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The Benefits of Rumen Boluses in Dairy Cows

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Budapest, Hungary
2024

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List of Abbreviations

AR	Antibiotic Resistant
BCS	Body Condition Score
BHB	β-hydroxybutyrate
IoT	Internet of Things
NEB	Negative Energy Balance
PLT	Precision Livestock Technologies
SARA	Sub-Acute Ruminal Acidosis

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Abstract

Precision livestock farming technologies (PLT's) have the potential to improve the sustainability of dairy production through their production performance, environmental, economic and welfare benefits. The objective of this study was to evaluate the benefits of using rumen boluses in dairy cows in a pasture-based system of production. Data was collected from a spring calving pasture-based herd in Ireland using rumen bolus technology (Moonsyst). In Ireland's pasture-based systems, aligning animal health and the lactation curve with natural grazing cycles is critical. Effective herd health management is critical for animal welfare and the economic sustainability of dairy production. Rumen boluses and PLT's offer farmers the ability to monitor and improve herd fertility and health through early detection of health issues and facilitating timed AI. Rumen boluses promote a proactive approach to animal welfare by enabling early interventions addressing health issues before conditions worsen, thereby enhancing animal welfare within the herd. Economically PLTs reduce operational costs by optimizing feed efficiency, minimizing health related losses and reducing reliance on veterinary interventions. Despite their advantages, the adoption of precision technologies varies widely across farms, influenced by factors including initial investment cost, user-friendliness, and perceived benefits. Eliminating these barriers could facilitate greater adoption, leading to improved farm productivity and better animal welfare outcomes in pasture-based systems.

This research is essential for evaluating the benefits of rumen boluses in pasture-based dairy systems, assessing their effectiveness in supporting herd health, productivity, and overall farm sustainability. In this paper I am going to be investigating PLTs, with a focus on rumen boluses and their potential benefits for farmers and livestock. Additionally I will examine the Irish pasture based grazing system and its impact on milk production in Ireland.

Introduction

Precision livestock technologies (PLT's) are a transformative tool for Ireland's dairy industry, particularly within our pasture-based systems of production making it essential to align cow health and productivity with natural growth cycles to maximize efficiency and profitability [1].

Rumen boluses, a key component of PLTs, aid in this alignment by providing continuous real-time data on key health indicators including rumen pH, temperature, and activity levels [2]. This data allows for precise feed adjustments, reducing the need for additional supplementation and enhancing nutrient efficiency across the herd. One of the primary advantages of rumen boluses is their ability to detect early signs of health issues before they fully manifest. Early detection enables timely intervention which reduces the need for costly veterinary care and can help stabilize milk yields which are critical factors in supporting profitability within Ireland's pasture-based, seasonal calving systems [3]. The use of rumen boluses contributes to overall herd welfare by helping farmers detect behavioural changes or subtle health issues early, allowing for swift corrective actions that support long-term animal health and productivity within the herd [4].

Rumen boluses also contribute to sustainable farming practices. They enhance nutrient management by optimizing feed use and minimize waste which helps lowers the carbon footprint of dairy operations. This sustainability aspect aligns with global environmental goals and the growing market demand for eco-friendly farming practices. The integration of PLTs including rumen boluses will help Irish dairy farmers to meet both productivity and sustainability demands, demonstrating a balance between high welfare standards and environmentally responsible operations [5].

In summary, rumen boluses support the Irish dairy industry's goals of efficient, cost-effective, and sustainable farming. By aligning herd health management with natural grazing patterns, reducing veterinary costs, and optimizing environmental impact, rumen boluses show promising benefits for modern dairy farming practices.

Pasture Based Dairy Production

A pasture based grazing system refers to a method of livestock farming where animals primarily feed on pasture, allowing them to graze on natural grass rather than relying on processed feed. Pasture-based grazing systems are the cornerstone of Irish dairy farming, with approximately 80% of agricultural land in Ireland dedicated to pasture, hay, and grass silage [6]. As a result, Ireland has one of the most grass-based agricultural systems in Europe. Generally, grass-based systems have lower costs of production per unit product whereas indoor systems rely on high volume and lower margin per unit [1]. While pasture-based systems have lower feed costs, they are more susceptible to fluctuations in feed availability due to the seasonal variation of grass growth [7]. Effective management of pasture availability and quality is essential for optimizing milk yield and maintaining cow health in pasture-based systems [8]. Grass utilisation is one of the key factors that influences profitability within a pasture based system of production [9, 10]. The goal of a pasture-based production system is to minimize concentrate supplementation by aligning the calving pattern with grass growth and herd demand, using supplements only when pasture growth fails to meet the herd's nutritional needs (Figure 1).

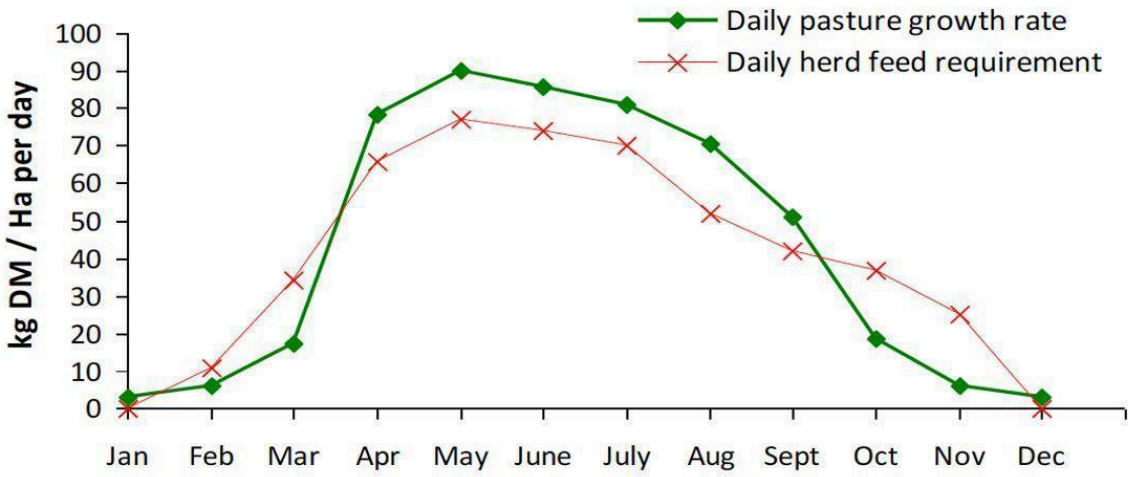


Figure 1: Grass growth pattern and daily herd feed requirement over the course of lactation.

Unlike many European countries, in Ireland the majority of dairy farms operate a spring calving pasture based system. Dairy farms in Ireland operate as spring-calving systems as this aligns the peak nutritional demands of cows with the highest grass growth rates during the

spring and summer months. After calving, cows are typically turned out to grass and remain on a grazing rotation until the onset of winter (November) or for as long as weather conditions permit. In pasture-based systems, cows typically experience peak milk yields around week 8 of lactation coinciding with peak grass growth (Figure 2) in May and June [11]. In recent years, grass growth in Ireland has been increasingly impacted by erratic weather patterns linked to climate change. Extended dry periods and higher temperatures, such as the drought in 2018, have reduced grass yields significantly, creating challenges for dairy farms dependent on pasture-based systems [12]. In a case study of spring-calving pasture-based dairy production systems in Ireland, physical and financial data for 868 seasonal calving dairy farmers with records for each of the years 2013–2017 inclusive was collected and analysed. The results highlighted that overall farm net profit was highly variable across the study years and was greatest in 2017 (€133,836) and least in 2016 (€65,176) [13]. The study highlighted the variability of farm profits, which are influenced by factors including weather conditions, fluctuating milk price, feed costs and herd health.

