induce mastitis or Na_2EDTA to induce hypocalcemia). Articles that evaluate other diseases (e.g., metritis and abomasum displacement) were not considered. For the diseases of interest, we included subclinical and clinical forms.

2.5. Assessment of risk of bias

The Newcastle-Ottawa Scale (NOS) for observational cohort studies (Wells et al., 2014) was used to evaluate the quality of the studies. The scale uses a points system, where each study is judged from three major perspectives: selection of study groups, comparability of groups and determination of outcome, with a maximum score of nine points. Studies with scores below five were considered low quality; between five and seven, moderate quality; and between eight and nine, high quality (Table 1).

3. Results

Thirty seven articles were considered eligible for the systematic review (Figure 1), with 7655 and 4229 healthy and non-healthy cows, respectively. Several articles evaluated more than one disease and more than one behavior. Five, 19, 11, five and three articles reported hypocalcemia, ketosis, laminitis, mastitis and rumen acidosis, respectively. The most common behaviors for predicting diseases were feeding time (five articles), lying time (13 articles) and rumination time (11 articles). The other behaviors analyzed in this systematic review, but with less expression in the illness early prediction were activity (five articles) using different units of measurement, activity time (four articles), dry matter intake (DMI) (four articles), lying bouts (five articles), standing bouts (three articles) and standing time (two articles) (Table 2).

3.1. Behaviors evaluated for prediction of hypocalcemia

Publications related to the occurrence of hypocalcemia and its relation with behavior pattern began in 2012. The evident majority of researchers evaluated the occurrence of the disease in multiparous cows during the transition period. At least two researchers evaluated both the subclinical and clinical disease (Barraclough et al., 2020; Hendriks et al., 2020), while two evaluated only the clinical form (Antanaitis, et al., 2020b; Daros et al., 2020) and one studied only the subclinical form (Jawor et al., 2012). The main behavior evaluated to predict the occurrence of hypocalcemia was lying time. Although not all authors presented the day when the behavior begins to change before diagnosis, Antanaitis et al. (2020a) stated that the activity time begins to change four days before calving, while the results reported by Hendriks et al. (2020) showed that changes in the lying time and lying bouts occur on the day of calving. Cows affected by hypocalcemia showed, previous to diagnosis, reduction in lying bouts and standing time, while increased activity time (Antanaitis et al., 2020a), lying time and DMI (Jawor et al., 2012) (Table 3).

3.2. Behaviors for early detection of ketosis

Although the first study associating the variation in behavior with the occurrence of ketosis was published in 2004, only after 2014 there was an increase in the number of articles reporting this subject. Of the 19 articles relating changes in behaviors to ketosis, only one evaluated primiparous cows separately (Kaufman et al., 2016a). Except for Antanaitis et al. (2020b), the authors evaluated the behaviors during the period close to calving (e.g., 7 days before up to 21 days after calving). These articles seek to evaluate the changes in behaviors during the days before and after the diagnosis of the disease, evaluating not only the variation of behavior for the clinical and subclinical forms of ketosis, but also the variation in behavior when it occurs in combination with other diseases (e.g. metritis). Behaviors used to early detection of ketosis were feeding time, lying time and rumination time. Rumination time begins to vary between 21 and (Kaufman et al., 2016a) three days (Stangaferro et al., 2016a) before diagnosis; lying time between 21 (Kaufman et al., 2016b) and 14 (Pineiro et al., 2019) days before diagnosis; activity time from 16 days (Antanaitis et al.; 2020b); 14 days before diagnosis for DMI behaviors (Goldhawk et al., 2009), standing time and standing bout (Itle et al., 2015) . Although there are some contradictions regarding the variation of some behaviors for healthy and sick cows, such as the values of standing time and standing bouts (Itle et al., 2015; Rodriguez-Jimenez et al., 2018), it is possible to state that prior to its diagnosis, ketosis causes a reduction in the time spent ruminating, in activity, feeding and in feed intake (DMI), while increasing lying time, lying bouts and activity changes. Pineiro et al. (2019) and Schirmann et al. (2016) showed that the variation in rumination time and lying time can be inversed, increasing rumination time and reducing lying time, when occurring of another disease along with clinical or subclinical ketosis (Table 4).

3.3. Behaviors for early detection of laminitis

The articles reporting behaviors to early detection of laminitis started to be published in 2011. In this systematic review, we identify 11 studies with this objective. The selected cows were mainly multiparous, and when primiparous were included, the results were not reported separately. Regarding the facilities, only Sepulveda-Varas et al. (2014) evaluated grazing cows, while the other studies evaluated confined cows. The period used to evaluate the behaviors to predict the laminitis occurrence is not specific, therefore they may be evaluated at any stage of lactation. Laminitis is diagnosed by visual evaluation, assigning scores for the locomotion status of cows. In the articles, authors classified cows according to the scores, so it was defined that slightly lame = Score 2, moderately lame = Score 3, and severely lame > 4, although many authors do not follow this classification and make the diagnosis of laminitis (lame) when cows present locomotion score greater than 3 (scale 1 to 5 points). The main behavior evaluated for this disease was lying time. Previous to clinical diagnosis, cows affected by laminitis reduced time spent in activity, feeding and ruminating, while increasing lying time (Table 5).

