SiallSCM: a nation-wide tool for milking monitoring to enhance efficiency and welfare of Italian dairy animals

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Introduction

The development of milking machines began in the late 19th century. Over the decades, the field of milking technology experienced significant improvements in performance, culminating in the complete automation of the milking process whit the advent of Automatic Milking Systems (AMS). Still nowadays, despite these advancements, the well-documented consequences of inconsistent milking due to improper functioning of milking machine continue to impact the udder health of dairy cows and hinder the competitiveness of farm. For example, poorly adjusted machine milking can contribute to the incidence of mastitis acting as vector of bacteria or causing traumas. Milking machine processes, including the equipment washing and cleaning can also influence milk quality diminishing its cheese yield potential. In conclusion, monitoring the milking process through data helps optimize labour time, which typically accounts for over 50% of the total labour input in the milking parlour.

Since 1970, the Italian DHI (AIA) has established and operated a national service called Milking Control Service (SCM). More than 100 highly skilled technicians serve within the SCM framework, with their distribution strategically aligned to the regional concentration of dairy farms. They are equipped with instruments to carry-out the dry test (flowmeter, pulsameter, vacuum gauge, etc). Equipment also includes VaDia® kit (Biocontrol, Rakkestad, Norway) and Lactocorders® (WMB AG, Balgach, CH). The SCM service operate in compliance with ISO standards 3918:2007, 5707:2007, 6690:2007 and 11008:2002.

SCM technicians assess the efficiency of milking systems through both dry tests (conducted without animals) and wet tests (performed with animals). Based on the test results, they calibrate the milking equipment, establish an effective milking routine, optimize the cleaning process and ensure the efficiency of milk cooling tank. Finally, in line with ICAR guidelines for DHI, the technicians ensure that the devices used for milk performance recording are functioning correctly. Those services will be further enhanced leveraging all herd available data and employing cutting-edge milking sensors. While milking technologies and devices efficiently generate massive and accurate information both on milking systems and animals, the real challenge lies in developing standardized methods for recording, organizing, and normalising this data and extract meaningful and ready-to-use information for farmers and technicians. To address this challenge, AIA developed a comprehensive procedure for monitoring the milking process and has engineered a software solution called SiallSCM. This system is designed to collect data, assist SCM technicians, and provide farmers with valuable tools to improve the efficiency and effectiveness of their milking operations. By integrating this solution with herd data and advanced milking sensors, AIA ensures a seamless approach to optimizing performance.

The App SiallSCM

The SiallSCM app is developed using Python 3.11.7, with the code written in the Spyder IDE. Spyder is an integrated development environment tailored for Python programming. In the development process, we utilized the CustomTkinter package, specifically its CTk() function, to create the main application window that gives users access to all available tools. Upon selecting a tool, corresponding child windows are displayed. The app incorporates various widgets and classes from the CustomTkinter package, including CTkButton, CTkLabel, CTkFrame, CTkToplevel, CTkRadiobutton, CTkCheckBox, CTkTextBox, and CTkEntry, to build the interface.

Each tool in the app is nested within its own class, which contains the functionality specific to that tool. Additionally, we create a main class that imports all the tool classes and assembles the complete GUI application. The project's file structure is neatly organized into three primary sections: data, GUI, and testing. The testing process was divided into several key steps: network testing (synchronization with the API), authentication, file sorting, data compilation and transmission to the central database, clearing the bin, and locating or extracting information from the database. The evaluation metrics used to assess performance included CPU utilization, memory utilization, and response time.

The Python script was then converted into an executable file. PyInstaller was used to bundle the Python application along with all its dependencies into a single package, allowing users to run the application without needing to install a Python interpreter or any additional modules. This packaged app can be run on both Windows and Linux operating systems, and it does not require an Internet connection for use.

The communication and data synchronization between the SiallSCM graphical interface and the AIA central database (SQL) is trough APIs. The communication framework is organized into six key API sets: user management, authentication, farm data extraction (retrieving general farm information from AIA's database), catalogue data extraction (including lists of milking machine types, models, and equipment), milking system configuration, and types of milking control.

When SCM technician logs-in with a personal password, a user token is generated, validating all synchronization activities (Figure 1), and identifying the technician's operational area, granting access to all farms within that area. Exceptions can be configured as needed. After successful logging in, the specific API allows the local storage of all machine systems and equipment catalogues in a JSON file.

