Open Innovation in Agribusiness: Barriers and Challenges in the Transition to Agriculture 4.0

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Abstract: Industry 4.0 digital technologies in agribusiness will enable traditional farming systems to migrate to Agriculture 4.0. Open innovation emerges as an enabler for implementing these technologies and increased sector competitiveness. However, there are still doubts and questions about how technologies and open innovation relate to and will drive Agriculture 4.0. This study identified which digital technologies of Industry 4.0 have more adherence to agribusiness, what the barriers and facilitators for using these technologies are, and how open innovation can increase the competitiveness of agribusiness. The results show that of the Industry 4.0 technologies related to agribusiness, the Internet of Things (IoT) is the most prominent. The main barriers are the users’ need for more knowledge and advanced skills, which evidences the need for investment in training operators. Among the facilitators stand the pre-existence of several technologies, which bring with them already defined basic structures, control of the technology, and communication between systems. To overcome the barriers and enhance the migration to Agriculture 4.0, developing devices, tools, systems, software, and machines is essential. More stakeholders, managers, and practitioners may share such opportunities for innovation in agribusiness through the concept of Open Innovation. To benefit from it, facilitators, managers, and practitioners of agribusiness should search for alternatives for their problems with engineering solutions providers.

Keywords: Agriculture 4.0; agroindustry; open innovation; competitiveness; Industry 4.0

1. Introduction

Industrial revolutions usually include adopting new technologies that impact economic sectors, such as industries and services [1]. The main consequences of such adoptions are increased efficiency and productivity in economic activities. The associated technological changes usually convey to industries innovative transformations that result in the emergence of new technical and economic paradigms [2,3]. Innovation processes usually rely on cost-focused actions supported by opportunities for open innovation [4]. Open innovation includes business models and service innovation and aims to access, leverage, and absorb knowledge beyond the organizational boundary [5,6]. The fourth industrial revolution, or Industry 4.0, presents such features [3]. Industry 4.0 develops new structural and corporate aspects relying on digital technologies, such as artificial intelligence (AI), internet of things (IoT), cloud computing, computer vision (CV), autonomous robots (AR), Big Data, cybersecurity, augmented reality, and horizontal and vertical integrations of
systems and software [7–9]. Several productive sectors, including agribusiness, already employ such technologies [10].

As for developing markets, the Brazilian agribusiness sector accounts for more than 26% of the gross domestic product (GDP) [11]. In recent years, the sector benefited from open innovation initiatives, mainly embracing crop and harvest productivity, loss reductions along the entire value chain, sustainability concerns [12], machine manufacturers [13], and logistics operators [14]. Even if the sector still depends on several artisanal processes [15], recent studies point to essential opportunities regarding efficiency in operations and resource-saving innovations [16,17]. An essential requirement for enhancing the economic results in modern agribusiness is disseminating open innovation findings. Open innovation implies adopting new technologies to boost agribusiness productivity, strongly contributing to affording future food requirements for an increasing global population [14]. Besides minimizing costs and losses, technological innovations supported by advanced electronics and information systems can help improve food quality and safety, reducing inequality in food availability, mainly in developing economies [18]. In short, Industry 4.0 technologies can trigger a massive migration process from traditional rural activity to the so-called Agriculture 4.0 [19]. Agribusiness can increase results by managing strategy, innovation, operations, and other competitive priorities [20]. Other studies consider the impact of innovation initiatives in other competitive criteria, such as cost, quality, and dependability, not only in enhancing business throughput [21,22]. Implementing open innovation through Industry 4.0 digital technologies should boost the migration from the traditional system to Agriculture 4.0, which may, even in the short term, expand the sector’s competitiveness.

1.1. Industry 4.0 and Digital Technologies

Digital technologies can drive economic and social development by including mechanisms from digital transformation processes already implemented in other industries, such as the automotive [23]. Digital transformation processes are continuous and dynamic and depend on digital strategies to achieve and maintain a proactive relationship between emerging technologies with the industrial processes and society [24]. Such an imbricated scenario develops upon Industry 4.0, which brings significant advances to the industry through disruptive applications of the digital technology [25]. Industry 4.0 primarily employs digital technologies, providing more efficient operations and supporting decision-making processes [26]. Usual implementations of Industry 4.0 comprise sixteen leading technologies, as presented in Table 1 [19].

