INTERNATIONAL SEVEN JOURNAL OF MULTIDISCIPLINARY
ISSN: 2764-9547

ENGINE ANOMALY MONITORING FOR PREVENTIVE MAINTENANCE: A CASE STUDY IN A CHEESE MAKING MACHINE

https://doi.org/10.56238/isevmjv3n6-003

Receipt of originals: 10/12/2024 **Acceptance for publication:** 11/12/2024

Jean Alves Gollmann[1], Kathellin Ribeiro de Souza[2], Pedro Henrique Figueira[3], Vinicius Silveira Bonicio[4], Marcones Cleber Brito Van Silva[5], Rogério Issamu Yamamoto[6] and Victor Inácio de Oliveira[7]

ABSTRACT
Cheese is a food with high consumption worldwide. In Brazil, according to a survey carried out by SEBRAE in 2021, exports reach more than 4 thousand tons of the product and occupy the sixth position among the countries that consume it the most. In its manufacturing machines, the electric motor plays a fundamental role and the loss of raw material is susceptible with the failure of this device. In order to reduce the risk of defects and increase agility in decision-making, ManutControl was developed, a system composed of a vibration sensor connected to a microcontroller. The system monitors the vibration of the engine in real time and sends the information to a database, finally, the data is consulted by the user through a mobile application, sending notifications to the cell phone if the device is operating under any anomaly. This project was based as a case study on the Pilot Plant for Cheese Elaboration of the Salvador Arena Foundation, in which tests were carried out to monitor the vibration of the equipment during the cheese production process at the institution, in order to assist in preventive maintenance. Tests show that the system is acting in a way that monitors the engine and sends alert notifications when necessary.

Keywords: Monitoring. Pilot plant. MERN. Internet of Things (Iot). Preventive Maintenance.

[1] Computer Engineer - Salvador Arena Engineering College
[2] Computer Engineer - Salvador Arena Engineering College
[3] Computer Engineer - Salvador Arena Engineering College
[4] Computer Engineer - Salvador Arena Engineering College
[5] Master of Engineering - Salvador Arena Engineering College
[6] Dr. in Sciences - Salvador Arena Engineering College
[7] Dr. in Sciences - Salvador Arena Engineering College

INTRODUCTION

Cheese has a considerable impact on the diet. According to the survey carried out by SEBRAE (2021), Brazil is one of the countries in which the most consume this product in the world, occupying the sixth position on the list, and with the expectation of growth in the Brazilian market, it will soon reach the fifth position. According to the same survey, Brazil exported 4,143 tons of cheese, earning 18.88 million dollars in 2020.

Food waste is directly linked to its production process, being one of the serious problems that occur both in Brazil and worldwide, and with this there is an impact on the economy, politics, culture and technology (RICARTE *et al.*, 2008). According to Embrapa (2016), in Brazil, on a large scale, food waste occurs in the stages of production, transportation and supply centers. In his research, the author identified that 90% of the cases of fruit and vegetable waste occur before reaching the customer. In 2019, about 931 million tons of food around the world, which arrived at supply centers and customers, were lost according to data collected by Zandonai (2021).

In the food laboratory of the Engenheiro Salvador Arena Faculty there is a machine that is the "Pilot Plant for Cheese Production", responsible for the production of the cheese consumed by the entire institution. This equipment holds up to 100 liters of milk, being one of the most used, with weekly frequency.

The complete process without external interference from the machine lasts an average of three hours, allowing technicians to work in other activities while this food is produced, however, if there is an unexpected stop of the engine or it begins to present defects, it is likely that the raw material will be deteriorated by the appearance of unwanted microorganisms.

In addition to the hypothetical waste of raw material, if the engine fails, the machine can be stopped for days, until it is repaired or replaced, causing impacts on cheese production. In this scenario, to repair the machinery, it will be necessary to apply corrective maintenance, which, according to Marques and Nei Brito (2019), is when the equipment receives maintenance only when it is operating irregularly, caused by the lack of maintenance management, directly implicating the productive indicators (MARCORIN AND LIMA, 2003).

Performing maintenance in a corrective manner is recurrent in several companies, according to Marcorin and Lima (2003), however, they argue that using preventive maintenance, performed before the machine stops, is more efficient since this type of maintenance traces a diagnosis of the operation, which brings predictability, helping to increase the useful life of the equipment in addition to avoiding unexpected stops.

This case study aims to assist in the control of the cheese production process and the equipment, so that, with the use of the application, the technician can visualize the vibration of the motor and assist in the performance in relation to maintenance. According to the research carried out by Marcorin and Lima (2003), the vibration analysis of a motor contributes to the identification of device imbalances, allowing the planning of preventive maintenance, avoiding future unwanted stops and increasing the useful life of the machine, another functionality of the system is to issue warnings in real time, enabling the user to monitor the machine process and enabling the receipt of notifications in case of any failure in operation, with quick decision-making.

THEORETICAL FRAMEWORK

INFLUENCE OF MAINTENANCE MANAGEMENT AND CONTROL ON PRODUCTION COSTS

Preventive maintenance and maintenance management have a vast influence on the profits and productive capacity of an industry. Marcorin and Lima (2003) emphasized that maintenance is of vital importance to keep productivity high, and the main objective is to discuss the perspective of a cost that generates profit and which factors should be considered. Maintenance management techniques began to grow over time, thus developing strategies that directly affect the operating results of companies and their profitability, having a more precise and efficient application (MARQUES and NEI BRITO, 2019).

According to Marcorin and Lima (2003), maintenance is related to quality, productivity and availability, having as main factors that measure the results of the maintenance of an industry. Therefore, the authors determine that quality is measured mainly through the product generated, directly linked to the entire production flow, aiming that by identifying a high number of machine failures, quality is drastically affected. One of the main malfunctions that the machinery has is the intermittency in vibration, and that, if it presents abnormal vibrations, it should be considered irregular to its operation and, thus, causing harm to the industry or company, such as safety, financial damage and quality of the material or product (MARQUES and NEI BRITO, 2019).

Marques and Nei Brito (2019) found that maintenance is essential for the useful life of a machine. The predictive maintenance of equipment helps to increase and improve its useful life, making constant monitoring to be able to act in the best possible way. Every piece of equipment has its useful life and as time goes by, the probability of this equipment failing increases and maintenance is necessary to carry out the repair in a scheduled way and simultaneously act the production process, in short, reducing the chances of system downtime (SILVA and GONZALEZ, 2008).

According to the analysis carried out by Marques and Nei Brito (2019) using vibration sensors, it was observed that through the data obtained by the sensors, the prediction and planning of equipment maintenance is simplified and thus preventing more complex problems, increasing the efficiency of the machines and improving both the safety and quality of the processes (MARQUES and NEI BRITO, 2019).

SAFETY AND QUALITY MANAGEMENT IN THE MINAS FRESCAL CHEESE MAKING MACHINE

Rodrigues *et al.* (2022) aiming to automate the temperature control of the cheese-making machine and discover liquids that can replace milk in future experiments, carried out a research. In his studies, the process of opening a valve was mapped as a function of time, obtaining the response of the heating of the fluid.

Being the most consumed by Brazilians, mina cheese has a wide commercial acceptance and is part of the diet of the majority of the population in the regions of Brazil (VERÍSSIMO *et al*., 2019). Minas frescal cheese is a type of fresh cheese produced by enzymatic coagulation of milk pasteurized with rennet, with other appropriate coagulating enzymes or with both methods (BRASIL, 1997).

