MUSSELPRO

Grant agreement number. 863681

D 3.3 MUSSELPRO Demonstration

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Content

Executive summary

The report **D3.3 MUSSELPRO Demonstration** " led by TEINCO, belongs to the WP3 - Full-scale demonstration of MUSSELPRO at JEALSA cannery [Months: 18-39].

In this report, we described the main results related to TASKS:

- Task 3.1. Installation and integration of the full-scale industrial DEMO unit
- Task 3.2. 14-month full scale demonstration, calibrations and performance data obtainment.
- This work-packages concerns the installation of the DEMO unit in JEALSA's cannery and the execution of a 14-month full-scale demonstration of the system, including calibration and obtainment of the performance data.
- In this report, TEINCO and JEALSA present the entire process of the Full-scale demonstration of MUSSELPRO at JEALSA cannery with the hyperspectral equipment, the vacuum cooker and the smart autoclave coupled with the IoT 4.0

1 INTRODUCTION

The deliverable **D3.3 MUSSELPRO Demonstration** aims to describe the main public results achieved so far in the project according to the implemented tasks (Task 3.1 and Task 3.2). The partial results obtained so far in the MUSSELPRO project have been kept under industrial confidentiality. The industrial secret will be maintained until the tests and validation of the MUSSELPRO system at industrial level are made in the facilities of JEALSA. Therefore, the results that the MUSSELPRO consortium considers public at this moment will be shown below.

The results of this report are linked to the following tasks:

- Task 3.1. Installation and integration of the full-scale industrial DEMO unit
- Task 3.2. 14-month full scale demonstration, calibrations and performance data obtainment.

All these tasks belong to the WP3 “Full-scale demonstration of MUSSELPRO at JEALSA cannery “[Months: 18-39].

Task 3.1. Installation and integration of the full-scale industrial DEMO unit

Once the design and manufacturing phase of the MUSSELPRO systems has been completed. We start with the installation phase of the equipment in the production plants.

We installed the thermal systems (cooking and sterilization) in the ESCURIS plant.

While the raw material analysis system was done at JEALSA.

This installation strategy allowed us to validate the integration of equipment between different plants.

It allowed us to validate and test the exchange of information in real time between equipment located in different facilities.

This is very important because it allowed us to develop a tool not only for local use, we were able to develop a tool that allows remote use between equipment located in different plants of the company.

Task 3.2. 14-month fullscale demonstration, calibrations and performance data obtainment.

The objective of this deliverable is to show the results of the tests performed.

We performed tests of cooking and sterilization of mussels, in these tests we have applied different production processes. The objective of these tests was to optimize the process.

The cooking and sterilization tests were carried out at the ESCURIS plant. While the hyperspectral analysis was performed at JEALSA's plant

Therefore, the objective of this deliverable is to show the installation and integration of the MUSSELPRO demonstration system.

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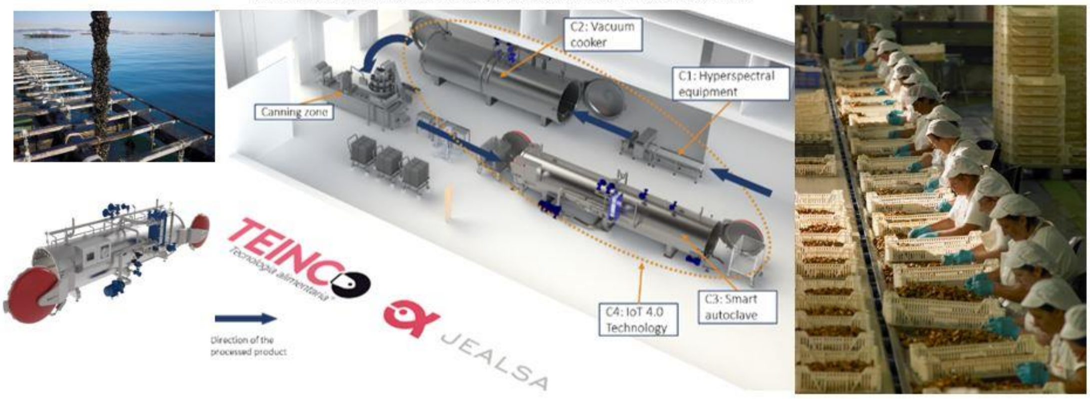
DEMOSTRATION OF AN IoT 4.0 MUSSEL PROCESSING SYSTEM FOR AN ADVANCED SEAFOOD CANNING INDUSTRY



