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MONITORING OF VARIABLES IN THE LOGISTICS DISTRIBUTION WITH THE USE OF THE MSR175 DATALOGGER

MONITORING OF VARIABLES IN LOGISTICS DISTRIBUTION WITH THE USE OF THE MSR175 DATALOGGER

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Abstract -- Compliance with international quality and safety standards for the international purchase and sale of food increasingly requires comprehensive traceability. During transport, factors such as temperature and vibrations can compromise the sensory properties and shelf life of products. To address these challenges, data loggers are used, which are technological devices that integrate sensors capable of recording key physical variables in real time. Their use allows not only the traceability of transport conditions, but also the identification of critical points within the logistics chain.

This equipment has applications in multiple sectors, as it can measure parameters such as temperature, humidity, pressure, flow, light, wind speed, and gas concentration, among others. Its versatility makes it an essential tool for industrial process control, environmental monitoring, and quality management.

This research will focus on analyzing the temperature and vibration conditions that affect sliced bread during distribution. The information collected by the data loggers will contribute to optimizing logistics management and ensuring product quality in the context of international food trade.

Keywords: sliced bread, monitoring, exports, logistics, supply chain.

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INTRODUCTION

In food import and export activities, product quality and safety are two essential elements for achieving end-buyer satisfaction. For this reason, compliance with international regulations governing this matter is essential. For logistics actions related to transportation, factors such as temperature and vibrations must be taken into consideration, as they can significantly affect the texture, flavor, and shelf life of the product, giving rise to considerable and circumstantial challenges for supply chain operators.

It is important to store monitoring readings relating to temperature and vibrations using data loggers, electronic devices that combine a variety of sensors to measure and record these variables. They have become indispensable tools for the logistics sector because they allow real-time data to be recorded on the conditions to which products are exposed during transport, from the storage phase to final delivery. This continuous recording of information provides the opportunity to identify potential risks and critical points in the distribution chain, as well as providing information to improve the logistics process and ensure compliance with national and international quality standards.

Data loggers are electronic devices that support accurate and continuous monitoring, facilitating the collection of essential data to support informed and optimized decision-making.

There is a range of variables that can be recorded by data loggers, among which the following stand out: temperature, which is one of the most important variables in a variety of industries, such as agri-food, pharmaceuticals, and environmental research; temperature recording via data loggers is an indispensable tool for monitoring controlled environmental conditions and critical industrial processes. The relative humidity variable is necessary for measuring the humidity present in the air, a substantial factor in the manufacturing process, product storage, and meteorological studies. With regard to the pressure variable, it is worth mentioning that it is unofficially relevant in the automotive, petrochemical, and aviation industries, where it is imperative to monitor pressure levels to ensure safety and operational efficiency. Similarly, in electrical monitoring, the implementation of data loggers is crucial.

to record voltage, with the intention of assessing electrical current and its variations within electrical circuits. It should be noted that the devices have the ability to measure vibrations and acceleration, which is essential for evaluating the condition of industrial machinery, since early detection of abnormal vibrations in key equipment within production would facilitate the diagnosis of potential faults. Likewise, flow measurement, whether for liquids or gases, is indispensable in activities such as water management and the chemical processing industry, as they can measure the liquid or gas flow through a system over a given time, ensuring efficient and accurate control. The measurement of light intensity within the agricultural and environmental sectors would support the proper management of sun exposure for crops or in closed storage spaces. In meteorological and renewable energy studies, devices that measure wind speed are particularly useful for determining both the speed and direction of the wind in a specific environment. Finally, it is important to note that certain data loggers have the ability to measure gas concentrations in the environment, including compounds such as CO2, oxygen, and methane, among other volatile gases. These devices play a crucial role in environmental monitoring and atmospheric condition assessment.

For all the reasons described above, data loggers are devices that can be implemented in a wide variety of industries, both in the environmental and scientific fields, as they support accurate and continuous monitoring, facilitating the collection of essential data for informed decision-making.

This research will focus on analyzing the temperature and vibration conditions to which sliced bread is subjected during the distribution process, using data loggers that can record relevant information on these factors. The aim is to improve quality management in food products within the field of international logistics.