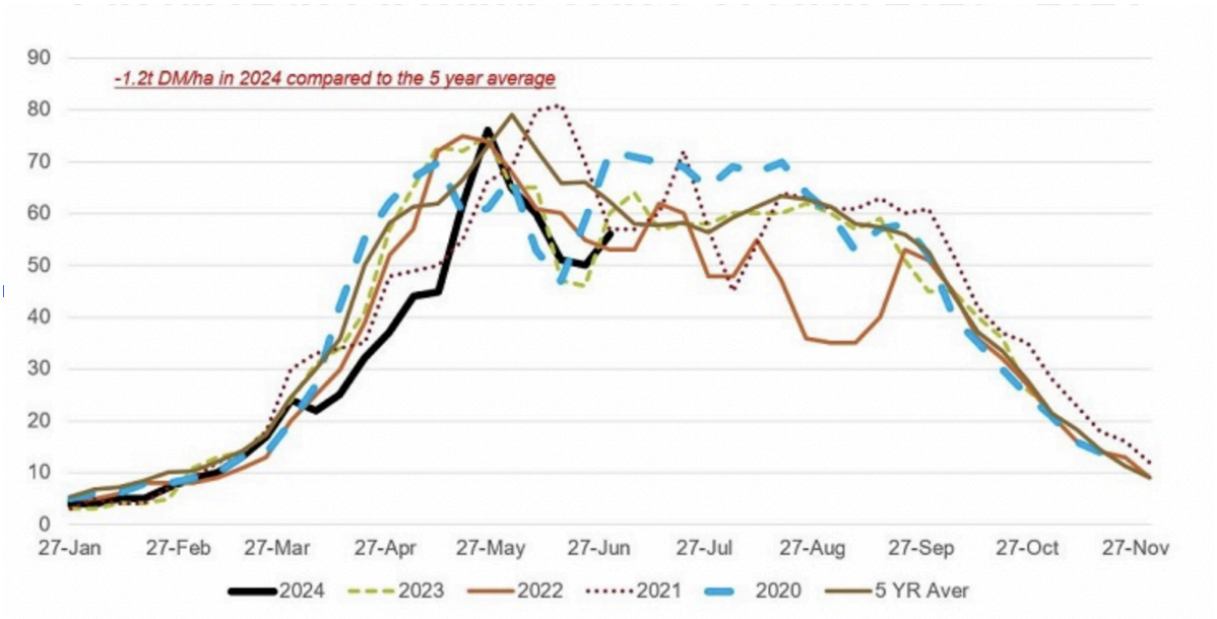


Figure 2: PastureBase Ireland Grass Growth Curve 2020-2024

As of 2023, there are approximately 18,000 dairy farmers in Ireland, managing an average herd size of around 90 cows [14]. The national dairy herd has grown to 1.5 million cows, with annual milk production reaching 8 billion litres [14]. The dairy industry plays a significant role in the Irish economy, contributing an estimated €17.6 billion annually [15].

This figure includes the direct, indirect, and induced impacts of dairy production, processing, and related activities across the supply chain. This significant contribution reflects the extensive role that dairy farming and processing have in supporting not just farm incomes but also wider economic activities throughout Ireland.

Precision Livestock Technologies

Precision Livestock Technologies refer to the use of digital tools, sensors, and automated systems to monitor, manage, and optimise animal health and productivity [16,17]. PLT's provides farmers with real-time data to support decision making while improving farm management, animal welfare, productivity and overall farm profitability. In dairy farming, PLTs can range from simple wearable devices to advanced monitoring systems such as rumen boluses. These technologies are capable of tracking health parameters, detecting estrus activity, monitor feeding behaviours, and even predict health outcomes.

The increased level of adoption of PLT's is driven by their ability to address challenges including disease management, fertility and welfare monitoring while also reducing labour and improving environmental sustainability. However, their integration varies depending on farm size, production system, cost, farmer age and the specific needs of each operation [18,19]. This section explores the application of PLT's in key areas such as fertility, health, welfare, and economics to highlight their impact on dairy herd management.

Fertility

Fertility is a key performance indicator in dairy production, and effective fertility management can significantly impact the profitability and sustainability of dairy farming, especially in pasture based systems of production [20, 21]. Precision livestock technologies, such as automated estrus detection systems and rumen boluses, have proven to be valuable tools in improving reproductive performance. These technologies are especially beneficials as they provide real-time data on cow health, helping to identify optimal breeding windows and accurately monitor estrus [22].

Monitoring changes in rumen pH and temperature can act as early indicators of estrus [23]. These physiological parameters fluctuate during the estrous cycle, a drop in rumen pH can correspond to changes in feed intake a behaviour that occurs during estrus. A rise in rumen temperature can also signal the onset of estrus as seen in Figure 3 below. Previous research

on the application of rumen boluses in estrus detection has shown that rumen temperature and activity level can serve as indirect indicators of estrus and can reduce missed breeding opportunities [24]. Rumination activity sensors can also detect changes in the cow's health early, allowing for timely interventions, which is crucial in maintaining optimal reproductive health.

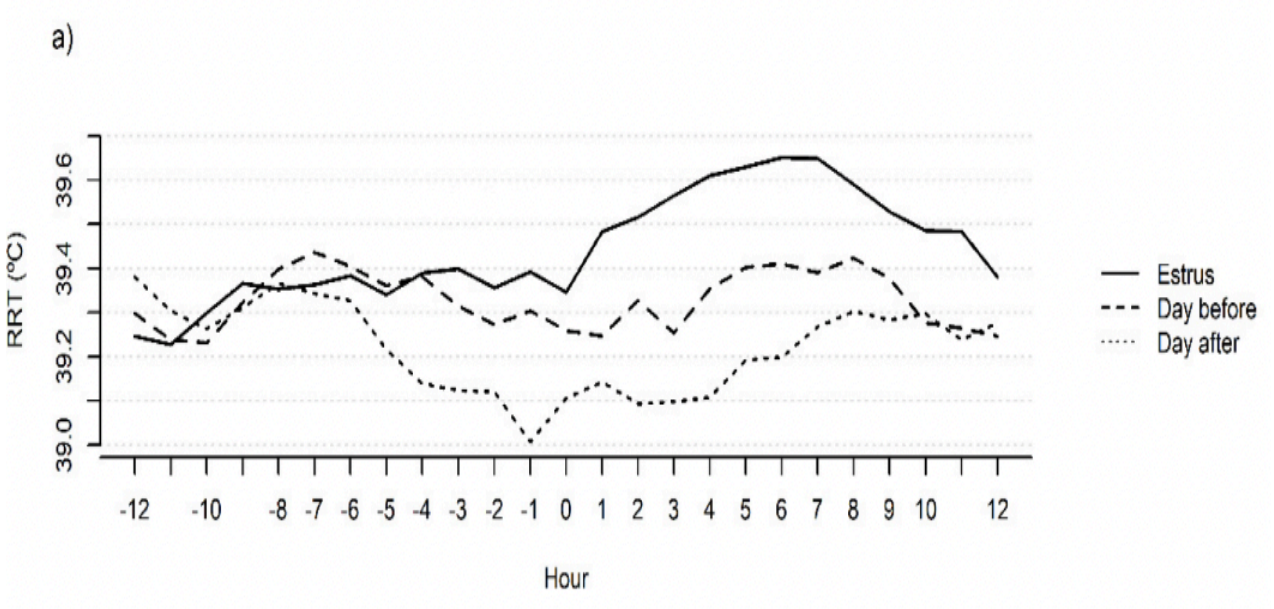


Figure 3: Observed mean reticulo-rumen temperatures (RRT) over the hours before and after first observed mount acceptance (0) on the day of estrus, on the day before, and on the day after [25].

