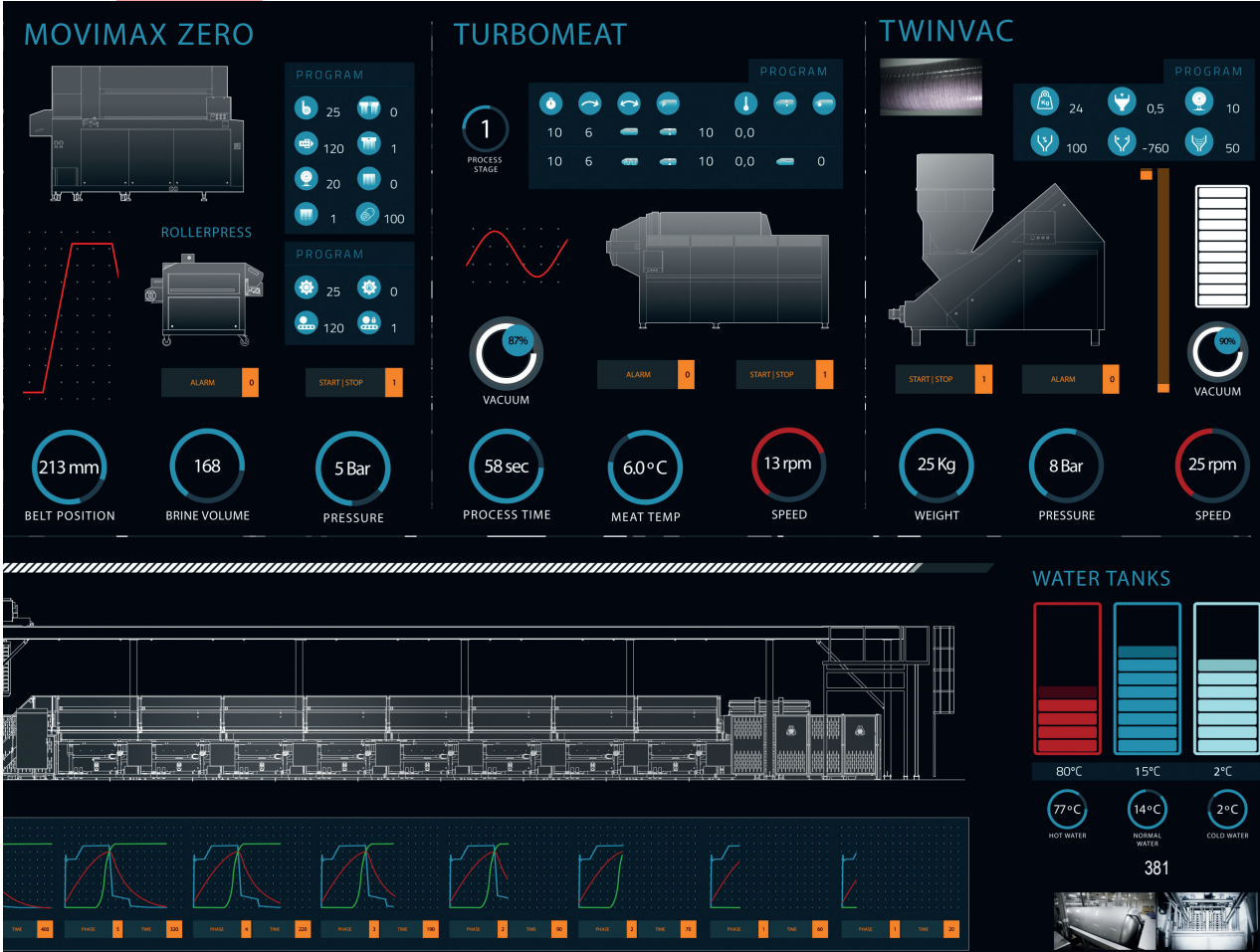


Digital transformation of cooked ham lines

Eva Fernandez, Marta Xargayó, Pere Canadell, Josep Tarradas, Josep Lagares

NEW



ABSTRACT

The COVID-19 pandemic has accelerated digital transformation in all aspects, and the meat processing industry is no exception. Specifically, cooked meat product lines have undergone a significant change in recent years. First, it was the automation of machines, then the automation of complete lines and now, in a changing and exponentially interconnected world, the implementation of digital technologies in existing processes is already transforming automatic manufacturing plants for cooked meat products.