Concept

A sensor is a device capable of detecting physical or chemical changes in its environment and converting them into electrical signals that can be measured and interpreted. These signals provide quantitative and qualitative information on various variables, such as temperature, pressure, humidity, movement, among others, allowing for real-time monitoring and control of processes (Angeles-Angeles., 2019).

Origin and Historical Evolution of Sensors

The history of sensors dates back to humans' first attempts to measure and control their environment. An early example is the thermometer invented in the 17th century by Galileo Galilei, which allowed for more accurate temperature measurement (Ruiz, et al., 2019). This device laid the foundation for the development of more sophisticated sensors by providing a way to quantify natural phenomena.

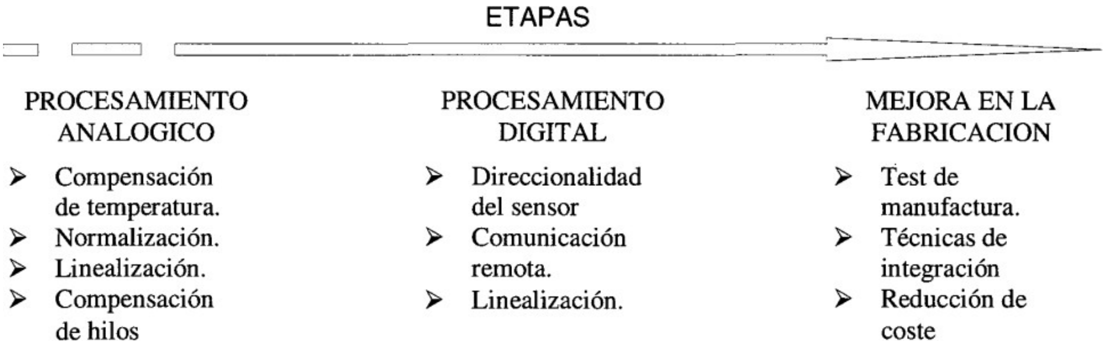


Figure 1. *Areas of interest in smart sensor research over time.*

Source: *Smart sensors: a history with a future.*

Advances during the Industrial Revolution

The Industrial Revolution of the 18th and 19th centuries significantly boosted the development of sensors due to the need to control complex industrial processes. The invention of the pressure gauge to measure steam pressure in steam engines is a notable example from this period (Garay-Rondero C. L., 2020). These devices improved the safety and efficiency of industrial operations. **Development in the 20th Century**

The 20th century witnessed exponential advances in sensor technology, driven by progress in electronics and semiconductor materials. The invention of the transistor in 1947 opened the door to miniaturization and improved sensor sensitivity (Garay-Rodero, et al., 2019).

In the 1960s and 1970s, with the development of integrated circuit technology, more compact and efficient sensors were created. The emergence of digital and microelectromechanical (MEMS) sensors revolutionized various industries, enabling applications in fields such as automotive, aerospace, and medicine (Marquez, D., & Cárdenas, O., 2006).

Digital Age and Smart Sensors

With the advent of the digital age and the Internet of Things (IoT) in the 21st century, sensors have acquired advanced capabilities, integrating with communication and data processing systems. Smart sensors can now not only measure variables, but also process and transmit information autonomously, facilitating the implementation of automated and connected systems in real time (Ben-Daya, et al., 2019).

Cargo Monitoring and Traceability

Sensors enable continuous monitoring of the conditions in which goods are transported and stored. For example:

- Temperature and humidity sensors: Crucial for perishable products such as food and medicine, ensuring that they are kept in optimal conditions during transport and storage (Salamanca, et al., 2021).
- Location sensors (GPS): These facilitate cargo traceability, providing real-time information on the location of shipments and optimizing transport routes (Denis, et al., 2021).
- Shock and vibration sensors: These detect impacts or conditions that could damage the goods, allowing immediate corrective action to be taken (Mesa, 2019).

DEVELOPMENT

Problem Statement

Currently, there is no research focused on the implementation of data loggers, which would mark the beginning of continuous and accurate monitoring and recording of various parameters such as temperature and vibrations. However, performing this monitoring manually is unfeasible due to the large volume of data and the need for constant measurement, which can result in the loss of critical information and human error.

Currently, the lack of an automated data recording system makes it difficult to make informed decisions, identify patterns or trends, and react quickly to changing conditions. For example, in an industrial environment, the lack of adequate temperature and vibration monitoring can lead to hazardous conditions or a reduction in product quality.

