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An integrated information systems architecture for the agri-food industry

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Abstract
As information systems and technologies grow in usage in the agri-food industry, the same has happened to the relevance of Information Systems (IS) that allow for a parallel control, monitoring and management of the organizations' activities and business processes. As the literature proves, the benefits of implementing adequate and interoperable IS are very numerous and tend to represent a significant determinant regarding the organizations' overall success. Despite this, to the best of our knowledge there currently is no IS architecture designed to serve the specificities of the agri-food industry. With this study a novel information systems architecture for the agri-food sector is proposed. The artefact is composed by 12 integrated main components and a set of subcomponents aimed at supporting all the monitoring, control and management activities. In order to validate the proposed architecture a case study was implemented at a mushroom production organization. This allowed us to perceive the ability of our artefact to serve as the basis for the development of IS that address all of the organization's business and environmental needs.

KEYWORDS
agri-food industry, information systems, IS architecture, mushroom production

1 | INTRODUCTION

The use of information systems (IS) and technologies in the agri-food industry has been continuously increasing in recent decades as a consequence of the development of existing farms and the overall increase in the knowledge needs of farm owners (Branco, Gonçalves, Martins, & Cota, 2015; Gebbers & Adamchuk, 2010). In developed countries it is pretty common in an agri-food company to use sophisticated systems for controlling and monitoring production by implementing a constant data collection, thus allowing to control a set of variables that are critical to the overall production, such as temperature, humidity and CO2 (Mulla, 2013; Ojha, Misra, & Raghuwanshi, 2015; Wang, Zhang, & Wang, 2006).

Despite being a business sector in such strong expansion, the existing literature does not provide for a global architecture for an information system that can be transversely applied to the agri-food industry. An aim is organizations that produce sensitive food, such as mushrooms. This is even more important when one considers that, currently, agriculture is an activity that implies significant knowledge and an extremely active decision making process. In the case study used, the necessity for a real-time decision making system, supported on accurate and detailed data, was decisive for the conceptualization of an information system that was able to support not only the vertical management of the organization, but also the specificities of the mushroom production management process.

Hence, with this research we aimed at conceptualizing an IS architecture that could not only be applied to mushroom production, but also to the entire agri-food sector. The proposed architecture, despite assuming a considerable degree of innovation, also ensures that legacy systems are integrated, and that data interoperability is a reality. It has a considerable degree of flexibility, modularity, scalability, replicability, adaptability, while respecting standards and regulations and implying a significant low-complexity maintenance. In order to validate the proposed conceptual artefact we have performed a case-study involving one of the biggest mushroom producers from the Iberian Peninsula, which allowed us to perceive not only the adequacy of our proposal, but also the positive impacts that it had in the organization's operational and managerial processes.

Despite the overall positive acknowledgements that emerged from the aforementioned case-study, as IS researchers we still believe that a continuous improvement of the proposed IS Architecture can be achieved by performing additional case studies with other agri-food companies that might have different operational, managerial, market and regulatory scopes.

The present manuscript starts with a brief description of the research context. In the second section we present the conceptual background analysis that served as the basis for the remainder of the research. The organization used as the research case study is described in the third section. The fourth section encompasses an analysis of the adoption of IS and technologies in the agri-food industry. The proposed information system architecture is detailed in Section 5 and we then finish with a set of final considerations on the research performed.

2 | CONCEPTUAL BACKGROUND

The constant evolution of the paradigms associated with productive systems that has been happening for the last coupe of decades has created multiple and significative changes in how both societies and organizations face globalization and existing data and information. As we evolve towards a more information-dependent society, one must ensure that organizations have the necessary means to manage not only their own organization but also that which is related to the surrounding environment (Bessa, Branco, Costa, Martins, & Gonçalves, 2016).

2.1 | Information systems management

From a conceptual perspective, IS have suffered multiple evolutions over time. Still, despite this development, most authors continue to consider IS as technological solutions aimed at supporting organizations in their daily business activities and addressing the constant challenges imposed by their own environment (Chaparro-Peláez, Pereira-Rama, & Pascual-Miguel, 2014; Mithas, Ramasubbu, & Sambamurthy, 2011; Mithas & Rust, 2016).

As argued by Chen, Mocker, Preston, and Teubner (2010); Laudon and Laudon (2017), IS are characterizable as a set of functional elements that use information for decision making activities, for supporting overall management and for controlling work and production processes. In addition, IS are also considered tools that can help organizations to address operational problems and the creation of new products or services.

Furthermore, as demonstrated by Brynjolfsson and Hitt (2000); Sabherwal and Jeyaraj (2015), an Information System is much more than a set of hardware and software responsible for information storage and handling. Despite being critical for IS success, the technological elements on their own are not able to conceive and accurately manage the existing information within a given organization. That is why IS must encompass the organizational context, its business processes and overall structural division, its human resources and its past, and its existing and future problems.

IS affect the manner in which business managers make decisions, plan and manage the available resources. The importance of IS and their complexity make them extremely pivotal for organizations. Considering the fact that IS are a critical part of organizations we cannot deny the importance of implementing and effectively managing IS (Otim, Dow, Grover, & Wong, 2012; Shatat, 2015). To know how to make the most of the available resources is a sign of effective management that completes the alignment between the organization's business strategy and the existing IS (J. Martins et al., 2019). Hence, IS management can be conceptually characterized as the management of all the available information and resources that are involved in planning, developing and exploring the existing IS. It is a truly challenging task as the information is spread across the entire organization. The increase in complexity of organizations has led to the necessity of using even more complex IS, thus increasing the difficulty of their management and maintenance, while also increasing the inherent costs (Pearlson, Saunders, & Galletta, 2016). From a theoretical perspective, IS management can be characterized by three main activities (Stair & Reynolds, 2011): (a) IS Planning; (b) IS Development; and (c) IS Exploration.