2 GENERAL BACKGROUND

2.1 THE MUSSELPRO´ CONSORTIUM

The consortium of MUSSELPRO is formed by AUTOMATISMOS TEINCO the project coordinator, and JEALSA (project beneficiary). TEINCO will provide industrial innovation expertise focused on thermal processes in canning industry mainly specialised in designing, manufacturing and market advanced equipment for the food processing industry and IoT 4.0 technologies. TEINCO will be responsible of the know-how of MUSSELPRO system. JEALSA, is the top manufacturer of canned seafood and fish in Spain and second in Europe with more than 4000 employees globally. Currently JEALSA is processing 130.000 annual tonnes of canned seafood and fish in the factory placed in Galicia. JEALSA is the technology validator providing, through several tests at its premises, crucial feedback for the MUSSELPRO optimisation, the fine tuning and demonstration of the system.

2.2 MUSSEL CANNING PRODUCTION

Mussels canning production takes place along a processing a line with multiple steps (Figure 1). Briefly, these are: (i) mussels washing and cleaning, (ii) mussels cooking in the cooker, (iii) meat removal from the shells, (iv) cans filling with the cooked mussels and the liquid medium (oil, water…), (v) cans sterilisation in the autoclave and (vi) labelling and dispatch.

The mussel canning process is characterized by high energy consumption. This is mainly due to the cooking and sterilisation steps. Indeed, these two steps alone consume **more than 70 % of the total energy** used in the sector (including transportation). High energy consumption cannot be avoided, but it can be optimized. The best approach to do so is by making an efficient use of the energy and by reducing processing times.

However, in the state-of-the-art, **energy is not efficiently used, and processing time lasts more than necessary**. Moreover, product quality is also negatively affected. The reasons behind these problems are:

- **Pre-fixed processing time**: depending on the characteristics of the raw matter (fat and humidity content), the processing time should be different. However, these characteristics are not assessed in the state-of-the-art, and so processing times are not selected accordingly.

- **Uneven heat distribution**: ideally, the temperature within the chamber of the cooker and the autoclave should be the same in all points. However, equipment currently available in the market is unable to do this. Consequently, cold spots are created. In order to compensate lower temperatures in the cold spots, the overall temperature of the chamber must be increased. This result in an **inefficient energy use** that could be avoided.

- **Overheating**: aligned with the previous point, compensating the lower temperatures in the cold spots by increasing the overall temperature, cause overheating in other spots. Since mussels (and fish products in general) are highly thermolabile, overheating ultimately results in **decrease product quality**, due to **excessive dehydration**, degradation of amino and fatty acids and oxidation of lipids.

2.3 MUSSEL CANNING INDUSTRY NEEDS

Based on the above analyses of the canning industry pain points, we highlight the following industry needs:

- **Reduce energy consumption**: through **minimisation of processing times and of processing inefficiencies at the stage of cooking and sterilisation**, allowing for better processing efficiency and profitability

- **Enhance final product quality**: through lessening the negative impact of processing on the product

2.4 MUSSELPRO SYSTEM INCREASES EFFICIENCY AND PRODUCT QUALITY

To answer the needs of the canning industry, MUSSELPRO is going to revolutionise the mussel canning sector solving its main pain points. MUSSELPRO system is an innovative technology-based solution that optimises and controls the conditions of mussel cooking and sterilisation, adjusting the processing times and temperature levels to the characteristics of each batch of mussels to be processed.

To do so, we have developed an **advanced vacuum cooker** and **smart autoclave.** Each one has:

- an **own-developed control system**, able to program the processing time and temperature according to the characteristics of the raw matter. To do so, a **hyperspectral equipment** specifically develop for the purpose of MUSSELPRO, measures the mussels' characteristics at the beginning of the processing.

- an **own-developed system for temperature optimization and homogenization.** It consists on a stem injection system and vacuum pumps (the later only for the vacuum cooker). Automatically managed by the control system, it avoids the creation of cold spots. Thus, uneven heat distribution and overheating issues are avoided.

Moreover, by leveraging the power of data, MUSSELPRO integrates an **IoT 4.0 platform**. It receives and process the data from the vacuum cooker, the smart autoclave and the hyperspectral system; enabling to offer further services: (i) real-time remote monitoring and tele-maintenance, (ii) augmented reality visualization and (iii) machine learning capabilities.