Rodrigues *et al.* (2022) assesses that artisanal Minas Frescal cheeses do not have a hygiene standardization compared to other factories that produce other types of cheese. About 55.6% of the Minas Frescal cheese produced did not comply with the coliform legislation (RODRIGUES *et al.*, 2022). To manufacture it, it is very common to use raw milk, thus causing several diseases such as *Salmonella sp.* and total coliforms when not previously treated, according to Rodrigues *et al.* (2022).

For safe and sanitized production of Minas Frescal cheese, Rodrigues *et al.* (2022) used pasteurization, which, according to the authors, is based on relatively low time and temperature binomials, thus eliminating pathological microorganisms and increasing shelf life without the product having a change in sensory and physicochemical characteristics (RODRIGUES *et al.*, 2022). For Rodrigues *et al* (2022), in addition to pasteurization being the only thermal process that occurs in Minas Frescal cheese, it maintains the stability of casein, which is an important protein for coagulation.

Rodrigues *et al.* (2022) carried out two heating and cooling tests on the cheese production machine, the first using milk and the second water, in order to examine whether the two liquids have the same behavior in terms of heating and cooling time. Following the same test, with equal amounts in liters of milk *versus* water, they showed that the two fluids had similar heating and cooling times, proving the effectiveness in replacing milk with water for future experiments in the cheese production machine and thus avoiding exacerbated expenses and waste of milk.

FOOD WASTE

According to Débora Carvalho (2009), Brazil is one of the ten countries that waste the most food in the world, about 35% of all agricultural production is thrown in the trash, that is, more than 10 million tons of food could be placed on the tables of more than 54 million Brazilians living in extreme poverty. Also according to the researcher, about R$ 12 billion in food is thrown in the trash daily, which can have a sufficient amount of food for breakfast, lunch and dinner for 39 million people.

According to Santos *et al* (2020), there is a distinction between the terms food losses and waste, stating that losses occur during production, post-harvest and processing, and in most cases, the food is not harvested or suffers damage at some stage of the process, such as transportation, storage and others. In view of the above, there is a reduction in the food available to the population and the inefficiency of the production chain. Regarding waste, it is defined as an intentional disposal of food due to consumer behavior (SANTOS et al., 2020).

TECHNOLOGIES USED IN THE SYSTEM

React native

According to Andrei (2021), React is a *low-code* and population-based JavaScript library, used in the construction of user interfaces (UI), and developed by Facebook from the limitation of the *HTML5 resource,* causing instability and slowness in the *mobile* version, and with this, created with the purpose of improving the user experience (ANDREI, 2021). Therefore, React had the differential of reducing the number of DOM processing.

According to MOZILA (2022), the *DOM (Document Object Model)* is a programming interface for *HTML* and *XML* documents, in which, in React, there was an opportunity for improvement, since updating the *DOM* and manipulation caused slowness when used in more complex applications (NEVES, 2023). That said, React introduced the *Virtual DOM*, which consists of an in-memory representation of the *real DOM*, being updated faster and first, as soon as the discrepancy between the *Virtual DOM* is that the representation is in memory and in the *real DOM* is in *HTML* and *XML* (NEVES, 2023).

Starting from React, React Native was created, a technology that highlights the development of high-resolution, quality and multiplatform mobile applications, in view of this, the *framework* enables the construction of more advanced, responsive interfaces, with the execution of complex tasks requiring less processing time, such as, for example, navigation, state management and screen animations (CUNHA, 2022). Another benefit of React Native is the possibility of creating custom components that go according to the behavior and appearance of the native platform, allowing the user to have a user-friendly experience and integration with the operating system (BUDZIŃSKI, 2022).

However, Andrei (2021) mentions some disadvantages found, in which the *framework* uses several dependencies that often become depreciated due to constant updating, resulting in software with high disk space consumption due to the fact that they load their codes and are not always used.

Rest api

According to IBM (2021), *APIs* (*Application Programming Interfaces*) are resources that enable the integration of two or more systems, considering that communication is possible through the use of sets of definitions and protocols. That said, the denomination *Application* refers to software that has different functions, in view of this the Interface is analogous to a service contract between the two *software*, and through an *API* an application can be designed by certain functions and resources to be accessed by external programs (SILVA *et al*., 2020).

To do this, the *REST API is used*, which is a set of standard architecture constraints of the *Representational State Transfer*. According to Fielding (2000), *REST* has the advantage of flexibility and freedom in the computing environment, considering the existence of this flexibility, there is a need to create architectural requirements such as *REST.* In short, according to IBM (2021), there are five primary requirements, namely:

- Uniform interface that determines that all *API* requests for the same resource must be the same, containing all the information that the client needs (IBM, 2021).
- Client-server decoupling defaults to determining that the client and server are independent of each other (IBM, 2021).
- Without a defined state, which has the characteristic that every request must contain all the essential information for processing, in which the server does not store any data related to the client's request (IBM, 2021).
- Caching capacity that aims to improve client performance and increase vendor stability from the caching of resources by the client or server (IBM, 2021).
- Layered system architecture as standard in *REST APIs* should be designed so that the client and server know if they are communicating with the final or intermediate application, and this is possible because calls and responses go through different layers, not evidencing that the client and server have communication directly (IBM, 2021).

Firebase

In the use of *IoT (Internet of Things)* applications, it is common to use Google's tool known as Firebase, since according to Li *et al.* (2018), the platform is the combination of several cloud services offered by Google, in which for this project the real-time database services and the transmission of data to the cloud applying SSL encryption stood out.

According to the project, the data is updated in real time, in which, using the Firebase tool, it was evidenced that the update of information takes a short period, proving the high scalability, performance and performance of the database. Accordingly, because it is an unstructured database, and since it is a warehouse where data is stored in *JSON* document format, the manipulation and generation of data for *IoT purposes* has become more appropriate (OHYVER *et al.*, 2019).

The choice of an unstructured database for *IoT projects* was based on the study produced by Ohyver *et al.* (2019), performing tests on an unstructured database and a structured database, using methods of Creation, Reading, Updating and Removal of data (*CRUD* method) in relation, in order to analyze performance under constant data storage conditions and submissions by mobile devices. In the study, the response time obtained through the unstructured Firebase database, hosted on Google's servers, was shorter compared to the structured MySQL database, hosted on its private servers, a result acquired through an experiment by Wilcoxon (OHYVER *et al.*, 2019).

Using the services offered by Firebase and a Microcontroller such as ESP32, Megantoro *et al.* (2022) describe a project that uses such tools for data generation and monitoring of hydroponic farms, containing five sensors managed by the microcontroller, to capture crucial indicators for hydroponic cultivation, in this way, the information collected is recorded and sent to the database service in real time through a wireless connection to a router with internet access.

In summary, through the initiative described by Megantoro *et al.* (2022), was feasible with the use of the instrument to monitor key crop indicators effectively, with low use of electricity and high accuracy, adapting the system to meet the needs found in relation to sensors for monitoring key indicators for desired scenarios. Combined with the addition of the high availability offered by cloud services, the solution proved to be viable and of high structural value for monitoring systems with multiple indicators that influence the result of the product, such as that of a crop.

MongoDB

MongoDb is open source and structured in documents, excelling in high performance, availability, and automatic scaling, ideal for use in *IoT projects* that require constant data submissions (CHAUHAN, 2019).

In addition, the database uses the JSON structure as a basis for insertion, querying, and data storage, abbreviated to *JavaScript Object Notation*, and as a resource the notation for JavaScript objects (TYSON, 2022). As a result, it is possible to structure the data collected through the sensors in this format, being consumed by applications to promote agility and practicality to the *IoT process*.