2.2 | The information systems role in the organization

The main goal of an information system, when implemented in a given organization, is to ensure the data flow and to provide for the necessary means so that it may continue to flow adequately. The IS supports, in an integrated manner, data processing, input and registry of business data, as well as the output requirements (usually to feed other existing systems). IS are composed by a set of sub-systems, each one responsible for a subset of organizational information and operational requirements and with its own data flows. Currently, IS has outperformed traditional management tasks supported by paper, and is thus becoming one of the most strategic resources of organizations (Peppard, 2018). The continuous increase in the strategic importance of IS has enforced IS management activities to become part of an innovative and strategic management approach.

IS represent a fundamental part of organizational production engines and their role in the organization can be divided into three main areas of focus: (a) support for business strategies aimed at generating competitive advantage; (b) support for the organization's decision making process; and (c) support for both the operational tasks and the existing business processes. As a result, managers understand the strategic implications of an economy drawn on Information, hence recognizing that adaptability speed, flexibility and constant innovation are fundamentals for an organization's success (Branco, Moreira, Martins, Au-Yong-Oliveira, & Gonçalves, 2019).

Information is now a vital resource for organizations, on a par with human and financial resources. Drawing on this perspective one can highlight that IS must be able to provide tools for the organization to be able to reach the business goals that it has defined. Hence, it is possible to define the main features of an IS as (Luisi, 2014): (a) collecting and treating business-related data; (b) regularly making information available to all management levels; and (c) adding value.

In the agri-food industry the use of IS has been increasing over the last decade, as they provide the tools necessary for not only effectively managing the organization, but also to keep track of the existing markets. According to Omran (2017); Pavlovic, Koumboulis, Tzamtzi, and Rozman (2008), the use of IS in agriculture is a clear advantage for organizations, as these platforms not only allow for the education of farmers, but also allow for a complete monitoring of the farms and of the productive processes in particular, thus allowing for more accurate decision making.

2.3 | Agri-food information systems

Most agri-food companies operate in a dynamic and very complex environment. To address the increasingly demanding needs of consumers, organizations are required to innovate, both in products and in processes, as well as in forms of network cooperation in supply chains. IS thus plays a very important role in the innovation of the sector. The structuring and integration of information is essential to obtain results. The correct integration of various technologies has a clear advantage for the organization as it is possible to follow business processes in real time and thus increase the appropriate information-sharing to support an increasingly knowledge-based economy (Verdouw, Robbemond, Verwaart, Wolfert, & Beulens, 2018; Wolfert, Verdouw, Verloop, & Beulens, 2010).

Consumer concerns related to food safety and the globalization of food production have led to a globalization of safety and quality standards adopted by the agri-food sector. In recent years, there has been a strong increase in concern about these factors, which has led to a more intensive use of IS, leading companies to bet on their certification and accreditation. The adoption of IS by organizations can lead to increased costs, but its cost/benefit ratio is clearly advantageous in the referred sector. The sustainability of food supply chains is strongly linked to IS, as these support the communication between the various actors in the system. The identification of solutions that restore the confidence of consumers, and provide them with information, and also to managers, is done through the use of IS (Wognum, Bremmers, Trienekens, van der Vorst, & Bloemhof, 2011). Food security is currently seen as a relevant issue in the agri-food supply chain, and the legal and regulatory framework is increasingly restrictive (Manning, 2018). According to Liao, Marshall, and Swatman (2012), the use of Web 2.0 by primary producers can also reduce costs and improve marketing opportunities.

Food products and the whole agri-food sector represent an important part of logistics across Europe, facing daily challenges such as high trade dynamics and uncertainty in demand and supply. The Internet and IS are thus critical to meeting specific agri-food logistics challenges (Verdouw et al., 2018; Verdouw, Sundmaeker, Meyer, Wolfert, & Verhoosel, 2013). Supply chains are increasingly computerized, as a way to respond to market challenges, and to incorporate the opportunities offered by the technologies available in the market. Virtual management of the supply chain no longer requires physical proximity between the various actors in the chain, and control and coordination can take place at any physical location and with any of the actors (Verdouw, Beulens, & van der Vorst, 2013).

The successful implementation of Supply Chain Management (SCM) in food supply chains promotes an improvement in productivity and in the efficiency of some organizations. For agri-food organizations to be successful in their strategies, cooperation between the various players in the supply chain and the correct use of information technologies is essential (Sharma & Patil, 2011). Currently, most agri-food organizations aim to improve competitiveness and business practices by introducing innovative business and e-business IS models into their management processes (Zioupou, Andreopoulou, Manos, & Kiomourtzi, 2014).

The latest technological advances have paved the way for the rapid expansion and development of IS-related services in the agri-food sector. The paradigm shift is thus a reality. Simply monolithic (large but not dividable, and which require time to change) and proprietary tools are no longer being used. The aim is open systems based on the Internet and the cloud concept, that allows the most effective collaboration between the different system actors. This new paradigm includes development tailored to the needs of the organization, so as to create specialized and personalized services (Kaloxylos et al., 2014).

According to Domenech, Martinez-Gomez, and Mas-Verdú (2014), there is currently a standard that defines the adoption of web technologies in agri-food organizations. There are a number of characteristics that influence technology adoption, such as location, economic performance, and the history of technology adoption and innovation. According to these authors, the obtained results, together with some external factors of the organizations, lead us to affirm that the adoption of web-based technologies is more frequent in the organizations that are implemented in an urban environment as compared to the more rural ones.

Hence, and drawing on Reed, Miles, Butler, Baldwin, and Noble (2001); Kashkoush and Avigad (2018) arguments, the process of harvesting mushrooms through highly robotic and computerized mechanisms represents a clear advantage for the organization. Mushroom production, supported by technological equipment, is already a reality, and harvesting, sorting, cutting, transporting and transferring are implemented with custom-designed equipment and IS-supported equipment. These authors show that mushroom picking is a very important step for the business and that this highly robotic step represents an advantage for the organization as it saves human resources, physical space, as well as other resources.