3.4. Behaviors for early detection of mastitis

Only five articles reported changes in behaviors caused by mastitis, with the first published in 2016 (Stangaferro et al., 2016). Mastitis can occur in any phase of lactation, so the authors presented the evaluation period in relation to the diagnosis of the disease (Table 6). This observational period varied from 60 days before to 80 days after the diagnosis of mastitis. Although authors showed values of behaviors previous to diagnosis, they did not present the day when the behavior began to vary before diagnosis. Activity and rumination times were the most reported behaviors used to early detection of mastitis, and both decreased before the diagnosis while lying time increased (Table 6).

3.5. Behaviors for early detection of subacute ruminal acidosis (SARA)

Subacute ruminal acidosis was the disease with the fewest number of studies associated to changes in behavior, with only three articles, the first published in 2015 (Antanaitis et al., 2015). The period evaluated, from calving up to 60 days postpartum, is a critical phase of lactation and also the period of higher incidence of SARA. The behavior usually used in the early detection of SARA was rumination time. The authors did not show the day when the behavior began to vary, but showed that the rumination time and the activity exchange decreased (Table 7).

4. Discussion

This systematic review about behaviors that can be used for early detection of diseases encompassed five behaviors (activity, feeding, rumination, lying and standing), but when the articles were analyzed, some behaviors were presented in different ways (e.g., feeding was presented as feeding time and/or dry matter intake; lying was presented as lying time and/or lying bouts). This systematic review showed that the behaviors most used by researchers for early identification of sick animals were time spent ruminating, lying and feeding.

The feeding time is the time spent on the feed bin and includes periods of eating and not eating, which represents about 30 to 50% of the period intended for meals (Beauchemin, 2018). High production cows can spend from 4 to 6 h/d in feeding divided into up to 12 feeding events (DeVries et al., 2003). Some diseases, especially at its beginning, can reduce the appetite of cows and, consequently, feeding time (Schirmann et al., 2016). Among the factors that affect feeding time, pain is a major cause of its reduction (González et al., 2008). Sick cows might they develop adaptation mechanisms, such as visit the feeder less often and in a period with less competition, reduce feeding time, but consume quickly in an attempt to maintain feed intake (Schirmann et al., 2016; Sepúlveda-Varas et al., 2013).

In fact, one behavior can influence another, for example, cows with laminitis tend to remain lying for longer, and so the number of visits to the feeder and feeding time are reduced (de Mol et al., 2013). According to Cattaneo et al. (2020), sick cows that spend less time feeding, drinking and breeding, increase lying time to conserve energy. In turn, rumination time is affected by diet characteristics and nutritional factors such as dietary composition and digestibility of the feed, NDF intake, and forage quality (Kaufman et al., 2018).

The cows spent 8 to 12 h/d lying, and its restriction causes stress and impairs productivity and welfare (Cattaneo et al., 2020; Solano et al., 2016). Lying time is influenced by a number of factors such as the management, design of housing, density of animals, bedding conditions, climatic condition and the occurrence of diseases (Ito et al., 2010). Thus, the reduction in lying time may be a consequence of involvement in other behaviors, such as competition in the trough (Neave et al., 2018) or discomfort (DeVries et al., 2009).

Rumination is a cyclic process characterized by regurgitation, rechewing and new swallowing, which has the important function of facilitating digestion, particle reduction and passage through reticulum-rumen (Schirmann et al., 2016; Soriani et al., 2012). The rumination time of cows lasts approximately 7 h/d (Beauchemin, 2018), and variations may occur due to ethological behavior, reproductive status, production level, climatic condition and health status (Calamari et al., 2014).

The use of changes in behavior for the early detection of diseases in dairy cows requires the understanding of several physiological and psychological factors that affect the motivational hierarchy of cows in relation to expressing disease behavior (Siivonen et al., 2011). It is not possible to establish a single behavioral pattern for all cows, as they are individual animals, and each expresses their behavior according to their personality (Fernandes et al., 2017). Therefore, the comparison of behavior within animals (its own behavior compared with a5 to 7-days mobile average) deals with their individuality and are currently used in the automated monitoring systems. Rumination, as well as lying and feeding time, which can be measured by automatic sensors equipment, are promising behaviors to the early detection of diseases in cows (Kaufman et al., 2016).

Associations between clinical hypocalcemia, lying time and activity behaviors are notable (Barraclough et al., 2020). In some of the studies, lying time decreased in affected cows (Kaufman et al., 2016b). Hendriks et al. (2020) compared healthy cows and cows with subclinical or clinical hypocalcemia, and reported that cows with clinical hypocalcemia spent 9.4 h/d lying down, while healthy cows or cows with subclinical hypocalcemia spent 6.8 h/d lying down. Barraclough et al. (2020) reported that after calving, cows with clinical, subclinical and healthy hypocalcemia spent time lying down of 643.7, 555.3 and 518.3 min/d, respectively. Daros et al. (2020) did not reported significant difference in feeding time for healthy cows or those with clinical hypocalcemia (249 vs 267min/d, respectively, P=0.24).

