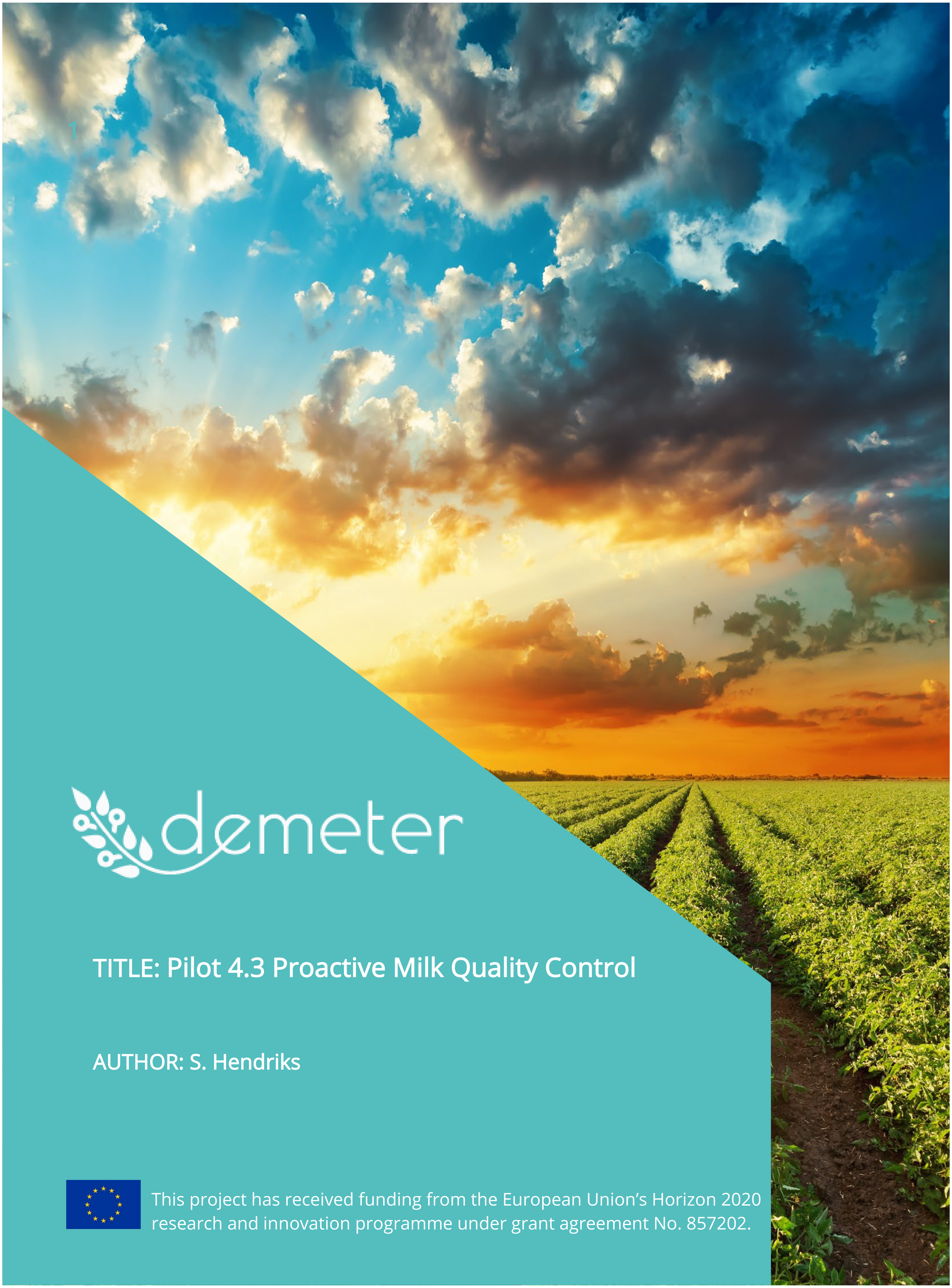

# TITLE: Pilot 4.3 Proactive Milk Quality Control

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# Pilot 4.3 – Proactive Milk Quality Control

