Development of a mobile application dedicated to monitoring the temperature of the mammary quarters of dairy cows

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ABSTRACT

For Brazilian agribusiness, dairy farming is a production culture of great relevance, both in economic and nutritional aspects and in the social sphere. Mastitis is one of the most recurrent diseases of this production chain, whose presence causes several losses, causing a decrease in both the quality and quantity of the milk produced. The monitoring of its occurrence in the herd is paramount, since early identification, accompanied by adequate management, prevents negative impacts on production. There are several studies that relate the change in temperature in the breast quarters with the presence of mastitis, using somatic cell count as an intermediate parameter. Thus, the objective of this work was the development of a mobile application capable of receiving the temperature capture of the breast quarters of cattle and sending it to an online database, in addition to providing the user with simple statistics of each animal and the herd as a whole. The temperature was captured through the use of an embedded system that has contact temperature sensors and infrared matrix - which allows the creation of thermal images - as well as a Bluetooth module for connection to the application.

Keywords: Mastitis, Application, Temperature, Monitoring, Livestock.

1 INTRODUCTION

For Brazilian agribusiness, dairy farming is a production culture of great relevance, both in economic and nutritional aspects and in the social sphere. Dairy cattle farming is present in all regions of the country, and about 47% of the national milk production comes from small farms, being an activity that fosters the creation of many jobs in the various segments of the dairy production chain (COOPERATIVAGV, 2018; ROCK et, 2020).

In the first quarter of 2021, production was approximately 6.5 billion liters of raw milk, chilled or not – according to the Federation Units – of which almost all of it was destined for industrialization (IBGE, 2021). Milk is a food of great nutritional value, consisting of a large amount of proteins, as well as calcium and nutrients – such as vitamin B12 and magnesium – and can also be directed to the production of various dairy products, such as cheeses and yogurts (COOPERATIVAGV, 2018).

The quality of milk is a primary factor, directly related to the profitability of producers. In this sense, the normative instructions 76 and 77 establish a set of physico-chemical parameters and good practices in the different stages of production, aiming at a food production that takes into account the zeal for human health, animal welfare and the increase of profitability capacity, which are the competencies expected of national milk production systems, in addition to contributing to the possibility of increased exports (FUNDAÇÃO ROGE, 2020a).

Among the parameters established in IN 76, the presence of microorganisms and the quantity of somatic cells present in milk are indicative of quality (BRASIL, 2018). The presence of microorganisms occurs through inadequate management and hygiene issues, while the increase in the amount of somatic cells results from inflammatory processes of the mammary glands of cattle (REHAGRO, 2022).

One of the most common diseases that affect dairy farming is bovine mastitis, which consists of inflammation of a region of the mammary gland - called parenchyma, which is responsible for milk secretion - being a multifactorial disease that has as causes different pathogens, intrinsic factors of the animal and factors of the environment (COSER et al, 2012). Its origin can be physiological, allergic, traumatic, metabolic and/or infectious, estimating that 90% are of bacterial origin, and its presence can cause the early disposal of animals, need to purchase medicines for treatment, decreased production, milk disposal, in addition to the death of the animal (LOPES et al, 2012). Through the anatomical location of the disease, it can affect one or more breast quarters of the udder of the animal, and if it occurs only in one of the rooms, it can quickly spread to the others (FUNDACIÓN ROGE, 2020b).

The highest occurrence of mastitis occurs in adult dairy cows, and its development, when of infectious origin, occurs through the entry of the microorganism through the sphincter of the roof and its consequent development that depends on the nature of the pathogen (NETO et al, 2021). The milking process, when performed improperly or carelessly – both lack of hand hygiene and with uncalibrated machines, in addition to the accumulation of animals in the same environment – favor contamination (SANTOS et al, 2019).

The economic impact of mastitis in dairy farming can reach the value of US $ 184.00 / cow / year, and the greatest influence on production comes from subclinical mastitis that comprises 70% of losses due to decreased production, 8% to the disposal of contaminated milk, 8% of expenses with veterinarians and 14% with labor, expenses with medicines, to the replacement of the squad and the

decrease in the commercial value (REIS et al, 2014). In this context, the continuous monitoring of the occurrence of the disease in the herd becomes paramount, and the early diagnosis and treatment is of great relevance for the application of appropriate management.

