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Development of Technological Capabilities through the Internet of Things (IoT): Survey of Opportunities and Barriers for IoT Implementation in Portugal's Agro-Industry

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Abstract: The agro-industrial sector consumes a significant amount of natural resources for farming and meat production. By 2050, population growth is expected, generating more demand and, consequently, more consumption of scarce resources. This challenging scenario is a concern of the European Commission, revealed in the Green Deal commitment and by the United Nations' 12th goal of sustainable development. Thus, organizations must increase productivity and be more sustainable as soon as possible. Internet of Things (IoT) is introduced as a solution to facilitate agro-food companies to be more eco-efficient, mainly facing difficulties on farms, such as food loss and waste, best efficiency in management of resources, and production. The deployment of this technology depends on the stage of maturity and potential of implementation. To assess and characterize companies, with respect of IoT implementation, a survey was applied in 21 micro, small and medium agro-food companies, belonging to milk, honey, olive oil, jams, fruticulture, bakery and pastry, meat, coffee, and wine sectors, in the central region of Portugal. As results, this paper reveals the stage of maturity, level of sophistication, potential, opportunities, solutions, and barriers for implementation of IoT. Additionally, suggestions and recommendations to improve practices are discussed.

Keywords: agro-food industry; IoT implementation; sustainable agriculture; smart farming; challenges and solutions; potential and barriers

1. Introduction

The agro-industrial sector uses about 20% of global land, 70% percent of water, and 32% of total energy produced [1]. Population growth is creating more demand and putting pressure on this sector. The number of global inhabitants is estimated to reach nine billion people by 2050, which means 30% more people than at present and an increase of 60% in food demand [2–4].

This scenario is even more challenging when considering the United Nations' (UN) report on sustainable development goals. This study reveals the importance of production and consumption for humanity. However, this draws attention to the unsustainable use of natural resources, with alarming numbers of material footprint growths at rates of about 17% between 2010 and 2017. Another concern is electric and electronic waste, which has been increasing faster than recycling can process. Another aspect is the significant proportion of food that is lost along the supply chain before it reaches the consumer, which

can be 13.8% on average, considering after harvesting and during transport, storage and processing stands [5]. However, if loss and waste through the entire food supply chain (FSC), farming (production), postharvest, processing, distribution and consumption is considered, this number could be up one third of all food produced. It is important to highlight that food loss and waste contributes to problems with food security and natural resource management [1].

Sustainability is a broad concept that addresses most aspects of human life, playing an important role in social, environmental and economic aspects. The European Green Deal provides an action plan to reduce greenhouse gas emissions by 40%, at least, when compared to 1990, increase the share of renewable energy by 32%, and improve energy efficiency by 32.5% by increasing the efficient use of resources by changing to a clean, circular economy, restoring biodiversity, and cutting pollution [6]. The EU aims to be climate neutral by 2050, and, in the next few years, this political commitment will become laws and thus a legal obligation. As such, these changes have to be considered by companies, especially micro, small, and medium enterprises (MSMEs) of the agro-industrial sector, transforming their processes to be more eco-efficient [7].

This picture leads to some questions: (1) How to improve efficiency using the Internet of Things (IoT)? (2) Are MSMEs prepared to use this technology? (3) Which are the opportunities and barriers for IoT implementation? A mixed method approach was chosen to address these questions, consisting in a combination of literature review, general interviews, and expert site visits, as well as a detailed interview, in order to carry out this research.

In combination with the literature review, a survey was carried out, in two phases, to assess Portugal's profile with respect to IoT implementation. Phase 1 was a survey devoted to assess the potential and maturity of IoT solution implementation, with twenty-one companies. In Phase 2, five companies were chosen based on the answers provided in Phase 1 to perform a detailed survey, considering a realistic project, budget, and customer expectations to assess IoT implementation. This approach aims to assess, in real case scenarios, IoT opportunities and solution implementations, and to overcome the lack of information in the literature. Additionally, this sample provides an overview of the IoT status in Portuguese agro-industry companies, which are composed mainly of MSMEs. The results of the literature research and surveys are shown and discussed in the following sections.

2. Background

The background of Portugal's agro-industry context is provided in this section. Additionally, the main results of the literature review related to IoT, applied in the agro-industry, are discussed.

2.1. Portugal's Agro-Industry Context

Portugal has about 10 million inhabitants, of which 30.1% live in predominantly rural regions, and the country had a nominal GDP of 212 billion Euros in 2019. In percentage terms, compared to the European Union with its 27 member states, the total population corresponds to 2.3%, the rural population corresponds to 3.5%, and the total GDP is 1.5%, as shown in Table 1 [8].

Table 1. Portugal and EU: comparative GDP, population and rural population, in 2019 [7].

Region	Nominal GDP (Million EUR)	Total Population	Rural Population
Portugal	212,303 (1.5%)	10,276,617 (2.3%)	3,176,328 (3.5%)
EU 27 (100%)	13,923,343	446,824,564	90,980,718

In agribusiness, the total production value was 6.796 million Euros, with participation of crops being 61.2% and the production of animals and their derivatives being 38.8%, in 2019. In percentage terms, compared to the European Union with its 27 member states,

total production outputs corresponds to 2.0%, crops corresponds to 2.1% and total animals is 1.8%, as shown in Table 2 [8].