This article reviews the evolution of this industry, from the tradition of the beginning to the automation of production lines, and analyses how digital transformation can integrate all areas of the processing lines to optimize processes, maximizing the quality of the products, improve the profitability of the sector and contribute to the sustainability of the planet.

EVOLUTION OF THE MEAT INDUSTRY THROUGH HISTORY

Throughout history, the manufacture of artisan sausages emerged to preserve and store the surplus of fresh meat that could not be consumed in a short period of time. At the beginning of the 18th century, the well-known industrial revolution began with a tremendous social and economic impact in all areas. The possibility of using industrial machinery began to be contemplated with the usual takeoff of the production of foods related to meat. In this context, there was a tremendous technological advance during the second half of the 20th century, with the proliferation of new meat products and new machinery guaranteeing the standardization of their quality and reducing process times. Now, this revolution is evolving towards new objectives with the introduction of greater control capacity, better efficiency in energy consumption, optimization of resources as appreciated as water, and waste reduction.

AUTOMATION OF THE PROCESS EQUIPMENT

Like the rest of the industrial processes, the preparation of whole muscle cooked meat products has been manual until recently. All the process phases (see Diagram 1) were carried out independently, without any connection between them. The operator was responsible for each and every one of them and was also responsible for the manual registration of all manufacturing data. Although most of the processes were carried out in the correct order, this was not always the case. Periodically appearing failures in the production line. In these cases, the scarcity of reliable records of all the processes made it difficult to clarify the root of the problem.

The regulations of the machines were executed through manual drives and did not allow many controls. In some cases, they were reduced to turning on/off and without any possibility of modifying operating parameters.



▲ Diagram 1. General Diagram of the cooked ham process

The first PLC Programmable Controllers appeared on the market in the 1970s. They represented a revolution in industrial processes by implementing a device that was easy to program and flexible to modifications, thus allowing greater equipment control.

Incorporating the PLC Programmable Logic Controllers in the machines improved intercommunication between them and the operators, thanks to the incorporation of a Human-Machine Interface [HMI]. The interface between the process and the operator allows him to supervise and control the process (see photo 1).

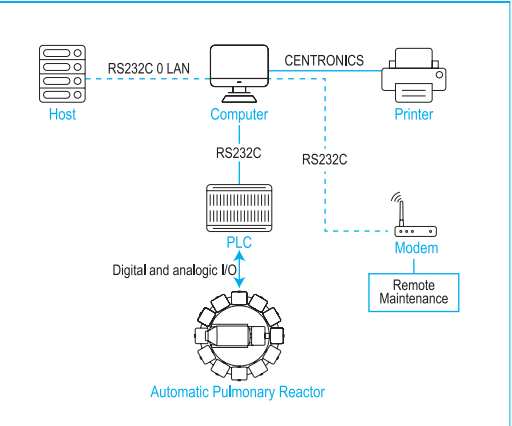


▲ Photo 1. 80's display

One of the first cooked ham manufacturing machines to appear on the global meat market with control via PLC and PC was the Thermocomputer massager reactor, which Metalquimia presented at the IFFA fair in Frankfurt - Germany in 1986, and it meant a turning point in meat massager processes. Being the same massager reactor used up to now, but with the massager/maturation process fully automated and controlled: product loading and unloading, massager phase with many more process options (a more significant number of variables), automatic control of meat temperature, optimization of maturation periods and programming of different types of CIP cleaning. In addition, it was possible to record all manufacturing operations and production schedules and alarm incidents and carry out maintenance programs. In short, a product that was truly ahead of its time.

Initially, the programming was adapted to the MS-DOS operating system, and over time, it was updated as the different versions of WINDOWS emerged (see photo 2).

This same machine evolved as computer science did. Although the basis of movements and functions



▲ Photo 2. Thermocomputer operating diagram

are similar today, interaction with the user has become simpler and more intuitive. In the years that followed, and following the example of the Reactor Thermocomputer, most of the machines in the sector progressively adapted to the new technology. At the same time, companies were also integrating all their management through Enterprise Resource Planning [ERP] software, which helped to automate and manage the different processes.