ESP32 Microcontroller

The ESP32 is a dual-core microcontroller developed by Espressif Systems. Its system was designed with the intention of achieving the best power performance, versatility and reliability in its applications, used in various scenarios that demand energy variations (ESPRESSIF SYSTEMS, 2023).

Its structure was designed to carry out different types of projects, such as *mobile* and *Internet of Things (IoT).* The microcontroller is capable of operating in a low-power state, allowing for energy savings during use, such as, for example, a system in which it uses several low-power IoT sensors, the ESP32 is periodically activated when a specified condition is activated, so the energy consumption is only when it is demanded (ESPRESSIF SYSTEMS, 2023).

A highlight of the microcontroller is the native compatibility of *Wi-Fi* and *Bluetooth communication systems* with an integration to the MESH network protocol, which consists of communication between boards to share data with each other on the same *internet* network, acting as *a host* or router (ESPRESSIF SYSTEMS, 2023).

Maintenance indicators

According to Daudt (2021), maintenance indicators are management instruments to measure the results related to a company's maintenance. Also according to the author, with the results obtained from the indicators, it is possible to distribute activities by type of maintenance, such as preventive and predictive, contributing to maintenance planning as operational variants, machine stops, among others, are made available.

MTBF

The *Mean Time Between Failures* (MTBF) indicator is the average time between failures, using parameters such as the time between one failure and the next one that will occur, that is, it is the time in which the machine should be running minus the time of the machine stopped. In Equation 1, it is shown how the calculation is made, being the Availability Time (TD) which is the ideal time of the equipment in operation if it did not find any defect, Maintenance Time (TM) being the total time of the machine stopped for maintenance and the number of stops (P) referring to the number of machine stops (SIGGA, 2021).

$$MTBF = (TD - TM)/P \quad (1)$$

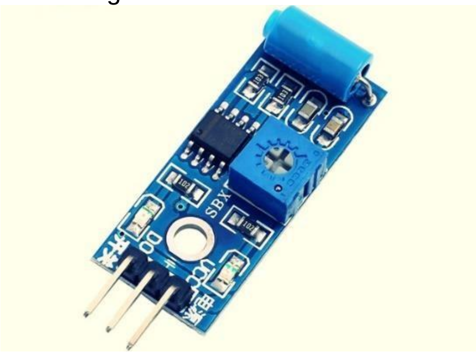
Wokwi

Wokwi is a free and online electronic circuit simulation tool, as it is a web application, this system runs directly from the browser, allowing the user to simulate robotics prototyping platforms such as ESP32 and Arduino, without the need for components and installation of any *software,* for this reason the tool was used to simulate the use of an ESP32 microcontroller receiving measurements from a sensor prior to an implementation in a real scenario. According to Antunes (2022), this simulator was developed to be an easy-to-use tool, being an excellent choice for consumers with different levels of knowledge in electronics (Marin and Reyes, 2022).

Sensor sw-420

The SW-420 sensor, shown in Figure 1, has a *trimpot*, allowing to adjust the sensor's sensitivity level, with calibration flexibility for high or low sensitivity, with a working voltage between 3.3V and 5V. The module of this sensor has a logic level output based on the vibrations and external pulses applied to it, that is, when the sensor does not capture the vibration, its logic state remains at *low* (L) and when it receives some vibration, its output state changes to the high logic level (H) (HAREENDRAN, 2022).

Figure 1 – SW-420 sensor



Font: Hareendran (2023)

RELATIVE SCALE WITH ARBITRARY UNIT

To carry out the vibration measurements of the cheese making machine in conjunction with the SW-420 sensor, research was carried out on measurement techniques in order to enable the analysis of these measurements in a clear way to the employees responsible for the maintenance and monitoring of the cheese machine.

With this, the Relative Scale with an arbitrary unit was reached, in which the scale is related to a reference standard. According to the study, numerous measurements were made using arbitrary unit, which is a type of measurement in which absolute values cannot be obtained, and in this way they are represented as u.a (arbitrary unit), under the same set of conditions, can be compared on a relative scale and thus establishing a trend. Thus, for example, it is to establish a minimum and maximum limit at a given point and evaluate their variation (KAMAT, 2019).

METHODOLOGY

In accordance with the theoretical framework, the control of the operation of the motor of an equipment helps to reduce production costs, for this reason the device called "ManutControl" was developed, which aims to monitor the vibration of the electric motor, issue an alert informing if an unexpected stop occurs, allows the planning of preventive maintenance with the purpose of minimizing machine failures.

For the application of "ManutControl", as a case study, the equipment where the system will be installed was selected, in order to assist employees in carrying out the maintenance and monitoring of the institution's cheese machine, as shown in Figure 2.

As the methodology was based on a case study of the "pilot plant" machine, this topic will address the *hardware*, software, tools used for the development of the device and the tests carried out at each stage of the construction of the system.

INTERNATIONAL SEVEN JOURNAL OF MULTIDISCIPLINARY
ISSN: 2764-9547

Figure 2 – Pilot Plant for Cheese Elaboration

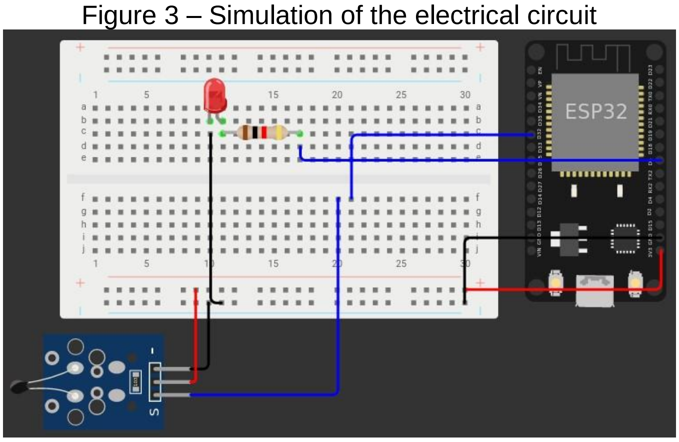
Source: The authors

HARDWARE

The developed prototype has the role of recording the measurements collected by the vibration sensor, treating and sending this engine operation data to monitor its operation. Therefore, it was necessary to survey what information is relevant for the analysis of the correct operation of the engine. Based on the topics addressed in the theoretical framework by Marques and Nei Brito (2019), it was decided to measure the variation of the vibration of the engine in operation, with this scenario the use of a SW-420 sensor for measurement is trivial.

Subsequently, when defining which type of sensor will be used, it was established which microcontroller will suit the system. That said, the Wokwi platform was chosen to structure a basic model with sensors in order to test and evaluate the microcontrollers as shown in Figure 3. Considering the results achieved through tests and some other factors such as cost, availability of sensors, system complexity and the size of the microcontroller, the group chose to use the ESP32 board.

Figure 3 – Simulation of the electrical circuit



Source: The authors

Sensors

Sensors are structures capable of detecting what happens in the environment, there are several types of sensors produced for the most diverse applications (OLIVEIRA, FREIRE, ZANATTA, 2006). For the ESP32, there are several types of sensors that detect the vibration of a piece of equipment. For the tests, several sensors were used to capture the data, such as the piezoelectric vibration sensor, however, none of them achieved the expected result. Finally, carrying out new studies to define the model with greater reliability, the SW-420 sensor was analyzed, which according to the experiments conducted, obtained a more satisfactory result, being an ideal sensor for low frequency vibrations.