Incorporating technologies such as rumen boluses for tracking health and estrus events can improve reproductive management and reduce the need for hormonal interventions [26]. This suggests that the use of boluses not only enhances reproductive outcomes but also improves dairy farm sustainability by reducing reliance on external hormones. Integrating data from rumen boluses and other monitoring tools improves the predictive accuracy of estrus models, leading to more timely and effective breeding strategies [27]. This is particularly valuable in extensive pasture-based systems, where farmers typically rely on tail-painting, visual observations, teaser bulls or chalking to identify mounting activity.

Health

Effective health management is essential for maximising productivity and welfare in dairy cows. In recent years, dairy farms have adopted health programs focused on monitoring and addressing health disorders to reduce their impact on animal productivity, health, welfare and farm profitability [28,29]. PLT's have emerged as a crucial tool for real-time health monitoring, helping to detect and prevent common metabolic disorders including ketosis, subacute ruminal acidosis (SARA) and mastitis. By continuously measuring rumen pH, temperature, and activity levels, these devices provide actionable data that can significantly enhance the management of cow health. Ketosis is a metabolic disorder in dairy cows defined by elevated blood concentrations of ketone bodies including β-hydroxybutyrate (BHB), - without clinical signs, often termed subclinical ketosis. Ketosis is typically triggered by negative energy balance (NEB) during the early stages of lactation (Figure 4) when the cow's energy intake cannot meet the high energy demands associated with milk production [30]. Rumen boluses can detect subclinical symptoms of diseases such as ketosis, allowing for early intervention reducing the need for more intensive treatments [31]. This can prevent the condition from progressing to clinical ketosis, reducing the risk of decreased milk yield and impaired reproductive performance. Prompt treatment of subclinical ketosis reduces the risk of secondary health issues, ensuring better overall herd productivity and health. Rumen boluses are also capable of detecting heat stress in dairy cows by continuously monitoring key physiological parameters including rumen temperature, pH, and activity levels [32].

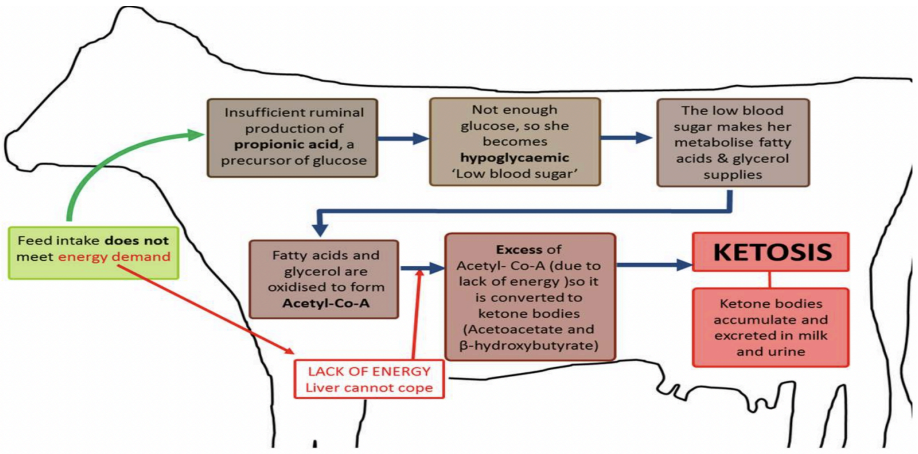


Figure 4: Ketosis diagram showing how ketosis is caused when the feed intake does not meet energy demands, causing hypoglycaemia, and the knock-on effects resulting in ketosis [33].

Subacute Ruminal Acidosis is a condition in dairy cattle where ruminal pH drops below 5.8 for several hours each day, typically caused by high-concentrate diets with excessive fermentable carbohydrates and low fibre content [34]. In the absence of rumen boluses or PLT's, detection of SARA would be based on clinical signs including decreased or cyclic feed intake, decreased milk production, poor body condition score (BCS) despite adequate feed intake, and unexplained diarrhoea [35]. Cows monitored with rumen boluses have been shown to have a 20% reduced incidence of SARA due to early detection and timely intervention [36].

Rumen boluses can detect mastitis in dairy cows by continuously monitoring physiological parameters including temperature and pH levels. Sudden increases in rumen temperature or changes in pH can indicate the onset of an infection or an inflammatory response, which are common indicators of mastitis [37]. Early detection through these physiological changes enables farmers to implement timely interventions, potentially reducing disease severity and duration. Early intervention can significantly lower treatment costs and decrease the risk of long-term udder damage [38]. Furthermore, detecting mastitis at an early stage can reduce the likelihood of culling affected cows, thereby maintaining herd productivity and longevity [39].
Heat stress in dairy cows occurs when the animal's ability to dissipate heat is overwhelmed by environmental factors including high temperature and humidity, leading to a rise in body temperature. Dairy cows are extremely susceptible to heat stress [40]. Cows suffering from heat stress decrease their feed intake and heat exchange capacity. Heat stress results in lower milk production and reproductive indices and increased costs for the dairy industry during the summer months particularly in countries such as the USA [41]. Real-time monitoring of rumen temperature allows for the identification of heat stress patterns, enabling farmers to adjust management practices [42]. This could include providing adequate shading or improving ventilation on the farm.

Milk fever or hypocalcaemia occurs when there is a temporary drop in blood calcium levels, typically around the time of calving. It is one of the most common metabolic disorders in dairy cows [43]. Rumen boluses can play a crucial role in detecting milk fever by monitoring key physiological indicators including body temperature and rumination patterns. A

significant drop in body temperature is one of the earliest signs of milk fever [44], allowing for prompt intervention before the condition becomes severe. Immediate intervention is essential when a cow develops milk fever, as prolonged untreated hypocalcemia significantly diminishes the likelihood of recovery and increases mortality risk [45].

Welfare

Animal welfare is a crucial consideration in modern dairy farming, as it directly impacts productivity, health, and public perception of the industry [46]. PLTs including rumen boluses have been shown to enhance animal welfare by providing continuous monitoring of physiological and behavioural parameters [47]. This allows for early detection of health issues and the ability to tailor management practices to the specific needs of each cow [48].

Real-time monitoring systems minimize the stress of manual health checks and enable immediate interventions when abnormal behaviours or physiological changes are detected [49]. By continuously tracking vital parameters such as rumen temperature and pH, these systems allow farmers to act swiftly, preventing diseases from progressing into more severe conditions [49]. This not only improves cow welfare but also reduces the need for labour-intensive management practices [50].

By detecting early signs of infection or disease, rumen boluses help reduce the reliance on antibiotics, thereby supporting both animal welfare and public health objectives by reducing the development of antibiotic-resistant (AR) bacteria [51,52]. Scientific evidence demonstrates that overuse of antibiotics in animals can contribute to the emergence of antibiotic resistance (Figure 5) contaminating the human food chain [53]. PLT's not only supports sustainable farming practices but also aligns with increasing consumer demand for antibiotic-free dairy products [54]. In addition, early disease detection through bolus technology can improve recovery rates in cows, reducing the likelihood of prolonged illnesses that would otherwise require extensive medical treatments [55].