3 | SOUSACAMP GROUP: THE MUSHROOM COMPANY

Mushrooms are considered to be a vegetable or a herb, but in reality they are a fungus (Camassola, 2013). Nevertheless, the production of mushrooms is considered part of the agri-food sector. The global business potential of producing mushrooms is very significant, as the five countries with the biggest production volume are able to produce around 7 million tonnes.

The Sousacamp company was created back in 1989 in a small village in rural Portugal. After a considerable initial effort and a clear bet on the international expansion of the business, in 2007, the company evolved into a business Group. The verticalization and diversification of the business allowed for the creation of multiple sectorial smaller enterprises and newer and more innovative production and transformation units. Currently, the Group includes all of the processes associated with the production of mushrooms: production of substrate, production, harvest and preparation of (fresh and canned) mushrooms, shipping and logistics, reuse of the substrate, either as fertilizer or as biomass. The Sousacamp Group currently leads the Portuguese market and has a significant quota of the Spanish market. Initial efforts are also being made to enter the French, German and Dutch markets.

In order to address the customer needs, a strong investment has been made in compliance with both national and international best practices: ISO 9001, ISO 22000, ISO 14001, Clube de Produtores Sonae, Linha Vida Auchan, Sociedade Ponto Verde, SATIVA, NOP/USDA ORGANIC (The National Organic Program—United States Department of Agriculture) and GlobalGAP (Global Good Agriculture Practices), among others.

Previously to the creation of Sousacamp Group (i.e., before 2007), the entire company was composed by small production units in multiple locations. At the time, the existing technological infrastructure was drawn on a traditional approach with small local networks interconnected with each other and composed by simple servers for service deployment and desktop computers for workers to perform their tasks. This solution was neither flexible nor scalable. Currently, the Group needs considerably bigger control and access to information as it needs to ensure that the production management tasks are completely aligned with the remaining business activities.

4 | AGRI-FOOD INFORMATION SYSTEMS ARCHITECTURE PROPOSAL

In order to thrive it is absolutely necessary to innovate, at least occasionally. However, despite this finding, it was difficult within this research project to decide which technologies to adopt, when to adopt them, and how to manage the implementation process in order to generate business value. Much of this difficulty was due to the complexity of the system and the permanent mutation of a large set of multi-level variables, together with a whole set of rationality principles based on a necessary cost–benefit analysis. To try to mitigate some of the difficulties, pilot projects or prototypes were developed whenever possible to reduce the risk associated with each change process (Magalhães et al., 2019).

Therefore, to understand the drivers that might be involved in the acceptance of agri-food IS, drawn to be transversal to the activities and business processes of the entire organization, an analysis has been made of the technology adoption literature. After a significant analysis of the most relevant adoption models, we were able to acknowledge that Rogers (2010) technology diffusion model was useful for understanding how the Group's human resources influence the adoption of innovation, but mainly to help identify key contributors who influence the adoption of new technologies. The TOE—Technology-Organization-Environment framework (Baker, 2012) was useful for understanding and analysing how factors associated with different contexts could affect the adoption of technologies at various Sousacamp Group companies. This understanding resulted in the proposal of an architecture for the Group Information System which respects the governance model and incorporates the functional logic. We recall that, although the Group is made up of multiple companies, most departments are functionally dependent on Sousacamp SGPS, SA, emptying the remaining companies from these functions, which posed a major challenge for aligning the Information System with operational, tactical activities, and strategic process strategies of all the Group companies.

In Figure 1 we can perceive the proposed IS Architecture (Figure 1) and how it encompasses five major components, eight secondary components (and their subcomponents) that make up the Information System, thus establishing the existing relationships. The following sections describe the components mentioned above in order to better understand their role within the Information System.