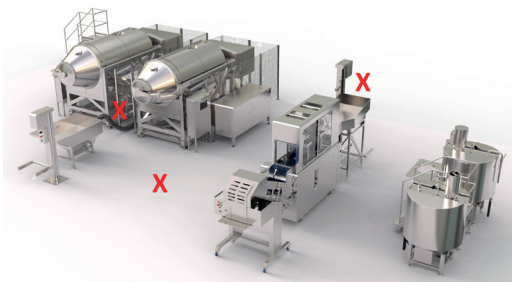
AUTOMATION OF PROCESS LINES

As previously mentioned, until a few years ago, there was no connection or communication between the different phases of the process. Today, this is still the case for many companies depending on the specifications of the products, their variety and daily production. Great flexibility is required from the lines and some operations are still carried out manually. In these cases, excessive automation would be counterproductive. Therefore, it is of utmost importance to define a long-term strategy to plan automation, exposing all possible options and studying the pros and cons of each change in detail. The automation of the lines must adapt to the products and the process plant and never the other way around.

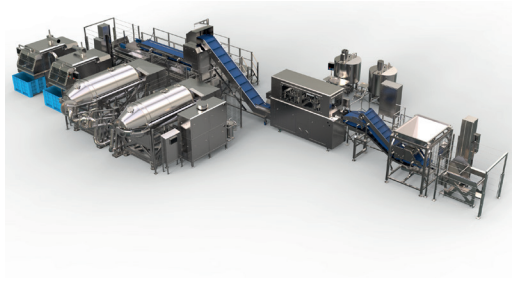
As the production volume increases, transporting the meat/product between stages manually (pallet jack, carts, etc.) is labour-intensive, difficult to control and can lead to manufacturing errors. To solve these problems, since the beginning of the 21st century, different types of continuous lines have been emerging where the machines involved in the process are linearly interconnected by belts, automatic conveyors, vacuum systems and pumps. Depending on the needs, these connections can be complete or partial (in part of the line).

In the following designs, different levels of connections between phases of the process are observed compared to a completely manual plant (see photos 3 and 4).

Once a certain degree of automation and union between the different phases of the process was achieved, the need arose to control the approach to the smallest



▲ Photo 3. Line with phases not connected. Manual transport



▲ Photo 4. Line with different stages connected by belts. Automatic transport

detail, minimize errors, obtain the maximum production data, traceability of the product, and demand for greater productivity and efficiency. These were the dawn of the Meat Industry 4.0

4.0 TECHNOLOGY AND DIGITAL TRANSFORMATION

The concept of Industry 4.0, also known as the Fourth Industrial Revolution, arises from the introduction of digital technologies in manufacturing processes. After the development of the steam engine and mechanization (second half of the 18th century), the development of electricity (end of the 19th century), and automation (20th century), the new stage (fourth stage) of Industrial transformation is based on the so-called smart factory, characterized by the automation and interconnection of machines and systems of the same production line, with an external fluent exchange of information (with the foreign market itself, suppliers, customers, etc.) and using resources much more efficiently to drive greater productivity and profitability.

The evolution of consumption habits, the growing demand for products and the continuous search for innovation are essential elements in the 4.0 industrial model, supported by technological and digital tools.

Digital transformation 4.0 implies a high degree of automation. At the same time, it allows an excellent capacity for self-diagnosis of each situation, allowing global control. The tools and machines involved in a factory production line are connected through an internal network and linked to the outside simultaneously.

Smart factories offer significant advantages through the digitalisation of industrial processes:

- Optimization and standardization of quality levels. Having a digitalised industry makes it possible to be much more precise in weights, operating parameters and variables, temperatures, etc.

- Improved control. Processes can be monitored and information generated to learn, improve and reduce costs.

- Reduction of costs due to greater efficiency, reduction of errors and lower labour cost.

- Reduction of production times that allow increased productivity and use of 24 hours a day without extension of working shifts.

- Greater operator safety by reducing non-ergonomic or dangerous processes.

- Better use of resources, reduction of waste and environmental impact.

- Improvement of Energy Efficiency and Sustainability

As it can be seen, not only do automation and digitalisation have a high transformative potential for the meat industry, but they also present risks. Therefore, it is essential to know and assess the challenges involved:

- Investment and installations. The majority of current installations must be adapted to digital technologies, which can mean a high investment. Therefore, it is crucial to choose the right level of automation so that it is profitable and brings an overall benefit.

- Specialized personnel are required to control the automation and digitalisation of processes and operators with better knowledge. The company requires continuous training. So, the different levels of workers can adapt to new needs.

