Handbook of Research on Reinventing Economies and Organizations Following a Global Health Crisis

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Chapter 24
Automated Remote Control of Cheese Ripening Chambers: Increasing Economic Value Added While Reducing the Risk of Transmission During the Pandemic

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ABSTRACT

A new prototype of a ripening chamber was proposed aiming to evaluate the application of computational fluid dynamics in the optimization of traditional cheeses ripening conditions. With the purpose of evaluating the possible impact in the production of cheese in three Portuguese regions, the potential

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economic benefits of the prototype were demonstrated. The proposed automation process would imply higher production efficiency, increasing sales, decreasing stock levels and a significant reduction in the consumption of water and electricity. Based on average values, it was estimated potential increases of 133 010 € in sales and an individual net present value of almost 560 000 €. In addition to the economic impact in firms, which are mostly small and medium firms, the results also contribute to an increase on the sustainable use of natural resources. However, it is important to highlight the contribution of the project in a pandemic situation to develop a better financial situation of the firms based on a higher margin of the business.

INTRODUCTION

Traditional dairy industry, based on small ruminants sector, is very relevant in the Alentejo region, with an important impact on the specialization and employment profile of the region. It has been stated that livestock rearing conditions, namely diet composition and extensive systems, the raw milk, as well as the manufacturing process and the ripening conditions contribute to the chemical and sensorial characteristics of the cheeses, being responsible for such unique specificity, influencing the buying decision and appreciation of consumers (Rodrigues et al., 2018). Portugal is recognized as a country where traditional economic activities related to agriculture remain important, not only because they are relevant in rural areas but also because it is possible to find several products with recognized quality, with traditional cheeses being one of the examples. Of the different types of cheese available, made with ewe, cow, goat or mixed milk, the firmness, organoleptic properties and composition, among other characteristics, vary depending on the region of production (Fox & McSweeney, 2017). The improvement of the production conditions of a given activity is crucial both at the microeconomic level, enhancing the results of the individual firms, but also at a macroeconomic level, potentiating the economic development of the region. The importance of maintaining investments in the economic activities is well documented and is clear for several activities, including investments in traditional manufacturing firms in general (Nybakk & Jenssen, 2012), but also in the specific case of the dairy industry (Aziz et al., 2019; Ragkos et al., 2015). As expected, the investments in this sector, in particular, have an important relevance on the productivity (Barać & Muminović, 2013; Sauer & Latacz-Lohmann, 2015) and consequently on the economy as a whole. The investment decisions in the dairy sector could also have relevant impacts on environmental issues, which could contribute for the achievement of the objectives of sustainable development (González-García et al., 2013; Valta et al., 2017).

In the last decades, the traditional ripening rooms, using empirical knowledge for the control of environmental conditions, have been replaced by modern ripening chambers with automatic control of temperature and humidity. However, the use of refrigeration systems based on the vapor compression cycle are largely responsible for the high energetic costs, that in some enterprises may reach 60% of the total energetic costs (Alves et al., 2014). Within the scope of the "CFD4CHEESE – Application of computational fluid dynamics in the optimization of traditional cheeses ripening conditions" project, new insights were used to improve the environmental conditions in small ripening chambers using computational fluid dynamics but also using remote monitoring and sensing to evaluate operational costs like energy and water consumption. With these improvements it is expected to increase the quality and the efficiency of the cheese produced with raw ewe's milk and thus increase the quantity of cheese granted with Protected Designation of Origin (PDO). The efficiency of the production process is also fundamental

for the profitability of the activity, since it allows the optimization of the use of the raw materials and the increase in the quantities of final product available to the market. It is hence possible to optimize the relationship between inputs and outputs of the activity, being this one of the major concerns of the project. The eventual PDO cheese production is important because it guarantees producers to have higher economic results in terms of firms (Sellers-Rubio & Más-Ruiz, 2015) but also in a macroeconomic level (Vakoufaris, 2010). These new conditions of the businesses, turn the firms less dependent of economic cycles and more robust to the volatility of the demand in a time of a pandemic situation.

In order to continue to preserve the characteristics of traditional cheeses, different geographic production areas were created in Portugal, in a total of thirteen PDOs and one Protected Geographical Indication including "Queijo de Azeitão" (Azeitão cheese), "Queijo de Évora" (Évora cheese) and "Queijo Serpa" (Serpa cheese), which are under analysis in this paper. In 2015 it was estimated that the cheese sector represented about 25% of the dairy sector in general, with a sales volume of about 1.800M € (Roteiros e eventos, n.d.). However, the trade balance (in the cheese category) is quite unbalanced, with a deficit of about 30% in terms of the national production (Roteiros e eventos, n.d.). Nevertheless, this deficit has been reduced in recent years, since the national industry has made great efforts to strengthen its external competitiveness, through the promotion of its brands and through the adaptation to the requirements of the various destination markets. However, some barriers to the export of Portuguese's high-quality cheeses persist, as they are obtained from raw milk and, mainly soft cheeses, need care such as maintenance external appearance of the cheese and control the development of molds.

Although prices still remain an important variable, adding some value to the supplies products such as obtaining the PDO label, allows selling to more demanding customer segments in terms of the quality of the final product and less sensitive to the price. In general, cheeses with PDO could have an increase of the price of about 23% compared to the non-PDO ones, allowing these companies have a higher margin to cover their activity expenses (Cabo et al., 2017).

According to the last available data on the database of Central de Balanços do Banco de Portugal, Portugal had a total of 249 firms in the dairy industry corresponding to a total of 5710 employers and about 1.4 billion euros. This is a highly concentrated sector with 20% of the firms having almost 96% of the sales. Sales were decreasing from 2013 to 2016 with a slight increase in 2017. The cost of raw materials, mainly milk, is the most important factor (about 69% of the total) followed by external services (including water and electricity) and human resources.

Despite of the importance of national results, for this study the information about the firms devoted to the production of cheese in the regions under analysis is more relevant. Considering the elements identified in the methodological section, a total of 46 firms were identified with the available data, with a total of 22 firms which could produce cheese of Évora, 16 of Serpa and 8 of Azeitão regions, most of them with more than 10 years in the market. From the economic analysis it was possible to find the results for a total of 31 firms, considering only the ones which presented results from 2015 to 2018. The results are consistent with the general findings of the dairy sector, with an increase of sales and profits in the final of the sample and with the predominance of the cost with raw materials in the cost structure of the firms, although a lower percentage (about 55%), with a higher share, in this case, for the external services (about 31%). Despite the apparently good financial results, the gross added value is much lower in 2018 than in 2015, which could mean some difficulty of the firms to be competitive and with some incapacity of differentiate themselves from the competitors in general.