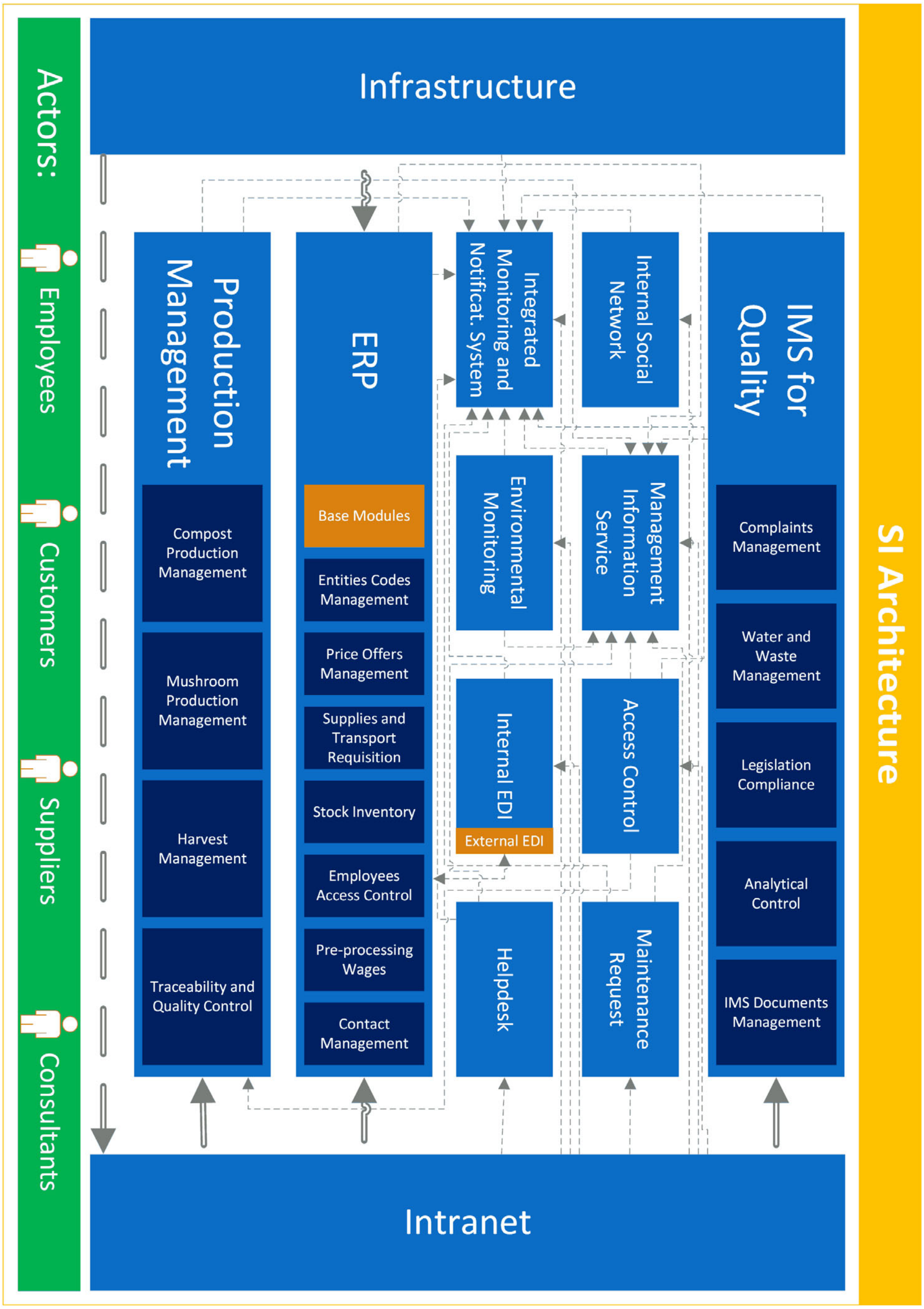

FIGURE 1 Agri-food information system architecture proposal

4.1 | Infrastructure

In order to simplify the maintenance and operation of the entire system, it was decided to place all critical Information Technology (IT) systems at the headquarters, where the Department of Information Systems should be physically located. In the remaining units we posit that they should only have the necessary extension means for the operation of the unit.

At the network equipment level, all units should have routers, switches, access points, and more, scaled to the size of the unit and to the number of users, and be prepared to scale with the increasing need for media allocation. Additionally, in terms of physical resources, and in order to maintain a low cost, servers with virtualization capacity should be used. Virtualization allows for the use of the same hardware to run multiple instances of operating systems, that is, multiple (virtual) servers running on the same physical server. The adoption of this technology is driven by features such as: harnessing hardware, ease of administration, significant cost savings, error tolerance, high availability, ease of implementation, scalability and, last but not least, reduced electricity consumption. Each workstation is equipped with thin clients that are computers with very minimalist and reduced hardware that only serve as an interface to the real work session. The working sessions are running on the server with terminal services capabilities. Using thin clients drastically reduces equipment costs and improves maintenance efficiency.

4.2 | Intranet

Corporate intranets are a fundamental means of accessing organizational memory in order to retrieve business information. According to Chua, Eze, and Goh (2010) the Intranet is seen as a place for knowledge sharing within the organization. This knowledge, its rapid dissemination and subsequent use, improve employee response times and interactivity, which in turn translates into the development of the company's internal processes to increase the satisfaction of all stakeholders (employees, customers, suppliers and consultants) (Ali, Paris, & Gunasekaran, 2019).

When well developed, the Intranet enables high business flexibility, meaning any business, regardless of its type, can have an Intranet tailored to its core business. At the same time, the available collaboration and management tools improve communication by reducing the amount of e-mail, work hours and number of steps for each task. An Intranet optimizes the business process as a whole (Mani, Byun, & Cocca, 2013).

With the "Intranet" component, companies have a space, not only for information searching, but also for publication, interaction and work, that is, a collaborative and interactive space for the purpose of sharing. Hence, the proposed Intranet component is intended to be unique and used across all organizational units and departments. It is organized into companies, departments, units and services. The Intranet should have collaborative tools (e.g., forums, wikis, blogs and surveys) and should allow one to keep part of the data synchronized offline (a very useful feature for those travelling), with changes automatically synchronized when users come back online. This capability also exists for mobile devices. From an overall perspective, one can acknowledge that the proposed Intranet encompasses both document and project management, thus having the necessary features to support the work teams' tasks.

4.3 | Production management

Production processes are often scattered around the world, leading suppliers and customers to be interconnected by information, materials and capital flows. Associated with the value of the product, we have to add the burden of environmental and social responsibility that occurs in the various stages of the production process, being equally responsible for the performance of its suppliers (King, 2019).

Intensive mushroom production uses automation control systems, ensuring measurements and adjustments of variables such as temperature, ventilation and humidity at all stages. Although, in recent decades, agriculture has increased the use of IT (Huang et al., 2010), there are several stages of the mushroom production cycle that are carried out manually and are difficult to automate, such as mushroom picking (Figure 2).

The Production Management component breaks down into the following subcomponents: (a) Substrate Production Management; (b) Mushroom Production Management; (c) Harvest Management; and (d) Traceability and Quality Control. Thus, from a conceptual perspective we posit that this component must ensure that it addresses all of the business processes and activities directly related to the production process.