Table 2. Portugal and EU: comparative total agro-industry output, crop output and animal output, in 2019 [7].

Region	Total Output (Million EUR)	Crop Output (Million EUR)	Animal Output (Million EUR)
Portugal	6796 (2.0%)	4157 (2.1%)	2639 (1.8%)
EU 27 (100%)	341,098	196,082	145,015

New technologies can be applied in the agro-food sector to provide sustainability, competitiveness and increase efficiency in different operations along all FSCs. Several studies point to the Internet of Things (IoT) as a key solution to improve an organization's performance, unlocking the potential they already have; however, in many cases, these are hidden, not measured, not processed or even just ignored [9].

Considering the questions that this framework aims to answer, the literature review design started by the definition of keywords and the selection of scientific databases. The chosen keywords were: IoT OR "internet of things" AND review AND Agro-industry OR "smart farming" OR "precision agriculture". The selected scientific databases were Science Direct and MDPI. Papers selection was based on the most recent five years, title analysis and content, resulting in 33 relevant publications. Additionally, some exploratory research was conducted to reinforce this research. The main results of IoT application in agro-industry are grouped by subject and summarized in Table 3.

Table 3. Main results of IoT applied in agro-industry.

Main Subject of Papers	Identified Papers
Application of IoT in agro-industry	33
Smart farming, intelligent farming or precision agriculture	14
Monitoring, measuring, controlling and tracking	6
Artificial Intelligence, data driven decisions	5
Block chain	2
(Cyber)security	2
Big data	5
Robotics	2
Unmanned aerial vehicles (UAV)	2
Opportunities and barriers for IoT	5
Others	3

Note: The papers described above can be related to one or more categories.

The next sections highlights the main concepts related to the current study.

2.2. Internet of Things (IoT)

The Internet of Things, or IoT, allows physical objects to be identified and tracked through the collection of relevant data, which will be transformed into useful information and transmitted over a network, enabling the creation of alerts for situations that may require some type of correction. This concept provides agility and visibility in tracking and sharing information, facilitating the planning and in the control of processes. Thus, an object capable of establishing connection through the Internet and that communicates with other objects in a network is considered a "thing". Its application can improve efficiency in several fields, such as, households appliances, electronics, furniture, agriculture, industrial machinery [10,11]. In general, IoT architecture is composed of four layers, considering the main components of IoT solutions: perception, transport, processing and applications.

- Perception/smart device: this layer enables to connect physical devices in a digital network, allowing real-time information to be collected and processed. Sensors can

perform measurements of temperature, air quality, speed, humidity, pressure, flow, movement, electricity, etc.

- Transport: after measurements are done, the results must be transmitted. This layer enables Internet connection through networks and protocols, such as WiFi, global system for mobile communications (GSM), Bluetooth, etc.
- Processing: the collected and transmitted information becomes data and needs to be stored, filtered, processed, and analyzed.
- Application: this is the interface layer, allowing monitoring, decision-making, controlling, regulating, command, etc. Concepts are changed when, for example, they are applied to agriculture, turning a simple a farm into a smart farm.

Some other authors refer to IoT with three layers [12] and others with five layers [13].

2.3. Smart Farming and Precision Agriculture

Smart farming can be understood as the application of supplementary technologies to agricultural production techniques to help minimize waste and increase productivity. The application of IoT in farming allows to boost the production process through plantation monitoring, soil and water management, irrigation scheduling, pest control, delivery tracking; using data from temperature, luminosity, humidity, pressure, ground chemical concentration, and images, which are collected by sensors and cameras, using unmanned flying equipment (UAV), agricultural information management systems, global positioning systems (GPS) and communication networks. This integration results in the optimization of scarce resources.

Precision agriculture has its concept linked direct to precision, which means, to manage precisely resources, such as energy, soil, water, fertilizers, herbicides and pesticides, among others, using different methods and techniques [14]. To achieve the best management, the most correct information is fundamental. Thus, IoT is noted as a solution to optimize agriculture and for precision agriculture.

2.4. Unmanned Aerial Equipment (UAV) or Drones

One of the most versatile IoT devices are the Unmanned Aerial Equipment (UAV). This unmanned vehicle is usually composed of a ground controller and a communication system. Usually, its function in agriculture is related to aerial surveillance in precision agriculture for monitoring weeds, vegetation growth, irrigation, crops, etc. [15]. To enhance system efficiency, other technologies can be aggregated, such as artificial intelligence (machine learning or deep learning), mobile edge computing, and software-defined networks [16]. Associated with specialized sensors, UAVs are becoming powerful sensing systems that complement IoT-based techniques [15].

2.5. Artificial Intelligence/Data Driven Decisions

The use of IoT brings a huge amount of information and variables. This information must be treated, otherwise it is useless. The process for optimization includes system modeling, which sometimes is difficult due to the number of variables. There are algorithms that are specialized to overcome these difficulties. In the agro-industry, the most common are deep learning and machine learning, based on big data. An example is the greenhouse microclimate, which is complex, multiparametric, non-linear and depends on a set of external and internal factors. Artificial neural networks have been used to reduce energy consumption [17]. Other artificial intelligence (AI) applications are related, for example, to the detection of diseases in crops, to distinguish plant or flower types [18], optimization for UAVs [16], and the detection of insects [19].