MUSSELPRO is highly versatile. On the one hand, the vacuum cooker and the smart autoclave are manufactured on-demand according to each client's needs. This way, the processing capacity of the vacuum cooker and the smart autoclave can be adjusted (from 400 to 600 kg/cycle for the vacuum cooker and from 10,000 to 30,000 cans/cycle for the smart autoclave). On the other hand, it can either be installed in already existing processing lines or in new processing lines. Moreover, if the client wants to, their regular and autoclave can be upgraded, by implementing the control systems and the system for temperature optimization and homogenization. This way, they do not have to purchase the whole equipment but only the upgrades that are a key differentiating factor.

Finally, it is possible to connect to the M2M network other equipment of the processing line (e.g., the scale or the canning machine) so that the control systems can have a broader view of each batch and optimize even more the processing times and temperature.

Below in Figure 1, we show a schematic representation of the mussel canning processing line with the MUSSELPRO system implemented (highlighted in orange) and a render of the hyperspectral system, the vacuum cooker, and the smart autoclave:

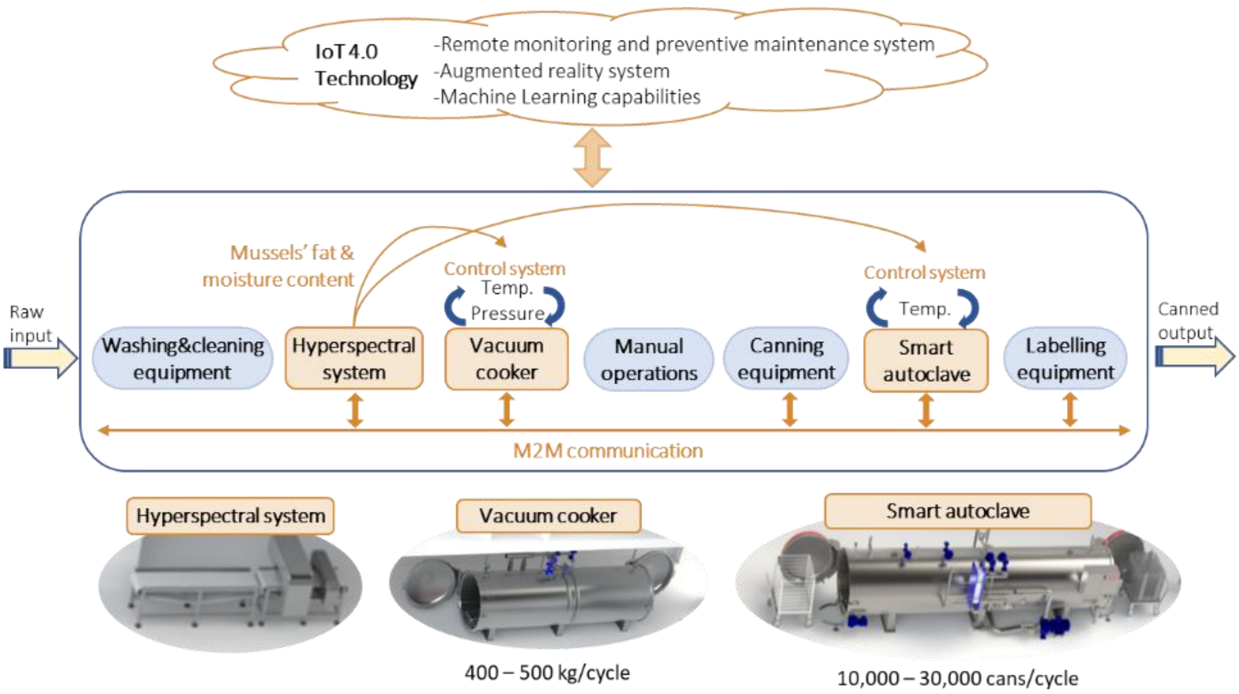


Figure 1. The MUSSELPRO system in the mussel canning process.

The MUSSELPRO system allows for **full optimisation and control of the parameters** of mussel cooking and sterilisation, adjusting the temperature and processing time to the mussels' characteristics of each batch as well as enabling homogenous temperature conditions and better heat transmission to the inside of the processed product.

As a result, MUSSELPRO ensures the following revolutionary impacts for an average mussel cannery when compared with the state-of-the-art.