Therefore, there is a need to develop a data logger that is capable of:

1. Collect data from multiple sensors with high accuracy.

2. Store data efficiently and securely.
3. Operate autonomously for long periods of time.
4. Facilitate data transfer and analysis through appropriate interfaces.
5. Adapt to different environments and specific requirements of each application.

This data logger must be an optimal and easy-to-implement solution, capable of improving efficiency and accuracy in the monitoring of critical parameters.

Objective

Verify the accuracy of the data logger's temperature and humidity sensors for reliable monitoring during the transport of sensitive goods.

Methodology

The work was carried out in the logistics laboratory, where typical conditions for handling products in an industrial environment were recreated. The stages of the experiment are described below:

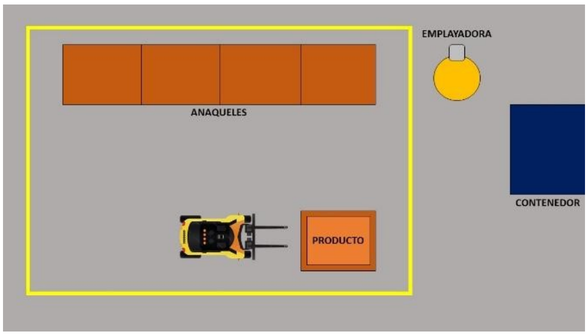


Figure 2. Layout of the logistics laboratory.

Source: Own work, 2024.

Preparation of the experiment

- A package of Bimbo sliced bread was selected as a representative sample.
- A data logger was placed inside a box containing the bread. This device was configured to record temperature and impact data every 10 minutes throughout the experiment.

Figure 3. Loaf of bread with the data logger inside the box.

Source: Own work, 2024.

Wrapping the pallet

- The box with the bread and the data logger was placed on a pallet.
- The pallet was carefully wrapped, simulating the standard process used in the industry to ensure load stability.

Container Transport and Location

- With the help of a forklift operated by an expert in vehicle handling, the pallet was moved and stored in a container located outside the laboratory.
- The container was exposed to normal environmental conditions for a defined period of time (1 hour).

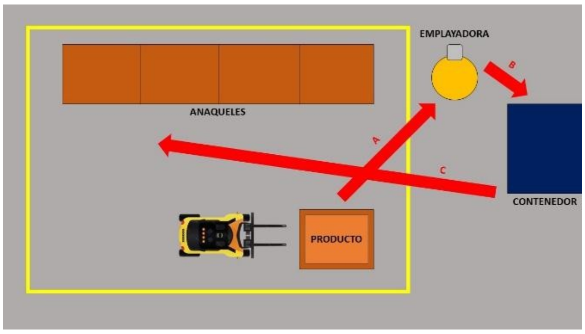


Figure 4. Layout with forklift routes inside the warehouse.

Source: Own work, 2024.