4.4 | ERP: Enterprise resource planning

Enterprise Resource Planning (ERP) systems are the "backbone" of organizations as they aggregate information and business processes into one system. An ERP uses a multi-module architecture to improve the performance and operation of the business processes inherent to the

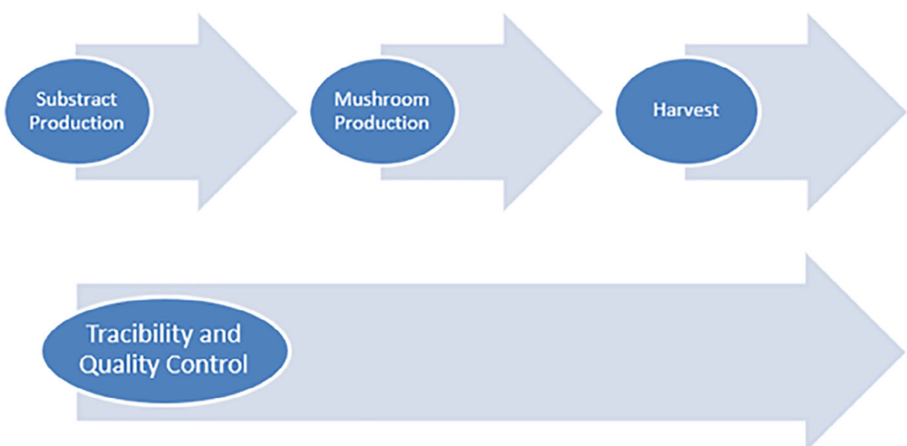

FIGURE 2 Mushroom production flow

organization, integrating different departments or other functional areas, providing and sharing information whenever necessary. As argued by (O'Brivvven & Marakas, 2011), an ERP is considered a mandatory tool in order for organizations to be efficient, agile and responsive in a business environment that is increasingly dynamic.

Integration is an extremely important part of ERP systems. The main goal is the integration of all data and processes across all of the desktops of an organization, unifying them to enable easy access and a dynamic workflow. ERP systems typically integrate, creating a single database that employs multiple software modules specific to different areas of an organization and different business functions. The data used by each module is stored in the main database where it can then be manipulated by other modules.

Although increasingly sophisticated and complex, an ERP alone is not able to meet all of the organizations' IS requirements, mainly due to existing legacy systems and, given the need to integrate new components, that is, to meet the specifics of the Business model. In this sense, we predict the necessity for custom developing of the following subcomponents, complementary to the base modules, which work in parallel with the implemented ERP: (a) Product and Packaging Coding Management; (b) Quotation Management; (c) Material and Transportation Requisition; (d) Production Quantity Management; (e) Attendance Control; (f) Pre-processing of Salaries; and (g) Contact Management.

4.5 | Integrated management system for quality

The concept of continuous improvement follows the evolution of quality. With growth, companies are no longer focused on operational needs, but instead focus on process management and, in turn, improvement activities that involve the entire organization (Manders, de Vries, & Blind, 2016). According to Murphy and Leonard (2016) satisfaction is fundamental to the well-being of customers, the profits of companies supported by purchasing and standardization, and the stability of economic and political structures.

The need to respond to management benchmarks and to integrate new and existing components into this process, together with the absence of quality management support software packages tailored to the current agri-food organizations' needs, has led to the proposal of the following subcomponents: (a) Complaint Management; (b) Water Resources and Waste Management; (c) Legislation; (d) Analytical Control; and (e) SGI Document Management.

4.6 | MIS: management information system

Organizational intelligence involves gathering information, analysing it, disseminating it, obtaining new opportunities, and reacting in time. This organizational capacity should be an integral part of every organization's daily life, so that business decision making is adequate and of good quality (Branco, Martins, & Gonçalves, 2016). Today's organizations are complex, highly dynamic and competitive. When there is a need to make quick decisions based on a high degree of certainty, the choice of an action plan should be based on: reliable data, accurate predictions, and an assessment of potential consequences. The diversity of facts and analysis dimensions in today's companies make the task of management analysts and decision makers extremely time consuming and complex. To respond to this lengthy process of data analysis Business Intelligence (BI) emerged (Laursen & Thorlund, 2016).

Gangadharan and Swami (2004) have defined BI as an architecture consisting of an integrated set of operational information, as well as decision support applications and data storage infrastructures (databases), which provides the business community with easy access to data from business and allows you to make decisions related to it.

The proposed component was idealized to use traditional BI technology but, at the same time, incorporating new technologies that allow it to be classified as a Self-service Business Intelligence (SSBI) solution, that is, to provide to users, without IT technical knowledge, the ability to make properly supported decisions. Decision-making is enriched by the situational context, that is, the data relates to a specific business problem, which typically has a shortened lifetime for a specific user group (Alpar & Schulz, 2016; Turban, Sharda, Delen, & Efraim, 2007).

BI systems should enable trends to be extracted from data in repositories to provide managers with information for strategic decision-making and planning purposes. With a broader scope for Strategic Management, these systems appear as an important support mechanism for meeting the needs of managers in information management, whether at the strategic, tactical or operational level of an organization (Costa & Santos, 2012).

4.7 | Internal EDI: Electronic data Interchange

EDI is the acronym for Electronic Data Interchange, that is, the data exchanged electronically. This concept alone is insufficient as all forms of communication between computer systems can fit this definition. Either way, EDI is a standardized way of transferring data, usually business/legal documents, from one place to another electronically (National Institute of Standards and Technology, 1996).

EDI is already used by most companies in the agri-food industries, that is, customers and suppliers outside the organizations. This subcomponent involves an external EDI service provider which results in costs of some significance. As organizations are enforced to establish relationships with customers and partners, a high number of documents has to be exchanged between these same companies. Thus, employees must issue, for example, sales documents which then have to be recorded in the customer's ERP as "purchases". Hence, in the proposed architecture we incorporated a solution aimed at transferring documents between companies without using external suppliers.

4.8 | Integrated monitoring and notification system

For the proper functioning of any company employees must be prepared and be able to respond in a timely manner to events of various kinds. In the case of continuous production industries, the lack of interesting levels of preparedness or the ability to rapidly respond can result in global losses of several million euros. A significant part of these losses can be attributed to error or malfunctions, which makes it possible to assume that the efficiency of operators for these industries is critical. This requires increased skills and abilities by the operator, and the need to provide them with tools and work environments that favour wise decision making (Gonçalves et al., 2014).