- **20 % higher processing output** allowing higher profit.
- **15 % lower energy consumption per cycle.**
- **30-45 % less water consumption.**
- **15% lower green-house gas emissions per cycle.**

AUTOMATICALLY OPTIMISED TEMPERATURE LEVELS AND HOMOGENEOUS HEAT DISTRIBUTION, which result in:

- **Enhanced product quality** by 1-3% due to lower product dehydration.

Figure 2. Final product.

3 DEFINITION OF THE MUSSELPRO DEMOSTRATION

This report - D3.3 MUSSELPRO DEMOSTRATION by TEINCO and JEALSA – is a summary of the 14-month full-scale demonstration, calibrations and performance data obtainment under WP3 - Full-scale demonstration of MUSSELPRO at JEALSA cannery.

To carry out this activity, technical meetings have been held at the JEALSA´s facilities, studying and analysing the details that were considered appropriate for the mussel production line of **JEALSA, the technology validator.**

The objective of the deliverable, *"3.2. Full-scale industrial Demo"*, is the full-scale demonstration of the MUSSELPRO system, which was performed at JEALSA´s factory in ESCURIS (since the factory in Boiro – where the demonstration was planned originally - was damaged in the fire). The demonstration lasted 14 months (start in December 2021 which was M26, end in January 2023, which was M39) during which the DEMO unit underwent calibrations and adjustments. In addition, the demonstration provided crucial industrial performance data.

This report contains the industrial demonstration test of the MUSSELPRO components that make up the MUSSELPRO system as an industrial demonstration:

- Hyperspectral system for raw material control
- Mussel cooking system= advance vacuum cooker
- Sterilization system=smart autoclave
- IOT System

Figure 3. Mussel production line at JEALSA.

3.1 THE MUSSELPRO SYSTEM INSTALLATION

Once the design and manufacturing phase of the MUSSELPRO systems has been completed. We start with the installation phase of the equipment in the production plants.

Initially, the installation of the equipment was carried out entirely at JEALSA's factory. However, part of the installation was affected by the fire at that plant.

We installed the thermal systems (cooking and sterilization) in the ESCURIS plant. While the raw material analysis system was done at JEALSA.

This installation strategy allowed us to validate the integration of equipment between different plants. It allowed us to validate and test the exchange of information in real time between equipment located in different facilities.

3.2 THE DEMONSTRATION OF THE MUSSELPRO SYSTEM´ COMPONENTS

3.2.1 THE HYPERSPECTRAL SYSTEM

The first activity to carry out was the hyperspectral system tests.
For the calibration of the hyperspectral equipment, the characteristics of the mussels (fat, moisture) were analyzed both by the hyperspectral equipment itself and by a laboratory. Salt and the presence and identification of foreign bodies were also analyzed, as well as other elements analyzed by JEALSA (byssus and moisture).

Target analytical values were set for each of the elements analyzed, based on JEALSA's usual quality requirements. In this way, it was possible to compare the results of the hyperspectral equipment with reliable analyses and calibrate the evaluation of the hyperspectral equipment accordingly.

Figure 4. Mussel test in Hypespectral system

The samples extracted from the different tests performed as well as control samples were passed through the hyperspectral system and modelled in order to improve the results of the system when passing the sample through it, looking for the identification of foreign bodies and of what type, as well as the analytical values under study.