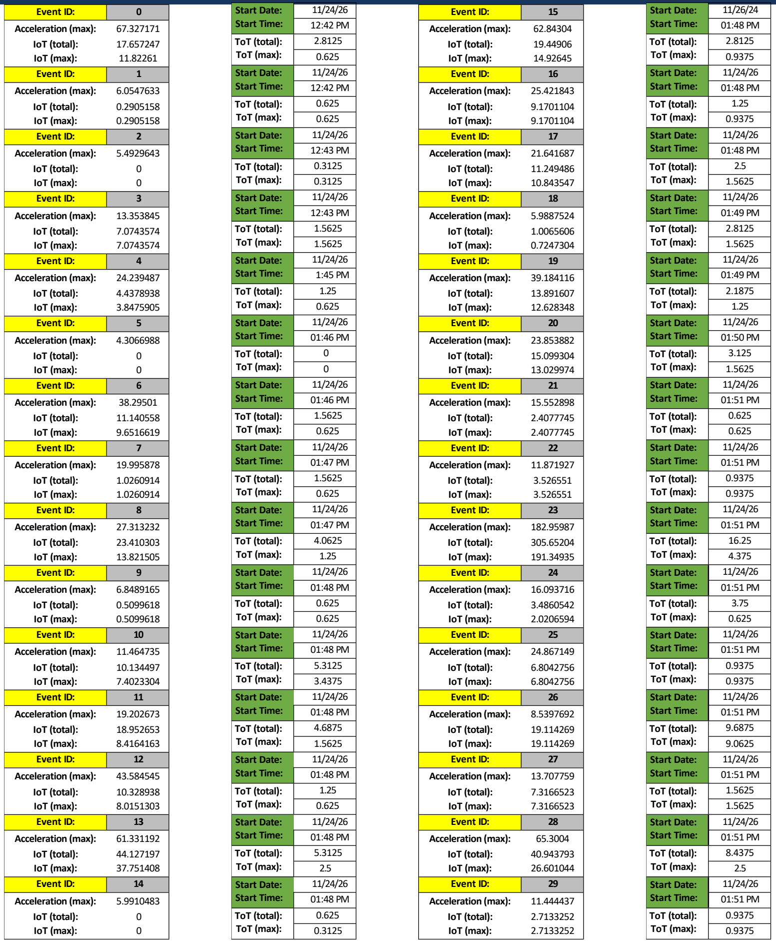
Data Monitoring

- During the storage period, the data logger recorded continuous data that was subsequently downloaded and analyzed.

Data Analysis Method

For data analysis, the DMAIC methodology (Define, Measure, Analyze, Improve, and Control) will be implemented, which allows for a systematic and rigorous approach to evaluating the information provided by data loggers during the logistical distribution of products (Carrillo-Landazabal, et al., 2022). This procedure aims to identify variations in critical variables that affect the quality of the distribution process. Through accurate monitoring of key indicators, such as temperature and the impacts to which products are subjected, the aim is to minimize the risks associated with the integrity of these goods. This will not only ensure compliance with current regulations, but also improve the overall performance of the logistics process.

Based on the data collected, the following tables have been created to summarize the events analyzed. They show both the minimum and maximum values and the maximum acceleration recorded, along with the start time and corresponding date. Two runs (tests) were performed, in which 30 events were taken for the first run and 15 events for the second, with each event yielding an average of 800 data points generated by the sensor at the time of the runs.



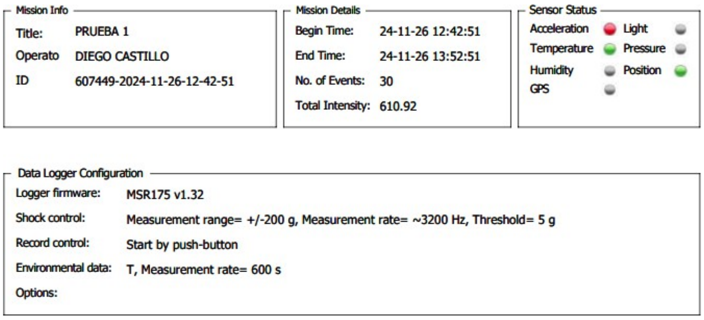
Event ID:	Acceleration (max):	IoT (total):	IoT (max):	Start Date:	Start Time:	ToT (total):	ToT (max):
0	67.327171	17.657247	11.82261	11/24/26	12:42 PM	2.8125	0.625
1	6.0547633	0.2905158	0.2905158	11/24/26	12:42 PM	0.625	0.625
2	5.4929643	0	0	11/24/26	12:43 PM	0.3125	0.3125
3	13.353845	7.0743574	7.0743574	11/24/26	12:43 PM	1.5625	1.5625
4	24.239487	4.4378938	3.8475905	11/24/26	1:45 PM	1.25	0.625
5	4.3066988	0	0	11/24/26	01:46 PM	0	0
6	38.29501	11.140558	9.6516619	11/24/26	01:46 PM	1.5625	0.625
7	19.995878	1.0260914	1.0260914	11/24/26	01:47 PM	1.5625	0.625
8	27.313232	23.410303	13.821505	11/24/26	01:47 PM	4.0625	1.25
9	6.8489165	0.5099618	0.5099618	11/24/26	01:48 PM	0.625	0.625
10	11.464735	10.134497	7.4023304	11/24/26	01:48 PM	5.3125	3.4375
11	19.202673	18.952653	8.4164163	11/24/26	01:48 PM	4.6875	1.5625
12	43.584545	10.328938	8.0151303	11/24/26	01:48 PM	1.25	0.625
13	61.331192	44.127197	37.751408	11/24/26	01:48 PM	5.3125	2.5
14	5.9910483	0	0	11/24/26	01:48 PM	0.625	0.3125
15	62.84304	19.44906	14.92645	11/26/24	01:48 PM	2.8125	0.9375
16	25.421843	9.1701104	9.1701104	11/24/26	01:48 PM	1.25	0.9375
17	21.641687	11.249486	10.843547	11/24/26	01:48 PM	2.5	1.5625
18	5.9887524	1.0065606	0.7247304	11/24/26	01:49 PM	2.8125	1.5625
19	39.184116	13.891607	12.628348	11/24/26	01:49 PM	2.1875	1.25
20	23.853882	15.099304	13.029974	11/24/26	01:50 PM	3.125	1.5625
21	15.552898	2.4077745	2.4077745	11/24/26	01:51 PM	0.625	0.625
22	11.871927	3.526551	3.526551	11/24/26	01:51 PM	0.9375	0.9375
23	182.95987	305.65204	191.34935	11/24/26	01:51 PM	16.25	4.375
24	16.093716	3.4860542	2.0206594	11/24/26	01:51 PM	3.75	0.625
25	24.867149	6.8042756	6.8042756	11/24/26	01:51 PM	0.9375	0.9375
26	8.5397692	19.114269	19.114269	11/24/26	01:51 PM	9.6875	9.0625
27	13.707759	7.3166523	7.3166523	11/24/26	01:51 PM	1.5625	1.5625
28	65.3004	40.943793	26.601044	11/24/26	01:51 PM	8.4375	2.5
29	11.444437	2.7133252	2.7133252	11/24/26	01:51 PM	0.9375	0.9375

