Universitat Rovira i Virgili

Escola Tècnica Superior d'Enginyeria Química

Process Improvement in a Baby Food Industry: A Case Study

Master thesis presented by Emilia Castro Otero

to obtain the Master's Degree in Chemical Engineering from the Universitat Rovira i Virgili

Company Supervisor: Josep Ramón Marsal Díaz

URV Tutor: María Montserrat Ferrando Cogollos

Tarragona, February 2024

Master’s thesis 2023-2024

Acknowledgements

I would like to express my deepest gratitude to all the people who have been fundamental in the completion of this Master's thesis. The guidance and support provided by all the contributors to this project were essential for its completion, with special mention on the valuable guidance of my two tutors.

Furthermore, I would like to extend my gratitude to Delafruit's production department. From the very beginning, they have made me feel like an integral part of the team, contributing significantly to the development of my professional career.

However, I wish to particularly highlight my desire to dedicate this entire work to my family, with a special emphasis on my parents and my sister.

Mamá, papá e Laura, gracias por apoiarme sempre, por darme esta oportunidade, por crer en min, por non deixarme soa en ningún momento e por estar preto de min aínda estando a centos de quilómetros de distancia. Este traballo tamén é voso. Non existen palabras que poidan demostrar o agradecemento. Quérovos moito.

Last but not least, I would also like to take the opportunity to also dedicate this work to myself. In acknowledgment of the constant determination, tireless effort, and dedicated time that have concluded in the completion of this project, also I am thankful for not giving up in moments of fatigue. This work represents a tribute to my own process of evolution because the way is also the goal.

Summary

Almost all companies face the challenge of improving their productivity and efficiency, while reducing their operating costs. Nowadays, this must be achieved by focusing on the environment and sustainability and, in the case of this company, also on maintaining the quality of its products.

As a response to these needs, the development of the present project is framed, which has as its primary objective the improvement of the process by means of two approaches. The first one focuses on seeking to improve and optimise the process through the implementation of different strategies and measures belonging to the lean manufacturing philosophy. While the second one focuses on quantifying the company's water consumption points, with the main objective of searching options for its reuse or reduction.

To achieve the first approach, methodologies from different strategies and tools of the lean philosophy were applied. For the second approach, the methodology focused on carrying out a water balance, together with on-site data collection, validation of parameters by analytical methods, and subsequent economic and environmental evaluation.

The project concludes with an in-depth analysis of the results obtained for both approaches, demonstrating the tangible improvement of the process, together with possible lines of future research and work. Finally, a series of conclusions are included, reflecting that the development of both approaches has enabled the project's main objectives to be achieved.

INDEX

Nomenclature list

World Health Organisation (WHO)

Spanish Society of Clinical Immunology, Allergology and Paediatric Asthma (SEICAP)

International Featured Standard (IFS)

Safe and Sustainable by Design (SSbD)

Compound Annual Growth Rate (CAGR)

High-Pressure Processing (HPP)

First-In-First-Out (FIFO)

Hazard Analysis and Critical Control Point (HACCP)

Critical Control Points (CCPs)

Just in Time (JIT)

Total Productive Maintenance (TPM)

Key Result Indicators (KRI's)

Performance Indicators (PI's)

Key Performance Indicators (KPI's)

Result Indicators (RI's)

Cleaning in Place (CIP)

Enzyme-Linked ImmunoSorbent Assay (ELISA)

Limit of Detection (LOD)

Value Added Tax (VAT)

Wastewater Treatment Plant (WWTP)

Sequential Biological Reactor (SBR)

Dissolved Air Flotation (DAF)

Biochemical Oxygen Demand (BOD)

Chemical Oxygen Demand (COD)

Oils and grease (O&G)

Total suspended solids (TSS)

Life Cycle Analysis (LCA)

Sustainable Development Goals (SDGs)

1. INTRODUCTION

For a long time, and especially nowadays, infant feeding has become a very relevant topic of special interest due to the growing awareness of the importance of a complete and high-quality nutrition in the early stages of a human being's life.

Among the most popular commercial products in food industry to meet the nutritional demands and needs of babies, fruits, vegetables, cereals and dairy purees, smoothies and tubs occupy an important place since they have a high nutritional value. They are a suitable complementary feeding option to introduce new textures, flavours, and essential nutrients into the diet of young children, because they are rich in micronutrients such as vitamins, minerals, and antioxidants, and are easy to digest. In addition, they provide fibre that helps digestion and a smoother intestinal transit.

1.1.Baby food market evolution

In order to provide a complete insight into the future of the baby food market, it is important to understand its current state and trends. It is noteworthy that the field of baby food and ready-to-eat products has suffered and continues to experience a significant evolution over the years.

According to the World Health Organisation (WHO), the introduction of new foods in the diet of the youngest children should be progressive and gradual, starting at six months of age. Moreover, it should always be complementary to breast milk or formula[1]. Among the most prominent products in baby food are fruit, vegetable and dairy purees, tubs, and smoothies, which have experienced a large number of transformations in order to adapt to the different and changing demands of parents, as well as to nutritional preferences.

In the early days, the product portfolio of baby and infant food industry was extremely limited in terms of products availability and variety. For that reason, most parents used to prepare them at home using conventional methods such as batch cooking and/or manual mashing. However, thanks to the technology improvements and the development of safe packaging processes, as well as large-scale production, ready-to-eat purees became increasingly accessible and were gradually introduced to the global market.

Over the years, the awareness of child malnutrition in the world has grown, and for that reason, manufacturers have gradually adapted the formulas of their products in order to ensure a high and good nutritional value. The latter is vital and depends on the selection of raw materials for the product, their composition, and the proportions of fruit and vegetables that contain. Also, to provide healthier options, special attention has been paid on reducing added sugars, artificial colours and preservatives, pesticides, chemicals, and other additives, promoting organic, natural, and ecological products[2][3].