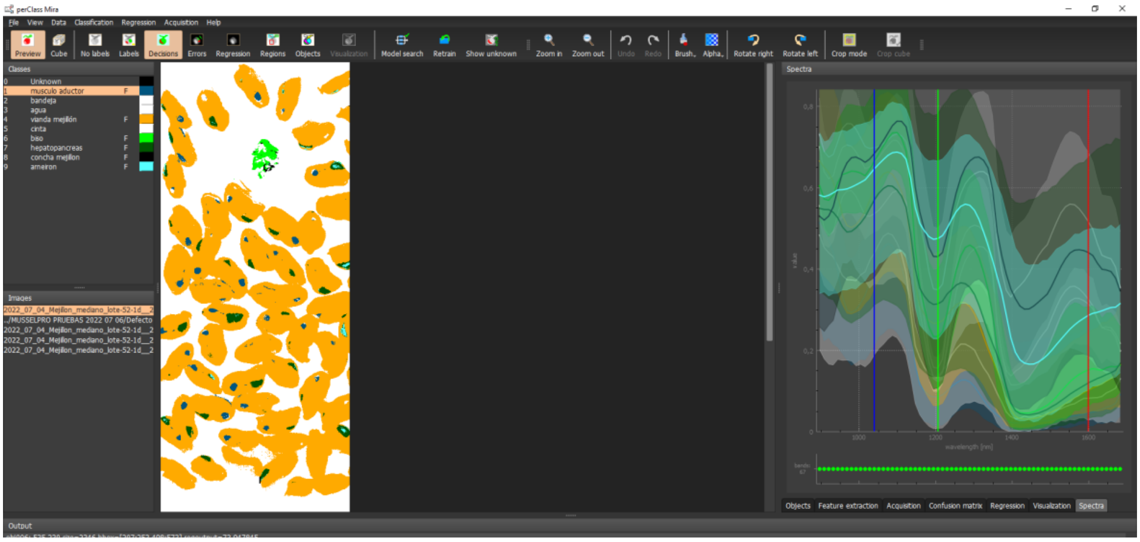


Figure 5. Testing in Hyperspectral Software (I).

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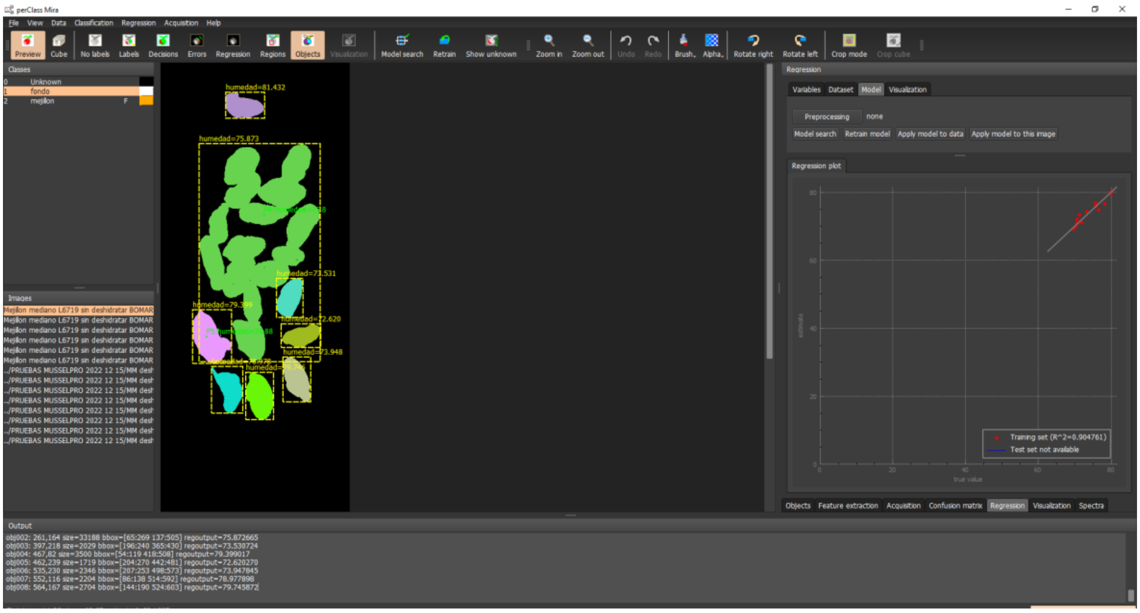

Figure 6. Testing in Hyperspectral Software (II).

The model transfers the moisture value of each individual mussel. There is some variability in the individual values, which means that with this system we can work with an average moisture value, as well as allowing us to evaluate the differences between the individuals analysed

3.2.2 THE IoT 4.0 SYSTEM

We worked on the validation of the IoT 4.0 Platform developed in Task 2.5, testing and validating the performance of the services provided (remote monitoring, d preventive maintenance, augmented reality and machine learning capabilities).

The monitored points were identified, and an improvement plan was outlined where those improvements that were identified during the system testing were implemented.

The main parameters monitored are:

- Process times
- Temperatures
- Pressures
- Energy consumption

Figure 7. *IoT 4.0 platform home page.*

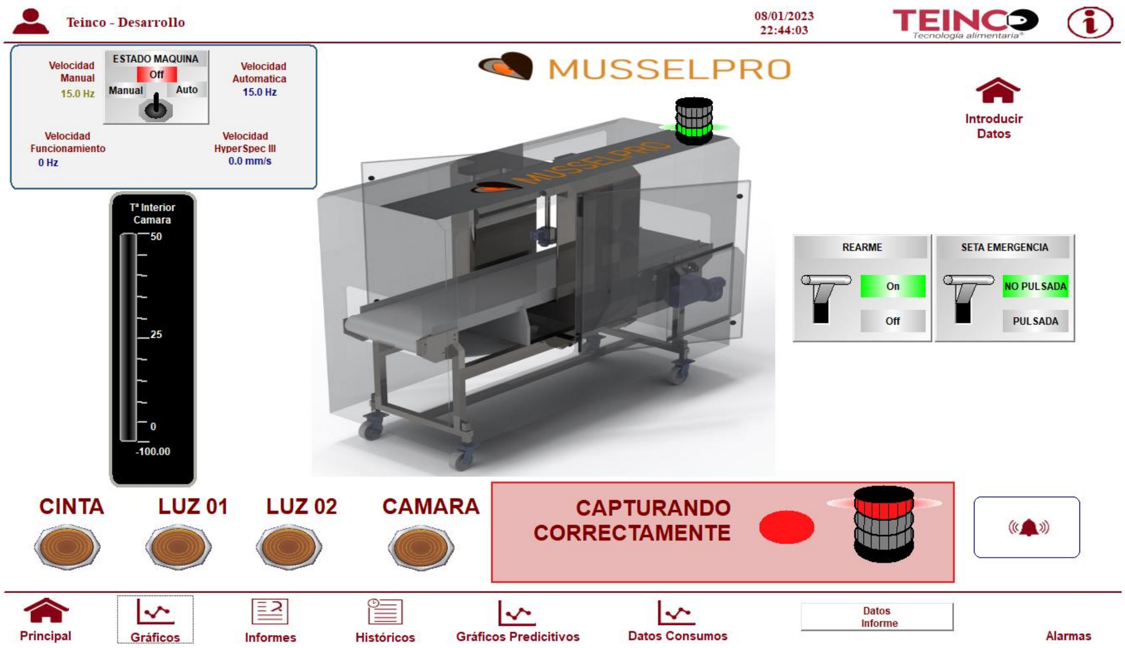

Figure 8. *Hyperspectral system home page.*

In the initial screen we can see the main features of the system:

- Status lights
- Camera status
- If the machine conditions are suitable for capturing.
- Operating speeds

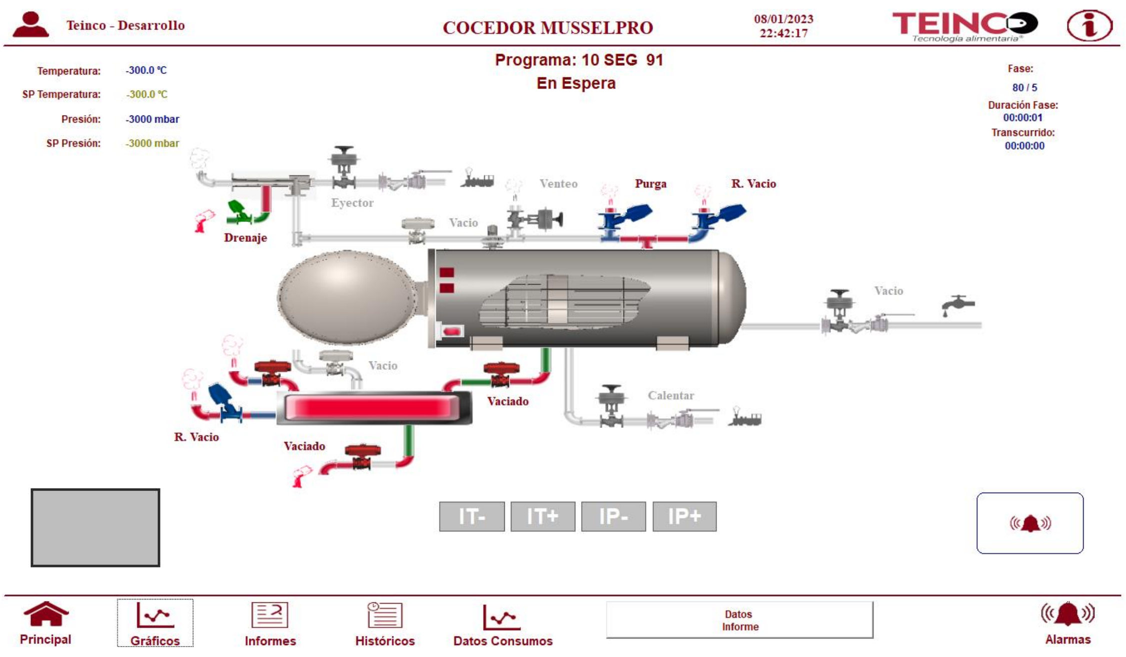

Figure 9. *Main screen remote monitoring vacuum cooker.*

On this screen we have the main synoptic of the cooker. Here we can visualise:

- Temperatures.
- Pressures.
- State of the different valves.
- Cycle phase.
- Elapsed times.