Bovine mastitis can be divided into clinical and subclinical mastitis. Given the presence of clinical mastitis, the symptoms observed in cattle are the increase in both volume and temperature of the ceilings, and there is also the presence of hardening. The milk of a cattle that contains mastitis usually has discolored characteristic, appearance of clots and large number of leukocytes (BENEDETTE et al, 2012). In subclinical cases, the changes are usually a decrease in the production and increase of somatic cells in the milk, but not presenting visual symptoms characteristic of inflammation or clots in the milk (COSER et al, 2012).

In this sense, numerous methods of detecting the disease can be used in monitoring. Through clinical mastitis, it is possible to obtain the diagnosis through the use of physical examinations - which consists of the observation of the parameters of the animal using palpation and visual inspection of the ceilings - and the use of the dark-bottomed mug test, in order to observe changes in physical characteristics through visual changes in milk, such as the formation of lumps. For the mug test, the first jets of milk must be removed and evaluated for abnormalities before milking each animal (FAO and IDF, 2013).

For the detection of subclinical mastitis, however, Somatic Cell Count (SCC) tests are used, since the increase in somatic cells is indicative of the presence of the disease (SÁ et al, 2018). Another test that can be used is the *California Mastitis Test* (CMT), which seeks to measure the presence of somatic cells by observing the reaction of milk with a chemical compound, of each of the breast quarters, with a CMT reagent in 1:1 dosage (2 ml of milk to 2 ml of reagent) and observing the viscosity resulting from the reaction (COSTA, 2020).

The early identification of mastitis in dairy cattle is essential for maintaining the quality of production. Thus, for herd monitoring, it is recommended that physical examinations and mug testing be performed daily before milking and CCS tests be performed at least once a month (REHAGRO, 2022; CRUZ, 2017)

Thinking of alternative methods for the detection of mastitis, the literature presents a series of studies that found a strong relationship between the occurrence of the disease and temperature. Among such works, we can mention Silva (2021), who created an algorithm capable of differentiating thermographic images of cows with clinical and subclinical mastitis from normal cows, Pandorfi (2020) who used statistical methods to identify the disease in cows by the use of thermographic images, allowing the differentiation of the respective clinical pictures and Digiovani (2014) who demonstrates that the use of temperature, Through the use of infrared thermography, it is a promising tool in the

diagnosis of subclinical mastitis. Thus, it is noted the potential of the use of monitoring the udder temperature of cattle to aid in the identification of bovine mastitis.

With the growing technological advancement - since the fourth industrial revolution, where there was the emergence of several technological innovations of collection, transmission, management and application of data - both the improvement of processes and the increase of assertiveness in decision-making were not restricted only to industry, gradually approaching agriculture and livestock, seeking to meet a series of demands and challenges existing in the productive chains (SILVA, 2017).

In this way, this work aims to develop a *mobile* application that is able to receive the capture of the temperature of the cow's breast rooms and send this data to an *online* database, in addition to providing the user with simple statistics of each animal and the herd as a whole. The temperature was captured through the use of an embedded system that has contact temperature sensors and infrared matrix - which allows the creation of thermal images - as well as a *Bluetooth module* for connection to the application.

2 MATERIAL AND METHODS

The development of the *mobile* application was based on three stages, these being the choice of development tools and the database, the planning of the screens and the validation. Figure 1 shows the scheme of operation of the *mobile application*.

Figure 1 - Scheme of operation of the *mobile application.*

Source: Authors Themselves (2022)[1].

2.1 SPECIFICATION OF DEVELOPMENT TOOLS AND DATABASE

For the preparation of the application, it was decided to use Kodular, a platform for the development of *online* and free applications. Kodular allows the making of *Android applications using* no-code-based *programming, that is, working with a visual programming through drag-and-drop logical blocks, which contributes to the increase in both speed and ease of development.* The specification of an application development platform focused on the *Android* operating system was due to being a more popular system in smartphones nationwide, being present in 86.06% of *smartphones* in Brazil (STATCOUNTER Global Stats, 2022).