Table 1. Industry 4.0 Digital Technologies.

<table>
<thead>
<tr>
<th>Technologies</th>
<th>Contributions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big data analytics</td>
<td>Can handle and process large volumes of structured or unstructured data [27].</td>
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<tr>
<td>Smart sensors</td>
<td>They can generate and receive data and information, increasing the processes’ efficiency, flexibility, and security, and can cover up to four dimensions [28].</td>
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<tr>
<td>Cloud computing</td>
<td>It presents on-demand internet access to computer resources, data storage, network resources, development tools, and other functions [29].</td>
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<tr>
<td>System Integration</td>
<td>It allows the connection of different subsystems to a single system, integrating various Information Technology systems, services, and software, allowing them to work together [30].</td>
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<tr>
<td>Cyber–physical systems</td>
<td>Systems that relate computing, communication, and control through networks and physical processes, through which it is possible to perform simulations, tests, and wear prediction [31].</td>
</tr>
<tr>
<td>Autonomous and collaborative robots</td>
<td>Seek to achieve automation with flexibility and efficiency, allowing autonomous robots to act collaboratively [32].</td>
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</tbody>
</table>
Table 1. Cont.

<table>
<thead>
<tr>
<th>Technologies</th>
<th>Contributions</th>
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<tbody>
<tr>
<td>Internet of things</td>
<td>It comprises the network of physical objects joined with sensors, software, and other technologies to connect and exchange data with devices and systems connected to the internet [33,34].</td>
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<tr>
<td>Mobile systems and devices</td>
<td>Comprise diverse sets of mobile devices and systems [35].</td>
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<tr>
<td>Artificial intelligence</td>
<td>Artificial intelligence enables the enhanced use of machines and computers, reproducing human intelligence to act on relevant problems and make decisions [36].</td>
</tr>
<tr>
<td>Digitalization and virtualization</td>
<td>Digitalization refers to the interaction between physical and computational systems, consisting of the virtualization of structural elements, which can reflect the reality aiming at the integration of technical and business layers of the enterprise [37].</td>
</tr>
<tr>
<td>Machine-to-machine communication</td>
<td>Machine-to-machine communication allows connection through sensors and actuators, connecting machines efficiently, over considerable distances, and flexibly, with high safety, robustness, and availability [38].</td>
</tr>
<tr>
<td>Simulation</td>
<td>Adopting digital simulation systems allows the early identification of problems in the processes, allowing the search for resolution before application [39].</td>
</tr>
<tr>
<td>Industrial internet</td>
<td>This technology requires other technologies, such as cloud computing, networking, and big data, emphasizing the interconnection and collaboration between systems, devices, and people in the industrial environment, leading to lower costs and higher productivity [40,41].</td>
</tr>
<tr>
<td>Additive manufacturing</td>
<td>It deals with emerging manufacturing based on 3D model data, producing parts on demand and according to need [42].</td>
</tr>
<tr>
<td>Cybersecurity</td>
<td>Facilitates digital transformation through local protection and data security actions [43].</td>
</tr>
<tr>
<td>Augmented and virtual reality</td>
<td>They are powerful tools capable of dealing with learning and training issues, achieving more efficient, interactive, and participatory responses [44].</td>
</tr>
</tbody>
</table>

1.2. Agriculture 4.0

In the past, the now-called Agriculture 1.0 era employed simple tools and animal traction, requiring manual labor and achieving low productivity. After industrial development, agriculture activities introduced new production strategies [45], such as Agriculture 2.0, which employed machinery and chemicals, increasing crop productivity and efficiency [46]. The development of the first computer programs created alternatives to improve production and agro-industrial systems [45]. One of them was the global positioning system (GPS), used until today to assist in satellite management, establishing the so-called Agriculture 3.0 era [43]. With the emergence of Industry 4.0, digital technologies came into agriculture, marking a new technological frontier [47] and incorporating open innovation into agribusiness, giving rise to the so-called Agriculture 4.0 era. Agriculture 4.0, or precision agriculture, is a logical development of existing food production systems [48], employing remote sensing strategies and embedded technologies to manage and control the overall systemic performance [49].