Cows with subclinical ketosis also present higher lying time when compared to healthy cows (651.3 vs 636.7 min/d respectively) (Kaufman et al., 2016b). Beyond lying time, other behavior might also change such as feeding time. Schirmann et al. (2016)

reported a decrease in feeding time in cows affected by subclinical ketosis (236 vs 168 min/d, for healthy and sick cows, respectively, *P*<0.05), in opposition to Daros et al. (2020) who did not reported significant difference in feeding time (256 vs 234.5 min/d, for healthy and ketotic cows, respectively, *P*=0.24). Pineiro et al. (2019) evaluated healthy and ketotic cows at different parities (primiparous and multiparous), evidencing that in primiparous cows there is no significant difference in lying time between healthy and ketotic cows (561 vs. 588.6 min.d respectively, *P*=0.36), while in multiparous cows, the difference is significant (657.6 vs 706.8 min/d for healthy and ketotic cows, respectively, *P* =0.001). Moreover, rumination time is promising for the early detection of ketosis, both for clinical and subclinical disease. King et al., (2018b) evidenced decrease in rumination in ketotic cows (501.69 vs 484.54 min/d for healthy and subclinical ketotic cows, respectively, *P*=0.001). Steensels et al. (2017) also noticed reduction in rumination time (477.6 vs 404.4 min/d for healthy and ketotic cows respectively, *P*<0.05).

According to some researchers, lying time is the most indicated behavior for the early detection of laminitis, because cows tend to stay lying down for a more extended period due to pain, while they feed and ruminate during a shorter time. Healthy and cows affected by laminitis spent time lying 731.7 and 801.7min/d (*P*=0.02), respectively (Chapinal et al., 2010). Healthy cows spent more time feeding than cows affected by laminitis (259.5 vs 238.5min/d, respectively, *P*<0.001) (Daros et al., 2020). Moreover, Steensels et al., (2017) reported that healthy cows ruminated more than cows attained with laminitis (477.6 vs 436.8min/d respectively, P<0.05). On the contrary, King et al., (2017) obtained very similar values for rumination time for healthy and laminitis cows (492.6 vs 483.4 min/d).

There are few studies evaluating behavior to predict mastitis. Stangaferro et al. (2016b) reported reduction (P<0.001) in the rumination time (493.81 vs 450.75min/d, for healthy and mastitic cows, respectively). Conversely, Herskin et al., (2020) evaluating the lying time of healthy and mastic cows, before and after treatment, reported similar lying time of 668 and 709 min/d (*P*=0.42) for healthy cows and with mastitis, respectively, before treatment and 671 and 654min/d for healthy and mastitic cows, respectively after treatment (*P*=0.81).

There are few articles that evaluated the use of behaviors for the early detection of subacute ruminal acidosis. In the search for articles for this review, 5 articles were found, but two were eliminated, one for inducing acidosis (Coon et al., 2019) and having a few days of evaluation and the other for evaluating the risks of developing the disease without its occurrence (DeVries et al., 2009). Controversial results have been reported such as those of Antanaitis et al. (2019b), that reported reduced rumination time (448.9 vs 429.6min/d, P=0.02, for healthy and SARA, respectively), while Antanaitis et al. (2019a) reported similar (P>0.05) rumination time, 422.1 vs 419.9min/d for healthy and SARA, respectively.

Automatic systems and sensors have facilitated monitoring of cow behavior over the past few years (Solano et al., 2016; Stangaferro et al., 2016a). Several systems are being validated, where sensors present themselves in various forms such as collars (which record behaviors such as rumination time, activity time and lying time), pedometers to record activity movements,(Eckelkamp and Bewley, 2020) feeders and smart drinkers, and even robotic milkings have incorporated sensors to record behaviors (Huybrechts et al., 2014) . These systems consists of sensors that capture movements and send data to the receivers, the software that analyzes the information with the help of an algorithm to issue the alerts that farmers receive on their computers (Wagner et al., 2020) and smartphones

(Brassel et al., 2019). These equipments allow the individualization of the cow in the midst of the herd, facilitating the identification of animals with altered behavior and indicating the possible risk disease of (King et al., 2018a) or the occurrence of estrus (Pineiro et al., 2019).

Many researchers have applied the behaviors in prediction models for early detection disease (Siivonen et al., 2011a). Sahar et al. (2020) used feeding behavior to develop predictive model by multivariate binary logistic regression, the model did not specify diseases, but presented sensitivity, specificity and accuracy of the 73.3, 80.0 and 77.1%, respectively for multiparous cows, and 71.4, 84.2 and 78.8% for primiparous cows. Steensels et al. (2017b) developed a model, by logistic regression, using rumination time, activity and milk yield that has capacity of the detect ketosis one day before the routine of health examination conducted by the veterinarian, with an average accuracy of 76%. The validate model by de Mol et al. (2013) was based in activities as postural behavior, standing and lying, and presented 80.0% of sensitivity and 89.9% of specificity for laminitis detection. In the future, behaviors will be able to compose models for the effective early detection of specific diseases (King et al., 2017)and it is expected that the models can be incorporated into remote behavior monitoring systems of cows.

5. Conclusion

This systematic review demonstrates that the behavior monitoring can be used to develop models for early detection of diseases. In the articles includes in this systematic review, rumination, lying and feeding time are the most used behaviors with this objective. During the course of a disease, rumination and feeding time are reduced, while lying time increases. Other behaviors, such as activity and standing time, can be better studied, considering that they were little evaluated. Diseases can change multiple behaviors at the same time, and it is interesting to evaluate them together.

There is a long way to predict illnesses before the onset of clinical symptoms. Although we have not yet been able to predict the occurrence of a specific disease using one or more behavior changes, the monitoring of behaviors identify of cows at high risk of getting sick, allowing the diagnosis to be made at the first signs of the disease.