[1] Assembly made from the icons of Chattapat, Flat Icons, Uniconlabs and Bombasticon Studio, from www.flaticons.com

An advantage of using Kodular for application development is the possibility of integrating components that use Java and Javascript languages, expanding the possibilities of development. Thus, for the preparation of the charts, the extensions TaiFunTools, CustomWebView, in addition to the use of an integration of the chart.js library were used. The TaiFunTools extension was used to retrieve the internal file storage address, while the CustomWebView was used to view the Javascript files and the chart library.js was used to construct the charts.

The database specified for integration with the application was Firebase, a *Backend-as-a-Service* (BaaS) - a service that automates the development of the database *backend*, outsourcing these functions - which assists in the creation, development and expansion of applications, being a non-relational database (EDUCATIVE, 2022). The Kodular platform has an integraability with Firebase that occurs through the components: Firebase Database - which allows the establishment of communication between the database and the application, allowing both the storage and retrieval of data - Firebase Authentication - which allows the use of authentication of users registered in the database - and Firebase Storage - which allows saving and retrieving images and videos from the database. The data received by the application is stored in JSON format - a format that is compatible with *Android*, IOS and web - and can be synchronized in real time with all connected users (FIREBASE, 2022). Another advantage of the selected database is the possibility of storing images and videos. Its versatility, data storage format and the ability to facilitate the development of the application were the determining factors for the choice.

2.2 PLANNING OF APPLICATION SCREENS

A *mobile* application has a set of screens where all the necessary functionalities for data acquisition, management and transmission are distributed, and a good interface planning contributes to better usability and operation as expected. The planning of the screens took place through the listing of main operations that the application should have, followed by a scheme of how these operations would be arranged in a logical way. Chart 1 presents the main functions of the developed application.

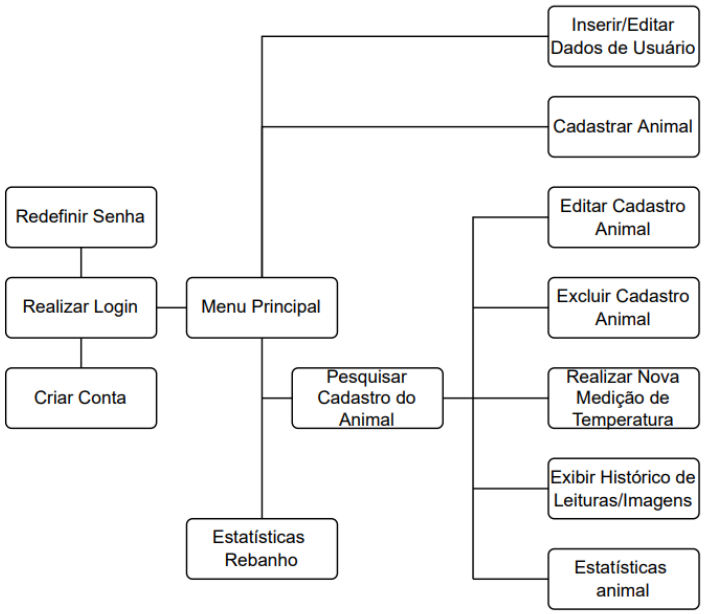
Table 1 - Main functionalities of the developed application.

Functionality	Observations
User Login	If the login is unsuccessful, a warning message should be shown
User registration	Confirmation of a user's creation takes place via E-mail.
Cow Registration	It is only allowed to register a cow after user login
Edit Cow Register	Editing occurs after a survey of the register
Search Cow Registry	The survey should return all the cow's data
Delete Cow Register	The deletion occurs after a search of the register that you want to delete. A message must be shown to confirm the deletion.
Perform a new reading for a cow	One should search for the cow to which the new reading will be added, connect to the embedded device, receive the readings and disconnect from the embedded device
List on one screen the history and simple statistics for a cow	One should carry out a cow survey that one wishes to view the history and simple statistics.

Source: Authors Own (2022).

Figure 2 shows the schematic of the logical arrangement of the application's functionalities.

Figure 2 - Schematic of the logical arrangement of functionalities.



Source: Authors (2022).

As a condition of restriction, it was decided to allow only one temperature reading per day for each breast room for each different sensor. In this way, two readings from the same breast room with the same sensor result in the overlapping of the older reading by the more current reading.

2.3 VALIDATION

For the validation of the development of the application, a bench test was performed using a *hardware* consisting of contact sensors and a temperature matrix sensor used in the thermal imaging process, as well as a *Bluetooth* module capable of sending the data to the *mobile* application. Table 2 presents the *hardware* components used for validation.