## 1 Introduction

DEMETER aims to lead the Digital Transformation of the European agrifood sector based on the rapid adoption of advanced technologies, such as Internet of Things, Artificial Intelligence, Big Data, Decision Support (DSS), Benchmarking, Earth Observation, etc., to increase performance in multiple aspects of farming operations, as well as to assure the viability and sustainability of the sector in the long term. It aims to put these digital technologies at the service of farmers using a human-in-the-loop approach that constantly focuses on mixing human knowledge and expertise with digital information. DEMETER focuses on interoperability as the main digital enabler, extending the coverage of interoperability across data, platforms, services, applications, and online intelligence, as well as human knowledge, and the implementation of interoperability by connecting farmers and advisors with providers of ICT solutions and machinery.

DEMETER focuses on the deployment of farmer-centric, interoperable smart farming-IoT (Internet of Things) based platforms, to support the digital transformation of Europe's agri-food sector through the rapid adoption of advanced IoT technologies, data science and smart farming, ensuring its long-term viability and sustainability.

Twenty real-world pilot projects, grouped into five pilot clusters, are running within DEMETER to demonstrate and evaluate how agricultural innovations and extended capabilities benefit farmers, technology providers, and society. The topics, scope and size of the pilots are diverse, from saving resources, such as water and energy, to a more environmentally compatible crop management with reduced application of fertilisers and pesticides, to improved animal welfare and the tracing of complete supply chains.

This white paper describes the pilot 4.3 'Proactive Milk Quality Control'. The overarching aim of our project is to integrate animal behaviour and other physiological data into a welfare and health scoring framework with the progression to a reference system that could increase animal well-being standards on dairy farms.

## 2 Importance of digital agriculture

Animal health and welfare is an important component of agricultural sustainability. There is increasing evidence that supports the complex trade-offs and synergies between all dimensions of food production systems, and therefore, changes on farm that aim to improve dairy cow health and welfare have the potential to impact other domains such as the environment. Environmental impacts and agricultural sustainability are of concern to key stakeholders, in particular, farmers due to increased regulation to measure, manage, and reduce environmental impacts. Greater rates of disease in dairy cows can increase greenhouse gas emissions per unit of milk production due to reduced efficiency and reduced lifetime productivity of an animal. Therefore, providing producers with new tools to reduce disease and increase the lifetime of animals within the herd may have significant impacts on a farm's emissions profile. Therefore, digital solutions to improve health and welfare are of interest to farmers, food suppliers, and public citizens.

Animal welfare is another key area of interest to these stakeholders. Dairy cow welfare assessment protocols are being increasingly implemented by industry stakeholders to characterise the welfare of dairy cows on farms and there is growing interest to use these protocols in accreditation programs. Dairy cow welfare assessment protocols are typically a set of animal centric and on-farm measures that may be subjective or objective in nature and can be used to assess the overall welfare of animals at the farm-level. These assessments can also help producers to assess how well they are meeting codes of practice for the care and handling of their dairy animals. It is widely agreed that dairy cow welfare assessment protocols should focus on using animal-based measures to accurately reflect welfare on farms; however, the use of animal-based measures can be time consuming and expensive to obtain, and these are major limiting factors in the implementation of dairy cow welfare assessments. It is possible that this limitation could be addressed to some extent by using data that is already routinely collected or is automatically collected on farms where sensor technologies measuring animal-based indicators are already installed. Then this data could be utilised and integrated into a welfare assessment framework. The use of technology is a unique opportunity to reduce the time required to collect animal-based measures for the assessment of animal welfare on farms.