The above-mentioned project itself is important as identifies the structure of a new ripening chamber to be used in the traditional cheese manufacturing. Considering those objectives, this work fills the

existing gap in the literature because it identifies the economic relevance of the application of those ripening chambers in the real economy. The aim of this work was to analyze the potential benefits and the potential costs of the new prototype, quantifying them and studying directly the economic viability of the prototype. Moreover, and for the particular case of the consumption of electricity and water, was studied the hypothesis of the reduction on such resources. Our main results show that the investment needed for the automation in the ripening chambers is viable once it creates enough cash flow in several items such as energy costs, increase of sales and stock divestments, contributing to a better financial sustainability of the firms in these difficult times of covid-19 pandemic.

Material and Methods

A questionnaire was applied to cheese producers using raw ewe's milk inside the regions of Azeitão, Évora and Serpa cheeses. The questionnaire was built for data retrieval, with direct interviews with the managers, organized into four categories: 1) Identification; 2) Cheese production; 3) Ripening conditions, and 4) Social and economic characterization. In total, 28 firms were interviewed, from the different PDO regions, respectively 4 producers of Azeitão, 9 from Évora and 15 from Serpa cheese regions. The selection of the participating companies was random, based solely on the operating income of the last available year, namely between Q1 and Q3, and represented around 60% of the total firms inside the study region. The interviews were conducted personally by the researchers involved in the project. The firms were identified in the SABI database (Sistema de Análise de Balanços Ibéricos) which allowed us to identify the firms dedicated to the production of cheese in the region. From that database, accounting data was retrieved from the firms and used to perform an analysis of the possible economic impact of the newly proposed ripening chamber. This information is then compared with the results of the prototype, to identify the advantages of its use.

Using the questionnaire, the main characteristics of the firms in the regions under analysis could be identified. Most of the firms are micro or small firms, with familiar structure and mostly oriented to local or regional markets, employing a reduced number of workers (about 92% have less than 10 workers). Most of the firms report that the electricity costs are very relevant, with about 32% identifying costs over 1.000€ per month with water having also a relevant weight (about 300€ per month). Regarding the produced cheese, about 1/3 of the firms produce with PDO label arguing that the costs of the certification process are high, associated with the needed bureaucracy.

The ripening process of the cheeses occurs in specialized chambers, which work under idealized conditions of temperature, humidity or ventilation, depending on the type of cheese. During the ripening process, biochemical changes occur mainly due to microbiological activity, leading to the development of the differential characteristics of such cheeses in terms of texture, flavor and aroma (Alvarenga et al., 2011; O'Sullivan & Cotter, 2017). In fact, temperature and humidity are crucial conditions in the process in order to have good production results.

Construction of a Prototype of Improved Ripening Room

A prototype of an improved cheese ripening room was developed, based on traditional ripening rooms inside study region. The distribution of temperature, humidity and air velocity was optimized through a set of simulations based on Computational Fluid Dynamics (CFD), aiming for the environmental

Figure 1. 3D model of prototype

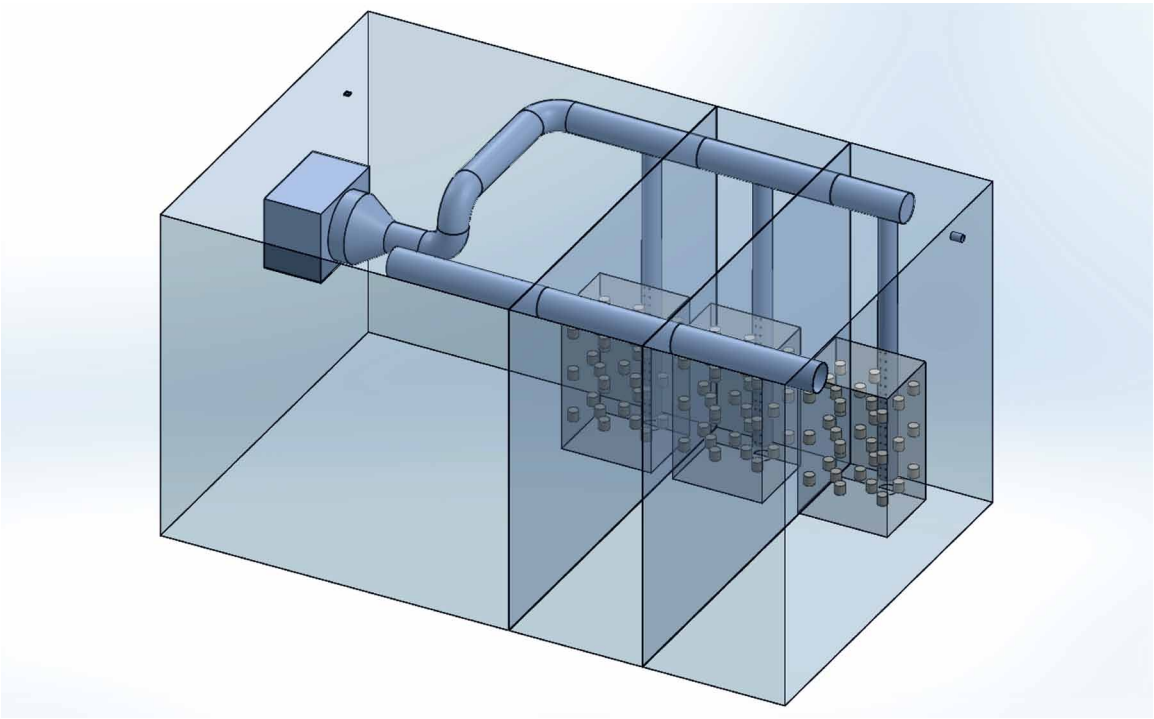
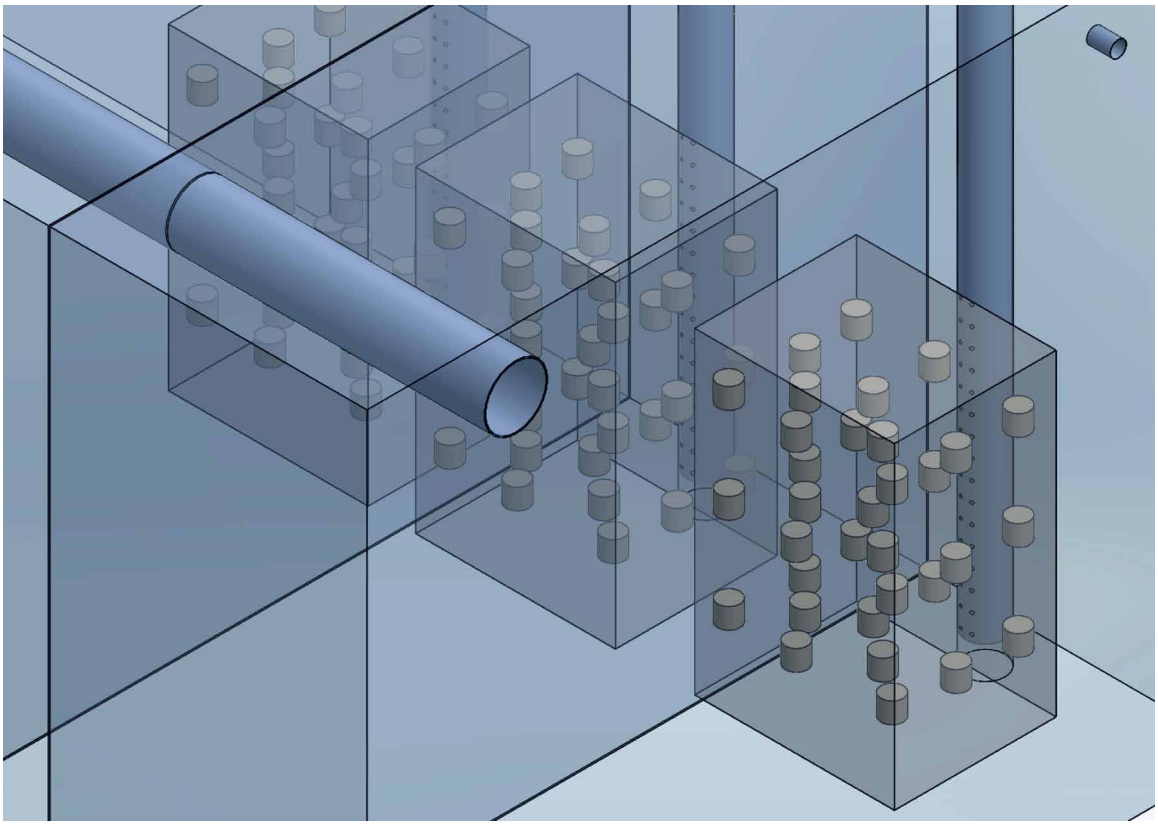