The monitoring and alerting component reduces the need for permanent human follow-up, and the component can issue alerts when the deviation from any standard is detected. The direct and indirect impact is cost savings, improved product quality and reduced production losses. The Integrated Monitoring and Notification System is thus the basis for all alerts generated by the system. The component allows the collection of various data, and according to the parameters triggers alerts. The types of alerts available are as follows: e-mail system, short message service (SMS) system, confirmation call system and authentication system.

In agri-food companies it is critical to ensure that the entire production process is monitored and controlled in real-time. For instance, when producing mushrooms there is a need to monitor the production tunnels, the climatization of the production rooms and the inherent cold chains. Any delay in responding to abnormal changes could invalidate the product, rendering it useless. Confidence felt by customers and suppliers is also influenced by the organization's responsiveness. It then becomes crucial to have a reporting component to respond quickly to diverse needs and take appropriate action. This component also allows a wide range of periodicities, such as snapshots, daily summaries, weekly summaries or free form scheduled summaries.

Component monitoring allows you to react not only to isolated events, but also to a set of events, that is, alerts can be triggered if multiple events occur simultaneously or in isolation. The component should also keep a history of all alerts that were triggered, to whom they were delivered and by which path. For alerts displayed at component authentication, you should even know how many times the alert was displayed and when it was viewed.

4.9 | Internal social network

According to Martins, Gonçalves, Oliveira, Pereira, and Cota (2014) and Fatima et al. (2019), social networks are used by millions of people to connect, find and share messages, images, videos and documents, among other media. Social networks like Facebook and LinkedIn are heavily used in organizations, and LinkedIn is even widely used by young professionals to build and maintain external professional networks. Facebook was quickly adopted by tens of thousands of users to connect with friends, family and colleagues. The direct benefit to work is the strengthening of ties. Traditional social networks have been used at the professional level, however, the mix of work and professional relationships generates tensions across various organizational levels (Skeels & Grudin, 2009).

According to J. Martins, Gonçalves, Oliveira, Cota, and Branco (2016) the use and motivation of social network users within organizations differs from Internet social network users. When motivated to achieve career advancement goals or success in a project, employees do not limit their connections to acquaintances, but use social networking strategically to connect and spread their message to a wide audience.

The Internal Social Network component was proposed to enhance the diffusion of knowledge within companies in a less regulated and centralized manner, allowing employees to have a personal space that aggregates personal and professional interests. The most relevant features of the component include the ability to track other users and other types of information, view users' recent and past activity chronologically, or integrate with various communication tools, including messaging instant messages and e-mail.

Tracking projects can be difficult in large companies. The Internal Social Network with its activity feed has filled this gap. It is possible for each collaborator to follow a project, website or person, and thus follow the evolution and work of each collaborator. For department directors, these tools also help to keep up with their tutelage. The constant exchange of e-mails, with replies, rerouting, and "Carbon Copy" (CC's) for those involved make managing mailboxes chaotic. Collaborative ability allows you to gather this information in one place and to know who read as well as who put the information there.

For employees outside the company, such as sales representatives and maintenance, in conjunction with a smartphone, they can access all of the information using the mobile-optimized version of the platform. The discussion of topics is also no longer done by e-mail, but rather the focus is on the Intranet. The ability to create and generate discussion blogs allows consultation, archiving and constant monitoring of discussions and project issues.

4.10 | Helpdesk

Helpdesk services support one of the most important roles of a department by providing users with the first point of contact with experts who can help them solve problems. Specialists must have knowledge in the area of support action, and knowledge acquisition is often difficult and has a major impact on the productivity of organizations (Mayo, Brown, & Harris, 2017).

Within a given organization, the existing departments need to respond to various internal and external requests. Internal orders are typically placed by company employees. In order to support these requests, the User Support component was proposed. Helpdesk Services should cover various functional areas of the organization, such as the Information Systems Department, the Finance and Administrative Department, and the Human Resources Department, among others. The idealized component should share a universal basis with the remaining IS and should be tailored to the needs of each departmental support and thus serve as a means of contact between the requester and the department.

From the point of view of requesters, it should be possible to place orders in the various areas without having to know who is responsible. By allowing the status of each order to be consulted through the component itself, employees do not have to go to the department to find out its status, reducing time wastage and thereby improving performance. When there is a request that does not fit the specific components for that handling, a support request is opened for that department, so user support is for handling generic requests.

4.11 | Environmental monitoring

Wireless Sensor Networks (WSN) are wireless networks made up of a large number of small, spatially distributed standalone devices that cooperatively monitor environmental conditions and send collected data to a central point. These networks have varied applications, both military and civilian, such as battlefield surveillance, habitat monitoring, health care and traffic control (Zhang & Varadharajan, 2010).

In the case of our proposal, it was defined that these sensing networks should use a low-cost wireless sensor network to monitor various values of interest (temperature, humidity, light, electricity, etc.). Data from the sensing networks should be periodically obtained and placed in a database for real time and later analysis. The goal is to reduce costs through, for example, energy efficiency optimization and production support.

The control of all the events associated with the organizational environment is extremely relevant both for improving the overall system management efficiency, and for ensuring that all events (even those that are not scheduled) are detected and those responsible for handling them are notified and informed of the situation. This prevents major faults and deviations, particularly for production management.

4.12 | Maintenance request

According to CEN/TC 309 (CEN) maintenance is the combination of all technical, administrative, and management actions during the life cycle of an item to keep it active or to restore it to a state in which it can perform the required function. Food production is a cyclical process that involves the continuous use of various pieces of equipment. The failure of a piece of equipment and the consequent shutdown can jeopardize all of production. In order to prevent and reduce the response time to breakdowns, there should be a department dedicated to the resolution and maintenance of equipment, the Maintenance Department.