Also from this screen we can move to:

- Graphics Screen
- History Screen
- Consumption Screen
- etc

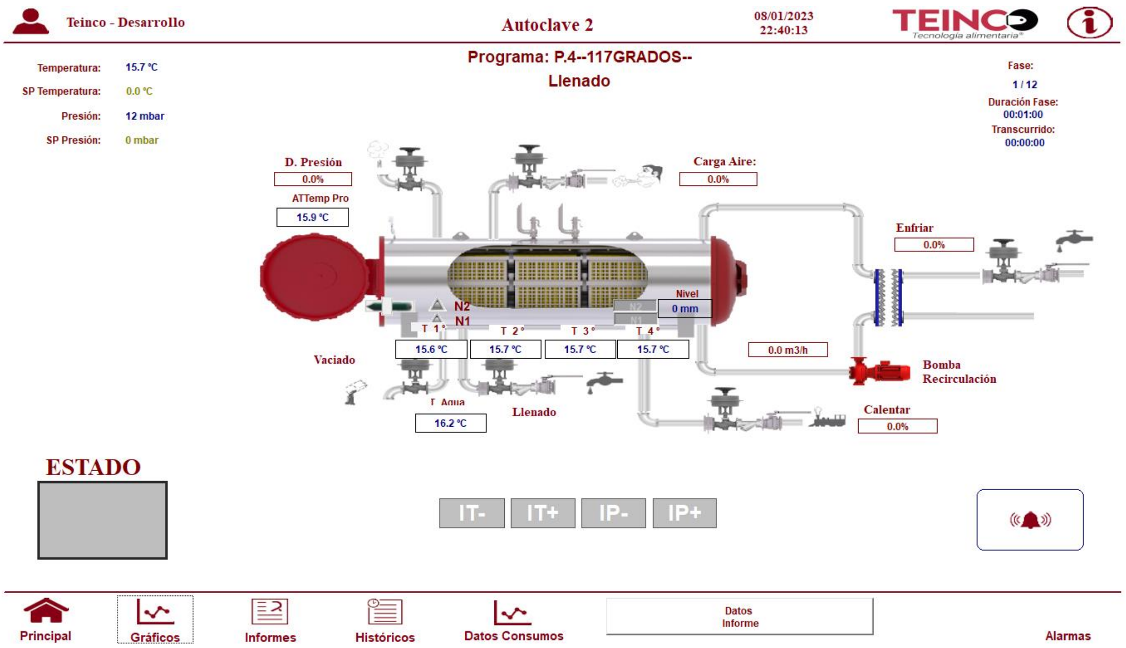

Figure 10. *Main screen remote monitoring smart autoclave.*

The IoT system developed allows us to monitor the different systems.

The system connects the different production processes, this allows us to make operational decisions of one process based on another.

The current system does not interact directly with the machine, i.e. the system tells us which is the best process to perform, but always an operator is the one who has to operate.

A point of improvement for future versions is to allow the system to operate directly on the processes.

The system complies with all the characteristics initially contemplated.

3.2.3 THE MUSSELPRO VACUUM COOKER INDUSTRIAL TEST

The parameters calibrated were the processing time and temperature levels of the vacuum stove.

In the case of the vacuum cooker, the processing time and temperatures were evaluated by the control system, which regulates accordingly the temperature optimization and the homogenization system (=steam injection system + vacuum pumps + temperature distribution control).

It has a continuous monitoring system of the temperature distribution along the cooker that allows identifying the appearance of cold spots and warns the user of a possible malfunction of the equipment, allowing preventive maintenance to minimize the possible occurrence of a serious operating incident as well as the heterogeneity of the raw material processed.

Figure 11. Mussel cooking test

Figure 12. Temperature control system

3.2.4 THE MUSSELPRO SMART AUTOCLAVE INDUSTRIAL TEST

The parameters to be calibrated are processing time and temperature levels of the smart autoclave.

The smart autoclave, processing time and temperature levels were also evaluated by its control system, which regulates accordingly the steam injection system taking into account the target sterilization value (F0 or "microbial destruction level").