In principle, the use of the piezoelectric sensor for vibration measurement was prioritized, the test conducted was premised on measuring the operation of a grinding machine, industrial equipment used to cut, sharpen, grind, remove rust, polish, clean and trim various types of materials. This machine was chosen for the initial experiment, considering the factors of containing a motor, the frequency variation, and the easy access to the electric motor, allowing the coupling of the vibration sensor. In the tests carried out, the piezoelectric sensor was able to monitor the vibration generated during the operation of the grinding engine, reaching an effective result for data analysis.

Then, a vibration monitoring test was performed on the pilot plant machine, and the same piezoelectric sensor was used, however, it was observed that the vibration produced by the pilot plant was not detected assertively, this is due to the fact that the pilot plant machine has a more stable support base compared to the grinding engine, not allowing an accurate measurement. From another angle, the electric motor existing in the pilot plant machine is firmly positioned in a box and with metal supports, as shown in Figure 4 below, and as a result of these characteristics, the vibration is lower in the structure of the equipment, in view of this, the piezoelectric sensor was not able to accurately distinguish whether the machine was in operation or not.

Figure 4 – Pilot plant engine housing

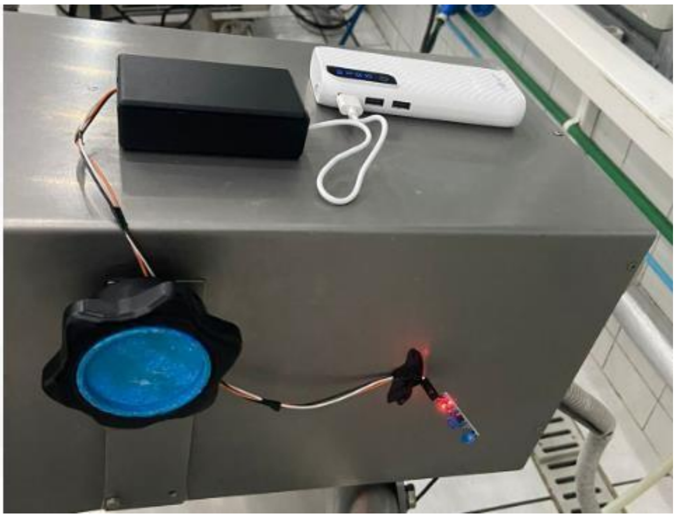
Source: The authors

After concluding the tests using the piezoelectric sensor and verifying its inability to measure the vibration in the target pilot plant machine, other vibration sensors were studied for monitoring and the successor sensor chosen was the SW-420 sensor. Following this assumption, the SW-420 has a spring system capable of detecting vibrations from the environment, unlike the piezoelectric sensor that is sensitive only to touch, which makes it more sensitive than the previous one. Tests were carried out on this sensor on the grinding engine, where its ability to measure the vibration of the engine during operation was verified.

As previously mentioned, the next test submitted to the sensor was the measurement of the pilot plant in operation. During the tests, the sensor detected the vibration of the equipment, but with low accuracy, which led to new experiments and studies to establish a better position for the detection of these vibrations. The result extracted was that the lateral surfaces of the motor box presented greater vibrations than the other surfaces, so the SW-420 sensor was implanted on the lateral surface for data collection in the machine, as shown in Figure 5 below.

INTERNATIONAL SEVEN JOURNAL
OF MULTIDISCIPLINARY
ISSN: 2764-9547

Figure 5 – Vibration sensor attached to the side surface of the motor housing



Source: The authors

Microcontroller Programming

The sensor responsible for measuring the vibration captures the vibration in numerical values, the ESP32 microcontroller takes care-of reading this data and sends it to the databases. This task is performed from a code written in the C++ language, a language recognized by ESP32, and is available in the repository at the following link: https://github.com/figueirapedro/ManutControlSensor.

This source code was initially structured including the libraries necessary for its operation, namely: "WiFi.h", for connecting to *WiFi* networks; "WiFiClientSecure.h" for security certificate used to authenticate connection to Telegram; "FirebaseESP32.h" for use of Firebase-related functions*; "*HTTPClient.h" to make the calls to send data to the MongoDB database*;* "Time.h" for use of time metrics; "UniversalTelegramBot.h" for sending data to the *Bot* on Telegram and *"*ArduinoJson.h" for handling data in *JSON format*.

In sequence, the variables that will be used during the operation of the microcontroller are declared, such as WiFi network credentials, value recorded in the sensor, database parameters in Firebase, request information to the MongoDB bank, among others.

In the body of the code there are two fundamental sections for the operation of the microcontroller, one being the operating configurations of the ESP32 and its initial parameters, and the other the logic of sending the data recorded by the sensors. In this second session, the code was developed to measure every second, connect to the banks in Firebase and MongoDB, define a minimum and maximum vibration metric for sending an alert by the *Telegram* Bot*,* structure the data to be sent and send it.

Prototype Box

The storage is an empty box made of ABS plastic with dimensions ten centimeters long, three centimeters high and 6.2 centimeters wide, with a thickness of 0.3 centimeters. In it, the ESP32 was fixed to its base using plastic rods to fit the microcontroller, where male-female *jumper connectors* are used to connect the microcontroller to the circuit, this is a printed circuit used for soldering the connectors. In the box, two holes were produced, one to power the original vertical rectangular opening system at the top of the box with dimensions of 1.5 centimeters high and 0.5 centimeters base, connected to a Power *Bank battery* with micro USB output, and a circular hole of 0.5 centimeters in diameter to evacuate the sensor connectors, as illustrated in Figure 6.

Figure 6 – Prototype box

Source: The authors

APPLICATION

The mobile application was developed in a solution architecture based on possible future integrations with other FESA production systems, enabling the registration of other machines, other types of sensing, among others, allowing the versatility of the project.