Figure 2. Control volume of cheese stacks



conditions which made possible the highest quality on cheese (Figure 1), including physicochemical, microbiological and sensorial parameters (data not shown).

The CFD numerical simulations were performed on software Fluent 19.3 (Ansys, USA), running in a computer CPU Xeon E3-1241 3.50GHz, RAM 16GB DDR3 1600MHz, GPU NVIDIA Quadro K2200 4GB. For the computation, a hybrid mesh type was considered (i.e., including hexahedral and tetrahedral elements) and constructed using software Ansys Meshing. A hexahedral mesh was considered for the volume inside stacks, while a tetrahedral mesh was considered for the remaining volume of ripening room. For the simulations, airflow was considered steady, incompressible and turbulent. The evaluation of the sensitivity of the model to turbulence was done comparing k–ε model, k–ω model and using a first and a second-order upwind. However, preliminary tests showed that k–ε model, in combination with the first-order upwind differencing scheme, presented the highest correlation to the experimental data. The convergence residues for simulations was 0.001, concerning continuity, turbulent kinetic energy (k), energy dissipation (ε) and velocity of the x, y and z vector components. Computation time was about 150 h (average) depending on the specific simulation.

After the optimization of the geometry using simulations, a physical prototype of the ripening room was built (276 width x 436 length x 232cm height) using expanded polyurethane thermal insulation panel as walls and ceiling. The top view of the prototype is represented in Figure 3 and the side view is represented in Figure 4. The prototype was equipped with a vapor compression refrigeration system (Eurofred, FAM040Z002, Spain), using refrigerant fluid R-404A, and a humidifier (Nordmann Engineering, DC4, Switzerland). Air inlet was located at the ceiling of the room (Figure 4), then air was conducted through the evaporator for proper refrigeration and into a 200mmØ PVC duct. Finally, three pneumatic butterfly valves (Trox Technik, B555DC2, Germany) regulated the admission of refrigerated air into three different zones inside the ripening room, separated by insulating material. Air outlet was located in the front wall, regulated by an 180mmØ fan (Figure 3).