Digital solutions may allow some of the assessment process to be automated and due to the ability to capture large amounts of data across time, it may also allow welfare to be assessed on a long-term or continuous basis. Recommendations from the EU-funded Welfare Quality® project indicate that development of automatic measures of welfare to reduce the duration of the welfare assessment, while remaining animal focused, should be a focus of future research. Animal behaviour is one key animal-based measure that is an important indicator of dairy cow health and welfare. Due to recent development in wearable technologies, animal behaviour can now be continuously monitored using commercially available wearable sensor devices. However, few farmers are adopting such technologies, and therefore, wider adoption may be required before wearable sensors could be part of welfare assessments. A key barrier for farmers investing in and fully utilising these technologies is that the commercially available technologies typically use different platforms to collate and analyse data, particularly if the technologies are owned by different commercial companies. Therefore, different systems and software's installed on farms rarely 'talk to each other', requiring farmers to interpret the information individually. Solutions that aim to better integrate data collected at farm-level, irrespective of the technology deployed to collect the data, may improve the usage and uptake of new technologies and improve their practical applications. This could support farmers to extract more value from their farms data while simultaneously allowing aspects of animal welfare to be continuously assessed. The use of digital solutions at the farm level for the monitoring and assessment of animal welfare could provide information that can be relayed back to the consumer and other stakeholders along the supply chain, so that more information is available regarding the food production process. This would help to position the dairy industry as a sustainable food production system.

# 3 Pilot Overview

<u>Challenge</u>

Health management is an important aspect of successful dairy farming and farmers have traditionally relied on their animal husbandry skills to observe and identify animals that are unwell or may be suffering from compromised welfare. Over the last decade, herd sizes have increased and continue to increase in many countries. Consequently, farmers sometimes need to hire additional staff to assist with on-farm tasks; however, farmers are reporting that they are finding it difficult to find skilled labour. In these situations, staff employed may have received little training or have limited experience in animal husbandry and animal care, and due to these larger herd sizes farmers have limited time to monitor individual cows. There is interest in finding novel ways to better detect health and welfare issues using existing and new technologies, and as a result, farmers are increasingly adopting

technologies to support dairy cow health management. One example is the use of wearable behaviour-monitoring technologies.
Wearable behaviour-monitoring devices can be fitted to a cow through ear tags, leg bands, or neck-worn collars and gather large amounts of data from individual cows through continuous monitoring. There are a range of behaviour-monitoring devices on the market, and they allow the monitoring of a range of different behaviours such as activity, and time spent ruminating and lying. The data that these devices can provide may be of value to improve cow health management. However, we must support farmers to interpret and utilise the information from these technologies to allow these tools to have real impact on farms.

Dairy cows alter their behaviour when they are unwell, and many behaviour-monitoring devices will alert a farmer to these abnormal changes. But the alerts are often not specific to a problem and require farmers to interpret the results from the sensor themselves. Therefore, a lack of training of farmers and advisors in how to utilise this information means the data is underutilised. Further, farmers routinely record other information about cow health and may use other monitoring technologies such as milk production recording inside the dairy parlour. Farmers have large amounts of data available, and many have digitalised records, but few software's or programmes combine behaviour data with other routinely collected farm data. This is a missed opportunity to extract value from this data. Combining data from multiple sources may allow individual cows' problems to be predicted and characterised and support farmers to make specific actionable decisions on-farm. Further, improved monitoring of individual animals provides an opportunity to provide assurance that food comes from production systems where the health and welfare standards for animals are high.  Thus, it is necessary to develop alternative systems to monitor welfare and health issues.

## Aim

software's or programmes combine behaviour data with other routinely collected farm data. This is a missed opportunity to extract value from this data. Combining data from multiple sources may allow individual cows' problems to be predicted and characterised and support farmers to make specific actionable decisions on-farm. Further, improved monitoring of individual animals provides an opportunity to provide assurance that food comes from production systems where the health and welfare standards for animals are high.  Thus, it is necessary to develop alternative systems to monitor welfare and health issues.