- Very high dependence on technology, which in situations of supply or technical failures can lead to interruptions in production.

- Cybersecurity risk and hacking of information and processes

DIGITAL TRANSFORMATION OF PRODUCTION LINES

Despite the inherent risks, what seems to be very clear is that companies that do not adapt or cannot adapt will be at a disadvantage and will lose competitiveness as it has been observed. The digitalisation of production lines for cooked meat products opens up a broad scenario in the interpretation and management of meat processing, offering all meat companies a tool to improve their processes and products and catapult their sustainability, efficiency and competitiveness global.

All the variables in the process are digitalised are sent and stored in a database for later processing. The most relevant can be temperature, pressure, position, etc. Once the physical signal has been converted to digital, it is generally transferred to the equipment's PLC through communication protocols such as Ethernet/IP, Profinet, EtherCat, etc...

The PLC manages the control of the equipment and allows connectivity features such as online viewing and remote assistance. The information is processed, used for its management and sent to a database through specific communication protocols such as OPC UA, OPC DA, MQTT, etc. This database can be local SQL type or remote in the cloud type AZURE.

Once the variables are obtained, they are treated to analyze the process. There are currently various data processing technologies, from mathematical analysis to Machine Learning or Artificial Intelligence techniques. Both Machine Learning and Artificial Intelligence are technologies with great potential that will be introduced more and more. Still, because they require large amounts of data and highly qualified technicians in the field, their implementation in the industrial field is minimal today.

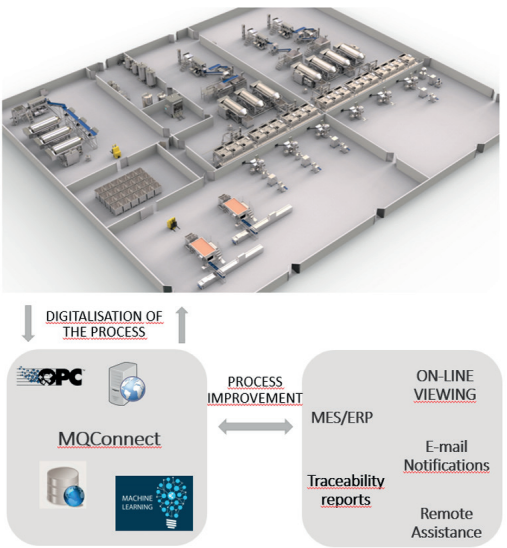
The result of data processing allows the following actions to be carried out:

- Production and traceability reports
- Incident notifications via e-mail
- Process self-tuning
- Communication with ERP or MES systems
- Predictive Intelligence
- Machine learning
- Management of formulas and recipes
- Augmented Reality digital service
- Energy Efficiency Management

The objective of analyzing the data obtained is to improve the process. This improvement can be carried out through user actions and process self-adjustments.

PARTICULAR CASE: “MQConnect” CONNECTIVITY SYSTEM

Metalquimia’s MQConnect system is a total connectivity system between meat processing equipment and its environment. A robust connectivity system is the key to obtaining good results in large-scale data acquisition



▲ Photo 5: 4.0 Meat Processing Line Scheme

[Big Data] and subsequent analysis. Predictive intelligence, process improvements and machine self-regulation would not be possible without reliable data [see photo 5].

The MQConnect system is designed to ensure the integrity of the data associated with a given temporary space. This is possible thanks to a robust registration system, immune to possible random communication interruptions and the latency of communication networks. This robustness is achieved through a self-design buffer for data storage in the PLC and a powerful "Handshake" system with OPC.

In addition to the captured data, it is important how it is treated and presented to the user. The system presents the data through an intuitive web format that allows you to obtain on any device:

- Information online on the state of the equipment and the flow of products.
- Data of production carried out and ordered at a chronological level that helps to make decisions to improve production.
- Process quality data, whether it is injection weights, product temperature records during the process, equipment parameters during production, cooking data, etc., to offer full product traceability.
- Maintenance information and anomalies that allow those responsible for maintenance to optimize their processes and increase their efficiency.
- Automated sending of operating alarms via email.
- Management of formulas and recipes. Including the possibility of backing up recipes.

Once the challenge of having reliable data without temporary interruptions has been overcome, with the help of the latest data processing technologies, global meat companies can be offered a complete

bank of digital tools to improve their processes and products, always keeping in mind the improvement in sustainability and energy efficiency.