Figure 3. Top view

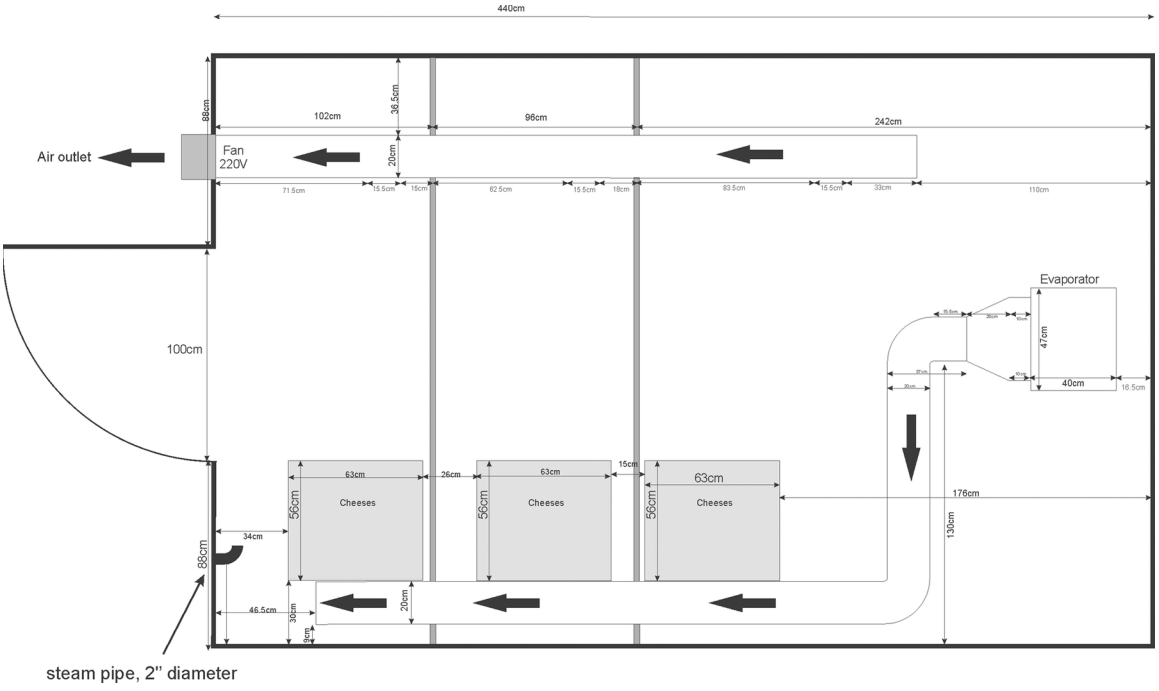
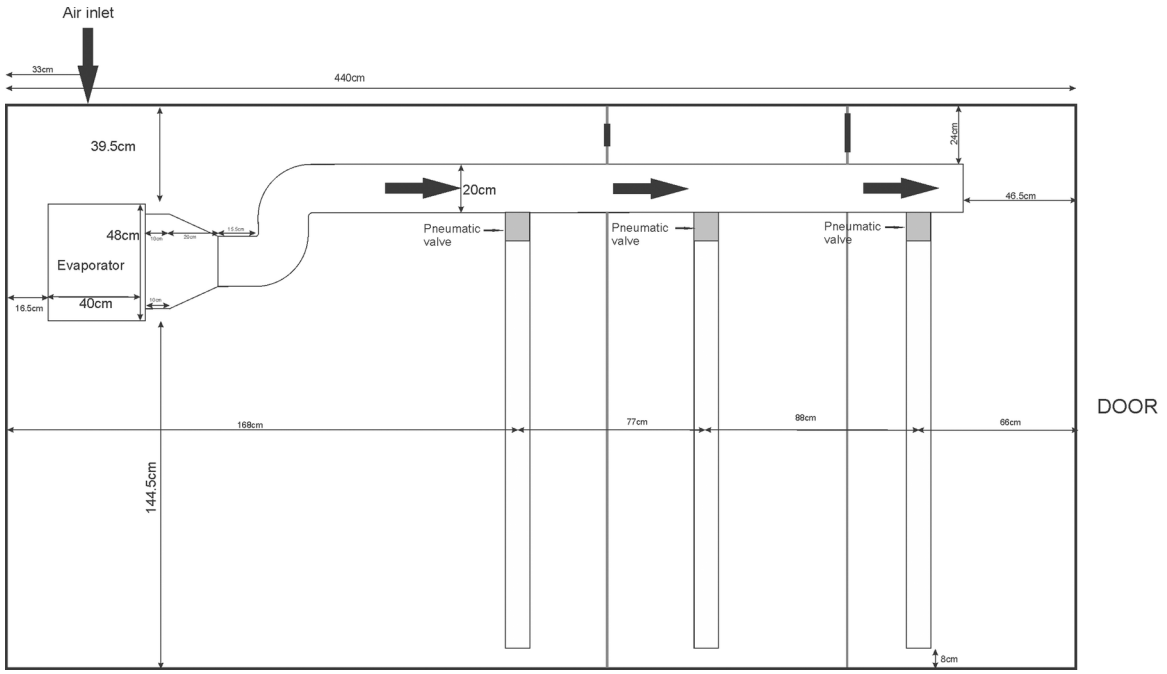


Figure 4. Side view



The architectural paradigm of designing systems based on sensors, microcontrollers and microcomputers of low-power and with an Internet connection, called "Internet of Things" (IoT) was adopted for the design and implementation of the prototype for the data acquisition and control system. The parameters considered in the monitoring of cheese ripening included the measurement of temperature, relative humidity (sensor DHT22/AM2302), and air velocity (F660, DegreeC) in three locations inside the ripening room. The consumption of electricity by the compressor, humidifier, and ventilation, was evaluated using current transformers (SCT-013, YHDC). The consumption of water by the humidification system was measured using a flow-rate sensor (YF-S201, Uruk) in the inlet water pipe of the humidifier. The monitoring and control system included two main modules: the monitoring module and the control module (Figure 5). The monitoring module was intended for the collection of data related to physical-chemical parameters, while the control module was responsible for the proper adjustments on temperature, humidity and air extraction by activating the refrigerator, humidifier and the fan extractor.

The monitoring module was based on a WiPy computational platform ("WiPy 3.0 - Pycom", 2020), based on the ESP32 microcontroller that contains an Xtensa LX6 microprocessor (Tensilica) with a 32-bit CPU architecture. It is characterized by its low-power consumption, reliability and electrical strength for use in industrial environments or thermally less favorable. The input and output ports of this microcontroller were particularly suitable for connection to communication systems and data collection. In this case it features a Wi-Fi communication module that can be used for wireless transmission of data collected from the sensors, placed inside the cheese ripening chamber, to the aggregator module that is outside. The individual acquisition modules were associated with fixed local Internet addresses, assigned by the aggregator module so that they can be accessed remotely at any time for the purpose of monitoring their operating status or for updating their data acquisition software.