Another key factor in the market for this type of product has been the increase in the number of cases and concern about food allergies and intolerances in the population, especially in children. In 2014, food allergies affected 6% of young children and between 3% and 4% of adults, as of the present day, after 10 years, they have increased significantly[4]. Specifically, according to the Spanish Society of Clinical Immunology, Allergology and Paediatric Asthma (SEICAP), every year the number of children with allergic reactions to food increases by 2%. There are various causes that may affect this increase, including early exposure to food allergens and/or genetic and environmental factors. As a result, baby food manufacturers have had to reinvent themselves and include new recipes to open up the range of possibilities for infants with allergies, as well as products must be properly labelled according to the type of allergen[5]. The emergence of food certifications, which guarantee that a product complies with certain requirements, has gained special relevance due to the large number of potential market niches. Examples of these are the Halal or Kosher certifications which comply with the dietary and ethical requirements of Islamic and Jewish religious laws, respectively. There are also quality certifications such as IFS (International Featured Standard), vegan and vegetarian certifications such as V-Label, among many others.

On the other hand, advances in packaging technology together with the latest and modern marketing strategies resulted in products that are more practical and portable for children, all of this added to visually attractive packaging designed for them. Today's packaging ensures that products remain fresh before their unseal, and that can be consumed within 24 to 48 hours of opening, extending the shelf life of the product without affecting its quality. These packs allow easy transport and take-away, besides adapting to current consumer needs. One of the market trends in recent years in terms of packaging is the pouch format. This format consists of a flexible plastic container that can be taken everywhere. In a survey conducted by ABC Packaging in 2017, in which participated a large number of families, entitled "*From Jar to Pouch: The Evolution of Packaging*", it was found that approximately 60.4% would change to the pouch format over other types of traditional formats for multiple reasons. These include the fact that flexible packaging is more economical and sustainable, more convenient, and lighter, as well as being safer for children. Related to all of the above, it is clear that one important aspect of the baby's food market expansion has been the development of new eco-friendly and recyclable packaging, also known as Safe and Sustainable by Design (SSbD), to reduce single-use plastic consumption and carbon footprint[6]. All these actions have been achieved thanks to the increase of social awareness regarding the environment and sustainability towards a green future.

In summary, the market for baby feeding products, especially the one that involves purees, tubs, and smoothies has been progressing to adapt to the new needs of children and their care takers. There has been a shift from simple homemade preparations to innovative products and bolder flavour combinations that encourage stimulating children's palates. Future trends show that some new challenges will emerge, such as transparency in the supply chain or the use of seasonal and local raw materials. Manufacturers must therefore remain flexible and responsive to market trends and invest in research and innovation towards new products, technologies, and emerging trends without losing focus on quality and food safety. It is estimated that by 2024, the revenues of the global infant feeding market will reach to an amount of 69.10 billion euros, with an increase in the Compound Annual Growth Rate (CAGR) of 5.73% between the years 2024 and 2028. In addition, growth forecasts for 2025 indicate that the baby feeding sector will grow by 3.4%. The largest revenues in the sector are generated in China, however, other of the most powerful regions are Japan, Spain, Russia, the Philippines, and Canada[7].

In the economic context, companies like the main national industrial brands for baby and infant food, are one of the main niches of economic growth in Spain, as well as in the contribution of job creation in the country[7]. Therefore, it is important to invest in proposals to improve, enhance and optimise the production processes, quality, and sustainability of this sector. The scope of this thesis responds to the needs of the described context framework.

2. BACKGROUND

3. SCOPE OF THE PROJECT AND SPECIFIC OBJECTIVES

The scope of this project focuses on two interrelated approaches, both meeting towards the improvement of a baby food production process. The focus on continuous improvement, the implementation of different lean manufacturing principles, and the searching for the integration of sustainable practices related with water consumption are highlighted as fundamental pillars and key elements.

The first approach is based on the optimisation of the production process through the application of different strategies and tools inherent to the lean manufacturing philosophy. The primary objective of this approach is the overall improvement of the process, by increasing performance, achieving a more suitable and effective decision-making, as well as the reduction and elimination of non-value-adding activities, which play a crucial role in reducing production costs, among other aspects. After, it is desired to analyse the effectiveness of each of the implemented measures individually. However, the overall tangible effectiveness derived from these actions will require a complete analysis through the company's KPI's. This analysis will help to determine whether there have been improvements or setbacks in the indicators, as well as to identify peaks and trends. In addition, it is possible that intangible benefits could be obtained, so their detailed analysis is also considered essential.

The second approach focuses on addressing sustainable and efficient water management, recognising that this fact is one of the main challenges within the sustainability strategies of the food industry. The primary basis is to identify the critical points of water consumption throughout the plant, and, afterwards, to identify areas for water recovery. Following this identification, the main objective is to quantify the volume of potentially recoverable water according to each identified point, validate the feasibility of recovery by complying with quality standards, and compare it with the total water supply to the plant. It is also desired to investigate whether to recover or regenerate the alkaline agent phase used in the cleaning processes and quantify its recoverable volume. Then, it is desired to propose a specific water recovery system for future implementation. To conclude this strategy, it is asked to make an economic and environmental assessment in order to determine the economic and environmental benefits associated with that possible water recovery.

As explained above, it is important to remember that within the scope, only the sterilisation and pasteurisation lines (production lines) are included, excluding the HPP plant and the production of doypack packaging.

For the development and success of this current project, the achievement of different specific objectives is required, in addition to the general objectives already explained. These specific objectives are the following:

To conduct different formation and training sessions by the company to understand quality standards, certifications, B Corp regulations, and machinery operation.

To rigorously investigate and understand each phase of the production process of the pasteurisation plant.

To get familiar with lean manufacturing and all measures associated with this philosophy that were already implemented in the plant, working closely with the with the company's lean promotor.

To identify possible areas or elements for improvement.

To analyse in detail the operation of the packaging machine and possible bottlenecks that may happen there.