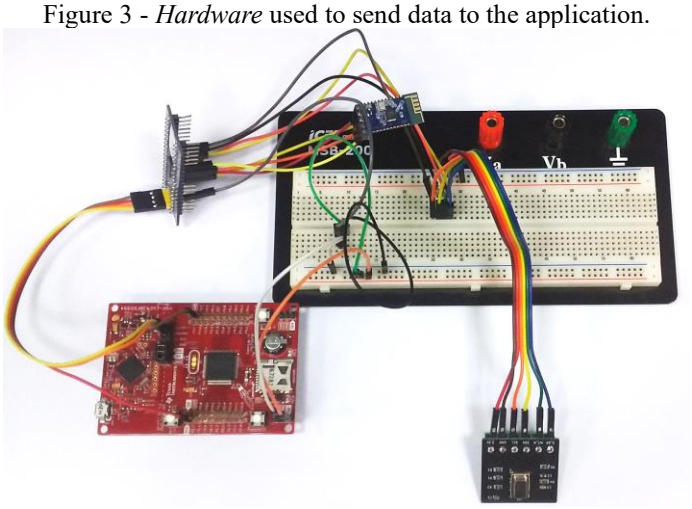
Table 2 - Hardware components used for validation.

Components
Microcontroller MSP430FR2155
MSP-EXP430FR5994 Development Kit with Recording Interface
LM 35 Temperature Sensor
AMG8833 Temperature Matrix Sensor for thermal imaging
Bluetooth Module JDY-31

Source: Authors Own (2022).

Figure 3 shows the *hardware* components used for design validation.

Figure 3 - *Hardware* used to send data to the application.



Source: Authors Own (2022).

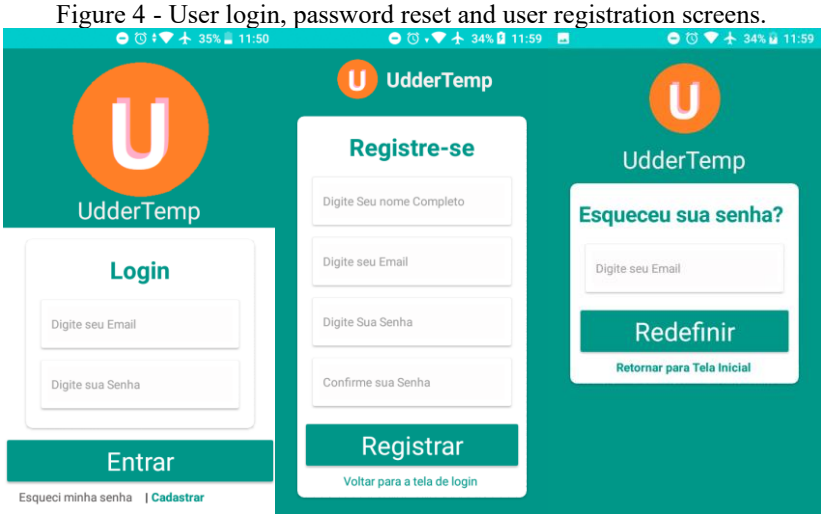
3 RESULTS AND DISCUSSIONS

Seeking to supply all the functionalities, a total of twenty-one screens were made, three of them related to the login and registration functions of the user/producer, one of them related to the additional information of the producer's registration, six screens focused on the functions of registration, registration research, editing and exclusion of animal registration from the system, five screens related to obtaining temperature readings and six screens related to accessing reading history and displaying statistics.

3.1 LOGIN, PASSWORD RESET AND USER REGISTRATION

Figure 4 shows the user login, password reset and user registration screens.

Figure 4 - User login, password reset and user registration screens.