2.6. Big Data

As result of collecting data from different sources, a huge set of data is generated and is combined as big data [9,20]. From the farmer's perspective, big data can add value to decision making. Data processing and analytics involve the transformation of farm decision

making, from a traditional decision to a precise data-driven decision [21]. However, the data have some challenges, related to their transmission, storage and processing security. Block chain is noted as a technology that can improve security. Despite large opportunities due to digitalization and digital tools to boost productivity and environmental improvement, they are limited by some issues, including data governance, a lack of skill in how to handle and interpret data, and unclear return on investments in new technologies, from farmer's point of view [9].

2.7. Block Chain

The block chain concept is based on a decentralized, distributed ledger for storing time-stamped transactions between many computers in a peer-to-peer network. Thus, any involved record cannot be tampered with retroactively. This concept allows block chain users to audit and verify transactions, independently and transparently. Nowadays, this technology is applied in cryptocurrencies, processing records called "blocks", which are connected using cryptographic techniques. Each block must have a hash code of the previous block, a timestamp, and a set of confirmed transactions [22,23].

This technology has many applications in precision agriculture and/or smart agriculture. The adoption of IoT brought a need to develop smart peer-to-peer systems capable of verifying, securing, monitoring, and analyzing agricultural data. These data must be secure and reliable. Block chain is changing the classical methods of storing, sorting and sharing agricultural data into a more reliable, immutable, transparent and decentralized manner. However, the adoption of blockchain in smart farming or precision agriculture still needs to mature to become a reality. Currently, there are several projects using this technology. A total of 40% are in the concept phase, 53% are in the pilot phase, and 7% do not have available information [22,23].

2.8. Robotics

Agricultural activities involving robotics exhibit a high degree of technology and autonomy to perform tasks. This degree of autonomy between a simple IoT device and a robot differs. Currently, most common applications in agriculture are linked to harvesting and weeding, followed by diseases detection and seeding [14]. Technological advances in machine vision, GPS, laser technologies, actuators, and mechatronics have allowed the implementation of robotic systems in agro-industry [24]. Several robotic harvesting systems have been developed for cucumber, strawberry, tomato, asparagus, grain, lettuce, mushroom, and orange crops, among others. Additionally, the integration of IoT, cloud computing and robotics is developing rapidly. Several sensors are applied in robotics, machine vision being one of the most important. Unfortunately, the number of applications completely developed which are used in real scenarios is still limited [12].

2.9. IoT in Agriculture

IoT applied in agriculture can reshape all concepts, transforming traditional farming into smart farming (or Agriculture 4.0). It uses different types of sensors to collect data (e.g., temperature, humidity, light, pressure, presence, etc.), and enables precision agriculture. Precision agriculture uses data-driven decisions with a base of information technology to ensure that crops and soil receive exactly what is necessary for optimum healthy and productivity [10,25–31]. Figure 1 summarizes most of the challenges in farming and livestock production, subdivided into monitoring, measuring, tracking, and controlling. The most important and common variables for production are connected to each of these sections. On the right side, different approaches based on IoT solutions through digitalization of a "thing" [32] are shown. Each of these solutions can generate a huge amount of data, called big data [33,34], which is collected in real-time and processed by optimization AI-based algorithms for data driven decisions and other technologies [16,17], aiming at monitoring, measuring, tracking or controlling, allowing to improve production results [10,11,13,15,18,19,24,25,35–44]. Block chain is an emerging technology and is con-

sidered a solution for the cybersecurity of IoT devices [22]. Several approaches like robotics are considered as solutions as well [12,14].

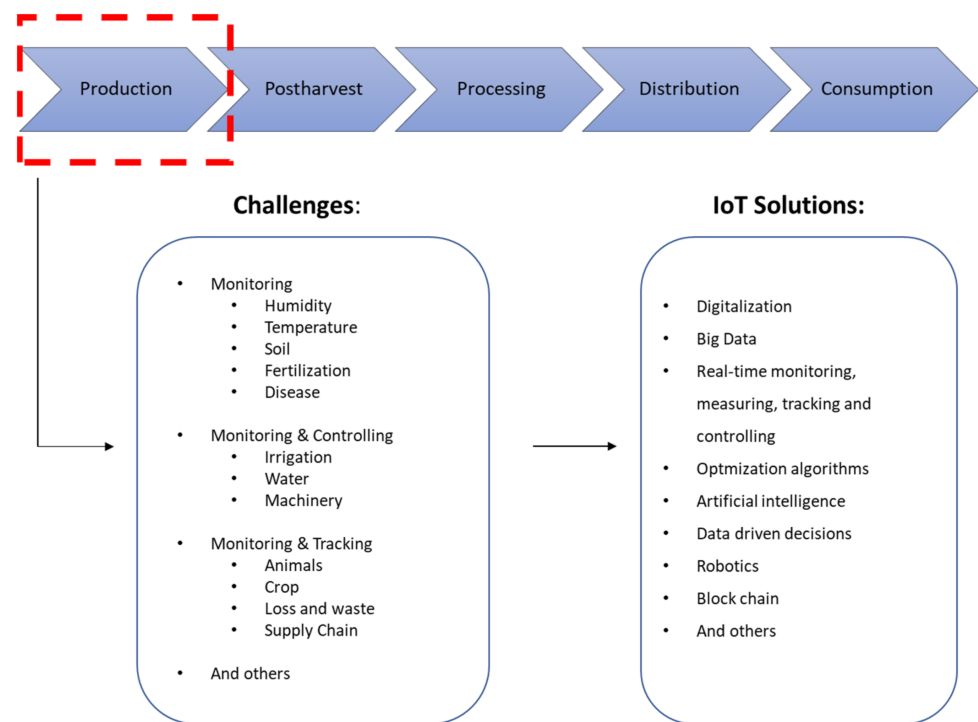


Figure 1. Main challenges and IoT solutions.