To fully understand each of the KPI's, as well as its targets, and their impact on the plant's productivity.

To understand the functioning and operation of the two databases used in the company, which allowed different tasks to be carried out in the completion of the Master's thesis, such as obtaining data for all on-site and past productions KPI's, units produced, CIP's executed, creating and modifying production routes, etc.

To collect data manually for further study and analysis.

To perform approximations and estimations based on conducting on-site tests within the plant and based on the knowledge and experience of different departmental managers and operators.

To know in detail the operation of each type of CIP conducted on the production lines.

Collect water samples from each type of CIP for analysis.

To understand the operation of both the network water treatment system and the wastewater treatment system, including their treatment volumes.

To identify specific opportunities for improvement in water use efficiency.

To work closely with other departments such as quality, laboratory, engineering, or maintenance in different phases of the project.

To propose specific recommendations for the quantification of water consumption.

To propose a water recovery system.

Furthermore, in order to achieve the main objective of the project, it was strictly necessary to consider the operators and machinists, through their active participation, providing them with training, motivation, and recognition. So, effective communication between the student and the operators was essential to maximise their knowledge and experience mutual feedback.

The specific tasks and actions undertaken during the execution of this Master’s thesis will be described in detail in the following sections.

4. STUDENT'S ROLE IN THE COMPANY

4.1.About the company

Delafruit is a company specialised in the development and co-manufacturing of purees, juices, and smoothies in different formats, specifically, pouch, bottle, and tub. This company has been operating since 2007 and is based in Tarragona. Delafruit manufactures for multiple brands and customers, especially in the international market, exporting to more than 40 countries, but it also serves in the national market.

Since its foundation and beginnings, this company has stood out enormously and is recognised in its sector thanks, among many other things, to the exceptional quality of its products and the availability of the best food processing technologies. From 2007 to 2011, the company exclusively focused on juice production. In 2011, they strategically closed the juice production and transitioned to the manufacturing of pouches. The year 2014 marked an important moment as they introduced the innovative HPP technology, to reopen the juice market branch. In 2016, the company incorporated sterilisation lines with retort technology, which uses an autoclave. In 2018, the production of tubs was introduced. In 2021 the company was officially renamed Delafruit, marking the definition of new values and strategies. In the same year, the company achieved the excellent distinction as a B Corp company, which means that the company meets rigorous social and environmental standards, along with public transparency and legal accountability. Few national companies have this seal of distinction. As can be seen, over the years, the company has experienced significant growth and expansion, exponentially increasing its production capacity. Consequently, one of Delafruit's main goals is to work for a healthier future.

4.2. Internship description

The internship at Delafruit took place from July to November 2023, with the agreement extending until December 2023, amounting to six months of experience. During this period, the student worked as an industrial and process engineer in the production department. The primary role involved the execution of the current project and actively participating in daily tasks to support the production area. Initially, the focus was on the first project approach. During this phase, the student closely collaborated with the company's lean promotor. By the middle of the internship period, work shifted to the second project approach. However, daily responsibilities related to the first approach were not interrupted, as their impact needed to be evaluated during the entire realization of the project. Moreover, the student took on the responsibility of continuing to monitor these measures to ensure their proper progression. The specific tasks carried out were mainly focused on the direct operation of the plant, that is, minimising office work and maximising on-site tasks, which allowed a deep understanding of the production process and the company's operational standards. It is important to highlight that the incorporation took place during the summer months, matching with the company's production peaks.

Thus, in an initial phase, with the aim of optimising the process, the tasks focused on becoming familiar with the plant's entire production process, its databases, and daily operations. From this point, a study of historical data was carried out to understand the current situation of each production line and to identify the customers whose production had a negative impact on the company's productivity. Among the specific tasks performed, the following stand out. In order to parametrize the packaging machines, detailed parameter data from different productions were collected to identify discrepancies between lines and products. This analysis allowed to distinguish between parameters dependent on the type of product and those dependent on the type of line, as well as those most susceptible to modifications by operators. Additional lean manufacturing measures were implemented, such as the development of decision trees to improve decision-making among operators, a system was established to identify and monitor bottlenecks in different productions, aimed to eliminate them whenever possible, in order to achieve the speed-up of the plant. As a result of this identification, planned speed routes were updated and created for specific products, always evaluating how the new speed affected the operation and machinery response. In addition, a manual for the use of the packaging machine was developed with the objective of facilitating the training processes for new operators. Finally, an exhaustive analysis of all the KPI's, and their evolution over a period that covered the duration of the internship, was carried out in order to evaluate the impact of these measures.

Under the approach of addressing the sustainable management of water resources, specific tasks were carried out, including a complete study of the plant's water treatment line, as well as the characteristics of the incoming water and its variability during the year. Historical data related to the number and type of cleaning processes executed during a given period were analysed and compared with production during the same period, in order to obtain a true approximation of the daily number of cleaning processes. Manual data collection and on-site tests were carried out to quantify different volumes and flows of water that were unknown due to the absence of data and flow meters. All possible water recovery points were identified and the volume of water that could be recovered was quantified. In addition, water samples were collected for laboratory analysis to determine whether they met the established quality standards. Another task was to analyse the possible regeneration or recovery of the alkaline phase of the cleaning processes, as well as to study the installation of the plant's wastewater treatment plant. Based on the volume of potentially recoverable water, a proposal for a specific water recovery system was made, concluding with an economic and environmental estimation to evaluate the benefits associated with water savings.