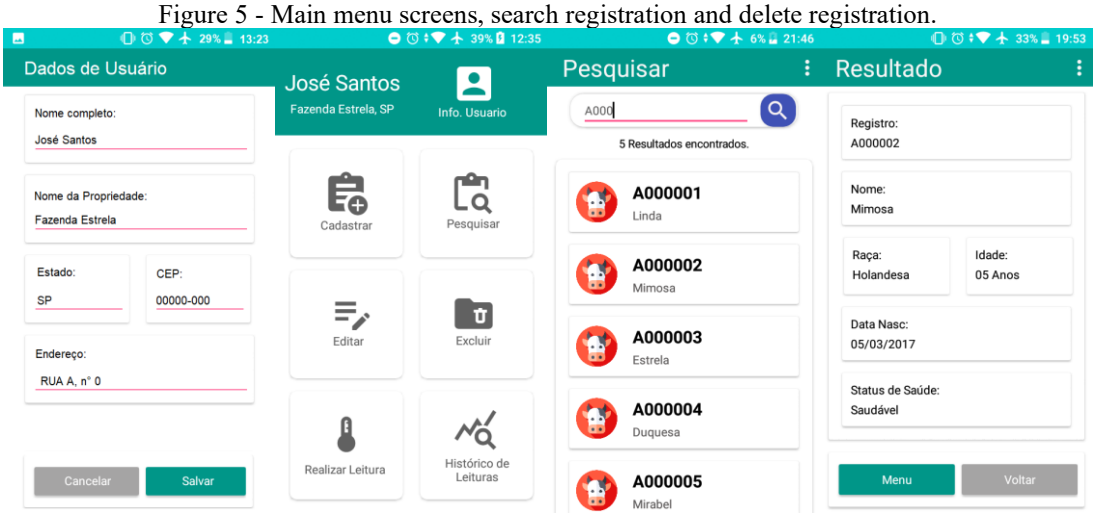
Source: Authors Own (2022).

When launching the application, the user is directed to a login screen where he must use an email address and a password. The login option is important for each user to have access to their own herd and if the user does not yet have a registration, he can perform it on the user registration screen. The Firebase database contains user registration functionality, requiring you to confirm user creation by email. The password reset becomes possible having the knowledge only of the E-mail.

3.2 MAIN MENU AND REGISTRATION OPTIONS

Figure 5 shows the main menu screens, search registration and delete registration.

Figure 5 - Main menu screens, search registration and delete registration.



Source: Authors Own (2022).[2]

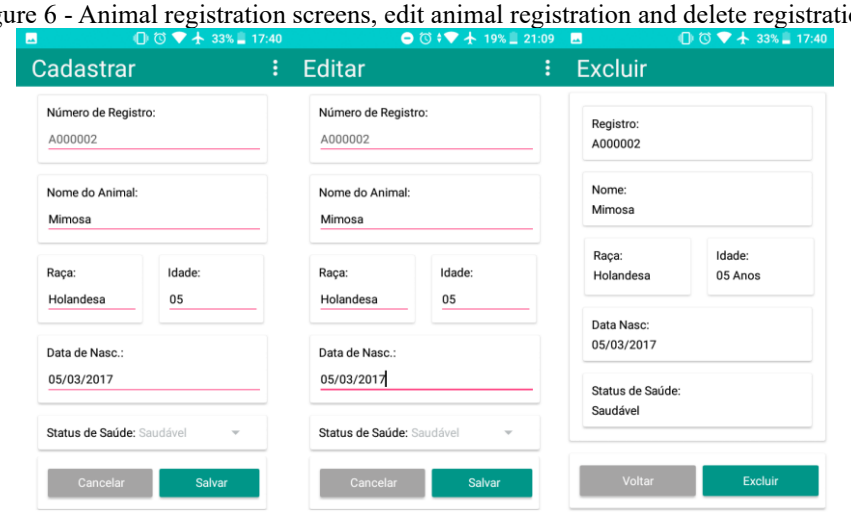
After logging in, the user is directed to the main menu screen, having access to the main functionalities of the application. If it is the first access, the user is directed to the user data screen,

[2] Icon made by Freepik, from flaticons.com.

where he can enter additional information in his registration. You can edit the information by clicking the "info. User", visible in the main menu.

In the main menu screen, the user has access to all the main functions of the application, which are related to the registration, consultation, editing and deletion of the registration of the animals, in addition to allowing access to the history of temperature readings and the realization of new readings. Figure 6 shows the screens to register animal, edit animal registration and delete the animal registration.

Figure 6 - Animal registration screens, edit animal registration and delete registration.