In the rest of the FSC, IoT can significantly reduce constraints, loss and waste during postharvest, processing, distribution, and consumption. While in postharvest, processing and in distribution, improvement is mostly linked to logistics; in the consumption level, it could change a consumer's perception or behavior, using intelligent packaging. In all FSCs food loss and waste can be reduced with the implement of IoT [45].

Despite of all benefits that IoT technology can bring to organizations, as previously noted, the main barriers for its implementation from a MSME farmer's perspective are infrastructure, knowledge, costs, risks, and cybersecurity. Most papers point to IoT as a solution and discuss technical issues and applications related to it. Just a few papers consider a farmers' reality in a generic approach. This research is summarized in Table 4 [4,11,46].

Thus, the best results and success depend, not only on the application of IoT, but also on the approach, choosing the right solution according to an organization needs. Thus, it is very important to discover an actual framework for MSME farming organizations in the central region of Portugal, and answers research questions 2 and 3. To assess the sophistication and the potential for IoT transferability for companies, a survey was carried with 21 organizations. Additionally, 5 companies were chosen for a more detailed survey.

Thus, this study reveals the maturity stage, sophistication, potential, opportunities, solutions and barriers of IoT deployment, through a case study performed in the central region of Portugal, within the scope of the project Development of Technological Capabilities for the Industrial Application of the Internet of Things (IOTEC) [47]. The results of the survey and discussions will be presented in subsequent sections. Section 3 includes a description of the Materials and Methods. It includes details of the two-step survey. The sample characteristics are provided, as is the structure of each questionnaire. Section 4 presents the results and includes a discussion. It includes an analysis of the Phase 1 survey, devoted to assessing the potential and maturity of IoT solution implementation, as well as the Phase 2 survey to assess a real scenario of IoT opportunities and solution implementation. Section 5 provides some suggestions and recommendations for the digitalization

of the agro-food companies, based on an analysis of the results of the surveys. Section 6 describes the main conclusions of the study.

Table 4. Brief description of main IoT challenges (adapted from [4,11,46]).

Barriers	Brief Description
(Cyber)security	Operational risks are related to natural causes, such as animal attacks, rain, lightning, or even regular maintenance, could cause stoppage at a farm. Additionally, hacker attacks are linked to accessing sensitive information, hijacking cloud information or databases, or even blocking wireless signals.
Cost	Implementation and operation are the main costs for IoT in agriculture. The implementation costs consist of hardware costs, such as IoT devices/sensors, base station infrastructure, and gateways. Furthermore, running costs include an uninterrupted subscription for the management of IoT devices, the exchange of information among other services, and centralized services that provide information/data collection.
Lack of knowledge	Most farmers are uneducated in IoT, which creates a great barrier to understanding how technology could contribute to improve production. Furthermore, it increases the costs of training to qualify people to use IoT on their farms.
Interoperability	Several IoT devices, standards and protocols are necessary to enable communication between devices from different manufacturers.

3. Materials and Methods

To assess the current state of agro-industry with respect to IoT implementation for companies in the central region of Portugal, a survey was selected as the methodology, which was divided in two steps, each one with its own objectives and activities, as shown below:

Phase 1: Assess the potential and maturity of IoT solution implementation.

- Definition of sample;
- Structuring script;
- Conducting interviews;

Phase 2: Assess real scenario for IoT opportunities and solution implementation.

- Selection of five companies for a deeper questionnaire to assess opportunities and constraints of IoT implementation.

3.1. Phase 1: Assess the Potential and Maturity of IoT Solution Implementation

An inquiry with several questions was made to assess the potential and maturity of IoT solution implementation. Additionally, the survey reveals the sophistication of interviewed companies. Detailed information about each step is shown in subsequent sections.

3.1.1. Definition of the Stratified Sample of Agro-Food Companies

The initial stage included the following methodological tasks:

- Limit of the sample of agro-food companies for questioning;
- Creation of an “Alternative Business Exchange”, in order to ensure, in due time, eventual failures/possibility of refusing to answer and/or last-minute impossibilities/imponderables of the pre-selected sample, even after due diligence of (re)confirmation;
- Survey and validation of e-mail contacts from the group of companies in the agro-food sector, in order to guarantee a sample with validated responses from at least 21 companies in the central region of Portugal.

As the cluster of agro-industrial organizations of the central region in Portugal, Inov-Cluster’s associates were potential companies for this part of the study [48], which was also in line with IOTEC project objectives. The contact list was analyzed, and after starting

the survey it was verified that some contacts no longer corresponded to the initial phone numbers and some of the initially contacted companies were closed.

Notwithstanding these constraints, the information provided, associated with the adopted survey method, enabled an important methodological advance, namely allowing the survey to be directed to all companies that fell into the desired category and whose headquarters were located in the central region of Portugal. These options increased the likelihood of obtaining more favorable response rates and guaranteed representativeness in the sampling process.