In the context of daily tasks, the following stand out. A blockage issue was identified in the slides and hoppers of the packaging machines with a specific type of cap. Solutions were explored, such as reinstalling vibration sensors in the hoppers and adjusting the slides, but as the problem was not completely solved, it was proposed to purchase new slides with an air blowing system to improve the sliding of certain caps. Moreover, collaboration took place in updating cleaning protocols for the production lines, involving the writing of procedures, and visually documenting the state before and after cleaning. In the search of optimising operational costs, a study was conducted to verify the accuracy of bag deliveries by the external supplier. By counting the bags of 20 boxes, it was concluded that the supplier was sending fewer than declared, contributing this finding to a more efficient resource management. Although this task was not completed and is still in progress today, the identification of bottlenecks within the automatic end-of-line machines was started, in collaboration with the lean manufacturing promotor, among other daily tasks.

The execution of all these tasks required constant communication with the production department and other departments, such as maintenance, engineering, mixing, quality, laboratory, and purchasing, as well as with operators and machinists. Most of the time this communication was highly effective, although small disagreements were noted at some points. The project directly aligns with the company's objectives as it aims to improve the process, addressing more sustainable practices related to water consumption. These practices not only reflect the company's core values, but also align with its future ambitions.

5. METHODS

6. RESULTS AND DISCUSSION

7. CONCLUSIONS

The development of the two different but interrelated approaches to improve a baby food production process has allowed to manage both operational and environmental aspects with a focus on sustainability. On the one hand, the project has culminated in the implementation of different lean manufacturing strategies and tools to optimise the process. On the other hand, a complete analysis has been carried out to lay the foundations for the future adoption of different measures and systems focused on sustainable water management.

Regarding the process optimisation approach, it can be concluded that the lean manufacturing methodology allows companies to achieve multiple benefits, both tangible and intangible. In this specific case, in view of the results obtained, the simultaneous implementation of five measures generated both.

In terms of tangible benefits, the detailed analysis of the company's KPI's revealed quantifiable improvements, especially in nominal performance, which increased by % in just half a year, surpassing the company's target. Also, in relation to OEE, which initially was considerably below the company's target of %, a very significant progress was observed. Specifically, in the second quarter of the year, it was % away from the target, and, with the application of these measures, the gap to the target was reduced to %. These results demonstrate that there has been an increase in productivity and an effective reduction in operating costs, derived from the decrease in the percentage of wastage, machinery downtimes, or the standardisation of the parameters in the packaging machines, among other aspects. This consolidates the effectiveness of the measures, supporting their validity and indicating that, if they continue to be implemented, all the company's targets could be achieved in the short-term.

Regarding intangible benefits, despite their non-quantifiable nature, they are essential to ensure the success of optimisation initiatives. Each implemented measure has considered the participation of the operators, encouraged their cooperation, and recognised their knowledge. This not only motivated them, but also helped to create a healthier and more collaborative work environment. The lean methodology establishes the importance of not being satisfied with the obtained progress but rather working every day to improve. Furthermore, each implemented measure, especially the development of decision trees and the identification of bottlenecks, led to more agile and efficient decision-making and problem-solving.

From the approach on sustainable water management, it can be concluded that, in the current context of global scarcity, it is strictly necessary for an industry of this nature to take measures to save water and promote its efficient and sustainable use. Moreover, optimising the use of this resource is aligned with the Sustainable Development Goals (SDGs), specifically with 12 and 13, responsible production and consumption, and climate action, respectively. The objective was to quantify water consumption and explore options to reduce it, so no specific reduction measures have been implemented, except for raising awareness of its use. However, this analysis and evaluation phase has led to obtaining specific conclusions derived from the main objective.

On the one hand, despite being a semi-continuous production factory, whose production depends on many external factors that influence its consumption patterns, the identification of the plant's consumption points, and their daily quantification has resulted in an increased awareness of the management of this resource within the plant. This action has also highlighted the need to significantly improve the facility in order to monitor and measure real water consumption to obtain reliable patterns. In many cases, the lack of concrete data and the impossibility of real quantification due to the multiple factors affecting it, has led to basing some consumption points on estimations.

On the other hand, the quantification of potentially recoverable water together with the proposal of a recovery system using the company's available resources, is presented as a measure that contributes to long-term sustainability. Furthermore, this recovery opportunity is supported by the multiple economic and environmental benefits that its implementation would entail. Although it is important to note, as detailed above, that these calculations have been made considering a % recovery for the water from the final rinse (and intermediate rinse of the CIP's that have it), and a % recovery for the water and NaOH from the alkaline phase. However, in practice, the recovery of water from the final and intermediate rinses is likely to be lower.

Finally, it should be highlighted that, in engineering projects, it is not usual to go into operational details in depth due to their complexity, instead, they typically remain in the design or preliminary project phase. However, in this case, especially for the approach to process optimisation with lean manufacturing measures, it was possible to work in detail on the operation of the process. This allowed to obtain a high level of knowledge of the process, which made it possible to focus on the most susceptible points to achieve process improvement.

As a result, new opportunities and valuable insights have blossomed, such as measures that have been carried out transversally during the execution of this project by other people in the department, or measures for future application. Some examples include changing the pressure gauges of the packaging machines, identifying the bottlenecks of the automatic end-of-line machine, or the proposal to install more flowmeters and program them for self-resetting. Furthermore, there is the possibility of extending the water saving of the CIP's of the production lines together with the recovery of the water used to cool the mechanical seal of the pumps, and the execution of product pushes without water.

8. REFERENCES

[1] 'Complementary feeding'. Accessed: Nov. 07, 2023. [Online]. Available: https://www.who.int/health-topics/complementary-feeding#tab=tab_1

[2] H. Čížková, R. Ševčík, A. Rajchl, and M. Voldřich, 'Nutritional quality of commercial fruit baby food', *Czech J Food Sci*, vol. 27, no. special issue, pp. 134–137, 2009.

[3] 'Estado Mundial de la Infancia 2019. Niños, alimentos y nutrición: crecer bien en un mundo en transformación.', New York, Oct. 2019. Accessed: Nov. 07, 2023. [Online]. Available: https://www.unicef.org/media/62486/file/Estado-mundial-de-la-infancia-2019.pdf

[4] R. Ryther, 'Food Technologies: Cleaning and Disinfection Technologies (Clean-In-Place, Clean-Out-of-Place)', in *Encyclopedia of Food Safety*, Y. Motarjemi, Ed., Waltham: Academic Press, 2014, pp. 149–155. doi: https://doi.org/10.1016/B978-0-12-378612-8.00276-6.