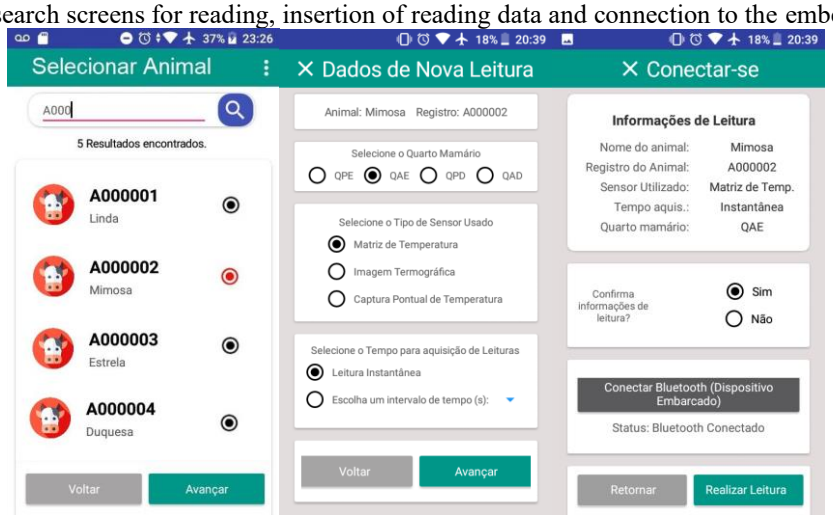
Source: Own Authors (2022)

For the identification of the animal, it was decided to use a registration key generated automatically, where each animal has a single key that identifies it and that cannot be edited by the user. The information used for the registration of animals are: name, breed, age, date of birth and health status at the time of registration. The health status has as options : Healthy, Clinical Mastitis, Subclinical Mastitis. It is worth mentioning that the day and time of the registration are automatically saved by the database. The edit screen allows the user to edit the registration of the animal, and to access one of the registers the user is previously directed to the search screen and the same happens when you want to delete the registration of an animal.

3.3 TEMPERATURE ACQUISITION OPTIONS

Figure 7 shows the animal research screens, the new reading data, and the connection of the application with the database.

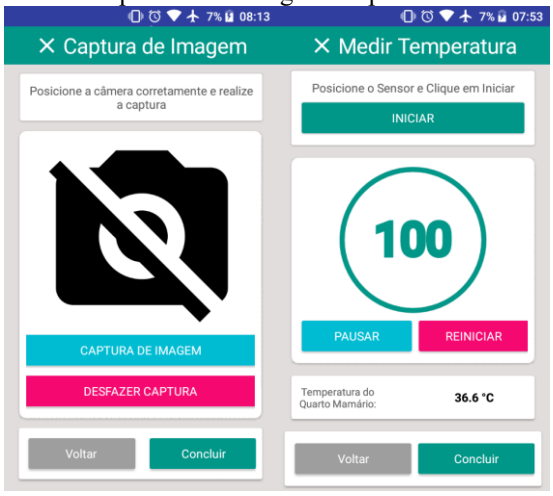
Figure 7 - Research screens for reading, insertion of reading data and connection to the embedded system.



Source: Own Authors (2022)[3]

The acquisition of a new reading takes place by researching the animal to which the reading will be attached, followed by the settings of the reading and the connection of the application with the embedded system. Note the presence of a function related to the time of acquisition of the readings, which is only available for the function "point capture of reading", since, depending on the nature of the point temperature sensor, it is necessary to wait a few seconds for signal stabilization. On the connection screen, you can check the information entered for reading and make the connection to the embedded system. Figure 8 shows the screens for point temperature capture and thermal image capture.

Figure 8 - Screens for temperature reading and capture of thermal images of cows



Source: Own Authors (2022)

By selecting the reading options by the user, the user is directed to a screen where he can perform the image capture or the readings. In the image capture, the user can click on "image capture", being allowed only a single daily image capture per animal for each of the breast quarters, and the