Figure 5: Potential routes of antibiotics and antibiotic resistance transmission, which have their origin in the use of antibiotics in the treatment of farm animals and can reach humans and the environment [56].

Combining rumen data with behaviour metrics allows for more accurate welfare assessments including lameness detection which may otherwise go unnoticed [57]. An example is digital dermatitis (Mortellaro Disease) which is a severe infectious disease which causes lameness in dairy cattle worldwide and is a significant welfare concern [58]. Digital Dermatitis is caused by treponema species (a group of spirochete bacteria) [59]. Early detection of this disease is crucial, as prompt intervention helps prevent the spread of bacteria to other cows and lowers the risk of chronic lameness [60].

Economics

The adoption of rumen boluses and PLTs in dairy farming extends beyond improving fertility health and welfare; it also has considerable economic implications [61]. Implementing these technologies can increase profitability through improved productivity, reduced veterinary costs, and optimized feed efficiency [62]. However, these precision livestock technologies have a high benefit-to-cost ratio [63]. The cost-benefit ratio is influenced by several factors, including farm size, initial investment, and the ability to effectively interpret and act on the

data provided by these systems [64]. Larger farms are more likely to adopt PLTs due to economies of scale, while smaller farms often struggle to justify the high initial costs [65]

Small herds are facing significant challenges in staying competitive due to economies of scale, global market pressures, and shifting consumer perceptions of livestock farming practices [3]. PLT's technologies, such as rumen boluses, could offer a potential solution by increasing operational efficiency and reducing costs associated with animal health management [66]. These technologies allow small farms to optimize their resources, improve productivity, and enhance animal welfare, ultimately helping them compete more effectively in the market [67].

In large dairy herds, the use of rumen boluses significantly enhances economic efficiency by reducing veterinary costs through early disease detection and minimizing unproductive days [3]. The ability to continuously monitor health conditions ensures consistent milk production, which leads to fewer disruptions and greater profitability [68]. A farmer in the UK reported they were able to save 70p per cow per day by eliminating a minor ingredient from the diet, which helped raise the average rumen pH and increased the amount of night time feeding, all without impacting milk yield [69]. Additionally, rumen boluses reduce labour costs, as automated monitoring reduces the need for manual health checks, providing scalability and improved resource management in larger operations [70].

The initial investment in rumen boluses for dairy herds can be significant, with costs ranging from €100 to €350 per bolus, depending on the technology and sensor capabilities included. However, the financial return on this investment is heavily dependent on the accurate interpretation and timely response to the data provided by the boluses. Incorrect or delayed responses to the data can lead to a failure in capturing early warning signs and can result in missed opportunities to prevent costly health issues [71]. Misinterpretation of data, such as failing to recognize early signs of acidosis or missed estrous cycles as seen in the Table 1 below, can lead to unnecessary veterinary costs, lost productivity, or inefficient feed use, ultimately negating the potential savings from the technology [72].

	Cycle Length (days)	Conception Rate (%)	Slip (days)	Cost (€/day)	Year 1 (€)	Year 2 (€)	Total (€)	12 week breeding season 91.9% in calf (€)	15 week breeding season 95.7% in calf (€)
Cost of calving date slippage	21	55	11.55	3.81	44.0	13.5	57.5	52.90	55.10

Table 1 : The effect of a cycle loss on calving date and profitability [73]

Adoption of Precision Livestock Technologies

The adoption of PLTs has seen substantial growth globally, fuelled by advancements in smart sensors, automated monitoring systems, and data-driven analytics [74]. The precision livestock farming market size was valued at 4.18 billion dollars in 2024 (Figure 6) and is expected to grow at a compound annual growth rate (CAGR) of 8.1% from 2024 to 2030 [75]. However, despite its benefits, several barriers limit the widespread use of PLTs in dairy farming such as the perceived complexity, high initial costs, and lack of perceived immediate returns [76]. Providing financial incentives, training programs, and technical support could play a pivotal role in increasing the uptake of PLTs [77].

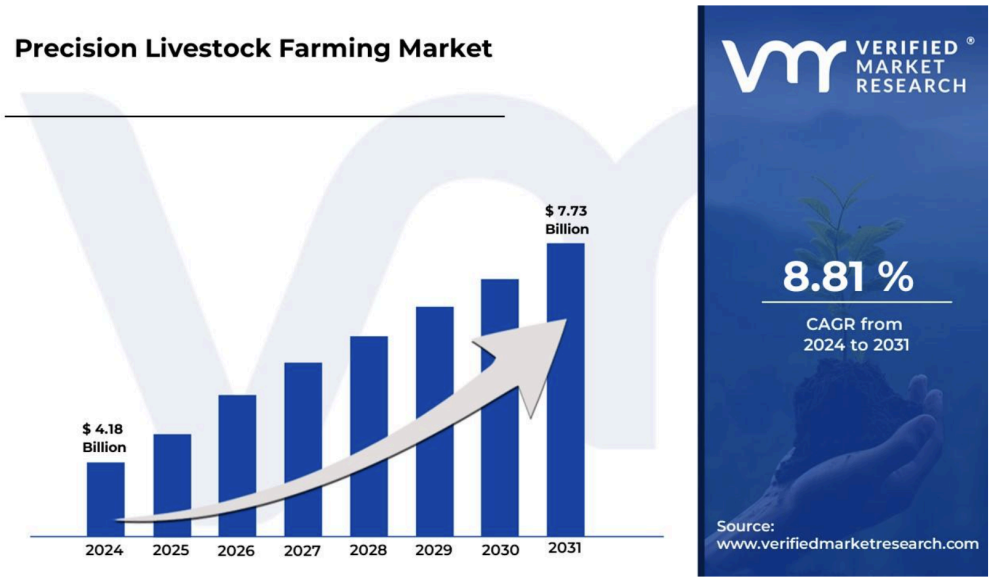


Figure 6: Projected growth of the global precision livestock farming market [75]

User-friendly interfaces and effective training programs can significantly enhance the adoption of PLTs by reducing perceived complexity and increasing confidence in technology use [78]. Reducing the perceived complexity of these technologies can increase farmers' willingness to invest and use them more effectively [79]. Confidence in utilizing these tools grows significantly when farmers are provided with targeted training programs that focus on real-time decision-making and practical applications. Farms that incorporate well-designed training initiatives see higher success rates in adopting PLTs and greater economic benefits from their implementation [80].

Privacy concerns around data are becoming a barrier to the adoption of PLTs in farming. Farmers are often hesitant to adopt PLTs due to fears over the security and ownership of the data collected by these systems. Since PLTs generate vast amounts of sensitive data about farm operations, there is growing concern about how this data is used and whether it could be misappropriated by third parties [81]. Without clear data-sharing agreements and privacy protections, farmers fear that sensitive information could be exploited, leading to potential financial or competitive disadvantage [82].

Rumen Boluses

Rumen boluses are a specialized form of precision livestock technology designed to provide real-time data on the physiological status of cows [83]. Rumen bolus systems became commercially available due to rapid advancements in battery and IoT (Internet of Things) communication technologies in recent years [84]. These devices are inserted into the cow’s rumen, (specifically reticulum), where they monitor parameters including pH, temperature, and activity levels, providing critical insights into rumen function and overall health [22]. Combining rumen bolus data with other PLTs, such as activity monitors and feeding systems, farmers can develop a comprehensive health management strategy that addresses both individual animal and herd-level needs [84]. The bolus is applied using a regular bolus gun. The bolus is made of acid-proof resin, which safeguards the electronic components and ensures it causes no harm to the animal's internal environment [85]. The inside of the bolus can be seen in Figure 7 below.