Once the sensors were calibrated and the autoclave was started up, temperature distribution tests were carried out with different operating conditions of the equipment (varying temperatures, flow, times, pressures, etc.) as well as F0 tests to ensure the microbiological safety of the product.

During temperature distribution and penetration tests, all process data can be displayed on the main screen of the autoclave. There is also a screen showing the energy consumed by the autoclave.

3.3 DEMONSTRATION OF THE INTEGRATED SYSTEM

3.3.1 Connection between the demo unit elements and control systems

During the industrial tests, the characteristics of the mussels (fat, moisture, salt) were analyzed at different stages (before and after cooking and before and after sterilization) with hyperspectral equipment.

Based on the results, the parameters of the vacuum cooker and the intelligent autoclave (processing time and temperature levels) were adjusted to achieve the final product quality values set by JEALSA.

This required adjusting the control systems of the vacuum cooker and the intelligent autoclave so that the cooking and sterilization parameters were adjusted according to the results of the hyperspectral analysis.

3.3.2 Machine-to-machine network

Together with the demonstration unit equipment and the IoT technology setting, the system was tested integrating a machine-to-machine network that allows interconnection between the system components, as well as their connection with other processing equipment in the canning plant. The schematic representation of the interconnection of MUSSELPRO components is shown in Figure 13 which presents the network as well as the communication between the network.

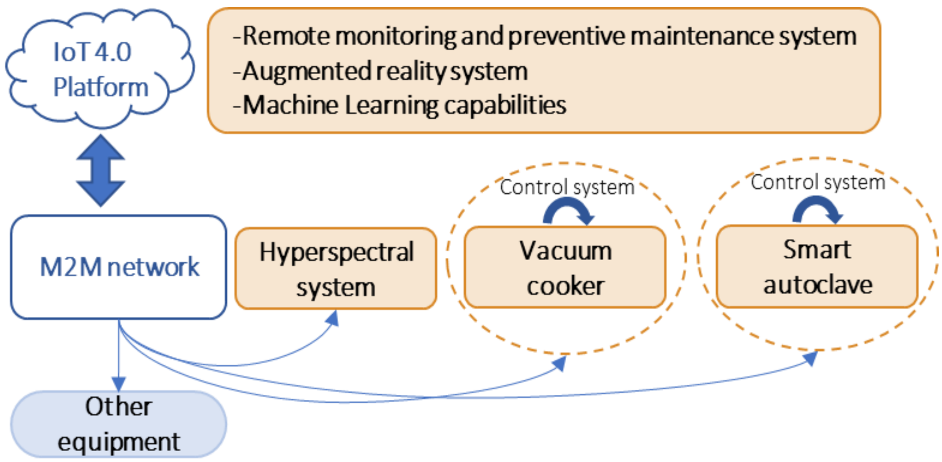

Figure 13. MUSSELPRO System Integration Structure

The IoT 4.0 technology software also enables real-time remote monitoring, remote maintenance of the equipment anywhere in the world, and visualization of the machine through augmented reality. It also enables machine learning to improve the performance of the vacuum cooker and the intelligent autoclave.

After the tests carried out, we have verified that the MUSSELPRO system satisfies all the requirements initially set.

The system allows us to evaluate the raw material and adjust the production processes to achieve the desired quality.

3.4 CONCLUSIONS

Throughout the 14-month demonstration, the demo unit was modified and improved as we tested the system under industrial conditions.

The demonstration allowed to obtain different analytical and industrial performance data regarding:

- Characteristics of the raw material.
- Quality of the final product.
- Processing times
- Correction of the cooking and sterilization conditions applied.
- System adjustments necessary to optimize processing based on raw material characteristics obtained from hyperspectral analysis.
- Equipment operation methodology (e.g. equipment cleaning and preparation for a new processing cycle).

The following are selected results:

CATEGORY	DEMONSTRATION VALUES
Processing times – vacuum cooker	1 seg. – 340 seg.
Temperatures – vacuum cookers	70ºC and 110ºC
yield improvement - vacuum cooker	0.5%-3%
Processing times – Smart autoclave	2 min – 35 min
Temperatures – smart autoclave	105 ºC – 130ºC
Hyperspectral system	Moisture, salt, foreing bodies
IoT 4.0 Platform	Development
Final product	ok

These data will allow further optimization of the system and modifications to the MUSSELPRO system design, which will be the next step in the project.