The next step involves planning configuration and milking control activities. In this phase, the farm API is used to retrieve information on previously completed and synchronized activities, as well as the forecast for adding a new service.

At this stage, the user can enter all data and information related to the scheduled tests into the APP tables, with the flexibility to work both online and offline. Once data entry is completed, the APIs synchronize the data with the central database.

The AIA' R&D department conducted a comprehensive analysis to anticipate potential areas of information and data acquisition related to milking machines configuration, setting parameters and milking tests.

The procedure follows a farm-specific approach, allowing for the collection of all tests and information at farm level. After selecting a farm, the first step in data entry involves configuring the complete milking system and its equipment (Figure 2) filling specific masks on:

- Farm general information (species, type of milking machine, etc).
- Milking system general information (number of claws, dimensions, etc).

- Vacuum system (milking pump type, model and characteristics, vacuum pipelines dimensions, etc).
- Milk system (milk pipeline dimensions and characteristics, milk receiver, etc).
- Cleaning and washing system.
- Milking units (type of tubes, material, claws model, liners, etc).
- Pulsation systems (type, model and settings of pulsators).
- Recording device (type, model and number, if present).

Specific input forms are developed for entering data based on the specific milking test selected (Figure 3)

SiallSCM facilitate the data entry and analysis of the following tests. Data entry is controlled by the input field, restriction which is configured to accept strings of number of specific length and composition according with the parameter being entered.

- Dry test (not under milking conditions): this test includes a physical assessment of the milking machine and the measurement of vacuum capacity at appropriate points, vacuum gauge accuracy, milk system leakage;
- Wet test (under milking conditions): the test evaluates the performances of the milking machine and the interaction between cow, milker and the machine. It includes precise measurements of vacuum levels at the claw, the liners, and the accurate monitoring of milk flows during different phases of milking.

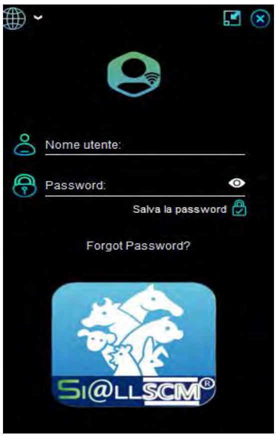

Figure 1. Authentication of SiallSCM.

Figure 2. Milking system configuration.

Figure 3. SiallSCM panel to initialize the selected test (left). Data entry mask for pulsation parameters and pump (right).

Figure 4. Data and information flow of SiallSCM procedure.

- Fall-of test: it assesses whether the system has enough airflow capacity to cope with a unit fall-off.
- Pulsation test: this test check whether the pulsator is correctly calibrated and ensure it remain consistent by monitoring various pulsation parameters and phases.

Table 1 shows the main parameters that can be collected for each test.

When used on-line, all tests' data and milking systems information are synchronized in real-time with the central AIA database and integrated with the DHI data, following two-tier normalization process.

The first tier of normalization ensures that data gathering complies with ISO standards by following official operative protocols. Additionally, the data gathering is validated using SCM' instruments and milking devices, which are officially calibrated at least once a year. The second tier applies a set of thresholds, from UNI-ISO standards, and algorithms to identify and flag any aberrant or outlier data entries.

Once the data has been processed and merged in the central database, it can be retrieved by the front-end application to generate dynamic, easy-to-read farm reports.

Table 1. Main parameters recorded per SCM test.

Test	Parameters
Dry test	working vacuum (kpa), effective reserve of milking (l/min), regulation sensitivity (kpa), vacuum pump airflow (l/min), airflow at vacuum and/or milk pipelines (l/m).
Wet test	claw vacuum during peak flow (kpa), bimodality, claw vacuum drop (kpa), milk flow during peak (kg/min), overmilking (min), milk yield overmilking (kg), overmilking (min), milking flows (kg/min).
Fall-off test	avg vacuum phase 1 (kpa), undershoot(kpa), vacuum drop(kpa), overshoot(kpa), avg vacuum phase 2(kpa), avg vacuum phase 4 (kpa).
Pulsation test	frequency (bpm), ratio (%), limping (%), dipping (kpa), a, b, c, d phases of pulsator (% and ms).