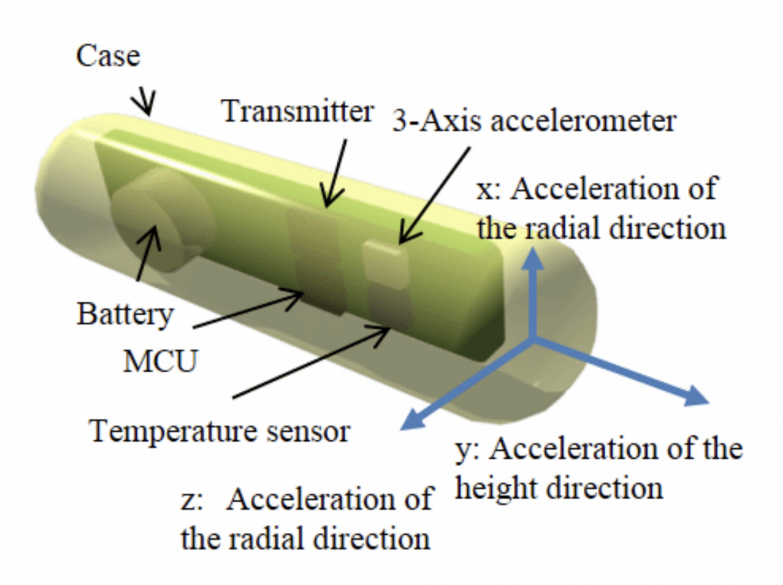


Figure 7: Model of a bolus-type sensor node [86].

Moonsyst

Founded in 2014, Moonsyst is a cattle monitoring company. They use a rumen bolus system that captures rumen data in real time and transmits it through a communication gateway to cloud-based servers accessible via phone or PC [87]. Farmers can use the Mooncloud software application to view information from anywhere in real time. Suitable for animals over 350 kg, the bolus monitors heat, health conditions, activity levels, rumen temperature, movement, and communicates with a gateway across a wide geographical range [88]. The boluses offer a 6+ year lifespan/battery life [85]. The rumen bolus, seen in figure 8 below measures temperature, activity and water intake at a cost of €99 per device and the smart rumen bolus pH which measures temperature, activity, water intake and pH is €349 per device.



Figure 8 : The moonsyst smart rumen bolus. It is 100 mm × 32 mm in size and 200g in weight [88].

Aims/Goals of Investigation

This study aims to assess the benefits of rumen boluses in dairy cows by examining cow temperature and activity levels during critical periods such as calving, breeding, and health events. By analyzing this data, the study seeks to identify specific advantages that rumen boluses offer in supporting herd health and productivity. In a constantly evolving economic climate for milk production, optimizing farm efficiency is essential for sustaining profitability. This research will highlight the areas where rumen boluses can contribute to improved herd management and profitability for dairy farms.

Materials and Methods

Production Study Details

The farm of Pat Gough, in County Waterford, Ireland, was used for the purpose of the study. The herd consists of approximately 174 milking cows with a grazing platform of 71 hectares. The overall area farmed is 105 hectares with the remaining 34 hectares used for heifer rearing and silage production. The predominant breed present on the farm is Holstein Friesian with a rising percentage of the herd being part Jersey. Cows are milked at approximately 7:30am and at 5:00pm.

Grazing Management

The farm operates a spring calving pasture system of production with a rotational grazing system from calving in late January or when weather conditions permit until housing in November. Cows are typically supplemented with 1000/1100 kgs of concentrates every year, in 2024 cows will be supplemented with approximately 1550kgs due to a late spring and poor summer grass growth. The predominant grass variety present in the swards on the farm is perennial ryegrass and clover. The overall current stocking rate on the farm is approximately 2.24LU/ha and on the grazing platform approximately 2.87LU/ha.

Data Collection

The data collected was based on the 2024 lactation. Animal activity data (heat alerts, calving alerts, and health alerts) were accessed through the Mooncloud web application. User ID and password for the Mooncloud application was obtained from the farmer to access individual animal records. The data was then collated for interpretation and analysis.

Results

Alert Types



Figure 9: Increased activity alert from moonsyst bolus

Figure 9 is showing an individual cow's temperature in the top chart and activity in the bottom. This cow is an example of having increased activity which is represented by the orange segment on the bar chart labelled very high activity.



Figure 10: High temperature alert

Figure 10 is an example of a cow with a high temperature. This can be seen on the top chart when the temperature recorded was at the 42 degrees Celsius line.

Eartag	Heat Event	Alert	Illness Event	Diagnosis	Action
1536		N/A	19-Mar-24	E. Coli Mastitis -Fatal	Charts Available
1709	02-May-24	Yes	17-Oct-24	Viral Infection	Reviva
1714	30-Apr-24	Yes	20-May-24	Shoulder Injury	Non-steroidal anti-inflammatory
1722	09-Jul-24	Yes	07-Aug-24	262 scc	Followed treatment protocols
1739	22-May-24	Yes	16-Nov-23	Lameness	Hoof Trimmer
1751	11-May-24	Yes	28-Jun-24	Mastitis	Followed treatment protocols
1761	23-Apr-24	Yes	12-Mar-23	Milk Fever	Calcium Bolus 12 hours apart
1768	12-May-24	Yes	31-Jul-24	Viral Infection	Reviva
1771	11-May-24	Yes	11-May-24	Heat Stress/Bulling	Reviva
1774	22-Apr-24	Yes	11-Sep-24	Failed CMT	Masprep Tube
1783	14-May-24	Yes	28-Apr-24	Caught up in Heat Activity	Voluntary Waiting Period
1787	23-Apr-24	Yes	10-May-24	Chronic Lung Disease -Fatal	Video Available
1798	28-Apr-24	Yes	24-Mar-24	Viral Infection	Reviva
1809	08-May-24	Yes	26-Jun-24	Failed CMT	Masprep Tube
1820	16-May-24	Yes	12-Mar-24	Failed CMT	Masprep Tube
1849	31-May-24	Yes	07-May-24	Shoulder Injury	Non-steroidal anti-inflammatory
1850	06-Jun-24	Yes	21-Feb-24	Metritis	Followed treatment protocols
1853	07-May-24	Yes	17-May-24	Viral Infection	Reviva
1855		None	21-Mar-24	Severe lameness	Culled
1863	22-Apr-24	Yes	16-Feb-24	Retained Placenta	Followed treatment protocols
1883	27-Apr-24	Yes	02-May-24	Viral Infection	Reviva
1886	30-Apr-24	No	30-Mar-24	Retained Placenta	Followed treatment protocols
2412	09-Jun-24	Yes	16-Feb-24	Metritis	Followed treatment protocols
2436	16-Apr-23	Yes	05-Feb-24	Bacterial vaginosis	Followed treatment protocols

Table 2: Health and heat alerts of cows during the 2024 lactation with health event confirmed by farmer

Out of the cows listed in Table 2, alerts were sent to the farmer for all of them when cows were in heat. An alert was sent for 21 out of the 24 illnesses recorded. An alert may have been triggered by a high temperature, low temperature, decreased activity or increased activity. The confirmation of health events by the farmer validates the bolus technology's accuracy in detecting clinically relevant health issues when an alert is sent.