Figure 2 shows the percentage of small businesses in the subsector of the agro-food segment surveyed in the central region of Portugal.

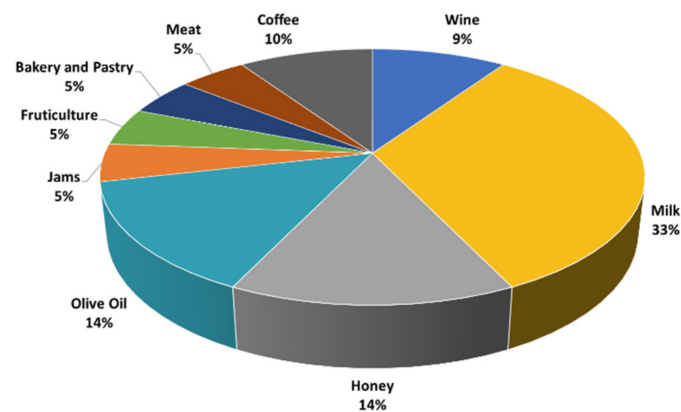


Figure 2. Distribution of surveyed companies by sector of activity.

It was verified that most of the companies that were made available to collaborate in the characterization study belonged to the dairy sector, followed by the olive oil and honey sectors.

Additionally, information about company sizes is shown in Figure 3. Half of the companies surveyed were micro-enterprises with fewer than five employees, with 40% of the companies being from the small business category. Only 10% of companies surveyed already had a size, considering the number of workers, which corresponded to a medium-sized company. This result highlights the reality of the agro-food industry, not only in the central region, but also in the whole country, which is composed mainly of micro and small enterprises, many of them being family businesses.

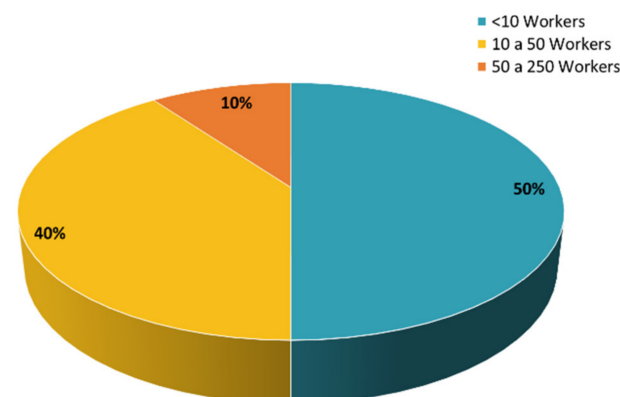


Figure 3. Distribution of surveyed companies by workers.

The main constraints found in the course of the study were:

- Different segments, processes and work shifts cause difficulties in making contact. As example, the productive section of bakery and pastry companies work during night

limiting the contact possibilities. Additionally, in agricultural activities, the work shift is during the day, without interruptions. In both cases, there are difficulties in contacting via telephone as well as with scheduling;

- Reduced sensitivity to the issues raised, as the business fabric in these sectors, with numerous family holdings, shows a strong dismay or perception of the issues at stake (low qualifications and advanced age of those/workers, learning from work itself).

After overcoming these constraints and validating the contacts, the survey was conducted in person or by telephone.

3.1.2. Structuring the Script and Building the Questionnaire

This stage comprised the definition of the script for face-to-face/telephone interviews, supported by a multitude of issues directly related to the sophistication of companies in the agro-food sector and their appetite for the use of multimedia tools. The survey consisted of 31 questions that aimed to enable the characterization of the sophistication of agro-food companies and their production process. The interviews were held throughout 2018.

This stage focused on the face-to-face and telephone interview process. We tried to establish a procedure for the collection of information via telephone, and face-to-face interviews were used when phone contact was impossible or interviewees were unavailable.

After compiling the 21 carried out face-to-face/telephone surveys, the data were collected with an online application in a comma-separated values (CSV) format, compatible with spreadsheet software, and were exported.

3.2. Phase 2: Assess Real Scenario for IoT Opportunities and Solution Implementation

The main objectives of this topic were to identify, by sector of activity, which parts of companies received more investment, potential for implementation of IoT, identification of opportunities, budget, return of investment, and expected results in order to assess if the project was realistic within a company's budget and calendars. In addition, to identify the main implementation restrictions.

Selection of 5 Companies to Deeper Questionnaire Assessing Opportunities and Constrains of IoT Implementation

This selection was made based on the previous questionnaire, which showed differences in company maturity. However, this criterion was not the only one considered, since even companies with a low maturity show high potential for transferability of IoT. The IoT implementation process should start gradually and incrementally over a period of time, and between 6 months and 2 years, depending on the maturity of the company, may be necessary.

The main objectives of this questionnaire were to identify, by activity segment, which parts of companies receives more investment, potential for implementation of IoT, identification of opportunities, budget, return of investment, and expected results, according to the state of each company. A survey of the opportunities was carried out by contacting the selected companies that, based on the questionnaire, were selected: Delta Cafés, Massimo Zanetti Beverage Iberia, Fumeiros da Guarda, Sabores da Guarda and Claro's Beekeeping.