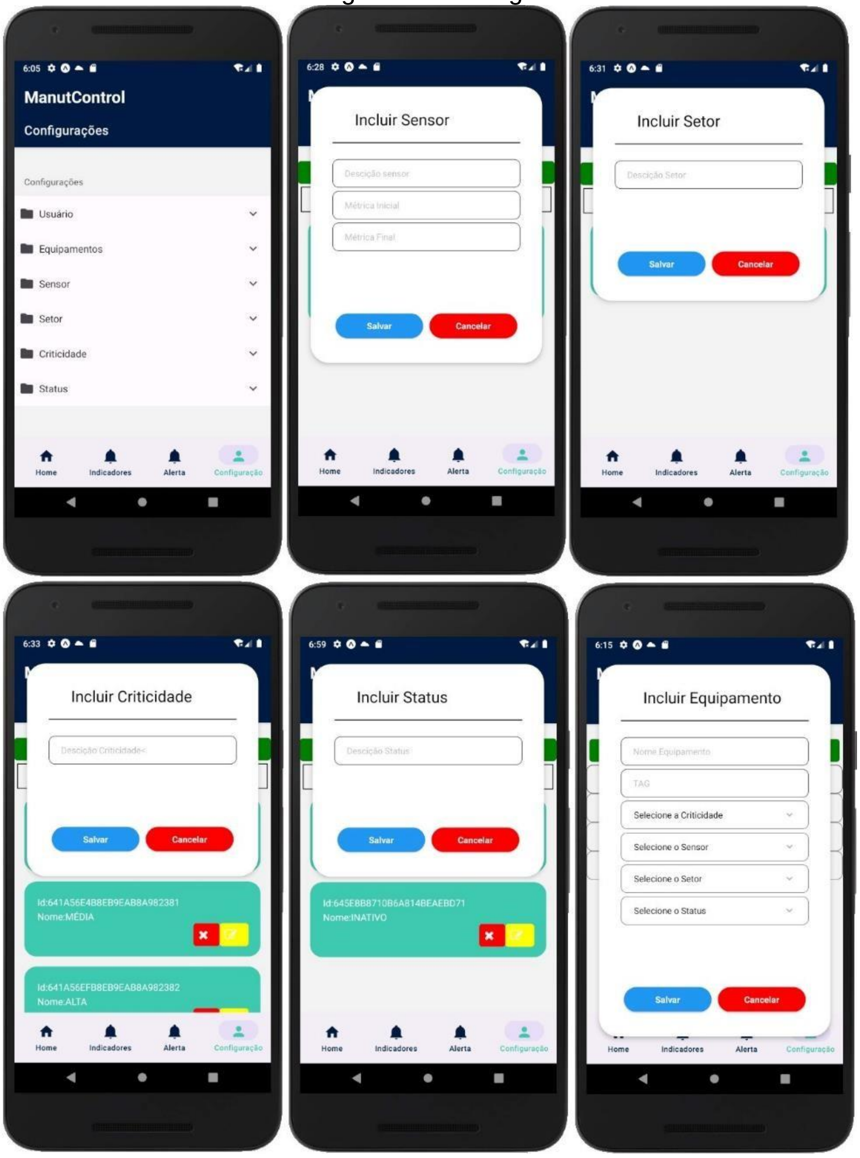
Mobile App

The Settings screen is responsible for listing the management of the application's functionalities, namely, User, Criticality, Equipment, Sensor, Sector, and *Status management*.

On the Sensor Registration screen represented in Figure 7, the user must enter three parameters, being the description of the sensor, the initial metric, the minimum value that the sensor can identify without having a failure in the equipment, and the final metric, being the maximum value where the sensor can capture so as not to be considered an anomaly in the machine. If the sensor identifies values outside these two metrics assigned by the user, the system issues an alert signal, detecting that this equipment has a possible failure.

The Criticality screen, also shown in Figure 7, aims to register the levels of risks that an equipment with anomaly can impact on production, costs, waste, profits and among others, as an example, the cheese machine, assigned by the team as high criticality. According to Figure 7, the Status Inclusion screen aims to register a metric that defines in which scenario that equipment is, such as, active or inactive. On the Sector screen, it is possible to register FESA sectors to facilitate the identification of the location where the equipment is positioned. Finally, the equipment registration screen uses all the functionalities mentioned, with the objective of determining the impact of the machine on the production system, as shown in Figure 7.

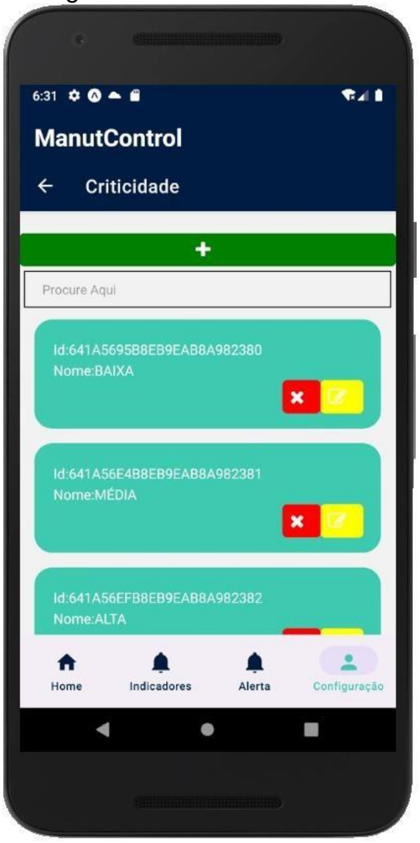
Figure 7 - Settings



Source: The authors

Another feature is the possibility of editing and deleting all parameters from the configuration screens, allowing the user to manage it more effectively, as an example can be seen in Figure 8.

Figure 8 – List of criticalities



Source: The authors

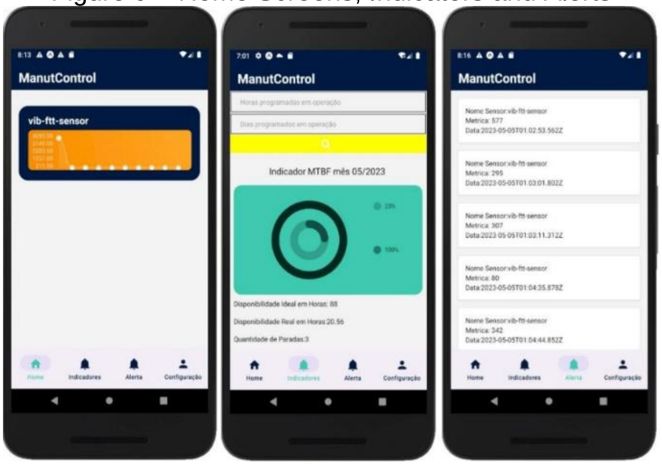
On the *Home screen* shown in Figure 9, it is possible to view the measurements of the sensors in real time, allowing the identification of future warning signs of anomalies.

The Indicators screen, also shown in Figure 9, was developed according to the study of the MTBF indicator for the purpose of calculating equipment availability and enabling the analysis of the sizing of maintenance effectiveness. Therefore, the user can enter two parameters, which are the number of hours that this equipment was in operation and for how many days, however, when the user does not enter any data, the indicator is generated considering by default the working days of the current month until the current date and as hours eight hours is used.

In summary, the Alert screen is intended to view the last thousand records of sensor notifications, considering that the sensor sends data to the bank every second, allowing in real time the monitoring of the measurements of the sensors registered in the application, as confirmed in Figure 9.

INTERNATIONAL SEVEN JOURNAL
OF MULTIDISCIPLINARY
ISSN: 2764-9547

Figure 9 – Home Screens, Indicators and Alerts



Source: The authors

Architecture

When planning the *software* architecture, the team analyzed the advantages of using various *development frameworks, however, due to benefits such as the possibility of creating more advanced, responsive interfaces, with the execution of complex tasks requiring less processing time, the group chose React Native.*

To transport the data requested by the user, the system uses a set of *APIs*, so that the user makes the request to a *RESTful API*, then the *API* transfers the information of the state of the resource to the requester, in which the information returns to the client via *HTTP* in *JSON format,* as shown in Source Code 1.

Source Code 1 – JSON Equipment

```
{
  "_id": {
    "$oid": "6286e388d83ec99c66a16b4a"
  },
  "Descricao": "Equipamento Z",
  "dataEntrada": {
    "$date": {
      "$numberLong": "1012020"
    }
  },
  "Tag": "XSD-TGD-KSK",
  "Status": "Inativo",
  "Local": "Produção O",
  "Criticidade": "Baixa"
}
```

Source: The authors

The data collected by the sensors will be sent to the databases in MongoDB and Firebase in order to increase the availability and reliability of the data, in which Firebase is used as a database for storing history, backup and report extraction, and MongoDb for data treatment and manipulation. For the application, the data consumption will be done through an *API* that will query the MongoDB base, chosen for its high scalability and return in *JSON format,* as an advantage the easy manipulation of the data, as shown in Figure 10, using *Swagger* for the documentation of the *APIs*, and is available at the link: http://15.228.3.6:3003/docs/#/.