Fertility

Parity	Mean Calving Date	First Heat Post Calving	Days to First Heat	Projected Calving Week 2025
1	07/02/2024	18/03/2024	31.6	22.1
2	29/02/2024	05/04/2024	36.2	18.1
3+	22/02/2024	02/04/2024	40.3	23.4

Table 3: Breeding report summary by parity

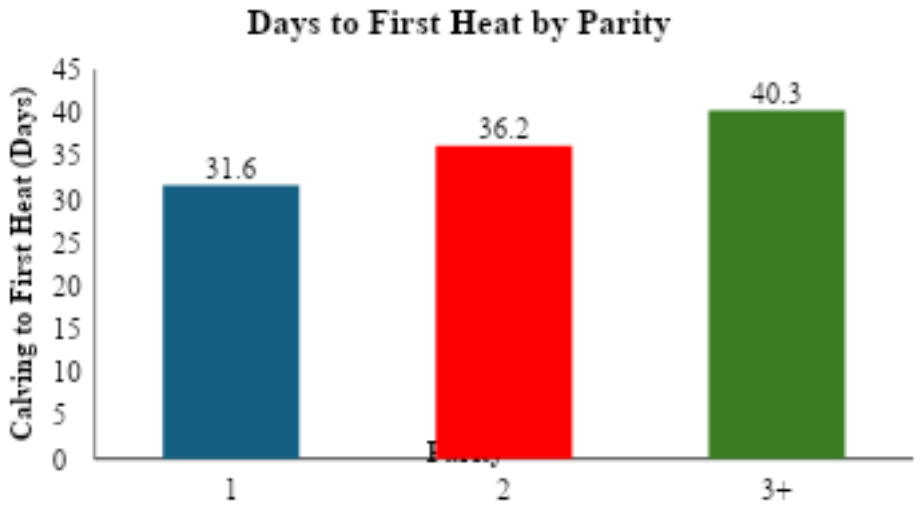


Figure 11: Days from calving to first heat by parity

The animals were split by parity into 3 groups - Parity 1, parity 2 and parity 3+. The mean calving date of the animals were all in February. The days to first heat increased by 8.7 days from parity 1 to parity 3+. Animals in parity 1 averaged 31.6 days from calving to first heat while parity 2 and parity 3+ took 4.6 and 8.7 days longer than parity 1.

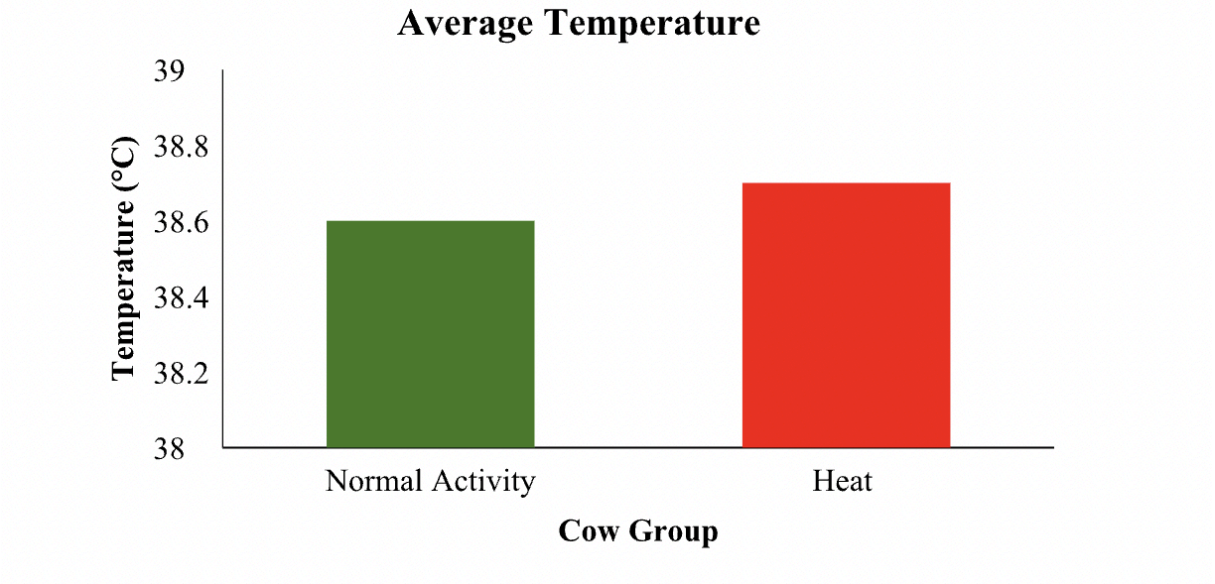


Figure 12: Average temperature for cows in heat versus normal activity

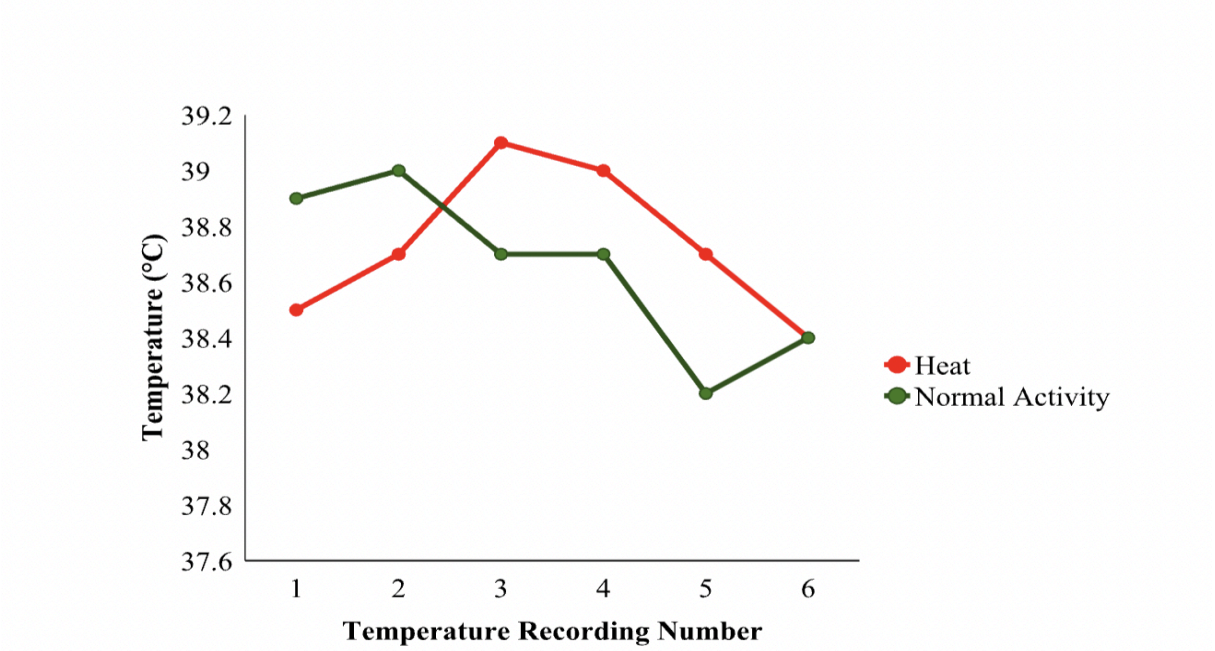


Figure 13: Temperature profile of cows with normal activity versus cows in heat across six recordings

As seen in Figure 12 and Figure 13 above, recorded temperatures in cows increase when the animals were in estrus/heat compared to animals with normal activity. This rise in temperature

is consistent with the physiological changes associated with heat, indicating a reliable correlation between elevated temperature readings and estrous cycles in cows.