**Where pilot is being deployed and who are the partners on this pilot**

The pilot is being deployed on 1 commercial dairy farm milking approximately 700 cows in Somerset in the United Kingdom. The data for the project is being collected on this farm by a dairy farmer and his experienced farm staff. We (Teagasc, Ireland) are partnering with four other groups to undertake this research. Firstly, Zoetis, an animal pharmaceuticals company, is providing dairy cow behaviour data through their commercially available SMARTBOW ear tag. Zoetis are also a commercial partner interested in potentially commercialising any new innovations from the project and bringing these to the market so that these innovations could support dairy farmers. Secondly, we are working alongside Tyndall (Tyndall National Institute, Cork, Ireland) to develop new sensors that could allow specific indicators of illness to be detected in milk. Tyndall are developing a point-of-care test that allows up to 6 different analytes to be measured in milk that may be indicators of health disorders. The point-of-care test is one of the key commercialisation opportunities within our pilot where our partner Zoetis may commercialise this sensor. The Walton Institute (Ireland) is involved in creating a dashboard where sensor and non-sensor information will be integrated to identify dairy cows experiencing health problems and compromised welfare.

**Solution/Innovation**

A key innovation of the project is to develop a novel sensor to detect indicators of illness in milk to potentially improve the accuracy of disease monitoring. The sensor being developed is a point-of-care test that allows up to 6 different analytes to be measured in a single drop of milk. To our knowledge, most point-of-care tests for monitoring dairy cow health that already exist on the market are singleplex, and therefore, can only measure one analyte, and consequently, only one disorder can be identified (e.g., ketosis by measuring blood ketone concentrations). Additionally, these previous point-of-care tests have been predominantly developed for the measurement of analytes in blood requiring blood sampling, which is invasive and labour intensive unlike milk collection. Further, cows are already milked daily, and therefore, there is potential for testing to be semi-automated if embedded into pre-existing milking parlours and robots for ease of milk marker determination. To support the development of this point-of-care test, our project aims to investigate concentrations of milk analytes in clinically healthy Holstein dairy cows and those experiencing health conditions to determine whether analytes in milk can be used as disease indicators. Due to the sensor being in the development stage, milk analytes need to be determined using standard laboratory methods in samples ollected on a commercial farm from dairy cows. This data will be available alongside other sensor and non-sensor data for integration into a dashboard.

Sensor information will include information from commercially available technologies as well as data from novel sensors. A range of commercially available wearable behaviour monitoring devices are available on the market and these devices are already being deployed on some farms, which will allow behaviour data to be included. In addition, milk recording systems are also readily available, and many farms have these installed in their dairy parlours, and therefore, milk yield information will also be available. Access to these proprietary services will allow data to be continuously collected via commercially available sensors.
Non-sensor information that is routinely recorded at the farm-level will include cow health management (recorded health problems and treatments), cow history (age, breed, and calving difficulties), periodic milk quality (somatic cell counts, and fat and protein content), and weather data (humidity, temperature, rainfall).

The non-sensor and sensor data described in the previous sections will be used to develop a dashboard. Dashboards that provide information about behaviour and milk production exist but most fail to integrate this data with other readily available on farm metrics and data. Further, to our knowledge, most dashboards fail to provide farmers with specific information to manage or treat problems that animals may be experiencing. The aim of Pilot 4.3 is to integrate non-sensor information that is routinely recorded on dairy farms with information from commercially available and new innovative sensors to identify cows experiencing health problems and compromised welfare.

**Key Benefits**

By the end of the project, we aim to have a fully developed and validated cow-side test that can detect the concentrations of up to 6 analytes in milk which may allow the identification of intramammary (inside of the mammary gland) and extramammary (outside of the mammary gland) conditions to be detected using non-invasive methods. We aim to have established the relationships between milk analytes, cow behaviour, and health outcomes to better understand how integrating this data may allow for the earlier identification of health issues and welfare compromise. We also hope to have integrated this data into a dashboard that can alert farmers to cows requiring attention.