Figure 10 – JSON format return

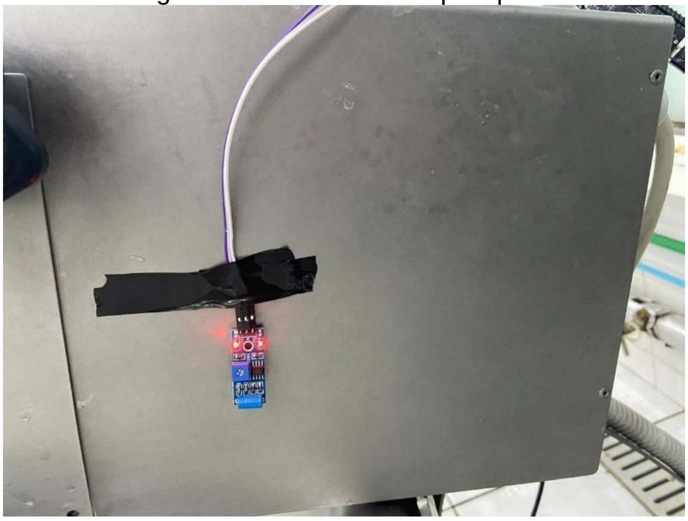
Source: The authors

With this, Firebase will store the collected data and present it in real time within the Google service, allowing you to use its own services for data extraction and report generation, this was planned as a result of the high volume of requests made by ManutControl and added to the use of BigQuery*,* Google's service for data manipulation via SQL commands, and in order to avoid additional costs, it was decided to use MongoDB as a database for integration with the mobile application.

TESTING

This topic consists of the final test performed on the pilot plant machine of the case study, and an analysis was initially carried out to identify the closest point to the machine motor, install ManutControl and thus obtain a better accuracy of data collection. After some experiments carried out at each point of the engine box, the lateral surface of the pilot plant was defined as the most accurate reference, as shown in Figure 11.

Figure 11 – Sensor in the pilot plant



Source: The authors

After configuring ManutControl on the machine, the motor execution was monitored for 20 minutes, to identify the minimum and maximum motor vibration metrics, which are respectively 280 and 1200 in an arbitrary unit, in the digital signal returned by the sensor in a normal operation of the machine, and if the captured value is outside these two metrics, the machine is anomalous. To perform this test, water was used to simulate the process with milk and reduce waste.

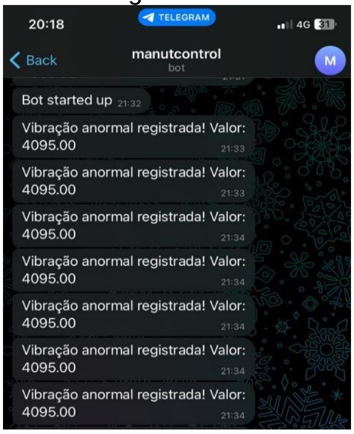
After the system was calibrated, the first test was started to validate whether the data collected by the sensor were being received by the application and projected on the graph according to the measurements, and as shown in Figure 12 the validation was assertive.

Figure 12 – Graphs with data emitted in real time in the software

Source: The authors

In order to carry out tests in the sending of notifications through Telegram and the application, the sensitivity of the ManutControl vibration sensor was manually reduced, to send a notification to the user informing that the sensor detected abnormal vibration of the programmed, this alert was sent through Telegram registered in the ManutControl system, as shown in Figure 13.

Figure 13 – Sending notifications via Telegram



Source: The authors

Then, the process was stopped to check if a notification would be sent to the user through the application and the messages were sent again by Telegram.

During the experiments, it was found that the presence of external factors can impact the values captured by the vibration sensor depending on the sensitivity at which it is configured, including air conditioning and excessive noise, interfering with the accuracy of the measurement.

RESULTS AND DISCUSSIONS

The prototype shown in Figures 4 and 5 was developed to remain in operation for a week even though it was not connected to a power grid, for this purpose, it was using a 10000 mAh Power Bank coupled to the system, considering that the user does not plan or cannot connect the prototype to a power grid.

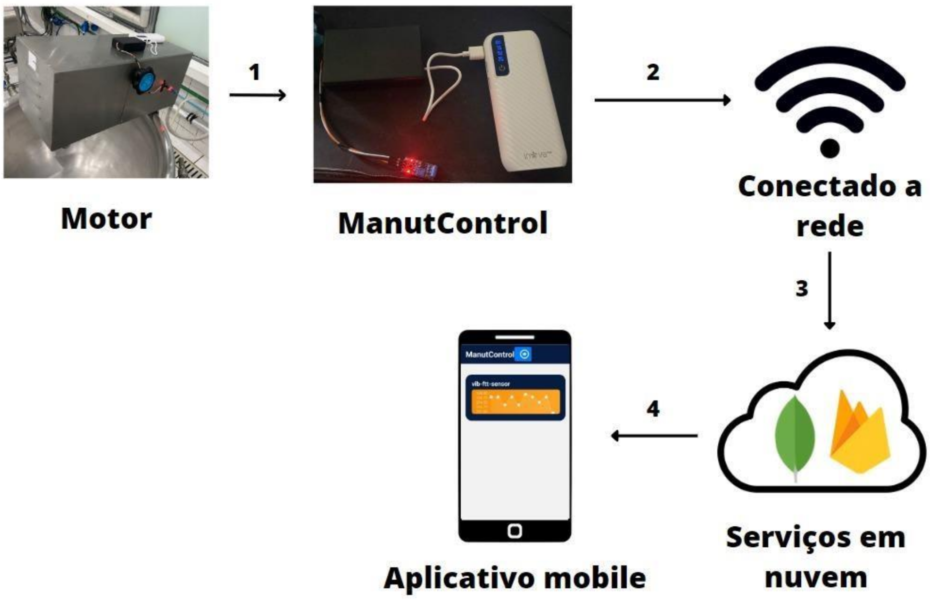
To avoid impacts such as low temperature variations and problems with the humidity of the case study environment, a plastic box was purchased for the storage of the prototype. The choice of this type of material was motivated by the low temperatures of the environment, so as not to influence the operation of the system, having as a characteristic the complete sealing of the circuit board and the sensor, reducing the chances of water droplets coming into direct contact with the ManutControl hardware.

As the SW-420 vibration sensor captures vibration data in real time, ManutControl was receiving a high volume of data, so it was necessary to map parameters to filter this data, receiving only those that would be useful for identifying anomalies in the system, such as the vibration value, measurement time, sensor name and machine name. Finally, the system sends data every second to the database and the *software* queries the data and deletes the old data to avoid performance problems.

The data sent to the bank is consulted by the application, in the *software* this data is displayed in real time through a graph and an alert screen. The application is also responsible for showing alerts to assist the user in case of any anomaly in the vibration of the engine, in addition to the warnings displayed by the application, a warning is sent to the Telegram of the employee who was registered in the system, to inform him of any inconsistency in the operation of the engine.

Based on the vibration changes reported by ManutControl, it is possible for the user to identify the need for preventive maintenance of the machine's motor, avoiding corrective maintenance, predicting future defects before they cause greater impacts on the operation of the equipment and the cheese production process. The architecture of this solution is shown in Figure 14.

Figure 14 – System architecture



Source: The authors

IMPLEMENTATION

For the implementation of the system in a functional way, it was pertinent to couple the box with the sensor near the motor, in a more precise region to detect the vibration of this equipment and execute the process, monitoring it for a period of 20 to 30 minutes, in order to define what is the maximum and minimum vibration, to be parameterized in the *software* of ManutControl. Another step is to evaluate which other external factors, such as air conditioning and excessive noise in the environment, can impact the results obtained by the sensor, to improve the accuracy of the data sent to the user.