Figure 5. System block diagram of data acquisition and instrumentation apparatus

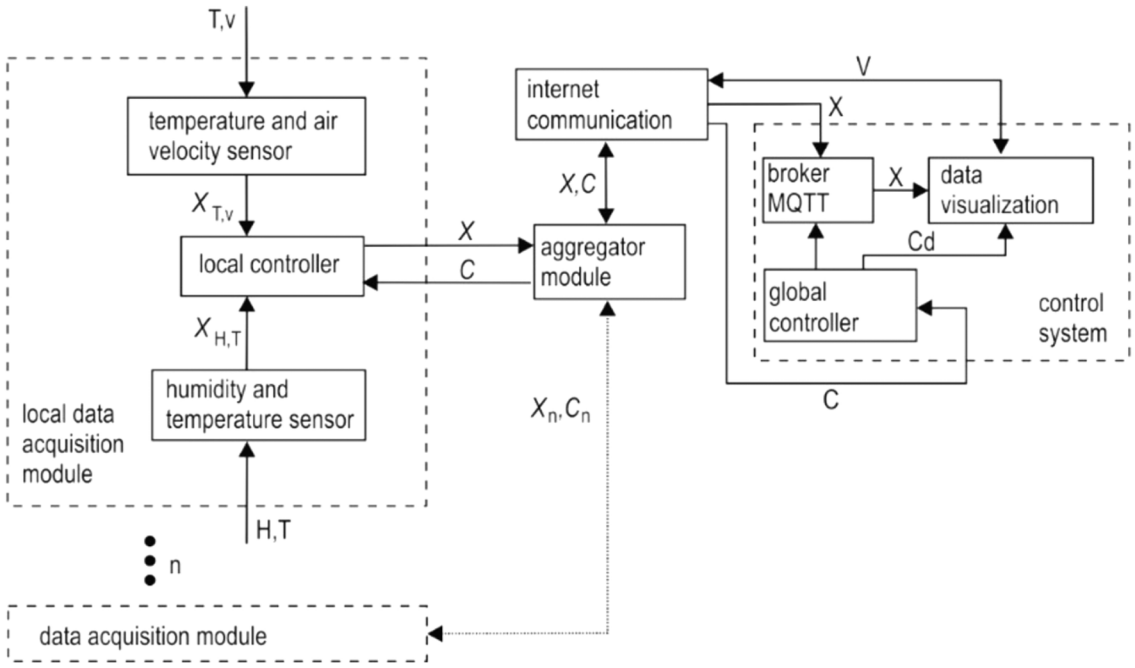


Figure 6. Placement of a monitoring system in a ripening room

This computational platform supports development with an interpreter version of the Python programming language called MicroPython ("MicroPython - Python for microcontrollers", 2020) which facilitates the development of applications by providing several libraries to access the various subsystems of the WiPy platform. The aggregator module was built with the computational platform Raspberry Pi 3B +, receiving the information from the data acquisition modules, storing such data locally but also transmitting through the communications subsystem, via Internet connection to a remote server. The Internet protocol used to transmit this data was MQTT, based on the message subscription model. The MQTT server was installed on a computer managed at IPBeja's SEPSI (Electronic Systems, Signal Processing and Instrumentation Laboratory) laboratory and using RabbitMQ software ("Messaging that just works - RabbitMQ", 2020) on an Arch Linux operating system ("Arch Linux", 2020). The data is collected using a program created through the Node-RED low-code visual programming platform for treatment, visualization and storage in a database ("Node-RED", 2020). This platform is especially used in systems based on IoT. The control system is also connected to the Node-RED server and receives the values of the readings made by the data acquisition systems.

Through SSH (Secure Shell) connection in reverse mode was possible to remotely access aggregator module and, thus, communicate with the local data acquisition modules. SSH connections were encrypted and the Internet addresses of each of these local modules were assigned by means of a DHCP server to be executed in this aggregator module. For the realization of the operation tests, the conditions presented in Table 1 were adopted.

Table 1. Environmental conditions inside prototype

	Pre-project	**Post-project**
Temperature	11.9ºC	13.5ºC
Humidity	83.2%	84.0%

Concerning investment cost, building the whole automation system of an already existent ripening chamber costs about 6.605€ (plus taxes): 4.000€ for the automation equipment, 2.000€ for tubes and accessories, and 605€ for hand labor for assembling and programming the system. These costs were based on the actual market prices. When performing the analysis, such amount, around 6.605€ and corresponding to the difference between the existence, or not, of automation in the system, must be considered due to its relevance in this study. This is one of the inputs of the analysis of economic viability of the new prototype. For this analysis, the average results of firms of the sector was considered as the reference, showing that this process ensures an increase of the competitiveness of SME's in the sector but also could have a high impact on the sector as whole. Moreover, the reduction of consumption of resources like water and electricity, apart from implying a reduction in costs, are also relevant for the environment, helping to attain higher sustainability levels.

RESULTS

The results of the query applied in the study region indicate that traditional cheese factories are mainly individual or family-owned companies and the owners are, on average, approximately 59 years old. About 92% of such companies present less than 10 workers (Figure 7)

Excepting a few specific cases in each region, the ripening rooms present small areas, between 22 and 46m^2 per room (Table 2).

During ripening, some care is necessary in order to ensure the final quality of the product, like the proper evolution of water loss or microbiological development. In most cases cheesemakers turn cheese everyday, however, in certain cases this operation was done every two days, weekly or even fortnightly (Figure 8).

The operation of washing the surface of cheeses aims to improve the external appearance of the cheese and control the development of molds. However, if it is important to perform this task, on the other hand, over-washing increases the risk of breakage for the cheese rind, especially in cheeses with buttery texture. The results show that the number of washings per ripening cycle was about 3 in the region of the Évora cheese and about 2.5 in the regions of Azeitão and Serpa cheeses.

Figure 7. Workers per cheese factory

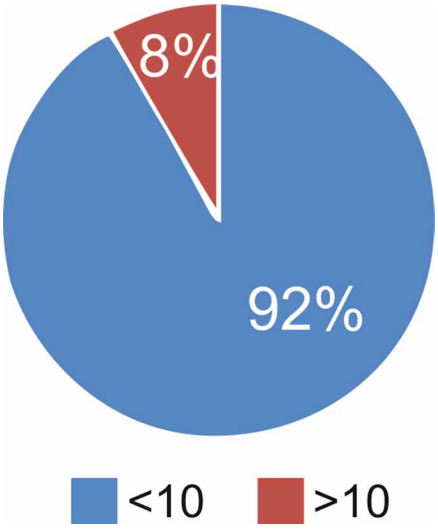


Table 2. Dimension of ripening chambers

	First ripening chamber				Second ripening chamber		
	Lenght (m)	**Width (m)**	**Height (m)**		**Lenght (m)**	**Width (m)**	**Height (m)**
Azeitão	4.7	6.3	3.2		4.7	6.0	3.2
Évora	5.2	4.3	3.2		8.1	5.7	3.2
Serpa	5.5	6.0	3.0		5.1	5.8	3.0