We foresee that the integration of additional information in a dairy health monitoring platform can provide improved real-time monitoring of the health and welfare of dairy cows. Early and accurate identification of health problems in dairy cows has the potential to improve health and welfare on farms. Providing specific information about dairy cow health will support farmers to make decisions about intervening and treating health problems and as a result improve dairy cow health and welfare. In addition, documentation, enabled by data capture, analysis and record keeping developed in the pilot will allow transparency in animal health and welfare status and management on-farm. In the future, integrated dairy cow health management platforms may support the development of objective animal-based measures of health and welfare that could be used in dairy cow welfare auditing programmes.


*Images 1-2: Dairy cow fitted with SMARTBOW ear tag behaviour monitor (Left) and close up of the SMARTBOW ear tag (Right).*


*Images3-4. Example of a point-of-care (hand-held) sensor that could allow analytes in milk to be rapidly detected (Left) and display of sensor reading on a smartphone (Right).*

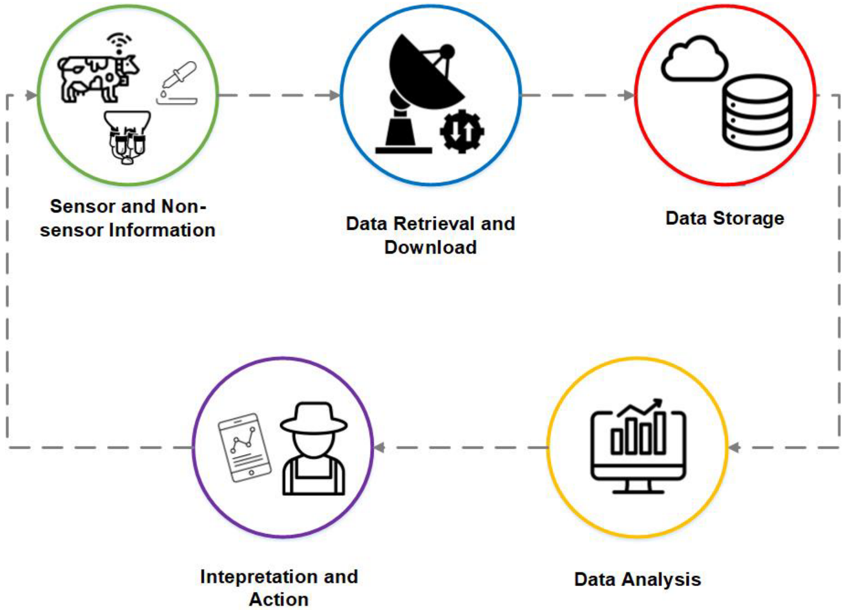


*Image 5. Example of monitoring using sensor and non-sensor data, integration into interpretable information to support farmers to make decisions on farm.*