Agriculture 4.0 employs the Internet of Things and Big Data tools to manage agribusiness, relating precision farming solutions (sensors, artificial intelligence, robots, drones) with Smart Farming, which uses tools, such as management software, analytics, and cloud system, in the search for the development of agricultural processes and techniques [50]. Digital technologies optimize the use of inputs, reduce labor costs, improve the quality of products and services, reduce environmental impacts, and collect a large volume of data to support decision-making processes [51]. In short, Agriculture 4.0 poses challenges in moving from experience-based agriculture to the so-called smart agriculture. Innovative solutions and open innovation actions were essential in the transition to Agriculture 4.0 [52,53].
1.3. Open Innovation and Agriculture 4.0

Open innovation is a methodological concept for developing environments with technological characteristics, encompassing the possibility of inserting new procedures and processes as new technologies enter the market. When applied, open innovation usually conveys economic local development [54] by transformative changes that influence the business [55]. Open innovation local systems typically rely on the interaction between innovation and technology [55], with the primary role of transfer of knowledge transferences and innovation diffusion. Open innovation is a distributed process involving knowledge flows within and across organizational boundaries [56].

Open innovation requires access to knowledge, depending on information flows, which can occur in two directions, from outside to inside and from inside to outside a company [53]. The outside inflow refers to adopting innovative processes from external systems. The inside outflow allows information generated within organizations to be used by other players, such as proprietary technologies and royalty payments [57]. Open innovation facilitates access to external partners, experiences, and knowledge, allowing, at the same time, to replace obsolete processes, improve existing systems, and avoid losses [58].

Adopting innovative processes to boost competitiveness in agriculture requires industrialization and digital technologies [14] provided by open innovation initiatives [59]. More competitiveness is essential to achieve higher productivity and increase the global food offer [60,61]. In this perspective, many companies and governments stimulate technological development to improve agriculture efficiency, aiming at rapid industrialization and innovation implementations in the agribusiness [62]. Business companies achieve several benefits from using digital technologies to minimize errors and ensure a higher quality of products [63]. The increase in competitiveness also gains prominence, especially with automation, since it can lead to increased productivity and, at the same time, reduce costs [60,64].

Based on the current literature, this study aims to answer three research questions: (i) Which digital technologies of Industry 4.0 have more adherence to agribusinesses? (ii) What are the barriers and facilitators for using these technologies in agribusiness? (iii) How can open innovation increase the sector’s competitiveness? Answering the research questions allows for identifying which digital technologies are most useful in agribusiness, the barriers to implementation, and how to overcome such barriers. The study also assesses whether there is a relationship between barriers and facilitators in implementing different technologies and how they can contribute to each other. Finally, to identify opportunities for innovation through knowledge and information sharing and open innovation, generating opportunities broadly accessible to users. The rest of the article includes materials, methods, results, and conclusions.

2. Materials and Methods

A Systematic Literature Review (SLR) helped to answer the research questions using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method [65–67]. Four keywords delimit the theme, based mainly on the research questions at the end of the Introduction section. The keywords were Agroindustry, Agriculture 4.0, Industry 4.0, and smart manufacturing. Table 2 shows the filters.

The PRISMA method follows four phases for selecting papers: identification; screening; eligibility; and inclusion. The process relies on inclusion and exclusion criteria. Figure 1 shows the flowchart regarding selecting studies using the PRISMA method and applying inclusion and exclusion criteria.
Table 2. Search filters.

<table>
<thead>
<tr>
<th>Filter</th>
<th>Scopus</th>
<th>Web of Science</th>
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<tbody>
<tr>
<td>Document Type</td>
<td>Article</td>
<td>Article</td>
</tr>
<tr>
<td>Searched in</td>
<td>Title, abstract, and keywords</td>
<td>Topics</td>
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<tr>
<td>Research area</td>
<td>No filter</td>
<td>No filter</td>
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<tr>
<td>Years</td>
<td>2011–2022</td>
<td>2011–2022</td>
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<tr>
<td>Idiom</td>
<td>English</td>
<td>English</td>
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<tr>
<td>Research terms</td>
<td>“agroindustry” OR “agriculture 4.0” AND “industry 4.0” OR “smart manufacturing”</td>
<td>“agroindustry” OR “agriculture 4.0” AND “industry 4.0” OR “smart manufacturing”</td>
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</table>

The PRISMA method follows four phases for selecting papers: identification; screening; eligibility; and inclusion. The process relies on inclusion and exclusion criteria.

Figure 1. Flowchart regarding the selection of articles.