[5] '¿Qué es la alergia a alimentos? - Seicap'. Accessed: Nov. 08, 2023. [Online]. Available: https://seicap.es/alergia/alergias-a-los-alimentos/que-es-la-alergia-a-alimentos/

[6] 'From Jar to Pouch: The evolution of packaging. A cint 2017 report.' Accessed: Nov. 15, 2023. [Online]. Available: https://cdn2.hubspot.net/hubfs/70169/reports/BABY%20FOOD%20PACKAGING%20REPORT.pdf?t=1516696274002

[7] 'Baby Food - Worldwide | Statista Market Forecast'. Accessed: Jan. 07, 2024. [Online]. Available: https://www.statista.com/outlook/cmo/food/baby-food/worldwide?currency=EUR

[8] M. Meghwal, M. R. Goyal, and R. S. Chavan, *Dairy engineering: Advanced technologies and their applications*. CRC Press, 2017.

[9] 'Tecnología del proceso de alta presión hidrostática- HPP Hiperbaric'. Accessed: Dec. 08, 2023. [Online]. Available: https://www.hiperbaric.com/es/tecnologia-hpp/que-es-la-hpp/

[10] 'What is the Difference Between a Stand-Up Pouch and Doybag?' Accessed: Jan. 03, 2024. [Online]. Available: https://www.packingpigeon.com/what-is-the-difference-between-a-stand-up-pouch-and-doybag/

[11] 'Nitrogen Gas in the Food Process | Compressed Air Best Practices'. Accessed: Dec. 23, 2023. [Online]. Available: https://www.airbestpractices.com/industries/food/nitrogen-gas-food-process

[12] J. E. Lozano, 'Processing of fruits: Elevated temperature, nonthermal and miscellaneous processing', in *Fruit Manufacturing: Scientific Basis, Engineering Properties, and Deteriorative Reactions of Technological Importance*, Springer, 2006, pp. 55–72. Accessed: Dec. 07, 2023. [Online]. Available: https://link.springer.com/chapter/10.1007/978-0-387-30616-2_3

[13] Food and Agriculture Organitzation, 'Sistema de análisis de peligros y de puntos críticos de control (HACCP) y directrices para su aplicación'. Accessed: Jan. 09, 2024. [Online]. Available: https://www.fao.org/3/y1579s/y1579s03.htm

[14] 'What is Lean? Lean Manufacturing & Lean Enterprise | ASQ'. Accessed: Dec. 08, 2023. [Online]. Available: https://asq.org/quality-resources/lean/

[15] M. Rajadell Carreras, *Lean Manufacturing: Herramientas para producir mejor*. Ediciones Díaz de Santos, 2021.

[16] A. R. Vargas, J. L. G. Alcaraz, S. Satapathy, and J. R. Díaz-Reza, *The PDCA Cycle for Industrial Improvement: Applied Case Studies*. Springer Nature, 2023.

[17] J. Aldavert, E. Vidal, J. J. Lorente, and X. Aldavert, *Guía práctica 5S para la mejora continua: La base del Lean*, vol. 3. Alda Talent, 2022. Accessed: Dec. 11, 2023. [Online]. Available: https://www.onlean.com/

[18] 'Total Productive Maintenance | Lean Production'. Accessed: Dec. 26, 2023. [Online]. Available: https://www.leanproduction.com/tpm/

[19] M. Dudbridge, *Handbook of lean manufacturing in the food industry*. John Wiley & Sons, 2011.

[20] D. Parmenter, *Key Performance Indicators: Developing, Implementing, and Using Winning KPIs*. John Wiley & Sons, 2011.

[21] D. Parmenter, *Key Performance Indicators: Developing, Implementing, and Using Winning KPIs*, 4th ed. New Jersey: John Wiley & Sons, 2019.

[22] A. Howe, 'Water Management in the Food and Drink Industry', *IChemE, Rugby, UK*, 2014, Accessed: Jan. 07, 2024. [Online]. Available: https://www.icheme.org/media/4808/an-icheme-green-paper-water-management-in-the-food-and-drink-industry.pdf

[23] 'El agua en 2050: escasez en el futuro - Fundación Aquae'. Accessed: Dec. 20, 2023. [Online]. Available: https://www.fundacionaquae.org/el-agua-en-2050/

[24] 'Optimising freshwater consumption in the food and beverage industry'. Accessed: Dec. 21, 2023. [Online]. Available: https://www.openaccessgovernment.org/optimising-freshwater-consumption-in-the-food-and-beverage-industry/166081/

[25] 'Calidad del agua en la industria alimentaria'. Accessed: Dec. 21, 2023. [Online]. Available: https://higieneambiental.com/calidad-del-agua-operadores-alimentarios

[26] H. L. M. Lelieveld, J. Holah, and D. Napper, *Hygiene in food processing: principles and practice*. Elsevier, 2014.

[27] T. J. Bowser, 'What is Clean in Place (CIP)?', Oklahoma Cooperative Extension Service, Aug. 2023. Accessed: Dec. 24, 2023. [Online]. Available: https://shareok.org/bitstream/handle/11244/339264/oksa_FAPC-0251_2023-08.pdf?sequence=1

[28] 'Clean In Place (CIP) Meaning in the Food Industry | Alsco'. Accessed: Dec. 24, 2023. [Online]. Available: https://alsco.com/resources/clean-in-place-cip-meaning-in-the-food-industry/

[29] A. Tamime, *Cleaning-in-place: Dairy, Food and Beverage Operations*, 3rd ed. Ayr, UK: Wiley Online Library, 2009.