4. Results and Discussion

4.1. Phase 1: Assess the Potential and Maturity for IoT Solution Implementation

A compilation of questionnaire answers is described in this section. Only the most relevant data are presented, analyzed, and discussed, as shown in Table 5. The results are divided into topics, as is the survey. Percentage was chosen for a better understanding and comparison.

Table 5. Summary of applied survey.

Questionnaire	Answers	
	(Yes)	(No)
(1) Does the company have an organized information system? (Network, servers, connectivity)?	62%	38%
(2) Does the company use planning and decision support tools?	38%	62%
(3) Does the company record the relationship between the different items or batches used as raw materials and used items or batches of finished products, through computers?	69%	31%
(4) Perform efficient handling including expiration date, temperatures, etc.?	67%	33%
(5) Is there any kind of control to guarantee the transport, storage and exhibition until the sale of the products?	52%	48%
(6) Is there a need for real-time data collection?	71%	29%
(7) Is the company connected to automated production systems?	29%	71%
(8) Are advanced control systems necessary?	43%	57%
(9) Does the company perform data analysis during the production process?	81%	19%
(10) The company cross-checks the results of these analyses with the traceability of production information?	57%	43%

4.1.1. Does the Company Have an Organized Information System? (Network, Servers, Connectivity)?

In Table 5, item 1 indicates that just over half of the companies in the agro-food sector that were part of the inquiry process have an organized information system, whether it consists of a data network, servers, or even connectivity. At this point, there is a need for the development of information and communication technology and implementation strategies in companies in this sector.

4.1.2. Does the Company Use Planning and Decision Support Tools?

In Table 5, item 2 indicates the use of planning and decision support tools. A percentage of companies (over 60%) indicated that they do not use any decision support tools. Nowadays, there is a set of computational tools and decision support information aimed at improving processes and activities in companies, which can enable cost reduction with raw material acquisition, storage, logistics, up to the definition of a price depending on a set of factors associated with production and planning. All these characteristics allow companies to have greater soundness in decisions. In general, companies that answered affirmatively to this question indicated that they make use of a company resource planning software, which is essentially an enterprise resource planning (ERP). In general terms, an ERP system is a software platform developed to integrate various departments of a company, enabling

the automation and storage of all business information, that is, the ERP system enables a unique, continuous and consistent flow of information. Data integration can follow a functional approach, e.g., integrating finance, accounting, human resources, manufacturing, marketing, sales, purchasing systems, among others, and from a systemic perspective, incorporating transaction processing systems, management information systems, decision support systems, etc.

4.1.3. Does the Company Record the Relationship between the Different Items or Batches Used as Raw Materials and Used Items or Batches of Finished Products, through Computers?

In Table 5, item 3 shows whether the companies surveyed record, and how, the relationship between different items or lots used as raw materials and used finished items or lots. About 70% made this registration using a computer.

4.1.4. Perform Efficient Handling Including Expiration Date, Temperatures, etc.?

In Table 5, item 4 shows the proportion of companies surveyed that performs efficient handling, including expiration date, temperatures, among other parameters. In this case, 67% of companies indicated performing efficient handling at this level. However, only 20% of the companies that responded affirmatively indicated that this process was carried out for the entire chain, using computer systems supported by human resources. The remaining affirmative answers indicated that this process was carried out in its entirety manually.

4.1.5. Is There Any Kind of Control to Guarantee the Transport, Storage and Exhibition Until the Sale of the Products?

In Table 5, item 5 analyzes the traceability of products, i.e., if there is any type of control to ensure transportation, storage and exposure until the sale of the products is performed. Just over half of the companies surveyed answered in the affirmative (52%) this issue shows the need for sophistication on the part of these companies to carry out traceability throughout the product chain, ensuring the maintenance of organoleptic characteristics, in addition to undeniable food safety. The only control carried out by the companies that responded in the affirmative was temperature control.

4.1.6. Is There a Need for Real-Time Data Collection?

This issue, closely linked to the capabilities of companies to know in real time how different activities are unfolding along the product chain, from production, storage for sale, infers the need for real-time data collection. This will take a set of sensors, communication systems and data acquisition and processing. In Table 5, item 6 shows this need, and about 70% responded affirmatively. These same companies indicated that the parameter which requires real-time data collection was temperature.

4.1.7. Is the Company Connected to Automated Production Systems?

This issue is related to the previous one. In Table 5, item 7 shows this need, to which about 70% answer affirmatively. These same companies indicated that the parameter which required real-time data collection was temperature.

4.1.8. Are Advanced Control Systems Necessary?

In Table 5, item 8 shows the need for advanced control systems for production activities for the companies surveyed. Only 43% of companies answered this question in the affirmative, indicating that these systems are intended for granular control of costs and production.

4.1.9. Does the Company Perform Data Analysis during the Production Process?

In order to evaluate the sophistication of management of the production process, this question aimed to analyze the appetite of companies to perform data analysis during the

production process. As shown in Table 5, item 9, 81% of the companies stated that they performed data analysis during the production process.

4.1.10. Should the Results of These Analyzes Be Cross-Checked with the Traceability of Production Information?

Following questions to assess sophistication, companies were asked whether they cross-referenced the analysis of collected data results during the production process with the traceability of production information. In this case, 57% of companies claimed to carry out this task, as shown in Table 5, item 10.