Figure 1. Flowchart regarding the selection of articles.
The identification retrieved 3070 papers. The second step was the screening of documents. The first exclusion criterion was the removal of articles with restricted access, which does not match the principles of open innovation. The criterion excluded 1833 papers. The second exclusion criterion was removing documents not categorized as peer-reviewed articles (n = 544). This point was essential to delimit pieces with scientific knowledge proven by scientific journals. The following criterion excluded papers written in languages other than English (n = 41) to ensure full access to any researcher. The last process of the screening stage removed pieces with less than five written pages classified as preliminary, not resolutive, studies. The eligibility step excluded six duplicate papers and 588 articles that did not match the scope according to the title, abstract, or keywords. Finally, the inclusion stage removed articles whose conclusions did not match the application of Industry 4.0 technologies in agribusiness.

The final sample included 19 articles, selected after reading the 57 articles from Figure 1. The eligibility stage excluded 38 articles, as they did not bring data specifically related to agribusiness, a sector present within agribusiness, which is the initial research’s target. All 19 articles included in the study bring the implementation of some digital technology, showing barriers and potentials for implementation. The data helped investigate and indicate open innovation opportunities, facilitating sharing of any innovations that may be implemented in agribusiness, as presented in Figure 2.

![Figure 2. Key barriers, facilitators, and opportunities for increasing agribusiness competitiveness by open innovation of Industry 4.0 technologies.](image)

3. Results and Discussions

3.1. Industry 4.0 Technologies with More Adherence to Agribusiness

Table 3 shows the most cited Industry 4.0 technologies related to Agriculture 4.0.

<table>
<thead>
<tr>
<th>Industry 4.0 Technologies</th>
<th>#</th>
<th>IoT</th>
<th>Big Data</th>
<th>Cybersecurity</th>
<th>Artificial Intelligence</th>
<th>Cloud Computing</th>
<th>Machine-to-Machine Communication</th>
<th>Autonomous and Collaborative Robots</th>
<th>Smart Sensors</th>
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Table 3. Industry 4.0 technologies found in the literature.
Table 3. Cont.

<table>
<thead>
<tr>
<th>#</th>
<th>IoT</th>
<th>Big Data</th>
<th>Cybersecurity</th>
<th>Artificial Intelligence</th>
<th>Cloud Computing</th>
<th>Machine-to-Machine Communication</th>
<th>Autonomous and Collaborative Robots</th>
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Table 3 also informs that the most reported technology in the survey was the IoT—Internet of Things. Such technology supports open innovation in the agricultural environment. The IoT in agribusiness can generate open innovation in several fields, such as the automation of services, the collection, processing, storage, and analysis of data captured in the field, and this alternative can lead to cost reduction in the long term and increased productivity and competitiveness of agribusinesses [84].

It was possible to observe that autonomous and collaborative robots were the second most reported technology. Still, many studies did not specifically deal with the term robots, but with intelligent machines guided via satellite leading to the improvement and practicality of the production processes. The other technologies received a low number of citations. This study also shows that in many systems, there is a direct or indirect relationship between the use of more than one of the digital technologies. It is possible to observe that Big Data, Smart sensors, Artificial Intelligence, and Cloud computing are strongly linked with IoT and autonomous robots because they are technologies often dependent on each other, as already highlighted in [85].

The analysis showed that some studies stand out and can contribute to developing technologies through access to information through open innovation. Using sensors and cloud computing would efficiently improve production processes and prioritize this proposal in future studies [72]. A framework was proposed and evaluated in actual conditions on a farm, remotely monitoring and controlling the precision agriculture installation systems [73]. Both methods presented satisfactory results for maintaining the precision agriculture installation environment, so sensory data were acquired, processed, stored, retrieved, and disseminated appropriately using digital technologies.

Almost all the articles studied present practical applications or testing of technologies in agriculture and agribusiness. The studies provide several subsidies so that innovation can be generated through technologies and made available. Therefore, other regions and countries can adapt technology to local realities, precisely as the concept of open innovation proposes. The following section presents a set of barriers and facilitators.
3.2. Barriers and Facilitators to the Use of Technology in Agribusiness

The individual analysis of the papers identified barriers and facilitators for applying Industry 4.0 digital technologies in agribusiness. Table 4 reports the results.

Table 4. Identified barriers and facilitators.