[30] M. Farber and R. Barth, *Mastering Brewing Science: Quality and Production*. John Wiley & Sons, 2019

[31] 'OEE NOMINAL VS OEE PRODUCTIVO - SmartMon'. Accessed: Jan. 04, 2024. [Online]. Available: https://smartmon.es/blog/oee-nominal-vs-oee-productivo/

[32] P. Belohlavek, *OEE: Overall Equipment Effectiveness*. Blue Eagle Group, 2006.

[33] T. Wireman, *Training Programs for Maintenance Organizations*, vol. 5. New York: Industrial Press Inc., 2010.

[34] 'What Is OEE (Overall Equipment Effectiveness)? | OEE'. Accessed: Jan. 04, 2024. [Online]. Available: https://www.oee.com/

[35] D. Saha, M. Syamsunder, and S. Chakraborty, *Manufacturing Performance Management Using SAP OEE: Implementing and Configuring Overall Equipment Effectiveness*. Springer, 2016.

[36] 'Bottleneck in Manufacturing: How Are They Identified and Eliminated? | Blog SYDLE'. Accessed: Jan. 05, 2024. [Online]. Available: https://www.sydle.com/blog/bottleneck-in-manufacturing-61aa121f5448461cf9143d8d

[37] LeanSis Productividad, 'Introducción a Lean manufacturing', Madrid, 2017. Accessed: Jan. 05, 2024. [Online]. Available: https://www.ecoembesthecircularcampus.com/web/app/uploads/2021/01/introduccion_lean_manfacturing.pdf

[38] J. Walter Jr, *Control de la calidad del agua: Procesos fisicoquímicos*. Reverté, 2021.

[39] '¿Qué son los sensores inductivos y capacitivos? Funciones y aplicaciones - Polaridad.es'. Accessed: Jan. 03, 2024. [Online]. Available: https://polaridad.es/sensor-inductivo-y-capacitivo/

[40] 'Pareto Chart | Introduction to Statistics | JMP'. Accessed: Dec. 22, 2023. [Online]. Available: https://www.jmp.com/en_nl/statistics-knowledge-portal/exploratory-data-analysis/pareto-chart.html

[41] O. Herrera-Márquez *et al.*, 'Cleaning maps: A multi length-scale strategy to approach the cleaning of complex food deposits', *J Clean Prod*, vol. 261, p. 121254, 2020.

[42] 'Dissolved Air Flotation (DAF) Systems'. Accessed: Jan. 05, 2024. [Online]. Available: https://www.evoqua.com/en/evoqua/products--services/clarifiers--separators/dissolved-air-flotation-daf-systems/

[43] 'Coagulante y floculante en el tratamiento de aguas | Contyquim'. Accessed: Jan. 05, 2024. [Online]. Available: https://contyquim.com/blog/coagulante-y-floculante-en-el-tratamiento-de-aguas

[44] 'Pigging | What Is Pigging? How Pigging Works - HPS Hygienic Pigging Systems'. Accessed: Jan. 06, 2024. [Online]. Available: https://www.hps-pigging.com/about-hps/what-is-pigging/

[45] 'Sistema PIG para recuperación de producto - Quilinox'. Accessed: Jan. 06, 2024. [Online]. Available: https://quilinox.com/producto/pig-system-recuperacion-producto-industrial/

[46] R. J. Durham and J. A. Hourigan, '14 - Waste management and co-product recovery in dairy processing', in *Handbook of Waste Management and Co-Product Recovery in Food*

Processing, K. Waldron, Ed., Woodhead Publishing, 2007, pp. 332–387. doi: https://doi.org/10.1533/9781845692520.4.332.

[47] F. Moerman, P. Rizoulières, and F. A. Majoor, 'Cleaning in place (CIP) in food processing', in *Hygiene in food processing*, Elsevier, 2014, pp. 305–383. doi: 10.1533/9780857098634.3.305.

[48] Hatlar Group Pty Ltd, 'Clean-in-place best practice guidelines-Part I: Compare CIP with best practice.', Melbourne, Aug. 2010. Accessed: Jan. 04, 2024. [Online]. Available: https://www.clearwatervic.com.au/user-data/research-projects/swf-files/final-guidelines---parts-1--2-and-3-combined.pdf

[49] 'Enzyme-Linked Immunosorbent Assay (ELISA) Kits'. Accessed: Jan. 07, 2024. [Online]. Available: https://www.sigmaaldrich.com/GB/en/products/protein-biology/immunoassay-platform-solutions/elisa-kits#sandwich

[50] '¿Qué es el gluten?' Accessed: Jan. 08, 2024. [Online]. Available: https://www.sanitas.es/biblioteca-de-salud/dieta-alimentacion/celiaquia/gluten-que-es

[51] 'Decretados los primeros estados de emergencia por la sequía en Catalunya'. Accessed: Jan. 15, 2024. [Online]. Available: https://www.lavanguardia.com/natural/20230802/9147316/decretada-primeros-estados-emergencia-sequia-catalunya.html

[52] 'Grundfos', Grundfos Ecademy. Curvas de bombeo. Principios básicos y tipos de bombas. Accessed: Dec. 18, 2023. [Online]. Available: https://www.grundfos.com/content/dam/global/page-assets/learn/ecademy/pdfs/es-36-module-4-basic-principles-and-pump-types.pdf

[53] 'Industrial. Agència Catalana de l'Aigua'. Accessed: Dec. 08, 2023. [Online]. Available: https://aca.gencat.cat/ca/laca/canon-i-altres-tributs/canon-de-laigua/industrial/index.html

[54] 'Precio del agua, composición, servicios y otros conceptos. Agencia Catalana del Agua'. Accessed: Jan. 04, 2024. [Online]. Available: https://aca.gencat.cat/es/laca/observatori-del-preu-de-laigua/preu-de-laigua-composicio-serveis-i-altres-conceptes/

[55] Reed Business Information Spain, 'Tecnología del Agua. Captación, Tratamiento, Distribución y Depuración del Agua y su Impacto Medioambiental', *249*, pp. 68–71, Jun. 2004. Accessed: Dec. 22, 2023. [Online]. Available: https://books.google.co.ve/books?id=iGAEAAAAMBAJ&printsec=frontcover&hl=es&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false

9. APPENDICES

9.1. Appendix A

9.1.1. Block diagram of the productive process

9.1.2. Decision trees

Below, it is showed an overview of the sheet, at a very small scale, with the distribution of the decision trees that was introduced in plant (in an A3 size).