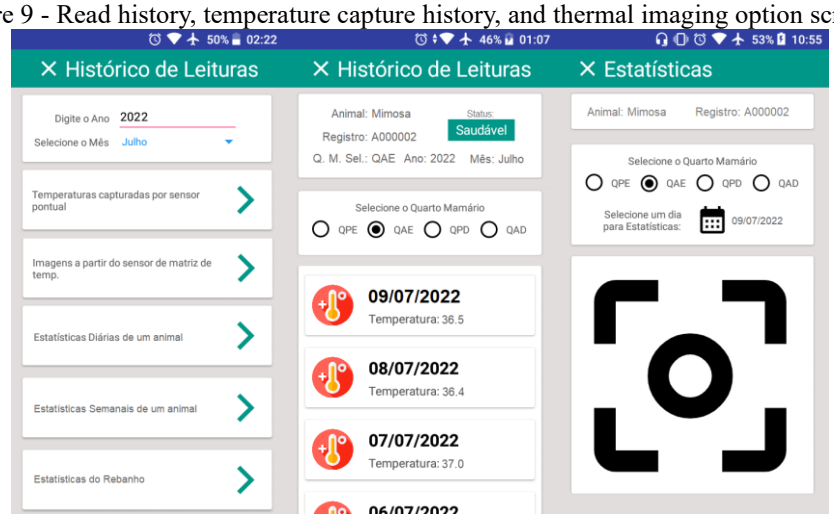
[3] Icon made by Freepick, flaticons.com

image is automatically saved in the database after clicking the "Finish" button. On the screen of performing readings, the user must click on "START" and wait for the time previously selected to perform the readings. After the measurements are made, the user can click finish and return to the main menu.

3.4 CONSULTATION OF READINGS PERFORMED

Screens were made to consult the reading history of an animal, statistics related to an animal and statistics related to the herd. Figure 9 shows the screens of reading history options, history temperature capture by point capture sensors and consultation of thermal images of the animal.

Figure 9 - Read history, temperature capture history, and thermal imaging option screens.

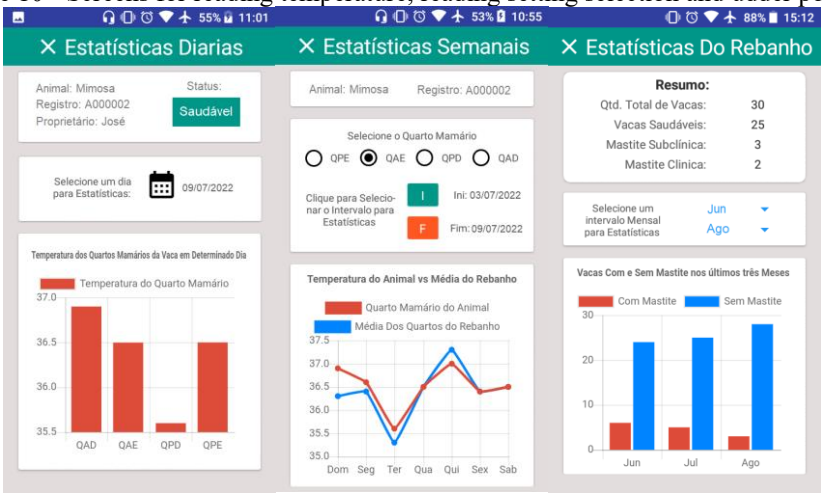


Source: Own Authors (2022)[4]

To access the reading history of an animal, the user is previously directed to the search screen where he selects the animal whose readings will be consulted. Subsequently, the user has the option to choose whether the query will be by the data coming from point temperature capture or thermal images, also having the option to view the daily statistics of the animal. If the user chooses to search for the temperatures captured from the point temperature reading, he will be directed to a screen that demonstrates the list of readings taken in the last month, while if he chooses to consult the thermographic images, he will be directed to a screen where he can select the fourth breast reading. The screen that presents the history of readings allows the user access to all the readings performed, organized by date. It is possible for the user to access the temperature of each measured breast room, as well as the thermal image. Figure 10 shows the herd and animal statistics screens.

[4] Icon made by Freepick, flaticons.com

Figure 10 - Screens for reading temperature, reading setting selection and udder portion.



Source: Own Authors (2022)

The daily statistics screen allows the user to graphically view the temperature of the breast rooms on a given day. The animal statistics screen allows the user to view the temperature variation of one of the breast quarters in relation to the average temperature of the herd rooms, while the herd statistics allow the user to have an overview of the herd situation. The use of graphs increases the user's understanding of the information demonstrated, giving an overview of how an individual's temperature behaves in relation to the herd.

4 CONCLUSION

The use of an application to monitor the temperature of the breast quarters of dairy cows is very practical to allow the sending of readings to a database, with potential for future studies involving the prediction of the occurrence of mastitis through temperature variation.

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