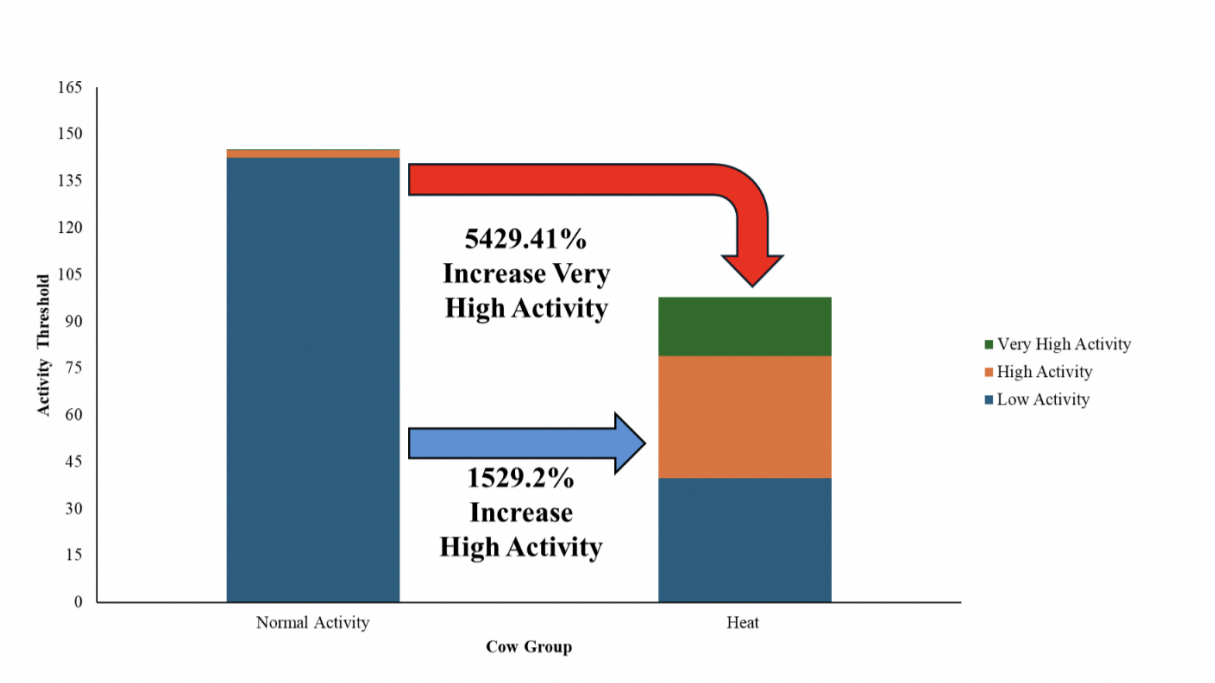


Figure 14: Activity level for cows in heat versus normal activity

The bolus classifies activity into low activity, high activity and very high activity. Cows in heat had an increase of 5,429.41% in very high activity and 1,529.2% in high activity compared to those animals that were not in heat.

Health

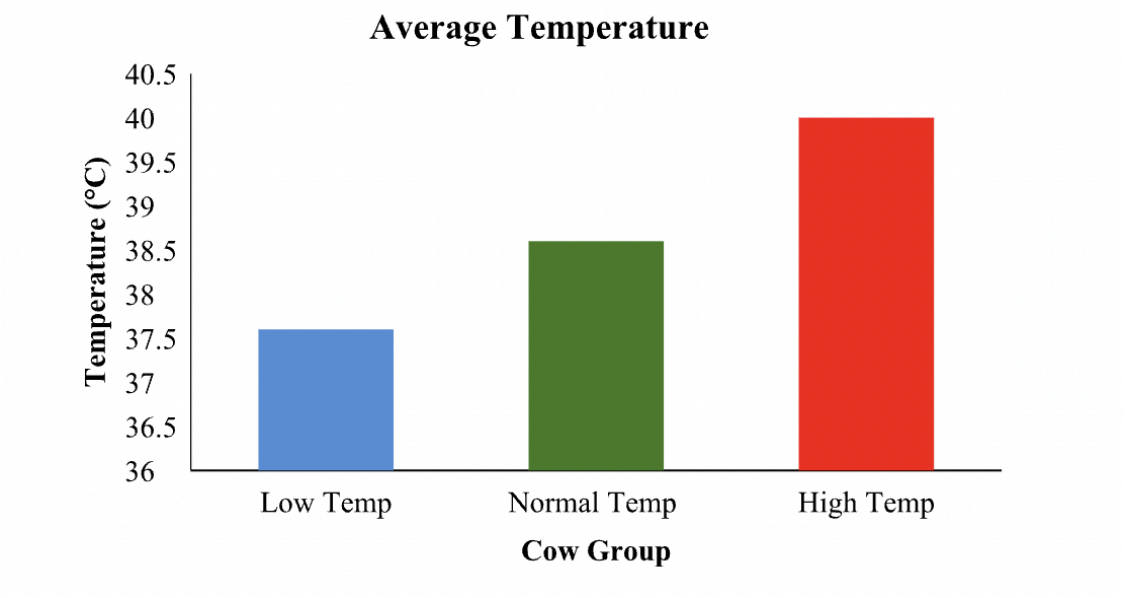


Figure 15: Average temperature for cows classified as having low, normal or high temperature

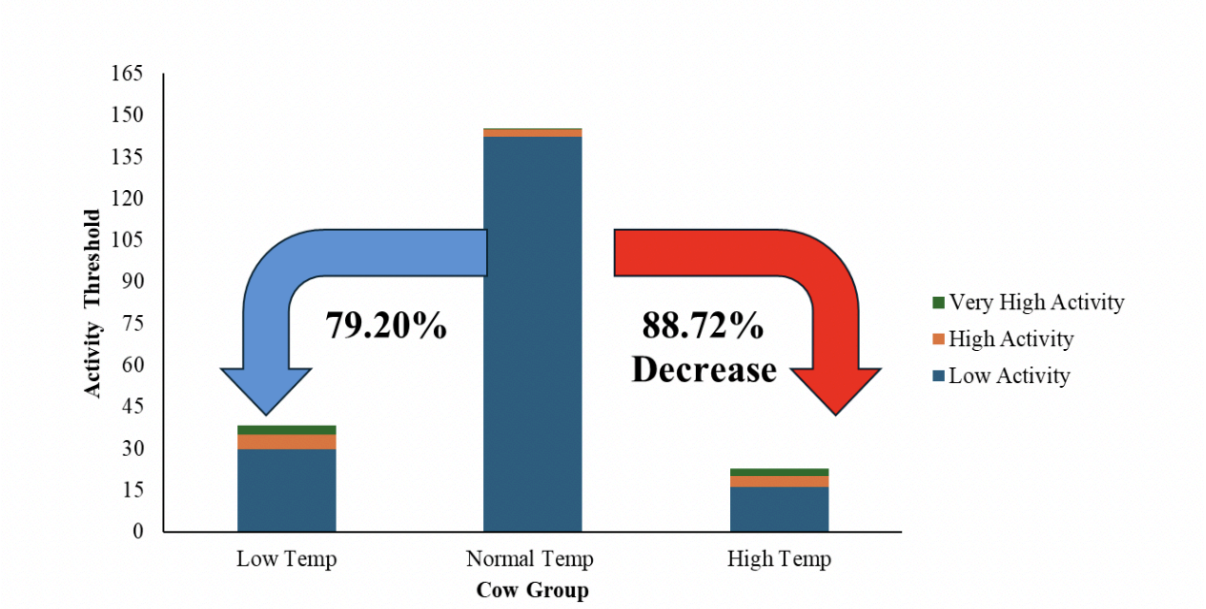


Figure 16: Activity level for cows classified as having low, normal or high temperature