4.2. Phase 2: Assess Real Scenario for IoT Opportunities and Solutions Implementation

Aiming to provide IoT solutions, this second phase survey of opportunities was carried out by contacting five selected companies, based on an analysis of the first questionnaire: Delta Cafés, Massimo Zanetti Beverage Iberia, Fumeiros da Guarda, Sabores da Guarda and Claro's Beekeeping.

The choice was made to precisely describe agro-food companies from Portugal. Thus, companies from different segments and maturity stages were chosen. According to this analysis, it was observed that the adaptability rate may take longer due to the complexity of the technology to be implemented. To this end, a model of identification of opportunities was designed according to each company.

Table 6 describes the main features of companies, such as designation, sector of activity, awareness of IoT, sector of major investment in company, potential for IoT implementation and expected time for IoT implementation. In this manner, this table reveals an overview of agro-food business in Portugal.

Notice that all companies interviewed were aware of IoT technology. Most of them had major investments in production, except Fumeiros da Guarda. All of them had potential to implement IoT solutions. However, some time is necessary to prepare people and installations to receive this technology, only Delta Cafés was ready to receive it immediately.

Table 7 shows the main advantages of implementation of IoT solutions in each company. Better relationships with customers was expected by all companies, except for Claro's Beekeeping. Fumeiros da Guarda e Sabores da Soalheira expected increase of food safety with better controls. Delta Cafés expected efficiency in technical assistance, anticipation of problems, to speed up maintenance, cutting downtimes, etc. Massimo Zanetti Beverage Iberia just expected monitoring of work status and Claro's Beekeeping was interested in an increase in productivity, with better monitoring, controls and, also, alarms that can inform possible problems.

Table 6. Main features of agro-food companies of Portugal.

Companies	Sector	Awareness about IoT	Sector of Major Investments	Potential for IoT	Time for Implementation
Delta Cafés	Coffee	Yes	Production	Yes	Now
Massimo Zanetti Beverage Iberia	Coffee	Yes	Production	Yes	6 to 12 months
Fumeiros da Guarda	Meat (cured sausages)	Yes	Prospecting and maintenance	Yes	Not informed
Sabores da Guarda	Dairy	Yes	Production	Yes	Not informed
Claro's Beekeeping	Honey	Yes	Production	Yes	Not informed

Table 7. Advantages of IoT solutions implementation according to each company.

Companies	Advantages
Delta Cafés	More efficiency in technical assistance, anticipation of problems, speed up maintenance, cutting downtimes, etc. Better relationships with customers.
Massimo Zanetti Beverage Iberia	More efficiency in technical assistance, anticipation of problems, speed up maintenance, cutting downtimes, etc. Better relationships with customers. Better forecasts.
Fumeiros da Guarda	Increase in food safety. Better customer relationships, promoting more business. Improvement in product quality, avoiding machinery faults.
Sabores da Soalheira	Better control and warranty of food safety. Better customer relationships, promoting more business reducing logistic difficulties.
Claro's Beekeeping	Quick detection of problems. Avoid unnecessary displacements. Detection of productivity levels. Allows for the definition of the best maintenance schedules for hives. Pattern detection can assist the beekeeper in more active management of the hive.

5. Suggestions and Recommendations

Suggestions and recommendations are provided for the digitalization of agro-food companies, based on an analysis of the results of the surveys applied to the sample of companies in the agro-food sector in the central region of the country. Note that the number of companies that have a high level of sophistication relating to the use of information and communication technologies, information systems, decision support systems, control system, regulation, command and measurement of production processes, is still reduced.

Table 8 shows IoT opportunities for each company, as well as each specific requirement for IoT application. The opportunities are directly linked to the needs of each company, due to internal processes which can be improve with IoT solutions. The requirements are linked to the specific reality of company, with their strengths and weakness.

All IoT opportunities or solutions are related to monitoring and data register, and also, access data as graphs in order to analyze them. Only Claro's Beekeeping was interested in threshold alarms to inform the company about possible problems. Basic requirements for all companies were related to preparation of people and installations to receive this technology. Deployment, tests, procedures, training, and maintenance are also a general concern.

Figure 4 shows a critical analysis of the level of sophistication in the sample of agro-food companies surveyed. Given the complete and cross-examination of the results of the survey, it was found that half of the companies had a zero level of sophistication, while 15% of the companies had a low level. Only 10% of the companies analyzed currently have a high level of sophistication.

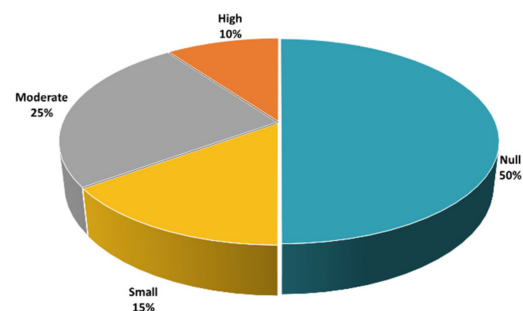
**Figure 4.** Sophistication level of companies in central region of Portugal.

Table 8. Opportunities and requirements for the implementation of IoT according to each company.

