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PERCEPTIONS OF THE USE OF SENSORS AND MODELS FOR SMART PROCESSING IN THE MEAT INDUSTRY

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I. INTRODUCTION

Digitalisation is important in the food industry as it helps companies improve product quality and safety, process efficiency, and pursue competitive advantages. Previous surveys have been conducted to better understand the level of digitalisation in the Spanish food industry [1]. However, in these surveys, digitalisation refers to a wide range of topics, such as paper-free factories and the digitalisation of stocks, rather than the digitalisation of the production process using sensors and algorithms for smart processing [2]. In meat industries, in-line non-destructive sensors coupled with data analysis algorithms can enable the optimisation of processes. How these control technologies work and how they can be used to improve industry efficiency and sustainability has been studied [3]. However, implementation is challenging due to the specific characteristics of the meat and meat analogue industry.
This study aims to explore the perceived challenges in implementing smart processing tools, such as sensors and algorithms, within the meat processing industry, conducting a strengths, weaknesses, opportunities, and threats (SWOT) analysis. Furthermore, the perception of the meat industry on meat analogues and alternative protein sources, and the use of smart processing for the manufacturing of those products, was also studied.

II. MATERIALS AND METHODS

Different subjects, working in different roles at small, medium and large-sized Spanish meat processing industries, were interviewed. The contacts were made with companies from 10 different autonomous communities. Ethical approval was obtained for the interviews, and every interviewee signed a compliance agreement. The interviews consisted of six different sections: a) company and interviewee profiles, b) implementation of innovative hardware (i.e. types of sensors), c) use of predictive algorithms for production monitoring and control, d) future technological innovation perspective in the sector, e) technological innovation surveillance, and f) opinion on meat analogues and alternative protein sources. For this preliminary report, 10 out of the 25 interviews planned were already conducted. The profile of the companies and interviewees and the responses to each of the topics described from each interview were analysed, and a SWOT analysis was performed to understand how smart processing and new food trends (such as alternative proteins and meat analogues) are perceived by industries.

III. RESULTS AND DISCUSSION

Interviews in this report involved technicians from R&D or production departments. Two were from small-to-medium-sized companies, while eight were from large firms, all fresh meat producers and processors (dry-cured, cured, and cooked meat). Some larger firms also offered ready-to-eat meat dishes. The interview results varied significantly by company, reflecting different product focuses, needs, and challenges. Employees in large companies perceived digitalisation levels from very low to very high, while those in small-to-medium-sized firms reported medium levels. In large firms producing various products, digitalisation levels could differ across processing lines (e.g., digitalised dry-cured ham line versus a non-digitalised sausage line). Consequently, analysing the overall results is complex.

All companies had temperature, relative moisture, pH, and weight sensors. Other technologies mentioned during the interviews were ultrasounds (2) and X-rays for the discrimination of carcasses depending on fat (4), computer vision for classification (4), magnetic induction for fat and salt content in ham (3), NIR sensors for raw-material and water activity (2), and metal detectors for detection of foreign bodies (1). Some of the considerations that companies make when implementing these sensors are the cost, the risk, the reliability, and the trustworthiness of the provider. They consider that the implementation of new technologies is not difficult, although it is harder to implement innovative technologies because of the risk involved. Once the technologies are implemented, they are not problematic.

Most subjects agree artificial intelligence (AI) and deep learning will help automate production. Intelligent robots using sensor data will be crucial. Digital twins were frequently mentioned, but attracting trained talent remains difficult, with limited funding for these technologies. Companies fear competitors may implement these technologies faster, affecting competitiveness. Additionally, cybersecurity risks and reliance on externally manufactured

technologies (e.g., microchips from China or the US) increase vulnerability to geopolitical issues. Dependence on these technologies can also disrupt production during power cuts or hacker attacks.

To be aware of the innovations available, technological insights are provided by technological companies, universities, research institutes, consultants, and competitors. Furthermore, to be aware of innovative solutions, R&D departments investigate and attend congresses and technological fairs. Research institutes were seen by some interviewees as potential partners to minimise the risk of development and implementation.

Regarding meat analogues, some companies had production lines dedicated to alternative proteins, although many were closed due to low profitability. Companies used plant-based texturised proteins from specialised suppliers. Soy was the most accepted protein source for its flavour and functionality. One company studied insect protein but doubted its future acceptance in Western countries. Mycoproteins appeared to be a better alternative. Other companies focused exclusively on meat or animal products, and alternative proteins did not fit their strategy. Most interviewees lacked experience with extrusion and did not comment on the implementation of sensors in this processing technology. Figure 1 summarises the SWOT analysis performed.

	Positive	Negative
Internal	**Strengths** - Smart processing tools improve product the quality and safety of the products made by the interviewed industries. - Sensors discriminate raw materials depending on quality parameters, optimising production. - Smart processing tools allow to improve decision-making processes, making them faster and more accurate.	**Weaknesses** - The lack of sensors, algorithms, and a general innovative culture or environment hinders competitiveness. - The heterogeneity of the products made by meat industries makes it very difficult to implement sensors and algorithms. - Most sensors implemented in line are in the initial stages of production (i.e. raw material discrimination) and are not integrated into a system that allows the optimisation of the process as a whole.
External	**Opportunities** - The implementation of new smart processing tools could help improve energy efficiency and product homogeneity. - Alternative proteins (e.g. meat analogues) can open new markets for the meat industry. - Artificial intelligence can be useful in optimisation, as it learns from data retrieved from different steps of a process.	**Threats** - Not investing in smart processing could lead to reduced competitiveness. - It is difficult to attract specialised personnel in topics related to sensors and algorithms. - The lack of public funding could hinder the possible investment in innovation. - The dependence on sensors and algorithms could mean companies are more susceptible to geopolitical problems (e.g. microchip crisis) and cybersecurity issues.

Figure 1. SWOT analysis of digital innovation and smart processing in the meat industry perceived by the meat industry.

IV. CONCLUSION

All the interviewed technicians think that, regardless of the digital innovation level of the company, there is room for improvement in terms of smart processing. Most meat industries perceive sensors and algorithms as strengths and view their implementation as an opportunity to enhance competitiveness by increasing quality, safety, and efficiency. The digital transformation of production lines is important for all companies, albeit at different levels, and all of them have strategies for implementing digital tools. The implementation of such tools requires funding and training; the former, according to the perception of the interviewees, can be provided by universities and research centres.

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REFERENCES

1. Castillo Díaz, F. J., Blaas Nacle, A., & Laínez Andrés, M. (2024). *Estado de la transformación digital de la industria agroalimentaria española*. Ministerio de Agricultura, Pesca y Alimentación. Secretaría General Técnica. Centro de Publicaciones y Cajamar Caja Rural.
2. van den Berg, F., Lyndgaard, C. B., Sørensen, K. M., & Engelsen, S. B. (2013). Process Analytical Technology in the food industry. *Trends in Food Science & Technology*, *31*(1), 27–35
3. Echegaray, N., Hassoun, A., Jagtap, S., Tetteh-Caesar, M., Kumar, M., Tomasevic, I., Goksen, G., & Lorenzo, J. M. (2022). Meat 4.0: Principles and Applications of Industry 4.0 Technologies in the Meat Industry. *Applied Sciences*, *12*(14), Article 14