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CRediT authorship contribution statement

Aline Cardoso Vieira: the conception and design of the study, acquisition of data, data analysis and interpretation of data, drafting the article and revising it critically for important intellectual content; Vivian Fischer: the conception and design of the study and critical revision of the article for important intellectual content; Maria Eugênia A. Canozzi: the conception and design of the study, data analysis and critical revision of the article for important intellectual content; Julia Fernandes Aires: acquisition of data; Juliany Ardegui Guimarães: acquisition of data.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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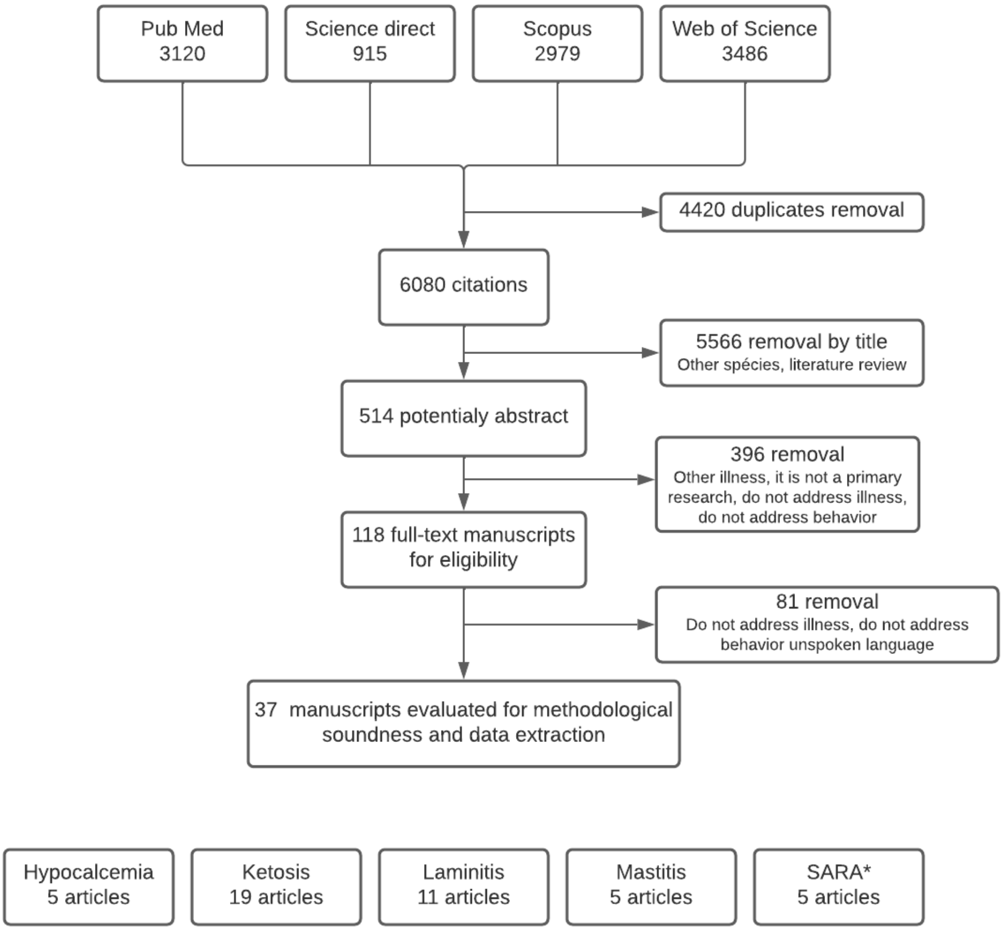

Figure 1: Flow diagram indicating the number of abstracts and manuscripts included and excluded at each step of systematic review.

Table 1: Results of analysis of risk of bias in the selected references.

	Selection				Comparability	Outcome			
Reference	Representativeness of the exposed cohort	Selection of the non-exposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at start of study	Comparability of cohorts on the basis of the design or analysis	Assessment of outcome	Was follow-up long enough for outcomes to occur	Adequacy of follow up of cohorts	Total
(Antanaitis et al., 2019a)	*	*	*	*	*	*	*	*	8
(Antanaitis et al., 2019b)	*	*	*	*	*	*	*	*	8
(Antanaitis et al., 2020a)	*	*	*	*	*	*	*	*	8
(Antanaitis et al., 2015)	*	*	*	*	*	*	*	*	8
(Antanaitis et al., 2020b)	*	*	*	*	*	*	*	*	8
(Antanaitis et al., 2020c)	*	*	*	*	*	*	*	*	8
(Barraclough et al., 2020)	*	*	*	*	*	*	*	*	8
(Calderonand Cook, 2011)	*	*	*	*	*	*	*	*	8
(Chapinal et al., 2010)	*	*	*	*	*	*	*	*	8

(Daros et al., 2020)	*	*	*	*	*	*	*	*	8
(Goldhawk et al., 2009)	*	*	*	*	*	*	*	*	8
(González et al., 2008)	*	*	*	*	*	*	*	*	8
(Hendriks et al., 2020)	*	*	*	*	*	*	*	*	8
(Edwards and Tozer, 2004)			*	*	*	*	*	*	6
(Herskin et al., 2020)	*	*	*	*	*	*	*	*	8
(Itle et al., 2015)	*	*	*	*	*	*	*	*	8
(Jawor et al., 2012)	*	*	*	*	*	*	*	*	8
(Kaufman et al., 2016a)	*	*	*	*	*	*	*	*	8
(Kaufman et al., 2016b)	*	*	*	*	*	*	*	*	8
(King et al., 2017)	*	*	*	*	*	*	*	*	8
(King et al., 2018a)	*	*	*	*	*	*	*	*	8
(King et al., 2018b)	*	*	*	*	*	*	*	*	8
(Pineiro et al., 2019)	*	*	*	*	*	*	*	*	8