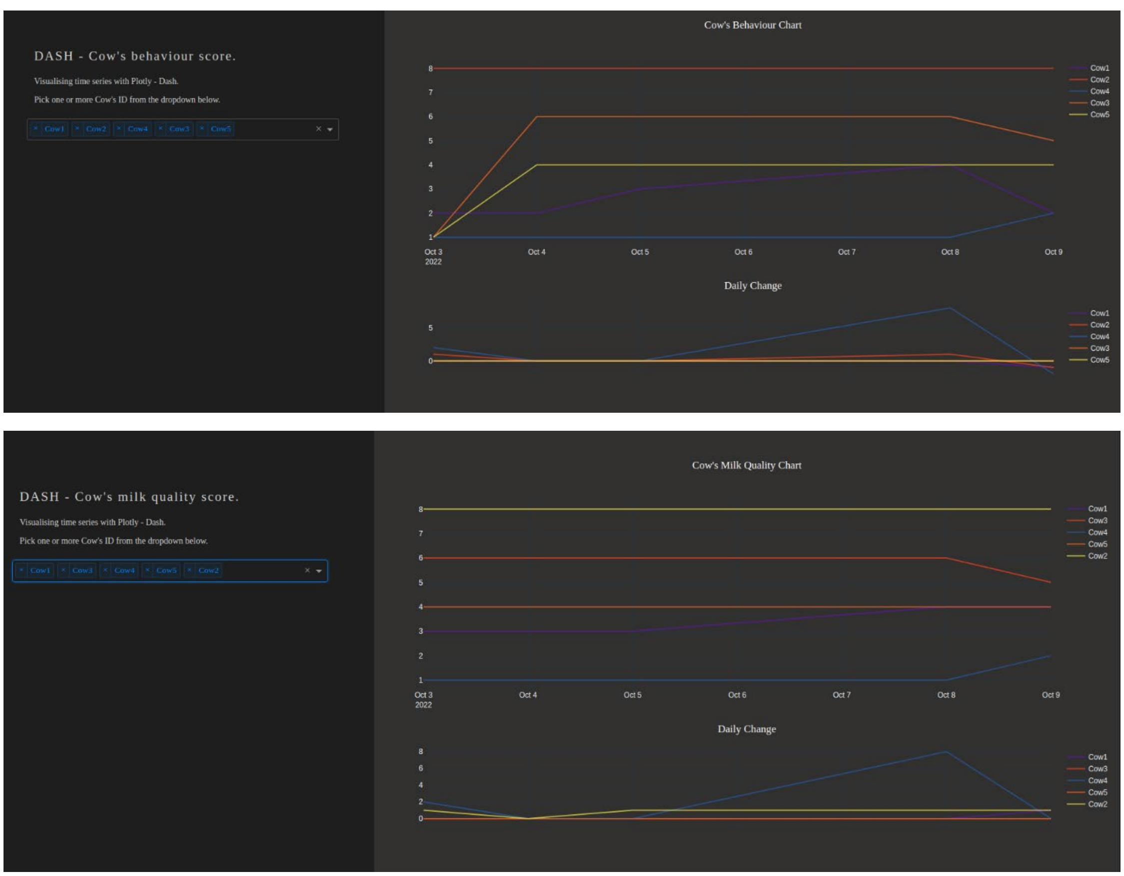


*Image 6-7. Screenshots of the current prototype for the dashboard where farm data will be displayed visually.*

## 4. DEMETER Integration

<u>Key technologies employed</u>

There are two key technologies employed in the project. Firstly, SMARTBOW is a commercial ear tag that allows the monitoring of dairy cow behaviour including rumination, activity and lying behaviours. Individual animal health data were recorded by farm personnel using the Uniform-Agri database. UNIFORM-Agri is a commercial platform that allows the recording of animal health problems, treatment of health issues, body condition score, and milk production data. Data from these two pre-existing technologies will be integrated with the DEMETER enable (Herd Health Monitor). As the point-of-care test for determining milk analyte concentrations was still under development, milk analyte concentrations were also determined using standardized laboratory methods including enzyme-linked immunoassays (ELISA) and colorimetric assays. This data will also be integrated into the Herd Health Monitor described below.

<u>DEMETER enablers and other technologies</u>

The DEMETER enabler being employed is the WP4: Herd Health Monitor which aims to monitor and predict animal health and welfare on farm. The purpose of the development of this enabler is to: 1) create a data fusion platform where the data from different sensors will be integrated and a predictive model developed for various well-being characteristics of the cow, and 2) create a well-being audit for dairy cows that may be used as a reference standard to develop management systems that improve animal well-being and that may also be used as a reference standard in the marketing of milk.

*AIM usage*

AIM: The DEMETER Agriculture Information Model, a common semantic data model.

*Importance of DEH*

As an enabler owner: For the enabler to be considered a DEH Enabler, the same requirement to be registered with RRM, and the exposed REST APIs needed to follow the AIM data model. Once the enabler is registered with RRM, the same will be assigned a unique reference ID called UID or RRM_ID. This ID will be used as an Identifier of the specific Enabler across the DEMETER ecosystem. As an enabler user, the pilot will refer UID or RRM_ID to the RRM (resource registration manager) to identify the enabler of interest.