In order to support the formalization and management of orders, the Maintenance Request component was idealized. The system should support the whole operationalization of maintenance, having as its main objectives occurrence recording, priority setting and task assignment. The maintenance request should centralize the various orders in one place, enabling the maintenance director to better supervise the events and tasks to be assigned. The system is accessible to all employees to report malfunctions. There should also be a definition of priorities so that it is possible to act more precisely regarding functional needs and leave non-critical requests for a later resolution. The historical analysis of orders over time allows one to know which equipment is most likely to fail and even determine the best material (brands, equipment) to use. This leads to maintenance getting enough data to perform preventive maintenance.

Whenever maintenance support is required, the requester creates a new maintenance order. In the request you put the details of the situation, for example the description, the location and the priority. In addition to being able to create orders, each requester can also refer to his/her previous orders. When a new order is created, a notification of the new order is sent to the maintenance personnel. The maintenance manager decides whether the resolution can be carried out by his team, or whether it will be necessary to use external services. In case external service is required, a budget is requested and then approved by the Finance and Administrative Department.

4.13 | Access control

Typically, in an agri-food organization it is very important to know who entered/left and even to know the date and time of each move, as logging such information is mandatory to ensure compliance with ISO 9001 and ISO 22000 certifications. The Access Control component is primarily intended to restrict unauthorized access to the organization facilities.

The access to the majority of industrial farms is controlled by security teams that register a number of details on each movement both in and out of the organization facilities. Hence, with the proposed component, in case of internal audits or incidents it is possible to analyse who was present, for how long, who left during that time, and so forth. The cross-checking of the access data with the attendance register should be done internally and will allow for a more specific analysis on the actual hours of work and the hours when the employee is present on the company's premises.

In addition, other types of registration are made, such as the removal of lorries from customers, suppliers and logistics teams which, together with the weighing scale, provide valuable information on the net weights of the cargo transported. This information feeds into other components such as Production Management.

5 | RESULTS ANALYSIS AND DISCUSSION: THE SOUSACAMP GROUP CASE

In order to validate the proposed architecture, a case study has been developed and put into production at the Sousacamp Group companies. As the “Infrastructure” component is basic, it was initially given priority in the design and development process. The remaining components presented were being introduced due to the need to support the Group's business. Some components are based on commercial products, while others are the result of internal development, and at all of the stages of development a high level of integration has been sought, sometimes requiring the development of middleware to align data structures of different systems, in particular proprietary or legacy systems. For some components, prototypes were created to gather the opinion of the collaborators and thus improve on the architecture components, allowing to more easily find the solution that answered the identified problem.

Implementing an IS supported in the proposed architecture will deliver the Sousacamp Group a processing and communications infrastructure as well as support for transactional needs—such as the need for a production management system, or a billing support system, or even to cater for collaborative needs and document management. In addition, it provides decision support at various levels of management with the implementation of a decision support system.

The “Infrastructure” component has been designed and implemented so that critical systems/services are centrally located in the Group's headquarters building. All infrastructure is based on structured cabling systems, and the logical systems adopted are scalable—for example, by adopting server virtualization technology, or by incorporating new units/companies via a simple technical act of adding a Virtual Private Network (VPN).

With regard to the “Intranet” component, a platform was adopted which, in addition to ensuring the required documentary and collaborative management, as well as effective project management, also provides a framework for the rapid development of tailor-made solutions. This is an essential requirement as it enables a reduction of specialized human resources and production times.

The incorporation of the “Production Management” component responded to the existing void in the Group, that is, it went from a production process based on manual paper-based planning, to a computerized system capable of generating a wide range of new possibilities—planning, execution and control. Operational, tactical and strategic decisions have an effective means of support.

The ERP component has been redesigned to incorporate the business requirements of the Sousacamp Group. In addition, subcomponents were developed that covered a broad set of specific needs, such as, among others, the standardization of inter-company coding systems, a centralized purchasing management system or a more efficient traceability model. This approach provided a better overview of the Group's activity.

As for the “Integrated Quality Management Systems” component, in turn, it responded to the need for the Sousacamp Group companies to have efficient management means that support the existence of increasingly competitive markets, forcing them to incorporate internationally recognized standards into their activities. The development of various subcomponents has met the cross-cutting needs of all of the companies, such as complaints management, analytical control or the knowledge management of applicable law.

The “Management Support Information Service” component addressed the to-date inexistent answer to the vital need to generate knowledge to support decision making. The current decision support system collects information from a multitude of sources, providing for an analytical support tool that is vertically integrated at different levels: operational, tactical and strategic.

Due to the generation of a large number of commercial documents among the Group's companies, the “Internal EDI” component was developed. This dematerialized the documents involved, leading to improvements in the time and cost elements in the process, reducing human error and ensuring the best optimized document flow and approval possible (D. Martins, Gonçalves, & Branco, 2013).

The current IS has a centralized and standardized monitoring system, adding functionality ranging from supporting environmental control systems, responsible for the climate control of the mushroom production rooms, to simply notifying the editing of documents on the Intranet. These features are provided by the “Integrated Monitoring and Notification System” component.

With the "Environmental Monitoring" component, a pioneering sensor network was implemented to monitor the energy consumptions of various critical pieces of equipment involved in the production process in all of the units of the Group. An additional sensor network system is also currently being developed to monitor the cold chain, that is, to record the temperature of the mushrooms, from their harvest in the room until their delivery to the customers' premises.

With the implementation of the "Internal Social Network" component, a better organization of the resources made available to employees was observed, and collaborative action was encouraged. To make this component simpler to use, all of the features are currently centralized on each employee's personal website.

The "User Support" component has been democratized and has led to standardized end-user support. In addition to a formal record of the support request and its resolution, there is now a basis for generating performance indicators to support the continuous improvement of services, but, above all, there is a reusable knowledge base that can be consulted independently.

The Maintenance Request component allows for the centralized management of the maintenance needs of all of the units / companies, thus meeting the defined requirements. The regulatory requirements, that require access control to the Group's facilities, in particular for food security reasons, are guaranteed by the "Access Control" component.