9.1.3. Speed-up sheet

9.1.4. Instruction manual for the packaging machines

9.1.5. Data collected on water consumption for cooling the mechanical seal of the pumps

Table 9.1 presents the data collected and used for the quantification of the water consumption for cooling the mechanical seal of the pumps.

Table 9.1. Data and calculations for the quantification of the water consumption for cooling the mechanical seal of the pumps.

9.1.6. Data collected on water consumption for each CIP type in production lines

9.1.7. Data and calculation for the quantification of the recoverable volume of each type of CIP

In Table 9.2 are presented the data used for the quantification of the recoverable volume of the final rinse of each type of CIP and the intermediate rinse of CIP's with acidic phase executed in the production lines.

Table 9.2. Data and calculations for the quantification of the recoverable volume of the final rinse of each type of CIP and the intermediate rinse of CIP's with acidic phase.

9.1.8. Standard curves obtained for each allergen type

For the three samples from the intermediate rinsing of a milk allergen CIP, Figure 9.1 below shows the standard curve obtained, along with its corresponding expression for calculating allergen concentration based on absorbance.

Figure 9.1. Standard curve of dairy allergen obtained for intermediate rinses.

Conversely, for the two samples from the final rinse, Figure 9.2 displays the standard curve obtained.

Figure 9.2. Standard curve of dairy allergen obtained for final rinses.

Figure 9.3 shows the standard curve obtained, along with its corresponding expression that facilitates the calculation of gliadin concentration as a function of absorbance.

Figure 9.3. Obtained standard curve of gluten allergen.

9.2. Appendix B

9.2.1. Self-Evaluation Questionnaire

a) Evaluate the acquired competences according to the tasks you have carried out.

Degree Competences		Task in which you have observed the competence	Self evaluation [Rank 1 to 10]	Aspects to be improved
SPECIFIC COMPETENCES				
A1.1	Effectively apply knowledge of basic, scientific and technological materials pertaining to engineering.	Understand the operation of the different sections of the production process for their improvement. Apply process engineering principles, such as the identification of bottlenecks and debottlenecking, together with lean manufacturing tools to optimise the process.	8.5	
A1.2	Design, execute and analyze experiments related to engineering	Implementation of different improvement measures and tools and subsequent analysis using the KPI's of the company. Determination of the feasibility of implementing a water recovery system and its impacts.	8	
A1.3	Be able to analyze and synthesize the continuous progress of products, processes, systems and services, whilst applying criteria of safety, economic viability, quality and environmental management. (G6)	Evaluation of the continuous improvement, validation of the quality of the recovered water and study of the direct economic savings derived from the water recovery, as well as the positive environmental impacts.	8	The economic study does not account for certain factors that have already been explained. Meanwhile, most of the environmental impacts could have been more accurate.
A1.4	Know how to establish and develop mathematical models by using the appropriate software in order to provide the scientific and technological basis for the design of new products, processes, systems and services and for the optimisation of existing ones. (G5)	N/A	-	-

A2.1	Be able to apply the scientific method and the principles of engineering and economics to formulate and solve complex problems that arise in processes, equipment, installations and services, in which the material undergoes changes to its composition, state or energy content, these changes being characteristic of industrial chemistry and other related sectors such as pharmacology, biotechnology, materials sciences, energy, food and the environment. (G1)	N/A	-	-
A2.2	Conceive, project, calculate and design processes, equipment, industrial installations and services in the field of chemical engineering and related industrial sectors in terms of quality, safety, economics, the rational and efficient use of natural resources and the conservation of the environment. (G2)	Development of the proposal for the system to recover water. Different proposals made for the future quantification of water consumption. Proposal for the purchase of new slides for the packaging machines, etc.	9	
A2.3	Lead and technically and economically manage projects, installations, plants, companies and technological centres in the ambit of chemical engineering and related industrial sectors. (G3)	To be responsible for coordinating and leading different continuous improvement measures and tools in the production lines.	9	
A3.1	Apply knowledge of mathematics, physics, chemistry, biology and other natural sciences by means of study, experience, practice and critical reasoning in order to establish economically viable solutions for technical problems (I1).	Apply different mathematical and engineering knowledge to analyse production data, identify trends and propose and execute improvements in the process. Application of engineering knowledge in the parametrisation of packaging machines and the optimisation of the production speed of each product route. Using biological and chemical techniques to conduct quality tests on water and ensure it meets established standards, etc.	9	The nature of the process did not demand super-high levels of mathematical, chemical, or biological concepts. Nevertheless, engineering skills at the operational level of the process were required.
A3.2	Design and optimise products, processes, systems and services for the chemical industry on the basis of various areas of chemical engineering, including processes, transport, separation operations, and chemical, nuclear, elctrochemical and biochemical reactions engineering (I2).	Design proposal for a water recovery system in the production lines.	6	The system design has not been developed in detail, including precise calculations for tank sizing and piping dimensioning, among other aspects. This is because, initially, the company aims to make use of unused tanks and equipment, in order to optimise resources and minimise investment. Consequently, it will