Table 1. Data obtained with the "Test 1" data logger.

Source: Own elaboration, 2024.

RESULTS ANALYSIS

The specific software for the electronic device was used to extract the data collected by the data logger. In the information analysis phase, specialized tools such as Excel and Minitab were used to facilitate in-depth data processing. Finally, a comprehensive report was generated in PDF format, which includes graphs representing the temperature variations and impacts observed, as well as detailed tables presenting the significant events recorded by the data logger.



Mission Info
Title: PRUEBA 1
Operato DIEGO CASTILLO
ID 607449-2024-11-26-12-42-51

Mission Details
Begin Time: 24-11-26 12:42:51
End Time: 24-11-26 13:52:51
No. of Events: 30
Total Intensity: 610.92

Sensor Status
Acceleration ● Light ●
Temperature ● Pressure ●
Humidity ● Position ●
GPS ●

Data Logger Configuration
Logger firmware: MSR175 v1.32
Shock control: Measurement range= +/-200 g, Measurement rate= ~3200 Hz, Threshold= 5 g
Record control: Start by push-button
Environmental data: T, Measurement rate= 600 s
Options:

Figure 5. General data "Test 1".

Source: MSR ShockViewer Analysis Software.

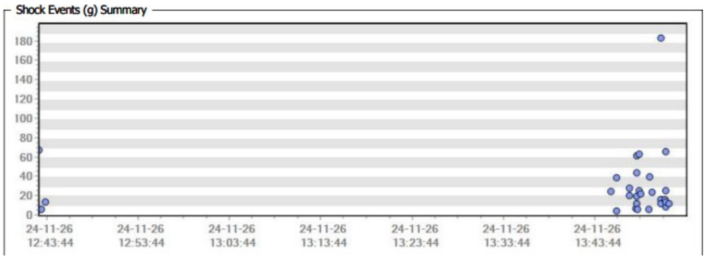
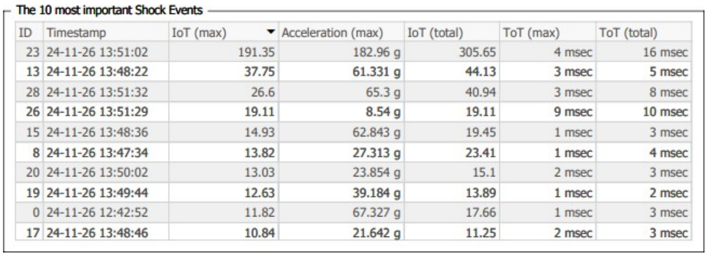


Figure 6. Impact recording graph "Test 1."