Figure 8. Turning cheeses

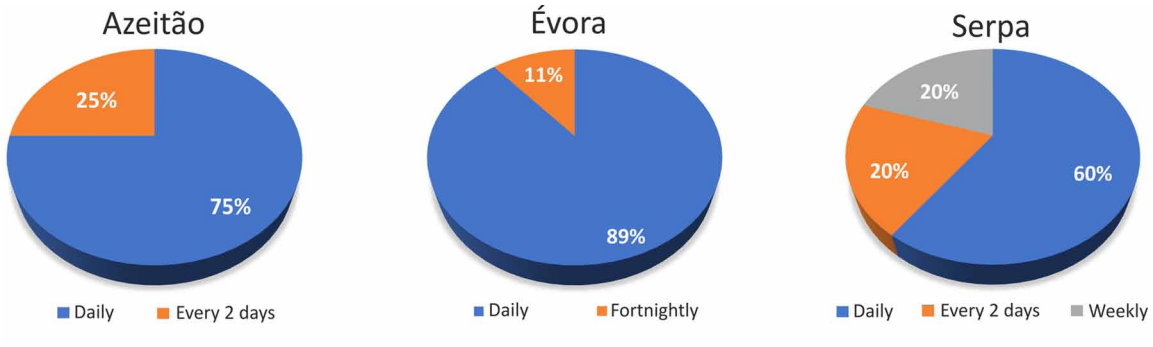
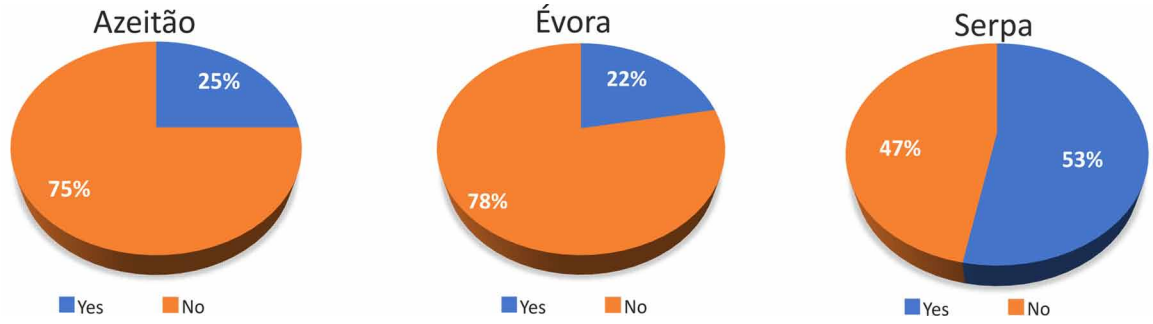


Figure 9. Is the ripening homogeneous inside the ripening chamber?

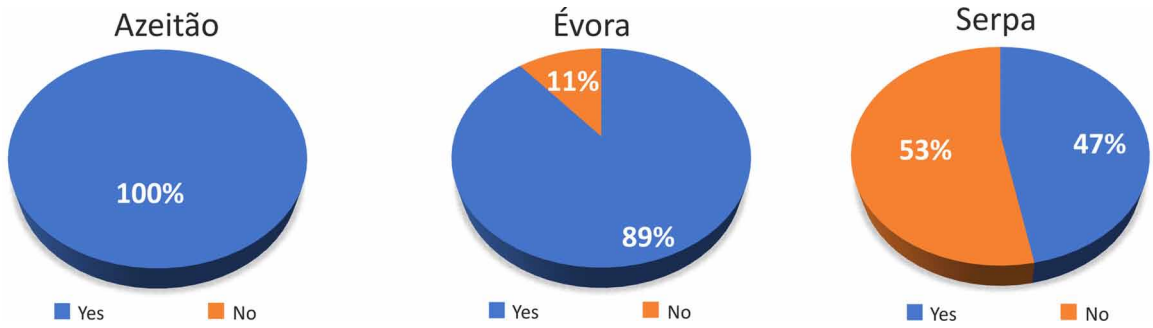


Regarding the homogeneity of the ripening conditions, in the regions of Azeitão and Évora it was found that in the vast majority (above 75%), the ripening of the cheeses inside the chambers was not homogeneous. In contrast, in the Serpa cheese region, only 47% stated that it was not homogeneous. Thus, it is possible to conclude that this is a fundamental aspect to take into account in the near future, in order to increase the homogeneity of the ripening conditions to improve the characteristics of the cheese during the ripening period and, consequently, its commercial value (Figure 9).

As a result of this lack of homogeneity inside the chambers, it is necessary to constantly change the location of the cheeses in order to avoid their constant stay in too dry or too moisty environments. As can be seen from Figure 10, the percentage of cheese makers where this practice was observed is consistent with the responses represented in Figure 9, thus verifying a cause-effect relationship. The immediate consequence of this need to change the location of the cheeses is, without a doubt, the greatest burden in terms of labor, since it is usual to spend no less than two hours a day.

As presented in figures 7 to 10, the results of CFD4CHEESE project were especially relevant in a pandemic crisis context. In order to obtain high quality products in the artisanal industries, especially when using raw milk, a daily handling is required, whether to change locations, due to heterogeneity in the environmental conditions in different locations, either by the need of turning cheeses daily to maximize homogeneous ripening and rind aspect. In the other hand, a daily wash of the rind of cheese is necessary to improve the appearance and prevent defects caused by moulds. On the other hand, is a common practice to perform the washing operations in teams and inside small openings near the ripening

Figure 10. Is it necessary to change the location of cheeses during ripening time?



rooms, for a better convenience. The energetic efficiency of the ripening chambers is directly related to the volume inside and is one of the reasons for not oversizing. For such reasons, is not easy to ensure the distance between workers required by the COVID 19 security rules and, the results of CFD4CHEESE project may have these added motivations because it aims to model environmental conditions in order to minimize handling needs on the process.

This section will identify a set of important economic variables about the prototype, namely the respective production and operational costs. After that, some potential benefits will be identified and, based on some assumptions, the potential economic impact of the project in the regions under analysis will be presented. It is noteworthy that all the values considered were based on the economic and financial values available in the central balance sheet of Banco de Portugal, as well as the various financial reports of the companies that constituted the sample.