In order for the system to be functional and connected to the mobile application, it is essential to connect ManutControl to an internet network close to the implemented environment, the user must download the application on their cell phone and register Telegram in the system, to receive emergency notifications in case of any stop or any unscheduled change in engine vibration.

COSTS

In this topic, the average cost of the parts needed for the development of the prototype hardware will be discussed, in which the total value shown in Chart 1 results in R$ 175.00, disregarding the value of labor and freight, which influences the total value.

Table 1 – Hardware Costs

Equipment	Unit cost
Sensor SW-420	R$ 12
ESP 32 DevKit 4	R$ 60
Storage Box	R$ 11
Power Bank 10.000 mAh	R$ 50
2x8 Embossed Circuit	R$ 15
AWS	R$ 7
Jumpers (kit com 100)	R$ 20
Total	R$ 175

Source: The authors

SOFTWARE

For this, three source codes were generated, namely: the programming for the microcontroller to record the measurements made by the sensors, structure the data to be sent to the Firebase databases, the *backend* application responsible for sending this data to MongoDB and alerts to Telegram. To access the source code used in the microcontroller, follow this address: https://github.com/figueirapedro/ManutControlSensor.git.

The application that communicates with the microcontroller is an *API* with the *RESTful architecture,* and performs the operations of inserting, changing, deleting and querying the MongoDB database, as well as informing what the maximum and minimum values of operation will be. The source code of this application is located at: https://github.com/figueirapedro/ManutControlBackend.git.

And the *mobile* application developed in React Native consults the data generated by the machine, shows real-time alerts, manages system components and equipment. The source code for this app can be found in the following repository: https://github.com/KathellinRibeiro/ManutControl_V1/tree/master, available for download from the Android app store at the following path: https://play.google.com/stor /apps/details?id=com.manutControl.manutcontrol.

FINAL CONSIDERATIONS

This article aims to propose a preventive analysis system for engines, with the main focus on identifying problems through the vibration analysis of a motor, helping the user in quick decision-making in cases of downtime and reducing corrective maintenance costs. The tool developed is low cost, and uses a relative scale with arbitrary unit to adjust and define what is the normal vibration pattern for the cheese machine motor. In view of this, it is possible to say that the developed system was able to meet the proposed objectives, since the vibration was monitored in real time and in case of sudden stops, the system sends an alert to the application.

The target audience of the system are owners of small factories or owners of small machinery that they use for cheese production, since they usually do not invest so much in technology and look for cheaper systems to help them reduce unexpected defects in the engines of their equipment and that generate alerts in case of stops, returning real-time vibration data from their equipment during execution, for the purpose of rapid decision-making and to allow the planning of preventive maintenance instead of corrective interventions.

The biggest difficulty found in the *hardware* was the coupling of the sensor to the cheese production equipment, because, if the sensor suffers any change in its physical position, it is necessary to recalibrate it, and as tapes were used for the development of the prototype, there may be interferences that impact its readings, influenced by the position in which it is, temperature and vibration of the environment.

Another obstacle faced during software development was the transmission of data between the *hardware* and the system hosted in the cloud, since the communication protocols between the board and the cloud have security problems, because the HTTP protocol is used, which is an open protocol and has security nonconformities with the cloud system, To solve this security impasse, it is recommended to use the *HTTPS protocol,* which is more secure, as the data trafficked under this protocol is encrypted and verified between the clients in the communication.

An obstacle that can impact the operation of the *software* is the use of the React Native framework in its development, in which there are several dependencies that often become depreciated, as they undergo constant updates, causing instability in the application.

For future studies, it is recommended to invest time implementing new sensors in order to increase the accuracy of detecting possible failures in the operation of the engine, thus also creating new tables for a better display of the data from these new sensors. Some future improvements studied for this system are:

- Use of a 3D accelerometer sensor as a vibration sensor, aiming that in addition to capturing data in real time, this sensor can analyze the vibration of the machine in 3 axes being the x, y and z, being able to analyze the vibration variation in these axes and thus obtain a more accurate diagnosis of anomalies;
- Preparation for the system to be able to integrate other measurement devices, increasing the machine's capacity to use other types of sensors, such as electric current and tilt sensors, as these measurements are needed;
- Develop a system to couple the sensor to the motor more efficiently, for example, using magnets for better coupling of the sensor, given that insulating tape is currently being used to attach the sensor to the machine and this can impact the accuracy of this device in collecting vibration data;
- Based on the data collected, be able to predict when a machine will need maintenance and send an alert informing about it, helping employees to plan predictive maintenance and make decisions regarding the operation of the equipment.

REFERENCES

1. Antunes, F. C. de C. (2022). Introdução a robótica: Uma proposta de sequência didática para o ensino de programação. Com a Palavra, o Professor, 7(19), 175–183. Disponível em: http://revista.geem.mat.br/index.php/CPP/article/view/880. Acesso em: 12 maio 2023.

2. Brasil. (1997). Portaria n°352, de 04 de setembro de 1997: Regulamento técnico para fixação de identidade e qualidade de queijo minas frescal. Ministério de Agricultura, Pecuária e Abastecimento - MAPA. Disponível em: https://www.defesa.agricultura.sp.gov.br/legislacoes/portaria-ma-352-de-04-09-1997,644.html#:~:text=O%20Queijo%20Minas%20Frescal%20dever%C3%A1,temperatura%20n%C3%A3o%20superior%20a%208%C2%BAC.&text=5.1.,para%20queijos%20de%20alta%20umidade. Acesso em: 05 mar. 2023.

3. Budziński, M. (2022). What is React Native? Complex guide for 2022. Netguru. Disponível em: https://www.netguru.com/glossary/reactnative#:~:text=React%20Native%20was%20first%20released,Instagram%2C%20Facebook%2C%20and%20Skype. Acesso em: 19 mar. 2023.

4. Carvalho, D. (2009). Fome e desperdício de alimentos. Desafios do Desenvolvimento, 6(54), 110. Disponível em: https://www.ipea.gov.br/desafios/images/stories/PDFs/desafios054_completa.pdf. Acesso em: 18 mar. 2023.

5. Chauhan, A. (2019). A review on various aspects of MongoDB databases. Rawal Institute of Engineering And Technology. Disponível em: https://l1nq.com/qMUFz. Acesso em: 15 mar. 2023.

6. Cunha, A. (2022, 20 out.). React Native: O que é e tudo sobre o framework. Alura. Disponível em: https://www.alura.com.br/artigos/react-native. Acesso em: 19 mar. 2023.

7. Daudt, L. (2021, 27 set.). Indicadores de manutenção: Veja os principais e sua importância. Antares. Disponível em: https://www.antaresacoplamentos.com.br/blog/indicadores-de-manutencao/#:~:text=A%20import%C3%A2ncia%20dos%20indicadores%20de%20manuten%C3%A7%C3%A3o&text=Al%C3%A9m%20disso%2C%20os%20indicadores%20de,funcion%C3%A1rios%20e%20paradas%20de%20manuten%C3%A7%C3%A3o.. Acesso em: 09 abr. 2023.

8. Embrapa. (2016, 24 jun.). Embrapa participa de audiência pública para o Plano Nacional de Combate ao Desperdício de Alimentos. Embrapa. Disponível em: https://www.embrapa.br/busca-denoticias/-/noticia/13801701/embrapa-participa-de-audiencia-publica-para-o-plano-nacional-de-combateao-desperdicio-de-alimentos. Acesso em: 25 abr. 2023.