# 4 Feedback from farmers

<u>Farmer interactions</u>

The key engagement for this project has been with the farmer where we collected data for the proof-of-concept research project. At this stage we have not engaged directly with larger groups of farmers, however, we have engaged with others either directly or indirectly involved with the farmer community including the general public and academic communities. We have engaged with these stakeholders by sharing our work through social media, blog articles, external presentations, and conferences.

Because the project is designed as a proof of concept using a novel solution, the feedback from farmers has been limited at this stage of the project. We foresee that if in the future the dashboard and point-of-care test are deployed in the field, then we could integrate farmer feedback into improving the innovations.

# 5 Benefits

The solutions and innovations developed in this project have several potential benefits to dairy cows and farmers as well as a range of stakeholders including dairy processors and suppliers, pharmaceutical companies, and public citizens. Key benefits for the farmer include improved and earlier detection of health problems on farms. Early detection of disease has several benefits including decreased antimicrobial usage, decreased labour and veterinary costs to treat sick animals, and improve welfare and lifetime of dairy cows.

***KPIs***

| KPIs | Time Bound | Target |
|---|---|---|
| Biomarkers developed successfully | End of project | 100% |
| Correct predictions of ill animals based on behaviour parameters | Annually | 95% |
| Percentage of cow herd healthy over entire lactation | Annually | 98% |
| Reduced use and cost of animal treatment | Annually | 10% |

## Benefits for key stakeholders

*Technical partners*

Zoetis may benefit through new commercialisation opportunities and products that could provide a competitive advantage such as the point-of-care test and the dashboard. Tyndall will benefit through knowledge acquisition of a new technique to create multiplex electro-chemical sensors using milk and blood as substrates.

*Dairy cows*

Firstly, dairy cows will benefit due to improved lifetime productivity through improved health outcomes. Dairy cows will be less likely to have painful experiences typically accompanying health conditions and have improved health and welfare.

*Dairy Processors and Suppliers*

Dairy processors and suppliers may benefit from improved marketability of dairy products from farms where they can demonstrate good animal welfare and improved milk quality demonstrating improved food safety and increased transparency about the origins of animal food products.

*Public citizens*

Public citizens may benefit due to improved milk quality and food safety. Increased disease in dairy cows increases antimicrobial use and the risk of antimicrobial resistance. This is a threat to public health. Disease is linked to lifetime efficiency of production where cows emit more methane per kg of product when unwell compared with healthy cows. This is a threat to meeting our climate targets within the agriculture sector and globally. Therefore, far reaching benefits include better health outcomes through less severe antimicrobial resistance issues and societal benefits from reduced climate impacts.

The data collected in the current project is being integrated into the dashboard retrospectively, and therefore, we foresee that in the future, we could deploy this dashboard across more cows and farms to validate the dashboard. The point-of-care test being developed by Tyndall also requires validation to determine if the device can accurately measure the analytes that it is being developed for.

# 6 Conclusion

We have undertaken our work in collaboration with a large 700 cow farm in the UK where we have collected behaviour, milk production, and milk analyte data to provide a proof of concept for the ability to use a point-of-care test to determine different metabolic and inflammatory analytes in milk, changes in milk production and behaviour data as indicators of health. We plan to also use this data retrospectively to develop a dashboard. Integration of additional information in a dairy health monitoring platform can provide improved real-time monitoring of the health of dairy cows. Providing specific information about dairy cow health will support farmers to make decisions about intervening and treating health problems and as a result improve dairy cow health and welfare. In the future, integrated dairy cow health management platforms may support the development of objective animal-based measures of health and welfare that could be used in dairy cow welfare auditing programmes. The involvement of DEMETER in our project has allowed us access to the necessary resources, expertise, and funding to develop a novel point-of-care test and to develop a dashboard.

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