From the different essays, it was possible to find several important impacts in the consumption of electricity and water, associated to the normal operation of the prototype. The consumption of water was estimated based on the instant flowrate (in ml/s), recorded by the aggregator module, multiplied by time (s). The consumption of energy was estimated based on the electric voltage, number of phases and instant current value (A), recorded by the aggregator module, multiplied by time (s) The results are described in Table 3 and allow us to conclude that the savings considering the operation of the prototype

Table 3. Consumptions of the system with and without automation

	Electricity		**Water**
	Refrigeration compressor (kWh)	**Humidificator (kWh)**	**Humidificator (liters)**
Conventional ripening chamber			
Average	11.85	8.71	11.66
KS normality test	0.360**	0.190	0.200
Automated ripening chamber			
Average	6.96	3.90	8.58
KS normality test	0.174*	0.093	0.112
H0: Conventional = Automated	-2.754***	4.075***	5.424***

the values correspond to the average levels of the essays). KS normality test refers to the statistical test of Kolmogorov-Smirnov. ***, ** and * denote, respectively, significance at 1%, 5% and 10% levels.

are about 26.44% in water and about 47.21% in electricity. Moreover, some statistical test were developed to confirm the statistical significance of the differences. For the conventional ripening chamber, data during 8 days was retrieved and during 23 days for the automated ripening chamber. After the analysis of the normality of the variables, the null hypothesis for the averages of the electric consumption of the compressor was rejected, while the averages of the consumptions of the humidifier (both for water and electricity) revealed normal data. The analysis of the equality of the variables was considered. In the case of the non-normal data Mann-Whitney test for the equality of the medians was used, while in the case of normal data was used the t-test for the equality of means.

It is important to note that the savings identified in Table 3 do not correspond to the total of savings in the costs with those two important external services. In fact, 47% of the saving in the electricity corresponds to the reduction of the consumption of the prototype and not the total of the firm. The whole essay had a duration of 21705 minutes, during which the compressor worked for 4263, implying that it about 19.6% of the time, which means a potential energetic gain of 9.21% for the firms. Nevertheless, a 9.21% reduction was considered as a significant value.

Regarding water saving, the prototype considers a reduction of about 26% of its consumption. The final impact is more reduced, not only due to the cost of this resource, but also because the amount of water used in the chambers is residual when compared with the total amount of water used in the whole firm, since most part of the water, according to the managers, is used in the washing of the cheeses and the in the clothing used in the firms. But considering that water is a crucial resource for human beings, even more so in the regions where the study was conducted, often suffering from weather droughts, all the savings are relevant to pursue to objectives of attaining sustainable development, even if the monetary costs are less relevant.

Even with the reduction of costs with the prototype, it is also important to evaluate the potential benefits of that equipment. On one hand, it is expected that firms could increase their sales, once they produce more cheese with higher quality using the same raw materials. This happens because the prototype allows for higher efficiency levels in the production, increasing the quality of the cheeses which contributes for a higher quantity of final available product. During the realization of the questionnaires, firms answered that in average, and per day, with the traditional chambers they had about 15 kg of defective cheeses, with the respective impacts in sales. As the prototype has a direct impact in the ripening conditions of the cheeses, it will enhance the quantity of final product and the necessary quality for the introduction in the market, optimizing the relationship between the inputs of the activity and the generated outputs. On the other hand, and as firms have higher quantities for sale, it could contribute for a higher financial sustainability which would allow business to be more solid and possibly to gain the necessary conditions to obtain the PDO valorization of their products, increasing the margins, since firms could practice higher prices.

Another possible relevant issue is the stock reduction promoted by the prototype. As referred, it is usual for firms to report cheeses which do not have the desired characteristics to be sold, implying that they have to remain stored for longer periods, losing water and being sold as old cheeses. This has an impact on the activity since these cheeses lose weight, implying less quantities are sold with a relevant reduction of revenue. With the prototype, it is expected that the quality of the cheeses will be optimized and thus minimize the quantity of stocks and of cheeses sold in these conditions.

Previous identified elements were considered in the economic analysis of the new prototype, considering the possibility of its introduction in each cheese producing firm in the regions under analysis.

Knowing the average added value per company, an extrapolation can be made to a macroeconomic level production sector. Some other assumptions were considered for the analysis.

Firstly, and as previously identified, and considering the increase of the efficiency in the production of cheeses, allowing for the increase of production, a potential growth of 15% in the quantities of kilograms of finished product available was considered to introduce immediately in the market. This percentage is based on the opinion of the producers, being an assumption taken in this study. Because it is not an estimate, during the analysis different scenarios were considered, allowing for a lower level of this increase in sales.

As direct consequence of this increase of sales the firms will reduce to a residual basis the quantity of cheese in stock and, regarding the price, a potential increase in market price around 10% can be considered, due to the possibility of PDO label production. Note that according to (Cabo et al., 2017), the PDO qualification could contribute to an increase of the prices up to 23%, which means that a conservative assumption was taken. The reduction in the cost of the electricity was of about 9%, as previously explained.

The reference values for the average monthly sales were established using the data obtained in the surveys conducted within the scope of the project. Considering the reports of the firms of the three regions, can be considered an average amount of sales of 3425 kg per month and an average price of 12.21€ per kg resulting on an average annual turnover of 501 920€. The reference annual electricity value was obtained through the average amount of electricity spent by the companies studied, which was about 2.3% of the sales volume over the years 2017 and 2018. This means an annual reference value of 11 544€, corresponding the 9% of savings to a decrease in this cost item of 1 038.97€. The eventual PDO production has associated costs and, in this sense, a value of 5 000€ was considered. For this assumption, was considered as reference similar costs for cheese producing companies of *Serra da Estrela* PDO cheese, which amounts to an annual cost of about 4 500€.

As previously referred, a relevant impact is considered on the stock of final products in the firms, once the productive efficiency increases with the prototype. For the economic analysis, a 80% reduction in the level of finished product stocks was considered, even if it is expected that with the implementation of the new ripening chambers, the number of cheeses involved in aging processes will be very residual. The reference value for stocks of finished products was based on its weight in relation to the turnover in the companies studied over the years 2017 and 2018, namely 9%, implying a monetary value of 45 172.72€.

An income tax for firms of 21% was considered, which is the actual tax rate in Portugal and a depreciation rate of 25%, a period of 4 years as the one to determine the potential economic value to be created with the investment was considered. The necessity of installing the automation system in two chambers was assumed, since it is the most common number of chambers in the studied firms. It is considered that the investment is made at the beginning of 2021 implying that firms take advantage of the increase of sales all over the year.

Finally, in order to determine the Net Present Value (NPV) of the project, a discount rate of 6% was considered, based on the average return rate on the assets of studied companies. It is intended, therefore, to ensure that the implementation of the ripening chambers provides investors with, at least, the same remuneration that most companies operating in the industry currently create.

Table 4 identifies, briefly, the assumptions used to study the economic viability of the implementation of the new ripening chambers.