<table>
<thead>
<tr>
<th>Articles</th>
<th>Barriers</th>
<th>Facilitators</th>
</tr>
</thead>
<tbody>
<tr>
<td>[50,68,69,73,78,81]</td>
<td>Lack of investment in technical staff. The big challenge is the transition from experience-based agriculture to data-driven smart agriculture.</td>
<td>The holistic exploration of the dimensions of Agriculture 4.0 serves as a framework for developing industries. Process improvement is still necessary despite using agriculture sensors, IoT devices, drones, and cloud computing.</td>
</tr>
<tr>
<td>[70–72,78,82]</td>
<td>The main challenges are process orientation, standardization, data communication and security, and knowledge transfer. Many new technologies are still in the testing phase, requiring simultaneous engineering practices for evaluations.</td>
<td>Developing software that focuses on intelligent data control and anonymization is already in the works, and implementation, adaptation, and testing are essential.</td>
</tr>
<tr>
<td>[48,67,74–77,79,80]</td>
<td>Significant dependency on investments in tools, machinery, structure, and software.</td>
<td>Intelligent machines can perform activities quickly and directly, minimizing costs and assisting processes. Notably, these technologies can help food security since they increase productivity. Thus, agriculture will increase its potential for innovation, intensifying competitive advantages, reducing risks, and increasing profits.</td>
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</tbody>
</table>

The analysis of the 19 selected articles pointed to three main barriers and facilitators. The first group of studies [50,68,69,73,78,81] advocates that the main barrier is the lack of investment to leverage workers’ skills. The authors reported that more knowledge is the major challenge for adopting Agriculture 4.0, and investing in new processes requires more technical education for the technicians who handle machines and tools. Otherwise, the efficiency of technological solutions may drop due to needing more advanced skills. These same authors reported that the facilitator for migration to Agriculture 4.0 is that there already exists intelligent equipment and software and that it is necessary to fine-tune the processes according to the needs of the agribusinesses.

Another point observed is that many new technologies are still in testing. The main obstacle is the investment in performing preventive tests with these technologies to verify if they will generate positive results and avoid future problems. On the other hand, software development will facilitate the application, intelligent control, and automation of the processes [70–72,78,82], generating results to be shared and replicated according to the concept of open innovation.

The application of digital technologies in the processes of open innovation in agribusinesses depends directly on investment in tools, machinery, structure, software, and specialized technical staff. However, these investments have a return because the trend of Agriculture 4.0 is that the intensification of Innovation potential leads to increased competitive advantages, minimized costs, and increased profits [48,67,74–77,79,80].

3.3. How to Enhance Open Innovation through the Use of Digital Technologies

Open innovation requires digital technologies and technological processes, intensifying competitiveness in the internal and external markets [78]. Innovations in agricultural technologies should offer solutions to farmers’ problems. Autonomous robots are excellent opportunities to reduce costs and achieve the goals of increasing food supply through new digital technologies [82]. Relations between Agriculture 4.0 and Society 5.0 show that it is possible to have an agriculture system based on digital technologies that maintain human well-being, pointing to the need to apply Industry 4.0 technologies to build autonomous systems with socio-environmental benefits [68]. Autonomous systems, such as
machine-to-machine communication and cybersecurity, were also highlighted in [69], proving more efficient for intrusion detection than conventional processes. The author [72] also reported on the automation of industrial processes through the adaptation of single-minute exchange of die (SMED) with cloud computing and smart sensors, leading to increased efficiency of the production process and gains in production capacity without changing the hours worked.

Using digital systems in agricultural machines generates several advantages for the business, acting in activity performance control, task support, crop monitoring, and loss analysis. However, it also requires the involvement of several specialty domains beyond the usual mechanics, forcing companies to employ concurrent cross-engineering of several specialties in the same situation and design moment [85]. Innovative systems are necessary to apply the developed processes and adapt them to the needs of each company [70] as well as to reduce manual efforts [71]. Digital technologies could be adapted to all processes in the production food system, forming an end-to-end traceability model that can identify quality, waste, and production risks [50]. The data exchange process generated in various precision farming environments may require an IoT-based model, usually easily adaptable, adjustable, and extensible to other precision farming systems [73]. Some of the benefits of IoT in agriculture are associated with cloud computing and artificial intelligence to monitor the stages of the product life cycle, automatically identify any cause in a defective product, and increase satisfaction and food safety [76]. IoT can also facilitate crop tracking by recording accurate information over time [79].