				be necessary to adjust the design according to such equipment (it has already been proven that the capacity of the disused tanks could make up for this recovery).
A3.3	Conceptualize engineering models and apply innovative problems solving methods and appropriate IT applications to the design, simulation, optimisation and control of processes and systems (I3).	N/A	-	-
A3.4	Be able to solve unfamiliar and ill-defined problems by taking into account all possible solutions and selecting the most innovative. (I4)	N/A	-	-
A3.5	Lead and supervise all types of installation, process, system and service in the different industrial areas related to chemical engineering (I5).	To be responsible for coordinating and leading different continuous improvement measures and tools in the production lines, always assisting and explaining them to the operators.	9	
A3.6	Design, construct and implement methods, processes and installations for the integrated management of waste, solids, liquids and gases, whilst also taking into account the impacts and risks of these products (I6).	Implement different improvement measures that contributed to the reduction of product waste percentage, thus optimising the process and maximising resources. Design proposal for a water recovery system in the production lines.	9	
A4.1	Lead and organise companies and production and service systems by applying knowledge and abilities regarding industrial organisation, commercial strategy, planning and logistics, mercantile and labour legislation, and financial and costs accounting (P1).	N/A	-	-
A4.2	Lead and manage the organisation of work and human resources by applying criteria regarding industrial safety, quality management, occupation risk prevention, sustainability and environmental management (P2).	An effort was made to promote increased awareness among the operators regarding the use of water, especially through the use of hoses.	6	Specific training sessions could have been organised focusing on specific water-saving strategies for the operators, along with increased awareness.
A4.3	Manage research, development and technological innovation whilst ensuring the transfer of technology and taking into account property and patent rights (P3).	N/A	-	-

A4.4	Adapt to structural changes in society caused by economic, energy or natural factors so as to be able to solve any resulting problems and to contribute technological solutions with a high commitment to sustainability (P4).	The entire approach aimed at reducing water consumption will help to the inherent and future drought restrictions in Catalonia. Always with a focus on sustainability and the environment.	9	
A4.5	Lead and monitor the control of installations, processes, products, certification, auditing, verification, testing and reports (P5).	In the completion of this Master's thesis, the monitoring of identified bottlenecks, as well as the speeds defined in the routes for each product, was carried out. Moreover, during the internship, the development of reports of results of different industrial tests was also carried out.	9	
A5.1	Carry out, present and defend (once all the curriculum credits have been obtained) an original individually produced piece of work before a university panel. The work will consist of a professional integrated Chemical Engineering project that synthesizes (TFM1)	In execution.	8.5	
TRANSVERSAL COMPETENCES				
B1.1	Communicate and discuss proposals and conclusions in a clear and unambiguous manner in specialized and non-specialized multilingual forums (G9).	Holding different meetings with different company's departments.	8	No different languages were used in those meetings.
B1.2	Adapt to changes and be able to apply new and advanced technologies and other important developments with initiative and entrepreneurial spirit. (G10)	Different tasks carried out in the internship.	8	Sometimes the lack of experience could be a problem.
B2.1	Lead and define multidisciplinary teams that are able to make technical changes and address management needs in national and international contexts. (G8)	N/A	-	-
B3.1	Work in a team with responsibilities shared among multidisciplinary, multilingual and multicultural teams	During all the completion of this Master's thesis and internship, I worked with a multicultural and multidisciplinary team, although the primary language of communication was always Spanish or Catalan.	8	

B4.1	Be able to learn autonomously in order to maintain and improve the competences pertaining to chemical engineering that enable continuous professional development. (G11)	Among other things, following the guidelines of the company's lean promotor, I autonomously learned many aspects, factors and tools of the lean philosophy that I was not familiar with.	10	
B5.1	Carry out and lead the appropriate research, design and development of engineering solutions in new or little understood areas, whilst applying criteria of creativity, originality, innovation and technology transfer. (G4)	N/A	-	-
B5.2	Bring together knowledge, make judgements and take decisions on the basis of incomplete or limited knowledge whilst taking into account the social and ethical responsibilities of professional practice. (G7)	Take decisions and make several assumptions or estimations as more realistic as possible with the help of different employees.	8	
NUCLEAR COMPETENCES				
C1.1	Have an intermediate mastery of a foreign language, preferably English	Writing the TFM and consulting bibliographic sources.	8	To be able to have used English at some point during the internship and Master's thesis execution.
C1.2	Be advanced users of the information and communication technologies	During the internship and the Master's thesis execution.	9	
C1.3	Be able to manage information and knowledge	During the internship and the Master's thesis execution.	9	
C1.4	Be able to express themselves correctly both orally and in writing in one of the two official languages of the URV	During the internship and the Master's thesis execution.	9	I am not Catalan so I do not know how to write it, but I understand it perfectly well and I can even hold a conversation.
C2.1	Be committed to ethics and social responsibility as citizens and professionals	During the internship and the Master's thesis execution.	10	
C2.2	Be able to define and develop their academic and professional project	During the Master's thesis execution.	7.5	Some difficulties and challenges in defining the project due to the fact that it does not belong to a pure chemical industry, but to the food industry, as well as being a semi-continuous process, facts which are not covered in depth in the bachelor's and master's degree.

b) Evaluate the final master project and suggest improvements.

Key steps	Evaluation [Mark 1 to 10]	Improvement proposed
Selection/assignment of the project (dissemination, communication, assignment requirements...)	7.5	The project took a long time to be defined due to the difficulties and challenges associated with finding and identifying specific objectives related with the Master's in Chemical Engineering, as it is a food industry. Nevertheless, a good project was ultimately defined, although it would have been better to start with a clearer idea of the project.
Stay (welcome, length, relationship, follow-up made by the company...)	8.5	The stay was very good from the welcome, and the relationship during the whole internship as well. However, there could have been a little more follow-up from the company, and sometimes there was difficulty in coordinating schedules for meeting with the supervisor.
Follow-up made by URV tutor	8.5	Difficulty in coordinating and scheduling meetings. Some minor confusion arose because it was the first time supervising a Master's Thesis in Chemical Engineering. However, communication was always good and fluid.
Other aspects to be considered (which ones...)	N/A	-