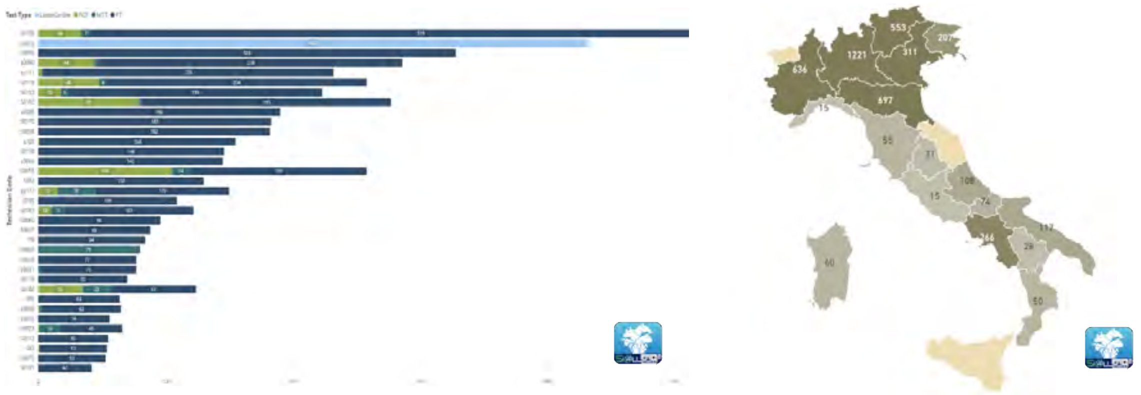

Figure 5. SiallSCM Power BI dashboards. Type of test per technician code (left). Farm tested per region (right).

Results and discussion

Data collected through the app

During the inaugural campaign of SiallSCM, held between September 2022 and April 2024, more than 500.000 milking machine milking machines configuration and setting parameters were acquired and about 25.000 pulsation tests were conducted on 1.255 farms by 56 SCM technicians. In addition, in the same timeframe, 4.348 milking wet test were performed involving 160.000 lactating animals and fall-of tests were carried in 398 farms. Finally, 2.374 data streams were uploaded from Lactocorder and Vadia direct link.

The tool and services potential spans the whole set of farms subscribed to DHI encompassing more than 15 thousand dairy farms and 1,5 million of heads (Table 2)

Data visualization and reporting is performed using Microsoft Power BI, a business intelligence tool developed by Microsoft, which enables interactive data dashboards and reporting. The SCM central office conduct a weekly review these statistics weekly to monitor the SiallSCM data flow by farm, type of milking test, and SCM technician (Figure 5).

Preliminary results on Buffaloes and Holstein

The limited understanding of buffalo udder physiology and optimal milking parameters prompted to utilize the SiallSCM dataset. The study aimed to investigate the influence of different milking conditions on milk quality traits and define the most appropriate milking machine parameters.

Milking machine configuration information and Dry test parameters (working vacuum, pulsation rate, effective vacuum reserve) were modelized together with official DHI data through a mixed linear model.

The preliminary analysis showed a direct relation between LS and the working vacuum level (Table 3). A higher pulsation rate (70:30) was responsible for significantly ($P < 0.001$) lower LS and higher FP compared to a 60:40 pulsation rate (Table 4). The presence of automatic cluster removal showed a significant effect ($P < 0.001$) on fat and milk yield and a slight ($P < 0.05$) reduction in LS.

Furthermore, a multivariate analysis revealed that different types of systems had different effect on milk quality and quantity traits. Notably, somatic cell counts (LS) was lower when a herringbone system was used compared to tandem system.

Results emphasized that buffaloes have specific requirements for milking parameters and incorrect setting can lead to an increase in somatic cell count and a reduction in lactose levels. In this study, we evaluate 10 different types of milking systems.

We also gathered preliminary finding using data from Lactocorders connected to the SiallSCM system. This analysis involved a sample of approximately 3,000 Italian Holstein cows and focused on three key parameters: vacuum level at the milking cluster, grouped into four classes; peak milk flow sustained over one minute; and total

Table 2. Numbers of farms, milking systems and lactating animals involved in Milking Control Service of AIA Source: A.I.A. (http://bollettino.aia.it)

Species	n° of farms	n° of milking systems	n° of lactating heads	Average heads per farm
Bovine	14,007	23,812	1,407,368	100.5
Ovine	833	953	127,427	152.9
Goat	395	512	36,498	92.4
Buffaloes	346	588	74,299	214.7
Total	**15.581**	**25.865**	**1.645.592**	

Table 3. Least square means ± standard error of milk characteristics for working vacuum classes.