(Rodriguez-Jimenez et al., 2018)	*	*	*	*	*	*	*	*	8
(Schirmann et al., 2016)	*	*	*	*	*	*	*	*	8
(Sepúlveda-Varas et al., 2014)	*	*	*	*	*	*	*	*	8
(Solano et al., 2016)	*	*	*	*	*	*	*	*	8
(Stangaferro et al., 2016a)	*	*	*	*	*	*	*	*	8
(Stangaferro et al., 2016b)	*	*	*	*	*	*	*	*	8
(M Steensels et al., 2017)	*	*	*	*	*	*	*	*	8
(Thomsen et al., 2012)	*	*	*	*	*	*	*	*	8
(Yunta et al., 2012)	*	*	*	*	*	*	*	*	8

Table 2: Distribution of articles by diseases and behaviors evaluated.

	Hypocalcemia	Ketosis	Laminitis	Mastitis	SARA[1]
Activity		Antanaitis et al., 2015; Edwards & Tozer, 2004; Stangaferro et al., 2016a		King et al., 2018a; Stangaferro et al., 2016b	Antanaitis et al., 2015
Activity time	Antanaitis et al., 2020[a]	Antanaitis et al., 2019a, 2020c; Steensels et al., 2017	Steensels et al., 2017	Antanaitiset al., 2020a	
Dry matter intake (DMI)	Jawor et al., 2012	Goldhawk et al., 2009; Rodriguez-Jimenez et al., 2018; Schirmann et al., 2016			
Feeding time	Daros et al., 2020	Antanaitis et al., 2020b; Daros et al., 2020; Goldhawk et al., 2009; González et al., 2008; Schirmann et al., 2016	Daros et al., 2020; González et al., 2008		
Lying bout	Hendriks et al., 2020	Rodriguez-Jimenez et al., 2018	King et al., 2017a; Sepulveda-Varas et al., 2014; Yunta et al., 2012		
Lying time	Barraclough et al., 2020; Hendriks et al., 2020	Kaufman et al., 2016b; Pineiro et al., 2019; Rodriguez-Jimenez et al., 2018	Calderon & Cook, 2011; Chapinal et al., 2010; King et al., 2017a; Sepulveda-Varas et al., 2014; Solano et al., 2016; Thomsen et al., 2012; Yunta et al., 2012)	Herskin et al., 2020	
Rumination time		Antanaitis et al., 2019b; 2020b; Kaufman et al., 2016a; King et al., 2018a; 2018b; Schirmann et al., 2016; Stangaferro et al., 2016	King et al., 2017a; King et al., 2018a; Steensels et al., 2017	King et al., 2018a; Stangaferro et al., 2016b	Antanaitis et al., 2019a; Antanaitis et al., 2019b
Standing bout		Itle et al., 2015; Rodriguez-Jimenez et al., 2018			
Standing time	Jawor et al., 2012	Itle et al., 2015; Rodriguez-Jimenez et al., 2018			

[1] Abbreviation for disease subacute ruminal acidosis

Table 3: Summary of articles reporting the hypocalcemia event

Reference	Study population (n/breed)[1]	Facilities	Parity	Monitored period[2]	Disease form	Day behavior change[3]	Behavior	Units[4]	Behavior before diagnosis	Behavior after diagnosis	Behavior of health cows[5]	Behavior of sick cows[6]
Antanaitis et al. (2020a)	30	Loose housing	More than one parity	(-60 a 60)	Clinical	4 days before calving	Activity time	min/d	170.24	89.85	113.04	163.52
Barraclough et al. (2020)	72	Straw bedded shed	Primiparous	(-21 to 21)	Subclinical		Lying time	min/d	742.67	509.00	547.71	609.14
			Multiparous		Subclinical		Lying time	min/d	732.00	546.29	596.00	623.67
					Clinical		Lying time	min/d	748.00	624.57	596.00	676.00
Daros et al. (2020)	159	Free-stall	More than one parity	-	Clinical		Lying time	min/d	-	267.00	249.00	267.00
Hendriks et al. (2019)	72		Multiparous	(-21 to 35)	Subclinical	Calving day	Lying time	min/d	612.6	463.80	519.60	529.20
					Clinical	Calving day	Lying time	min/d	612.6	544.20	519.60	547.80
					Subclinical	Calving day	Lying bout	no./d	8.85	12.27	9.13	8.82
					Clinical	Calving day	Lying bout	no./d	8.1	13.0	9.13	9.13
Jawor et al. (2012)	30	Free-stall	Multiparous	(-21 to 31)	Subclinical		DMI	kg/d	17.75	19.8	17.67	18.77
							Standing time	min/d	727.80	775.80	790.4	758.4

[1] Number of animals used in the study
[2] Period in relation to the calving in which the animals had the behaviors monitored and recorded in the study
[3] Day in relation to calving in which the researchers identified or demonstrated in graph the change in behavior evaluated with the occurrence of the disease
[4] Unit of measure used to measure behavior.
[5] Mean value recorded in unit of time, number or weight, according to the evaluated behavior for health cows.
[6] Mean value recorded in unit of time, number or weight, according to the evaluated behavior for sick cows

Table 4: Summary of articles reporting the ketosis event.