Companies	IoT Opportunities	Requirements
Delta Cafés	Monitoring working status, pressure and temperature of production machinery spread around the world, accessing reports and graphs easily.	<ul style="list-style-type: none"> • Team assignment for IoT, departments, responsibilities, procedure training, etc. • Compatibility and requirements for current information technology. • Deployment, tests, procedures, training, maintenance, etc.
Massimo Zanetti Beverage Iberia	Monitoring working status (working or nor working) of machinery spread around the world, accessing reports and graphs easily.	<ul style="list-style-type: none"> • Team assignment for IoT, departments, responsibilities, procedure training, etc. • Compatibility and requirements for current information technology. • Deployment, tests, procedures, training, maintenance, etc.
Fumeiros da Guarda	Monitoring temperature of refrigerators, accessing reports and graphs easily.	<ul style="list-style-type: none"> • Identify the correct places to install sensors. • Team assignment for IoT, departments, responsibilities, procedure training, etc. • Compatibility and requirements for current information technology. • Deployment, tests, procedures, training, maintenance, etc.
Sabores da Guarda	Monitoring temperatures of milk transported by specialized vehicles. Additionally, accessing reports and graphs easily.	<ul style="list-style-type: none"> • Team assignment for IoT, departments, responsibilities, procedure training, etc. • Compatibility and requirements for current information technology. • Deployment, tests, procedures, training, maintenance, etc.
Claro's Beekeeping	Monitoring temperatures and humidity with automatic alarm for specific thresholds. Measure and analysis of each hive's weigh. Additionally, accessing reports and graphs easily.	<ul style="list-style-type: none"> • Specification of temperature, humidity and weight sensors. • Team assignment for IoT, departments, responsibilities, procedure training, etc. • Compatibility and requirements for current information technology. • Deployment, tests, procedures, training, maintenance, etc.

Therefore, based on this survey, there is an urgent need to increase the sophistication of agro-food companies in terms of information and communication technologies, information systems and decision support systems. The aim of contributing to the improvement of information management processes with subsequent gains in production, quality, reduction of waste, response time, result in an increase in competitiveness. Thus, the suggestions and recommendations identifying opportunities for improvement originated by this analysis are transversal to all ranks, and are summarized as:

- Promote the updating of systems, in order to consider an internal network, which enhances the organization in the face of corporate e-mail and ease of communication via the Internet between employees of the company;
- Promote frequent use of financial management tools, not just billing software;
- Promote the use of customer relationship management (CRM);
- Promote the use of integrated enterprise resource planning (ERP);

- Promote the use of information and communications technology (ICT) tools in quality management-oriented processes;
- Promote the use of ICT tools in product traceability, monitoring of the company's productive activities, monitoring energy consumption;
- Promote the use of decision support tools in different areas of the company.

These results are important to understand and highlight the potential of IoT implementation in the sample of agro-food MSMEs that can be extended to the country scale. Additionally, the next section will discuss possible opportunities and solutions for such a niche.

6. Conclusions

Population growth is creating more demand and putting pressure on agro-industry. The food demand forecast is estimated 60% more by 2050. Due to this challenging scenario, the UN and EU share concerns about how scarce resources are to be managed, in terms of food loss and waste, land, water, energy, emissions, and so on. The European Commission is working on a Green Deal in order to reduce emissions. Thus, initial commitments could become laws and obligations, pushing companies to adapt and be more eco-efficient.

IoT is a technology that can revolutionize agro-food business, in terms of efficiency, mitigating challenges like monitoring, controlling and tracking of crops and animals on farms, and allowing precision agriculture. Additionally, changing old concepts of farming to new ones, like Agriculture 4.0 or smart farming, where data are collected in real-time and processed using optimization algorithms of artificial intelligence based in data-driven decisions and other technologies, aiming to optimize production results.

This survey assesses the potential implementation of IoT technology. It was applied to 21 agro-food companies, belonging to the milk, honey, olive oil, jams, fruticulture, bakery and pastry, meat, coffee, and wine sectors, which are located in the central region of Portugal. Additionally, this study helps, on basis of company characterizations, to propose actions and measures that promote the development, economic growth, employment by increasing competitiveness in the economy and traditional sectors.

The analysis of results for the first stage points to a low level of sophistication, which means low maturity for IoT implementation. However, it also indicates the possibility of enormous potential for efficiency growth by applying IoT solutions. Efforts need to be made to transfer knowledge to farmers, unlocking the potential they already have, but in many cases remains hidden, not measured, not processed or even just ignored, caused by a lack of information.

Deeper analyses were performed in a second survey stage, with of five companies, to assess a real scenario of IoT implementation. This approach revealed many opportunities for IoT solutions, mainly for monitoring and measuring variables of production that can possibly lead to better decisions by managers. Further, the results highlight the constraints at human resources and facilities levels that cannot receive the technology now, and need at least 6 months until 2 years to start any deployment.

In general, there is a great potential for implementation of IoT in Portugal, but also great challenges. The lack of knowledge related to IoT technologies by the company's human resources is highlighted. This condition can be mitigate by knowledge transfer and training, Maturity of sophistication is another concern, since installations are the basis to receive new technology. Thus, suggestions and recommendations identifying opportunities for improvement that can be started right now are: renew or install communications systems, use of CRM and ERP, use of financial tools, use of ICT tools to allow traceability, monitoring of a company's productive activities, monitoring energy consumption and the use of decision support tools in different areas. Future research work will include a larger sample of companies in order to improve characterization, generalization and representativeness of Portuguese agro-industry MSMEs.

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