	Activity Level			Temperature Recording Number						
Group	**Low Activity**	**High Activity**	**Very High Activity**	**1**	**2**	**3**	**4**	**5**	**6**	**Average Temperature (°C)**

Low Temp	29.6	5.4	3.3	37.4	37.6	37.34	37.6	37.8	37.9	37.6
Normal Temp	142.4	2.4	0.3	38.9	39	38.7	38.7	38.2	38.4	38.6
High Temp	16.1	4.2	2.5	40.2	40.2	40.1	38.9	39.7	39.8	40

Table 4: Profile of cows with low, normal and high temperatures

Cows with a low temperature had an average temperature of 37.6°C, compared with cows classified as having normal temperature of 38.6°C and cows flagged with a high temperature averaged a temperature of 40°C across six recordings (Table 4). The low temperature cows recorded 112.8 less low activity levels than cows with a normal temperature. Cows with a high temperature recorded 126.3 less low activity levels than cows with a normal temperature. Low temperature cows recorded 3.0 greater high activity levels than cows with a normal temperature and cows with a high temperature recorded 1.8 greater high activity levels than normal temperature cows. Cows with a low temperature recorded 3.0 greater very high activity levels than cows with a normal temperature and cows with a high temperature recorded 2.2 greater very high activity than cows with a normal temperature.

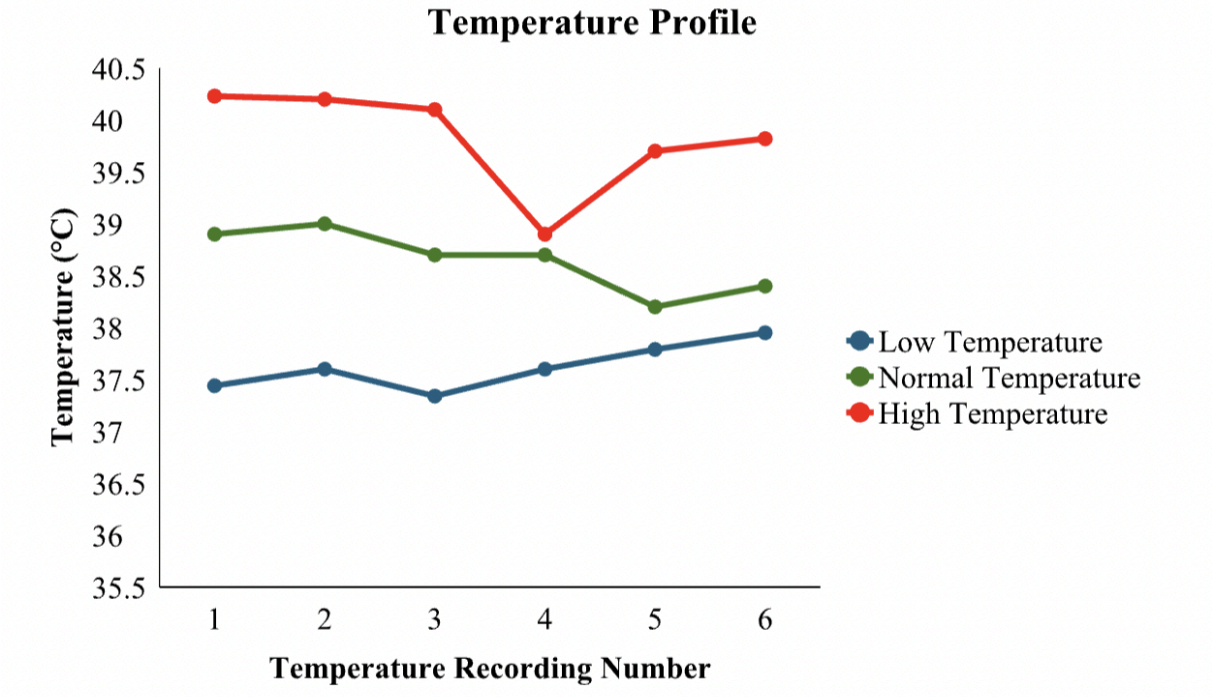


Figure 17: Temperature profile of cows with low, normal and high temperatures across six recordings

Discussion

Health

The diverse range of conditions detected in the results, from viral infections to lameness highlights the usefulness of rumen boluses in providing early indicators that facilitate early intervention. By identifying subtle physiological changes, these alerts enable farmers to respond before conditions become severe, thereby reducing treatment costs, preventing production losses, and improving overall animal welfare, consistent with previous findings [3]. Additionally, the confirmation of health events by farmers validates the accuracy of bolus technology. This early detection capability is particularly valuable in pasture-based systems where animals graze for extended periods potentially leading to missed clinical signs.

Fertility

Increased activity levels in cows during heat rise particularly in the high and very high activity segments, along with an increased temperature act as reliable indicators of estrus behaviour. As seen in the results, cows in heat had an increase of 5,429.4% in very high activity and 1,529.2% in high activity in high activity levels compared to those animals not in heat. These results highlight how boluses can be used to improve reproductive management by monitoring changes in activity and rumen temperature that signal estrus behaviour. This is consistent with previous findings [23] which noted the potential of bolus data to serve as an indirect estrus detection tool, enabling farmers to time artificial insemination (AI) precisely.

Conclusion

The results in this thesis underscores the substantial benefits of rumen boluses in managing dairy cows within Ireland's pasture-based system. By providing real-time monitoring of key health metrics, these devices allow farmers to detect early signs of health issues, significantly reducing the costs and losses associated with delayed interventions. The data collected supports proactive management of conditions including milk fever, mastitis, and lameness, which aligns with the goals of improving overall herd health and reducing reliance on labour-intensive monitoring practices. As demonstrated by the findings, rumen boluses play an essential role in optimizing health management, ultimately contributing to improved productivity and animal welfare.

Furthermore, rumen boluses have proven valuable in enhancing fertility management by enabling precise monitoring of estrous cycles and reproductive health. The use of these technologies minimizes missed breeding opportunities and helps maintain optimal calving intervals, which are crucial in pasture-based systems where aligning peak lactation with grass growth is essential. By improving reproductive outcomes, rumen boluses support more consistent production cycles, enhancing farm profitability. This benefit is especially valuable in a sector where production efficiencies and timely breeding can directly influence economic sustainability.

However, despite the demonstrated advantages, the adoption of rumen boluses is influenced by barriers such as initial investment costs and the need for specialized training. Although, the economic benefits from improved productivity, reduced veterinary costs, and enhanced animal welfare can offset these initial challenges over time. As precision livestock technologies continue to evolve, the integration of user-friendly features and supportive training initiatives could encourage broader adoption, thus further advancing sustainable and profitable dairy farming practices. The insights from this study supports the benefits of rumen boluses and their potential as a key component in modern dairy herd management.

If one was to further investigate, a larger data set with multiple herds would be beneficial allowing for a more comprehensive analysis of the production, welfare and economic benefits

Acknowledgments

I would like to thank my supervisor Professor Szenci Ottó for his guidance. I would also like to thank Gerard Carty, Desmond Savage and Peter Gesler from Moonsyst and Pat Gough for helping me collect the data used. I would like to thank Dr Rachel Doyle for her continuing help sharing her knowledge. I am incredibly grateful to all my family and friends for their unwavering support throughout my veterinary journey. A special thank you to Bill and Sinead Carroll for their constant belief, assistance, and encouragement.

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