Reference	Study population (n/breed)[1]	Facilities	Parity	Monitored period[2]	Diseaseform	Day behavior change[3]	Behavior	Units[4]	Behavior before diagnosis	Behavior after diagnosis	Behavior of health cows[5]	Behavior of sick cows[6]
Antanaitis et al. (2019a)	711	Loosehousing	More than one parity	(0 to 30)	Subclinical		Activity time	min/d	-	679,80	422.10	405.99
Antanaitis et al. (2019b)	93	Loosehousing	More than onep arity	(0 to 30)	Subclinical		Rumination time	min/d	742,67	509,00	448.91	391.75
Antanaitis et al. (2015)	90	Loosehousing	More than one parity	(0 to 60)	Clinical	2	Activity	steps/h	732,00	546,29	76.26	84.22
Antanaitis et al. (2020a)	30	Free-stall	More than one parity	(0 to 30)	Subclinical	15	Rumination time	min/d	748,00	624,57	618.48	418.32
							Feeding time	min/d	-	267,00	191.28	265.92
Antanaitis et al. (2020b)	20	Free-stall	More than one parity	(30 to 48)	Subclinical	16	Activity time	min/d	612,6	463,80	845.52	771.96
Daros et al. (2020)	159	Free-stall	More than one parity		Clinical		Feeding time	min/d	612,6	544,20	256.00	234.50
Edwards &Tozer (2004)	1445		More than one parity		Clinical		Activity	steps/h	8,85	12,27	180.33	181.02
Goldhawk et al. (2009)	101	Free-stall	More than one parity	(-14 to 21)	Subclinical	14	DMI	Kg/d	8,1	13,0	17.19	14.49
							Feeding time	min/d	17,75	19,8	178.79	140,54
González et al. (2008)	50	Yard			Clinical	3	Feeding time	min/d	727,80	775,80		136.94
Itle et al. (2014)	184		Multiparous	(-7 to 21)	Clinical	14	Standing time	min/d	-	679,80	834.00	900.00
							Standingbout	no./d	742,67	509,00	20.90	14.60
Kaufman et al. (2016a)	399	Free-stall	Multiparous	(-14 to 28)	Subclinical	21	Rumination time	min/d	732,00	546,29	434.25	429.08
					Subclinical + other		Rumination time	min/d	748,00	624,57	434.25	404.33
Kaufman et al. (2016b)	399	Free-stall	Multiparous	(-14 to 28)	Subclinical	21	Lying time	min/d	-	267,00	636.72	651.29
					Subclinical + other		Lying time	min/d	612,6	463,80	608.66	648.93
King et al. (2018a)	605	Free-stall	Multiparous	(-7 to 49)	Subclinical		Rumination time	min/d	612,6	544,20	477.00	420.50
King et al. (2018b)	172	Free-stall	More than one parity	(1 to 21)	Subclinical	6	Rumination time	min/d	8,85	12,27	501.69	484.54
					Subclinical + other		Rumination time	min/d	8,1	13,0	501.69	430.94

Piñeiro et al. (2019)	1024	Free-stall	Primiparous	(-14 to 14)	Clinical	14	Lying time	min/d	17,75	19,8	561.00	588.60
					Clinical + other		Lying time	min/d	727,80	775,80	561.00	547.80
Piñeiro et al. (2019)	1024	Free-stall	Multiparous	(-14 to 14)	Clinical		Lying time	min/d	-	679,80	657.60	706.80
					Clinical + other		Lying time	min/d	742,67	509,00	657.60	696.60
Rodriguez-Jimenez et al. (2018)	44	Tie-stall	Multiparous	(-30 to 30)	Clinical		Standing time	min/d	732,00	546,29	829.95	710.75
							Standingbout	no./d	748,00	624,57	8.50	10.30
							Lying time	min/d	-	267,00	610.05	729.25
							Lyingbout	no./d	612,6	463,80	9.70	12.20
							DMI	kg/d	612,6	544,20	14.80	11.81
Schirmann et al. (2016)	56	Free-stall	Multiparous	(-14 to 21)	Subclinical		Rumination time	min/d	8,85	12,27	517.50	471.25
					Subclinical + other		Rumination time	min/d	8,1	13,0	487.50	512.50
					Subclinical		DMI	kg/d	17,75	19,8	19.83	16.22
					Subclinical + other		DMI	kg/d	727,80	775,80	19.83	16.15
					Subclinical		Feeding time	min/d	-	679,80	228.25	190.75
					Subclinical + other		Feeding time	min/d	742,67	509,00	228.25	202.75
Stangaferro et al. (2016)	1080	Free-stall	More than one parity	(-21 to 80)	Clinical	3	Rumination time	min/d	732,00	546,29	502.00	421.59
							Activity	AU/d	748,00	624,57	546.82	459.32
Steensels et al. (2017)	703	Fullyroofed	Multiparous	(0 to 21)	Clinical		Rumination time	min/d	-	267,00	477.60	404.40
							Activity time	min/d	612,6	463,80	366.00	321.84

[1] Number of animals used in the study
[2] Period in relation to the calving in which the animals had the behaviors monitored and recorded in the study
[3] Day in relation to diagnostic in which the researchers identified or demonstrated in graph the change in behavior evaluated with the occurrence of the disease
[4] Unit of measure used to measure behavior.
[5] Mean value recorded in unit of time, number or weight, according to the evaluated behavior for health cows.
[6] Mean value recorded in unit of time, number or weight, according to the evaluated behavior for sick cows

Table 5: Summary of articles reporting the laminitis event.