The opportunity for computer vision in agriculture requires innovations in rapid image processing. Artificial intelligence should facilitate image processing [75]. Image evaluation can also be used for weed detection and spraying, employing deep learning algorithms in an embedded system mounted on a quadcopter [76]. Image processing also appears in cocoa bean classification and evaluation. IoT, in this process, reconciled with the gray-level competition matrix (GLCM) features, showing satisfactory results [77].

Agriculture 4.0 can act by generating benefits for production in the search for sustainable alternatives, reconciling the most outstanding efficiency and profitability of the processes [67]. The study [67] proposes the investigation for options to improve the flow of information, risk management, and system integration, in addition to collecting and evaluating climate, soil, and plant variables that can directly impact the quality of the coffee produced using IoT and machine-to-machine communication and geostatistics.

A supply chain tracking system optimized for Industry 4.0 was also proposed [80]. The system allows end-users to check the food before consumption, enables business optimization by obtaining future forecasts and food demand trends, and manages assets. The acquisition of diversified data in different crops, combined with advances in technical analysis and computational processing, will make possible the characterization of the factors that interfere with the productivity and quality aspects of the crop, allowing powerful management, and the increase in the yield and quality of agricultural products, besides the economy in inputs and greater sustainability of agricultural production [78].

Aiming to reach the already stated benefits of Agriculture 4.0, the sector should bridge relevant issues, such as data collection, analysis, interpretation, and security [81]. The same is true regarding the usual low qualification of the rural labor force.

3.4. Opportunities for Open Innovation in Agribusiness through Agriculture 4.0 Technologies

Agriculture 4.0 embraces agricultural processes that use information and communication technology in managing farms and, later, in processing products produced by agribusinesses [81]. To this end, the authors proposed the adoption of individual technologies based on farm size. In 8 out of the 19 examined articles, Industry 4.0 technologies correlate with agribusiness. Figure 2 demonstrates the main barriers, facilitators, and innovation opportunities of each of these technologies and what the possible impacts on the competitiveness of agribusinesses are.
The competitiveness column encompasses the potential positive impact of open innovation in each competitive criterion based on reading the final sample of articles related to agribusinesses. All the articles highlighted positive factors that affect competitiveness in at least one of the five competitive criteria. The analyses performed allowed the clarification of the main points found in the selected articles, as well as the identification of the technologies cited and the barriers and facilitators for implementation, thus being possible to analyze the applicability, or potential relevance, of these new technologies in agribusiness systems.

By answering the research questions proposed in the Introduction, the study led to an overall analysis and provided an outlook for the future of technology in agribusiness. Such an outlook shows where further research is required and where decision-makers need to concentrate more efforts to turn faster the transition to Agriculture 4.0. The main barriers are the need for knowledge and skilled operators for many agribusiness companies, which require more investment to form human resources. Besides the challenges, some facilitators were identified, such as the pre-existence of several technologies. Besides the pre-existence of several technologies, they bring with them already-defined basic structures, technology control, and communication between systems. Among the existing technologies, it is helpful to highlight the use of drones adapted for seed planting, irrigation, and pesticide application. This technology is a robotization and should overcome the challenges outlined in Figure 2. Open Innovation arises to break down these barriers or at least ease them. Open innovation offers opportunities by offering remote training, generating information unknown to humans, and incorporating specific reports for decision support.

In summary, to overcome the current barriers to technology implementation in agribusiness and to enhance the migration to Agriculture 4.0, the development of devices, tools, systems, software, and machines is fundamental. These are the opportunities for innovation in agribusiness, which will bring gains in competitiveness. If combined with the concept of Open Innovation, it can be shared with stakeholders, breaking down the existing barriers.

4. Conclusions

This study concluded that out of the eight technologies of Industry 4.0 related to agribusiness and agroindustrial activities, IoT is the more representative. IoT appears in 15 out of the 19 selected studies. The increase in IoT in several fields of agricultural sectors opens paths for adapting this technology in agribusiness, and it can be the main focus of innovation actions. We evidenced that the adoption of IoT is always related to other technologies, and this correlation is essential for the excellent development of the systems. The use of IoT, robot automation, and machine-to-machine communication generates the need for procedures guided by artificial intelligence and Smart Sensors, which create large amounts of data that need to be collected and processed, so the use of Big Data and Cloud computing becomes inevitable. In the same sense, it is essential to invest in data protection, consequently, the application of cybersecurity. Open innovation becomes key because creating new systems and their sharing and licensing for use by other companies can lead to much faster development.