Table 4. Assumptions used in the study of the economic viability of the implementation of the new ripening chambers

Assumption	Value
Beginning year for the prevision	2021
Annual sales volume of reference	501 919.15€
Monthly production (kg)	3 424.67
Price per kg	12.21 €
Increase of production quantity (%)	15%
Increase of price (%)	10%
Annual electricity savings	1 038.97€
Annual reference cost	11 544.14€
Energy saving (%)	9%
Annual cost with PDO certification	5 000€
Annual value of stock reduction	36 138.18€
Annual stocks of finished products (reference)	45 172.72€
Reduction of stocks (%)	80%
Investment in automation of the ripening chamber	6 605€
Number of chambers	2
Depreciation rate	25%
Income tax rate	21%

The cash flows of the project, used to calculate the NPV, are the ones presented in Table 5. More details about the calculation of the NPV could be found, for example, in (Ross et al., 2017). Considering the discount rate, and that the investment is made immediately at the beginning of 2021, the NPV is equal to 559 923.73€, meaning that, on average, the project has the potential to release funds over the useful life of the ripening chambers, showing the capacity to cover initial investments and to generate return to investors, considering an annual remuneration of 6%.

Although the assumptions taken in account in this study are the ones obtained in the questionnaires and from the databases, they are still only estimations. Considering the level of uncertainty, sensitivity analysis was implemented, considering possible variations on some assumptions, namely the following three scenarios: i) firms to not attain the PDO certification, not considering neither the increase of 10% on sales price increase nor the annual certification costs; ii) despite the non-consideration of PDO certification, to consider an increase of just 10% of the sales (while in the reference scenario it was considered an increase of 15%); iii) maintaining the absence of PDO certification, considering now an increase in sales of 20%. In this way, it is intended to verify the robustness of the project to the uncertainty always associated with economic and financial forecasts, verifying the impact on the project of variations in some fundamental variables of this business.

Table 6 summarizes the main results of each of the three scenarios, compared with the reference one. In the scenarios 1-3 the NPV value is lower than in the reference scenario, but the NPV is always positive. In fact, the investment needed to automatize the ripening chambers is fully overcome not only by the increase of the sales but also for the stock divestment. Thus, it appears that the ripening imple-

mentation project is economically viable and may contribute to greater financial sustainability for cheese production companies.

Table 5. Cash flows of the project

Item	2021	2022	2023	2024
Investment	13 210.00 €			
Stock divestment	-36 138.18 €	-36 138.18 €	-36 138.18 €	-36 138.18 €
Sales increase	133 008.57 €	133 008.57 €	133 008.57 €	133 008.57 €
Reduction of electricity	1 038.97 €	1 038.97 €	1 038.97 €	1 038.97 €
Costs with PDO certification	5 000.00 €	5 000.00 €	5 000.00 €	5 000.00 €
Depreciations	3 302.50 €	3 302.50 €	3 302.50 €	3 302.50 €
Increase of annual profits	125 745.05 €	125 745.05 €	125 745.05 €	125 745.05 €
Investment cash flow	-22 928.18 €	-36 138.18 €	-36 138.18 €	-36 138.18 €
Operational cash flow	129 047.55 €	129 047.55 €	129 047.55 €	129 047.55 €
Total cash flow	151 975.73 €	165 185.73 €	165 185.73 €	165 185.73 €

Table 6. Summary of results for the difference scenarios

Indicator	Reference scenario	Scenario 1	Scenario 2	Scenario 3
Annual sales increase	133 008.57 €	75 287.87 €	50 191.91 €	100 383.83 €
Annual profit increase	125 745.05 €	73 024.34 €	47 928.39 €	121 048.48 €
NPV	559 923.73 €	377 240.90 €	290 280.79 €	464 201.05 €

CONCLUDING REMARKS

In this paper, the main goal was to show the economic viability of the investment in the automation of ripening chambers in firms. This automation has the main objective of increasing the productive efficiency of firms, in three different PDO regions in south Portugal and in the firms producing each of the three cheese types under study, in a universe of less than 50 firms. Based on the answers of questionnaires obtained directly in the firms and on the retrieval of data from a database, the average characteristics of the firms could be identified.

For this objective, a ripening chamber was built and several essays were made, which allowed to conclude that the production increased its efficiency, increasing the quantities of products available for sale and reducing the level of investment in cheese stocks. At the same time, it was also verified, through tests related to the operation of the developed prototypes, that the new ripening chambers contribute to a reduction in energy consumption in the ripening process of more than 40%, meaning a saving in electricity costs of about 9%. Regarding the consumption of water, the savings reach levels of about 26%. All of these impacts are very relevant to create a better financial sustainability in pandemic situation.

In order to better demonstrate the impact of the implementation of the ripening chambers in this activity, an economic assessment study was carried out for the cheese production companies, concluding that the investment is viable, with the potential average increase of sales in individual firms of about 133 008.57 €. Considering the total of 46 firms in the regions under analysis, dedicated to the production of the three different cheeses, it could imply a total increase in the sector of more than 6 million euros. Regarding the NPV, based on the average firm it was estimated on 559 923.73 €, which could reach to an amount of about 27.4 million euros for the whole sector. Results clearly show that the investment needed for the automation in the ripening chambers creates value for the firms and for the society as a whole, being an economically viable investment.

In conclusion, it appears that the ripening chamber implementation project is economically viable and may contribute to a greater financial sustainability for cheese production companies, increasing not only the competitiveness of the firms individually (most of them SME), but also the sector as a whole. This is crucial information for managers and potential investors, but also for the economic authorities which could have in this kind of traditional sectors a good basis for enhancement of the economic development of their regions.

Moreover, the results also show that the project could promote not only an increase in the economic indicators but also help in the increase of sustainable use of some resources like electricity and water, also contributing to the environmental sustainability.

At this point, it is relevant to identify some limitations of this study. Firstly, the analysis is made for a reduced number of firms, because the study is related with the above mentioned project, which was limited to the analysis of cheeses in three different regions. Nevertheless, the results are promising regarding to the economic potential of the prototype. Other possible limitation is the fact that some of the assumptions should be confirmed in the future, namely the ones related with the increase of the sales. Although, in this case different scenarios for the sensitivity analyses were considered, with the results showing some robustness.

In the future, a multidisciplinary study should be performed to evaluate the impact on the physicochemical, microbiological and sensorial properties of ewe's cheese ripened in the prototype, comparing with the standard ripening chambers inside the regions under study. Moreover, the distribution of air inside the prototype should also be studied, using the computational fluid dynamics, in order to homogenize the environmental conditions like temperature, humidity and air velocity, minimizing the operational costs and continuing to improve the competitiveness of the businesses.

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