9. Espressif Systems. (2023, 16 jan.). ESP32 Series: Datasheet. Disponível em: https://www.espressif.com/sites/default/files/documentation/esp32_datasheet_en.pdf. Acesso em: 16 abr. 2023.

10. Fielding, T. (2000). Architectural styles and the design of network-based software architectures. University of California, Irvine. pp. 5-151. Disponível em: https://www.ics.uci.edu/~fielding/pubs/dissertation/fielding_dissertation.pdf. Acesso em: 19 mar. 2023.

11. Hareendran, T. K. (2022, 26 jul.). SW-420 Vibration Sensor – Quick Guide. Electro Schematics. Disponível em: https://www.electroschematics.com/sw-420/. Acesso em: 11 mai. 2023.

12. IBM. (2021, 6 abr.). APIs de REST. IBM. Disponível em: https://www.ibm.com/br-pt/cloud/learn/restapis?mhsrc=ibmsearch_a&mhq=porque%20usar%20api. Acesso em: 19 mar. 2023.

13. Kamat, P. V. (2019). Absolute, arbitrary, relative, or normalized scale? How to get the scale right. ACS Energy Letters, 4(8), 2005-2006. Disponível em: https://pubs.acs.org/doi/pdf/10.1021/acsenergylett.9b01571. Acesso em: 14 mai. 2023.

14. Andrei, L. (2021, 15 jul.). O que é React e como funciona? Hostinger Tutoriais. Disponível em: https://www.hostinger.com.br/tutoriais/o-que-e-react-javascript. Acesso em: 17 mar. 2023.

15. Li, W.-J., et al. (2018). Just IoT Internet of Things based on the Firebase real-time database. Disponível em: https://www.researchgate.net/profile/Wu-Jeng-Li/publication/323342152_JustIoT_Internet_of_Things_based_on_the_Firebase_Realtime_Database/links/5bceb416a6fdcc204a013325/JustIoT-Internet-of-Things-based-on-the-Firebase-Real-time-Database.pdf. Acesso em: 25 jan. 2023.

16. Loguercio, A. P., & Aleixo, J. A. G. (2001). Microbiologia de queijo tipo minas frescal produzido artesanalmente. Ciência Rural, 31(6), 1063-1067. Disponível em: https://www.scielo.br/j/cr/a/PKm3pNcvkYYSk94YBzXpQsC/?format=pdf&lang=pt. Acesso em: 05 mar. 2023.

17. Marcorin, W. R., & Lima, C. R. C. (2003). Análise dos custos de manutenção e de não-manutenção de equipamentos produtivos. Revista de Ciência & Tecnologia, 11(22), 35-42.

18. Marin, A. A., & Reyes, J. S. (2022). Development and implementation of a low-cost security system. Tekhnê, 19(2), 29-34. Disponível em: https://revistas.udistrital.edu.co/index.php/tekhne/article/view/20361/18821. Acesso em: 03 mai. 2023.

19. Marques, A. C., & Brito, J. N. (2019, jul.). Importância da manutenção preditiva para diminuir o custo em manutenção e aumentar a vida útil dos equipamentos. Brazilian Journal of Development. São João del Rei. Disponível em:

https://ojs.brazilianjournals.com.br/ojs/index.php/BRJD/article/view/2315/2322. Acesso em: 20 set. 2022.

20. Megantoro, P., et al. (2022). Instrumentation system for data acquisition and monitoring of hydroponic farming using ESP32 via Google Firebase. Disponível em: https://scholar.unair.ac.id/en/publications/instrumentation-system-for-data-acquisition-and-monitoring-ofhyd. Acesso em: 25 jan. 2023.

21. Mozilla. (2022). Introduction to the DOM. MDN Web Docs. Disponível em: https://developer.mozilla.org/en-US/docs/Web/API/Document_Object_Model/Introduction. Acesso em: 17 mar. 2023.

22. Neves, V. (2023). React: o que é, como funciona e um guia dessa popular ferramenta JS. Alura. Disponível em: https://www.alura.com.br/artigos/react-js. Acesso em: 17 mar. 2023.

23. Ohyver, M., et al. (2019). The comparison firebase realtime database and MySQL database performance using wilcoxon signed-rank test. Disponível em: https://tinyurl.com/2evp7kes. Acesso em: 25 jan. 2023.

24. Organização das Nações Unidas (ONU). (2015). Objetivos de Desenvolvimento Sustentável. Disponível em: https://brasil.un.org/pt-br/sdgs. Acesso em: 18 mar. 2023.

25. Oliveira, V. I., Freire, F. L., & Zanatta, A. R. (2006). Optical properties of Er and Er+Yb doped hydrogenated amorphous silicon films. Journal of Physics: Condensed Matter, 18(32), 7709–7716.

26. Ricarte, M., et al. (2008). Avaliação do desperdício de alimentos em uma unidade de alimentação e nutrição institucional em Fortaleza-CE. SABER CIENTÍFICO, Porto Velho, 158-175, jan./jun.

27. Rodrigues, A. V., et al. (2022). Gestão da segurança e qualidade da produção de queijo minas frescal por meio do desenvolvimento de protótipos para monitoramento das variáveis do seu processo. FTT Journal, Faculdade Engenheiro Salvador Arena, São Bernardo do Campo, 19.

28. Santos, K. L. dos, et al. (2020). Perdas e desperdícios de alimentos: reflexões sobre o atual cenário brasileiro. Brazilian Journal of Food Technology, 23. Disponível em: https://www.scielo.br/j/bjft/a/yhXZXHzvzPTqRWJpLcVt9Bx/?lang=pt. Acesso em: 15 mar. 2023.

29. SEBRAE. (2021). Agronegócio. Santa Catarina, maio. Disponível em: https://www.sebraesc.com.br/storage/imagem-principal/60b0d9eb5a6ae119905118_2021-10-25-025838_fftn.pdf. Acesso em: 05 mar. 2023.

30. Sigga Technologies. (2021). MTBF e MTTR – Saiba tudo sobre estes indicadores da Indústria! Disponível em: https://www.sigga.com/pt-br/blog/mtbf-e-mttr-indicadores-da-industria. Acesso em: 19 mar. 2023.

31. Silva, T., et al. (2020). APIs de Visão Computacional: Investigando mediações algorítmicas a partir de estudo de bancos de imagens. Logos, 27(1).

32. Silva, M. da A., & Gonzalez, M. L. (2008). Influência de fatores da manutenção que afetam a vida útil. Inducson. VII Conferência Internacional de Aplicações Industriais, 1-7.

33. Tyson, M. (2022). What is JSON? The universal data format. Disponível em: https://www.infoworld.com/article/3222851/what-is-json-a-better-format-for-data-exchange.html. Acesso em: 15 mar. 2023.

34. Veríssimo, J., et al. (2019). Análise de viabilidade econômica de uma fábrica de queijo minas frescal. XI Congresso Brasileiro de Engenharia de Produção, Ponta Grossa, 1-12. Disponível em: http://aprepro.org.br/conbrepro/2019/anais/arquivos/09302019_220935_5d92a7c74b73e.pdf. Acesso em: 05 mar. 2023.

35. Zandonai, R. (2021, 04 mar.). ONU: 17% de todos os alimentos disponíveis para consumo são desperdiçados. ONU. Disponível em: https://brasil.un.org/pt-br/114718-onu-17-de-todosos-alimentos-dispon%C3%ADveis-para-consumo-s%C3%A3o-desperdi%C3%A7ados. Acesso em: 25 abr. 2023.