In Figure 2, the study presents the potential positive impacts of applying technologies, considering the five key competitive criteria. These positive impacts are because Industry 4.0 technologies act directly on techniques that facilitate and speed up processes, thus inducing more efficient procedures and making them more competitive, with less risk and lower costs. In a general analysis, these new approaches’ main negative point is the lack of initial investments. Such technologies need high investments in the short term so that the cost reductions and productivity gains that make the industry more profitable occur in the long term. Moreover, the studies report a considerable need for investments in machinery manufacturers, so it is necessary to update the industry to develop other sectors. Open innovation can also be a facilitator since the investments made in creating new approaches can result in the sales and licensing of innovative products.
The study satisfactorily answered the research questions. A contribution of the study is Figure 2, which relies on the current literature to show which technologies have greater adherence to agribusiness. In addition, the figure lists the main barriers and facilitators for implementing and using digital technologies in agribusiness. Furthermore, due to the embedded technology applied to traditional agricultural processes, the study helps to understand how to characterize an agribusiness system, such as Agriculture 4.0. Finally, another result of the study was to discuss how Open Innovation and the sharing of innovative processes are essential for agribusiness. Sharing technologies and innovations can reduce production costs, improve product quality, speed up cultivation, have more agility and reliability in delivery, and increase food safety. Managing the five points is essential for increasing the sector’s competitiveness.

Limitations and Future Research

The competitive issues presented in Figure 1 are positive impacts of digital technologies, but negative impacts can also occur. This study did not embrace negative impacts, a limitation to be bridged by future research. Further research must also include a survey with managers of agribusinesses to know how the subject is being treated and implemented in practice, identifying whether there are and what may be the negative impacts on the agribusiness when it comes to open innovation processes.

The article opens room for future research. A first possibility is the development of in-depth case studies in various prominent agribusiness sectors, such as post-harvesting. Another possibility is the development of case studies on environmental concerns, such as eco-design [86], the employment of design techniques that aim not only at the performance of the project but also at the environmental implications all over the entire life cycle of the installation. Furthermore, warehousing and transportation should receive more attention, owing to their importance in agribusiness and the environmental implications of such activities [14]. Finally, the study opens room for a survey with agribusiness company managers and practitioners to identify the maturity level of agribusiness industries regarding the implementation of Industry 4.0 technologies.


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References


11. Cruz, J.; Medina, G.; Júnior, J. Brazil’s Agribusiness Economic Miracle: Exploring Food Supply Chain Transformations for Promoting Win–Win Investments. Logistics 2022, 6, 23. [CrossRef]


34. Bersani, C.; Ruggiero, C.; Sacile, R.; Sousi, A.; Zero, E. Internet of Things Approaches for Monitoring and Control of Smart Greenhouses in Industry 4.0. Energies 2022, 15, 3834. [CrossRef]


50. Scuderi, A.; La Via, G.; Timpanaro, G.; Sturiale, L. The Digital Applications of “Agriculture 4.0”: Strategic Opportunity for the Development of the Italian Citrus Chain. *Agriculture* 2022, 12, 400. [CrossRef]

51. Basso, B.; Antle, J. Digital agriculture to design sustainable agricultural systems. *Nat. Sustain.* 2020, 3, 254–256. [CrossRef]


54. Zarelli, P.R.; Carvalho, A. de P. Analysis of Open Innovation in Innovation Habitats. *Braz. J. Dev.* 2021, 7, 17380–17397. [CrossRef]


59. West, J.; Bogers, M. Open innovation: Current status and research opportunities. *Innovation* 2017, 19, 43–50. [CrossRef]


72. Ribeiro, M.; Santos, A.; Amorim, G.; Oliveira, C.; Braga, R.; Netto, R. Analysis of the implementation of the single minute exchange of die methodology in an agroindustry through action research. *Machines* 2022, 10, 287. [CrossRef]

73. Symeonaki, E.; Arvanitis, K.; Piromalis, D. A Context-Aware Middleware Cloud Approach for Integrating Precision Farming Facilities into the IoT toward Agriculture 4.0. *Appl. Sci.* 2020, 10, 813. [CrossRef]