Reference	Studypopulation (n/breed)[1]	Facilities	Parity	Monitored period[2]	Diseaseform	Behavior	Units[3]	Behavior before diagnosis	Behavior after diagnosis	Behavior of health cows[4]	Behavior of sick cows[5]
Calderon et al. (2011)	57	Free-stall	More than one parity	(-21 to 21)	Slightlylame	Lying time	min/d		660	637.20	649.80
					Moderatelame	Lying time	min/d		732	637.20	730.80
Chapinal et al. (2010)	48	Free-stall	Multiparous	post 214	Lame	Lying time	min/d		810	731.70	801.70
Daros et al. (2020)	159	Free-stall	More than one parity	(-60 to -14)	Lame	Feeding time	min/d		234,5	259.50	238.50
González et al. (2008)	50	Yard		Preand post diagnositic	Lame	Feeding time	min/d	132,03	96,88		122.57
King et al. (2017)	1218	Free-stall	Multiparous	Post 175	Lame	Lying time	min/d	727		676.00	727.00
						Lyingbout	no./d	9,27		9.29	9.27
						Rumination time	min/d	483,4		492.60	483.40
King et al. (2018)	605	Free-stall	Multiparous	(-7 to 49)	Lame	Rumination time	min/d	471,03		500.00	480.00
Spulveda-varas et al. (2014)	123	Pasture	Multiparous	post 22	Lame	Lying time	min/d		540	525.60	540.00
					Severelame	Lying time	min/d		636,6	525.60	636.60
					Lame	Lyingbout	no./d		8,61	8.61	8.61
					Severelame	Lyingbout	no./d		9,69	9.61	9.69
Solano et al. (2016)	5135	Free-stall	More than one parity	(10 to 120)	Lame	Lying time	min/d		666	630.00	666.00
Steensels et al. (2017)	703	Fullyroofed	Multiparous	(0 to 21)	Lame	Rumination time	min/d	288,6	476,52	477.60	440.64
						Activity time	min/d	296,76	318,24	366.00	314.16
Thomsen et al. (2012)	1340	Free-stall	More than one parity	(0 to 240)	Slightlylame	Lying time	min/d		624,5	631.00	624.50
					Lame	Lying time	min/d		646,6	631.00	646.60
					Moderatelame	Lying time	min/d		684,9	631.00	684.9
					Severelame	Lying time	min/d		766,4	631.00	766.4
Yunta et al. (2012)	200	Free-stall	Multiparous	Post 186	Moderatelame	Lying time	min/d		728	714.00	728.00
						Lyingbout	no./d		9,4	9.80	9.40

[1] Number of animals used in the study
[2] Period in relation to the diagnosis of laminitis which the animals had the behaviors monitored and recorded in the study
[3] Unit of measure used to measure behavior.
[4] Mean value recorded in unit of time, number or weight, according to the evaluated behavior for health cows.
[5] Mean value recorded in unit of time, number or weight, according to the evaluated behavior for sick cows.

Table 6: Summary of articles reporting the mastitis event.

Reference	**Studypopu lation (n/breed)[1]**	**Facilities**	**Parity**	**Monitored period[2]**	**Diseaseform**	**Behavior**	**Units[3]**	**Behavior before diagnosis**	**Behavior after diagnosis**	**Behavior of health cows[4]**	**Behavior of sick cows[5]**
Antanaitis et al, (2020)	30	Loosehousing	More than one parity	(-60 a 60)	Clinical	Activity time	min/d	344,40		471.00	344,40
Herskin et al, (2020)	43	Concretfloors			Clinical	Lying time	min/d			709	681.50
King et al, (2018)	605	Free-stall	Multiparous	(-7 to 49)	Clinical	Rumination time	min/d	405,35		450.00	400.00
		Free-stall				Activity	units/d	580		622.50	545.36
Stangaferro et al, (2016)	1080	Free-stall	More than one parity	(-21 to 80)	Clinical	Rumination time	min/d	455,83	446,52	493.81	450.75
						Activity	AU/d	504,16	502,08	596.20	503.02

[1] Number of animals used in the study
[2] Period in relation to the diagnosis of mastitis in which the animals had the behaviors monitored and recorded in the study
[3] Unit of measure used to measure behavior.
[4] Mean value recorded in unit of time, number or weight, according to the evaluated behavior for health cows.
[5] Mean value recorded in unit of time, number or weight, according to the evaluated behavior for sick cows.

Table 7: Summary of articles reporting the subacute ruminal acidosis (SARA) event.

Reference	Studypopulation (n/breed)[1]	Facilities	Parity	Monitored period[2]	Behavior	Units[3]	Behavior before diagnosis	Behavior after diagnosis	Behavior of health cows[4]	Behavior of sick cows[5]
Antanaitis et al, (2019a)	711	Loosehousing	More than one parity	(0 to 30)	Rumination time	min/d	450,00	419,92	422.10	419.92
Antanaitis et al, (2019b)	93	Loosehousing	More than one parity	(1 to 30	Rumination time	min/d	450,00	429,67	448.91	429.67
Antanaitis et al, (2015)	90	Loosehousing	More than one parity	(0 to 60)	Activity	steps/h	83,59	91,66	76.26	60.49

[1] Number of animals used in the study
[2] Period in relation to the calving in which the animals had the behaviors monitored and recorded in the study
[3] Unit of measure used to measure behavior.
[4] Mean value recorded in unit of time, number or weight, according to the evaluated behavior for health cows.
[5] Mean value recorded in unit of time, number or weight, according to the evaluated behavior for sick cows.