	VL					
	<41 (n=12,064)	41-43 (n=60,616)	44-45 (n=53,246)	>45 (n=27,298)	SEM	*P*-value
LS	3.19^{D}	3.23^{C}	3.29^{B}	3.37^{A}	0.01	<0.001
LP (%)	4.61^{B}	4.65^{A}	4.63^{B}	4.66^{A}	0.01	<0.001
PP (%)	4.71^{A}	4.73^{A}	4.72^{A}	4.69^{B}	0.01	<0.001
FP (%)	8.09^{B}	8.23^{A}	8.22^{A}	8.18^{B}	0.01	<0.001
MY (kg/d)	8.52^{C}	8.52^{C}	8.59^{B}	8.90^{A}	0.03	<0.001

Table 4. Least square means ± standard error of milk characteristics for working vacuum classes.

	PR			
	60:40 (n=81 925)	70:30 (n=71 309)	SEM	*P*-value
LS	3.55	3.44	0.01	<0.001
LP (%)	4.65	4.63	0.01	0.330
PP (%)	4.71	4.71	0.01	0.300
FP (%)	8.17	8.22	0.01	<0.001
MY (kg/d)	8.68	8.66	0.02	0.440

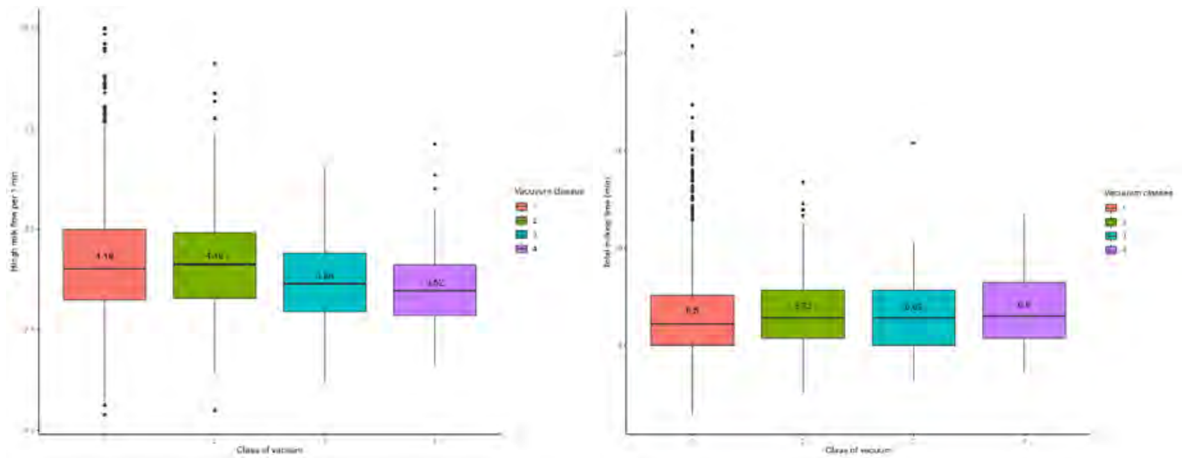

Figure 6. Max milk flow in one minute per class of vacuum (left). Milking time per class of vacuum (right).

milking duration. The data analysis indicates an inverse relationship between vacuum class and average milk flow (Figure 6, right). However, the total milking duration remains consistent across all vacuum classes ranging from 6.5 minutes for class 1 to 6.8 minutes for class 4 (Figure 6, left). These results suggest that the common practice of increasing vacuum levels to speed up milking may not be efficient. Lower vacuum levels likely reduce stress on the animals, creating optimal physiological conditions that allow for greater milk release within the same time frame.

Conclusions

The SiallSCM tool, with its capacity to collect and structure vast amounts of data, provides valuable insights for improving milking management across a wide range of farm types.

The design of the SiallSCM app facilitates farm-specific data management, offering key information for improving milking management, milk quality, and overall economic competitiveness. Additionally, the app unlocks broader possibilities, as the study and identification of negative impacts associated with milking processes. In-depth analysis of the large dataset can uncover critical insight on animal susceptibility to specific equipment settings or management practices, supporting farms and their advisors in optimizing both performance and welfare.

Further implementation of SiallSCM will expand its capabilities, including data and information collection related to milking routines and management, and the development of meaningful reports.

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