5.1 | Artefact validation

The proposed architecture has been implemented in the Sousacamp Group and has been refined over time. In order to do so, an agreement was reached with the Group's board of administration and with all of the department heads so that they would facilitate the real implementation of each of the proposed architecture components. This task endured for almost 18 months and was divided into three main moments: (a) the deployment of all of the technological equipment; (b) the installation and functional configuration of the application

TABLE 1 Summary of the acknowledgements collected during the validation of the proposed artefact

Objective	Acknowledgements
It must be designed and developed to be aligned with the business model over time.	It was observed that the artefact conceived allows an IS aligned with a vertical management model, with many of the core competencies centralized, but flexible enough to adjust to new realities.
IT should ensure adaptability to new IT, based on the premise of homogeneity and the stability of the initially adopted technological ecosystem.	The proposed architecture support technology has been found to meet stable standards, that is, broadly established and with a large supporting ecosystem. This characteristic of the referred architecture will tend to contribute to the reduction of problems arising from technological and functional incompatibilities.
It should have a high level of flexibility that makes it able to accommodate/absorb business requirements.	It was observed that the IS architecture allows to ensure alignment with business requirements, thus avoiding possible issues that typically arise from the lack of such an alignment.
It must be able to behave in a modular manner in which the specified components, or components to be specified, easily integrate with the other components.	It was appreciated that the architecture allows, at any given time, to include new systems to support new functional areas or the improvement of existing ones.
It should be scalable, capable of being prepared in its multiple components, whether logical or physical. That is, it should be capable of supporting additional components not initially considered, but it should also be scalable based on the business model, in which the initially defined components can carry loads with a minimum degree of adaptation.	It was found that the proposed architecture was able to adapt to the various changes that were introduced by incorporating new technical and functional requirements. Additionally, the infrastructure is prepared to add new physical and logical systems.
It should foresee, from the outset, that is, during the design stage, premises to ensure that the information system has a low degree of dependence on manual maintenance, at various levels of the human resources, allocated to the various functional areas of the organization, freeing them for more value-added tasks.	The technology, automatisms and procedures adopted reduce the time devoted by qualified human resources to maintenance tasks. The inclusion of automatic update systems or with a graphical parameterization process simplifies and optimizes the support process, making it more efficient. This gives employees additional availability to perform higher value-added tasks.
It should be susceptible to be audited, ensuring the incorporation of components that respond, in an integrated and transversal way, to the national and international standards adopted by the business.	It was found that the developed components are framed with the group integrated management system, supporting the normative requirements of the obtained certifications, and being prepared for future certifications. The documentary and analytical evidence, among others, necessary for the different references are managed in a dematerialized and centralized manner.

layer; and (c) the customization of each component to the organization's business needs and expectations and the training of the Group's human resources.

To validate the artefact developed in the organizational context in which it is being used, the research team decided to collect qualitative feedback from the Group's human resources, covering various levels of expertise, in order to understand the adequacy of the proposed solution to the identified problems. The adoption of the components was performed gradually. That is, initially, key collaborators were involved, capable of positively influencing others, who were hence later involved in this process.

In Table 1 we present the contributions recorded according to the objectives that we set out to achieve in this research project.

6 | CONCLUSIONS

At the present time IS are one of the most important tools that organizations have available to them, in order to remain both efficient and competitive. This reality is becoming increasingly relevant for the agri-food industry, particularly because of its highly specific production systems and management activities. Hence, despite IS relevance for the referred business sector, to our best knowledge there is no IS architecture established and focused on it. As a result of this gap, an effort has been made to not only idealize a proposal for an IS architecture for the agri-food sector, but also aiming to perform an initial validation of this artefact with a case study in which a mushroom production organization (the Sousacamp Group) has been used.

The proposed IS architecture is composed by 13 main components (Infrastructure, Intranet, Production Management, ERP, Integrated Management System for Quality, Management Information System, Internal EDI, Integrated Monitoring and Notification System, Internal Social Network, Helpdesk, Environmental Monitoring, Maintenance Request, Access Control), and a set of subcomponents, which allow for both an effective management of each functional area's Information, but also for a an active data interoperability capability within the entire organizational scope.

In order to validate the proposed IS architecture, the Sousacamp Group has been used as a case study. In this organization a set of technological solutions (one for each main component of the architecture) has been implemented and the results of this implementation have been tracked. According to a qualitative validation, supported by feedback directly collected by the supervisor of each functional area, the overall solution is very adequate. This is because it responds perfectly to the needs of this mushroom production company, mainly because it allows for a real-time monitoring and control of the operations at the same time that it allows for a very detailed analysis of all the data and information that is being recorded in the multiple platforms that compose the information system.

The proposed IS architecture for the agri-food industry might be considered a valid contribution for both science and practice, as it represents an innovative combination of multiple software solutions with new strategic manners of communication and interchanged data, and also represents an efficient and effective solution for the mushroom production, that might be considered applicable for the remaining agri-food sectors.

6.1 | Limitations and future work

Although the proposed architecture has been extensively tested at the Sousacamp Group and allowed us via the interactive process with the case study systems to improve the artefact, we are aware that the proposed architecture will benefit from its application at other production companies in the agri-food sector. Certainly, the inclusion of more case studies would not only improve the components of the proposed architecture, but additionally could lead to the inclusion of new components. Albeit, this was not achievable in this study due to the temporal limitation of the research project and the difficulty in having mushroom producing companies with the size and availability of means for such a complex study.

Production management currently has a support system that is well adjusted to the requirements, however, with constant interaction with employees and the need to improve process efficiency, RFID (Radio-Frequency Identification) technology will be introduced. Using these tags will automate the registration of harvested articles and improve their traceability.

The real-time monitoring of end products is a very wide area. Additionally, in the opinion of the research team, it is very interesting from the point of view of the internal management of the organization. Based on this, in the near future the geographic control system of the vehicles associated with the transport of products will be integrated with the production management system, thus allowing to know at any moment where a given product is and under what environmental conditions the transportation is being performed.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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