Source: MSR ShockViewer Analysis Software.



The 10 most important Shock Events

ID	Timestamp	IoT (max) ▼	Acceleration (max)	IoT (total)	ToT (max)	ToT (total)
23	24-11-26 13:51:02	191.35	182.96 g	305.65	4 msec	16 msec
13	24-11-26 13:48:22	37.75	61.331 g	44.13	3 msec	5 msec
28	24-11-26 13:51:32	26.6	65.3 g	40.94	3 msec	8 msec
26	24-11-26 13:51:29	19.11	8.54 g	19.11	9 msec	10 msec
15	24-11-26 13:48:36	14.93	62.843 g	19.45	1 msec	3 msec
8	24-11-26 13:47:34	13.82	27.313 g	23.41	1 msec	4 msec
20	24-11-26 13:50:02	13.03	23.854 g	15.1	2 msec	3 msec
19	24-11-26 13:49:44	12.63	39.184 g	13.89	1 msec	2 msec
0	24-11-26 12:42:52	11.82	67.327 g	17.66	1 msec	3 msec
17	24-11-26 13:48:46	10.84	21.642 g	11.25	2 msec	3 msec

Figure 7. Record of the 10 most significant impact events, "Test 1."

Source: MSR ShockViewer analysis software.

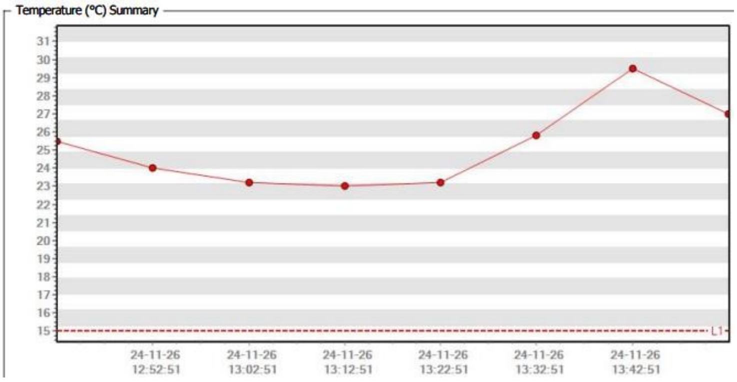
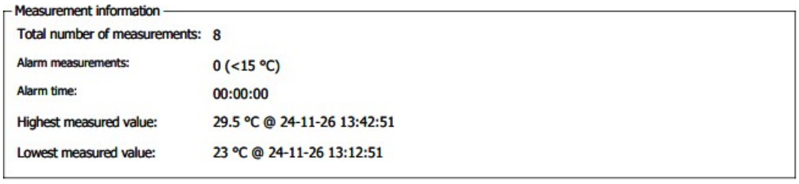


Figure 8. Temperature graph "Test 1."

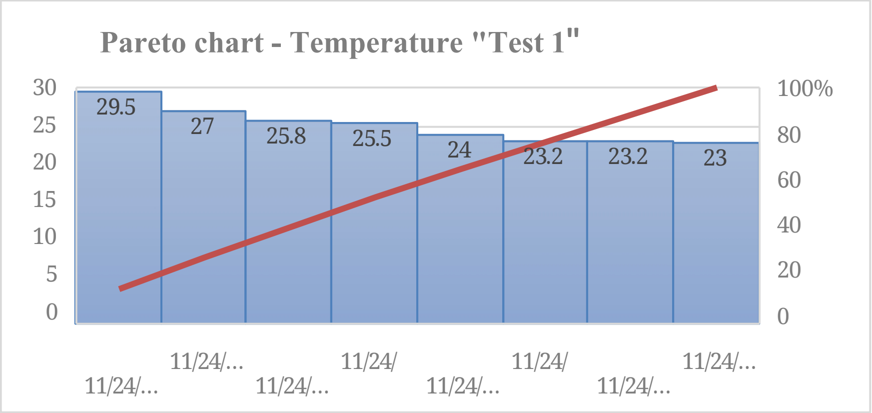
Source: MSR ShockViewer Analysis Software.



Measurement information
Total number of measurements: 8
Alarm measurements: 0 (<15 °C)
Alarm time: 00:00:00
Highest measured value: 29.5 °C @ 24-11-26 13:42:51
Lowest measured value: 23 °C @ 24-11-26 13:12:51

Figure 9. Temperature parameters "Test 1."