An application of this can be found in the Connectivity System of the new MOVIMAX ZERO fuel transfer machine from Metalquimia [see photo 6] which, in addition to presenting substantial improvements in terms of sustainability and energy efficiency, has control algorithms based on Machine Learning for automatic learning to achieve very ambitious challenges such as the detection of clogged needles and clogged filters.

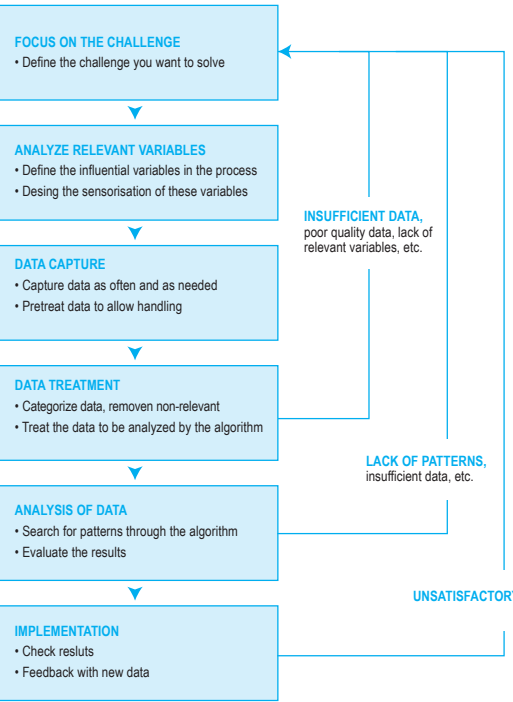
Machine Learning technology consists of analyzing a large amount of specific data related to the defined challenge and finding a behaviour pattern for its subsequent implementation in control through a mathematical algorithm.

The steps indicated in Diagram 2 have been followed to develop this system.



▲ Photo 6: MOVIMAX ZERO injector

As it can be seen, this development process requires a good knowledge of the technology and a huge amount of data. Still, it allows us to tackle challenges that, until today, were unattainable with other technologies.



▲ Diagram 2. Machine Learning Process Algorithm

CONCLUSIONS

The advantages offered by digital transformation 4.0 on the control and predictions of processes allow a much higher level of performance than an unconnected industry, offering the global meat processor manufacturing plants “unlimited” connectivity. That, without a doubt, already is revolutionizing the way meat processing equipment and people will interact.

Thanks to intelligent connectivity systems, the new digital platforms open up a wide scenario in the interpretation and management of the “Big Data” of meat processing, offering global meat companies a complete bank of digital tools to improve their processes and products, as well as catapult its sustainability, efficiency and global competitiveness.

Large-scale data management (or Big Data), predictive intelligence and process improvement, machine self-regulation, machine learning, online visualization of the flow of products, control of the traceability, the management of formulas and recipes, the intelligence of incidents and the Augmented Reality digital service are some of the key features introduced in these connectivity systems.

Although the implementation is slow, it is a fact that no company should ignore if they want to be competitive. It may represent a significant change in management and mentality for some of them. So, it should be conceived as a gradual process according to the capabilities and needs of each one, continuously training of staff. So, they can adapt to new demands.

BIBLIOGRAFÍA

- FERNANDEZ, M. (2020). Industria 4.0: Tecnologías y gestión en la transformación digital de la industria.
- GÉRON, A. (2020). Aprende Machine learning con Scikit-Learn, Keras y Tensorflow. Ed. Anaya
- JOYANES AGUILAR, L. (2017). 4.0 La cuarta revolución industrial. Ed. Marcombo.
- XARGAYÓ, M., LAGARES, J. (1992). Computerized Massaging of Meat, *Fleischwirtschaft*, 72, 744-747.
- XARGAYÓ, M., LAGARES, J. (2008). Profitability of cooked ham production lines: adaptation to different ripening cycles, *Eurocarne*, 172, 56-62
- NIEUWBORG, B., SOLÀ, X., CANADELL, P., TARRADAS, J., (2019) New Food Industry HMI, www.rockwellautomation.com/es

ACKNOWLEDGEMENTS

We would like to thank all the Technology and Engineering Department members and the Automation and Robotics Department of METALQUIMIA, S.A.U., for the help and collaboration provided to prepare this article.