CAPITULO V

CONSIDERAÇÕES FINAIS

Ao longo desses quatro anos de estudo, procuramos entender a como a ocorrência de doenças altera o comportamento animal. Inicialmente, estudamos como os produtores de leite detectavam precocemente doenças nas vacas, utilizando coleiras com sensores de atividade e ruminação. A parceria com a empresa Cowmed) permitiu o acesso aos produtores clientes, e ao avaliar a procedimentos adotados pelos produtores, percebemos que eles não conheciam e não exploravam todas as funcionalidades dos sistemas de monitoramento. Foi então, que surgiram questionamentos, como: Quem está adotando os sistemas de monitoramento? Qual o perfil do produtor e as características da fazenda? Quais suas motivações para adoção? Como estão utilizando os sistemas de monitoramento? E por fim, se os sistemas de monitoramento estão atendendo ao seu propósito. Acessamos também os produtores que não adotavam os sistemas de monitoramento, o que permitiu entender o perfil e a percepção quanto a adoção dos sistemas de monitoramento.

Os produtores de leite ainda são reticentes à participação em pesquisas. Os produtores usuários dos sistemas não apresentaram muito interesse em participar das entrevistas (por telefone) e cerca de 50% dos produtores indicados pela Cowmed não responderam nossos contatos. Como não tínhamos contato direto com produtores não usuários de sistemas de monitoramento, optamos por um questionário digital, e distribuímos por meio de redes sociais (facebook e whatsapp) e por e-mail, resultando em 40 participantes respondentes. Nos estudos realizados, constatamos que fazendas de todas as dimensões podem fazer uso do sistema remoto de monitoramento comportamental, mas a maioria das propriedades que adotam são ou estão se especializando na produção leiteira, investindo em animais produtivos, sistemas mais intensivos e em tecnologias. Foi perceptível que embora os produtores ainda não tenham protocolos claros para as ações após os alertas, os sistemas tem atingido seu objetivo, facilitando a rotina dos produtores na identificação dos animais que podem adoecer e facilitar a detecção do estro.

Para finalizarmos, realizamos uma revisão sistemática com a intenção de compreender quais comportamentos poderiam detectar precocemente uma doença. Selecionamos previamente cinco doenças com grande ocorrência em vacas leiteiras, principalmente no período de transição (hipocalcemia, cetose, laminite, mastite e acidose ruminal), e também cinco comportamentos que podem ser afetados pelas doenças (atividade, alimentação, ruminação, e comportamentos posturais deitado e em pé). Concluiu-se que os comportamentos são alterados com a ocorrência das doenças, e as alterações no comportamento geralmente acontece alguns dias antes dos sinais clínicos, embora ainda não esteja claro quantos dias seriam para cada doença. De forma simplificada, podemos dizer que a ocorrência de doenças causa redução nos tempos de atividade, alimentação, ruminação e tempo em pé, enquanto aumenta o tempo deitado, e pode também aumentar a alternância entre as atividades.

Baseando-se em nossos resultados podemos afirmar que ainda temos um longo caminho a percorrer para poder detectar precocemente a ocorrência de doenças com base em dados gerados por sensores. Avanços estão sendo observados, existem tecnologias e abordagens estatísticas que estão permitindo avanços na geração de dados e procedimentos de detecção precoce de doenças. Assim, já é possível identificar animas com risco de se acometidos com problemas de saúde. Assim, espera-se que naturalmente com o tempo seja possível incluir a funcionalidade de identificação de doenças específicas nos sistemas de monitoramento.

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VITA

Aline Cardoso Vieira, filha de Jair Serafim Vieira e Maria Regina da Silva Cardoso Vieira, brasileira, nascida em Canela-RS em 19 de junho de 1990.

Concluiu o ensino fundamental no Colégio Municipal Theóphilo Sauer e cursou o ensino médio na Escola Técnica Estadual Monteiro Lobato (CIMOL), ambas no município de Taquara-RS, onde cresceu.

No ano de 2010 ingressou, através do SISU (Sistema de Seleção Unificada), no curso de Bacharelado em Zootecnia, no Instituto Federal Farroupilha-Campus Alegrete (IFFar – Alegrete), no município de Alegrete RS, concluindo a graduação no ano de 2015. Durante a graduação participou de projetos de iniciação cientifica nas áreas de apicultura, bovinocultura de leite e cunicultura.

Em 2016, iniciou o Mestrado em Zootecnia, com ênfase em produção animal, no Programa de Pós-graduação em Zootecnia da Universidade Federal de Santa Maria (UFSM). Sob orientação do professor Dr. Clair Jorge Olivo, desenvolveu seu trabalho na área de bovinocultura de leite, avaliando a produção e valor nutricional de pastos consorciados de capim-elefante e amendoim forrageiro. Defendeu sua dissertação no em março de 2018. Durante o mestrado foi bolsista do CNPq.

Em abril de 2018, iniciou o Doutorado em Zootecnia, com ênfase em produção animal, no Programa de Pós-graduação em Zootecnia da Universidade Federal do Rio Grande do Sul. Com a orientação da professora Drª. Vivian Fischer e co-orientação da Drª. Maria Eugênia Andrighetto Canozzi, desenvolveu seu trabalho onde avaliava a utilização de sistemas remotos de monitoramento comportamental em fazendas leiteiras e, através de uma revisão sistemática, avaliou quais comportamentos estão sendo avaliados para utilização na detecção precoce de doenças.