Source: MSR ShockViewer Analysis Software.



Graph 1. Pareto chart "Test 1"
Source: Own elaboration, 2024.

According to Figures 6 and 7, when we started the relevant runs, we identified three slight impacts that we believe were caused by handling the sensor when placing it inside the box next to the loaf of bread.

The pallet containing the sensor was then transferred to the wrapping machine to be wrapped, however, there was a 30-minute delay in wrapping it due to equipment problems. But we received support from a third party. This is reflected in Figure 6, and it can be seen that the sensor did not detect any impact during that time period.

Once the pallet was wrapped, it was moved to a shipping container outside the laboratory and left there for about 30 minutes. Figure 8 shows that the temperature rises at point 6, which is at 1:22:51 p.m., due to the weather conditions outside the laboratory.

After 30 minutes in the container, the box was removed and placed back inside the laboratory on top of a shelf, where it was left for about 10 minutes. Figure 7 shows too many impacts due to sudden movements with the forklift when placing the box on top of the shelf. Similarly, the temperature decreased, as can be seen in the graph (Figure 8), due to the ambient temperature inside the laboratory compared to the temperature inside the container.

Similarly, using the data provided by the program, a Pareto chart (graph 1) was created showing the temperature variations during the first test with the data logger.

CONCLUSIONS

This research demonstrates how the implementation of data loggers and the use of the DMAIC methodology can significantly transform logistics processes, especially in the distribution of perishable products such as sliced bread. Dataloggers, advanced monitoring devices, allow critical variables such as temperature and vibrations to be recorded and analyzed in real time, providing accurate and reliable data. This is crucial in a supply chain where environmental and handling conditions can directly affect product quality and safety. The DMAIC methodological approach provides a clear and systematic structure for addressing problems in logistics processes. The Define, Measure, Analyze, Improve, and Control phases ensure continuous improvement based on data, facilitating the identification of root causes of problems, the implementation of effective solutions, and the establishment of permanent controls. During laboratory tests, it was evident how temperature variations and impacts influenced the condition of sliced bread, demonstrating the importance of constant monitoring to preserve its integrity.

It is worth noting that the implementation of data loggers in transport companies, as well as in micro, small, and medium-sized enterprises (MSMEs), has a significant positive impact. This is because these devices allow real-time measurement of the environmental conditions to which the final product is exposed during the process. In particular, the ability to record accurate data on critical variables such as humidity, temperature, and mechanical impacts—factors integrated into the functionality of the data logger—facilitates informed decision-making. These decisions have a direct impact on optimizing operational efforts, reducing costs, and strengthening the company's competitive position in the market (Martínez and Guevara, 2019; Cervantes et al., 2021). Consequently, the use of this technology represents an indispensable strategic tool for improving export performance and complying with current consumer regulations.

The results of the study not only highlight the benefits of using sensor technology in logistics, but also highlight the associated challenges, such as the need to train staff in equipment handling, optimize logistics operations, and ensure compliance with international standards.

FUTURE WORK

Future research should include the review and analysis of automation systems, as well as technology-based monitoring using neural networks or fuzzy logic, which will contribute to increased value and continuous improvement within logistics processes in this area.

It is recommended that a comprehensive study be conducted to analyze the optimization of distribution routes based on the environmental conditions specific to each season of the year, with a special focus on regions characterized by high climatic variability. This research has the potential to enable significant improvements in the transport of perishable goods. It is suggested that the analysis include a detailed evaluation of various routes, schedules, and transportation methods that favor optimal product preservation. In addition, it is essential to conduct a cost-benefit analysis of these adaptations, which will contribute to informed and efficient decision-making in logistics management.

Furthermore, it is imperative to incorporate predictive models based on artificial intelligence that allow for the anticipation of variations in demand and possible disruptions in the supply chain resulting from external factors, such as extreme weather events or fluctuations in international regulations. The integration of these models with advanced logistics management systems will facilitate a proactive response, minimizing losses and optimizing export performance, especially in sensitive sectors such as food and pharmaceuticals. To this end, interdisciplinary collaboration between experts in foreign trade, information technology, and logistics is recommended, thus ensuring a holistic approach based on robust scientific evidence.

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