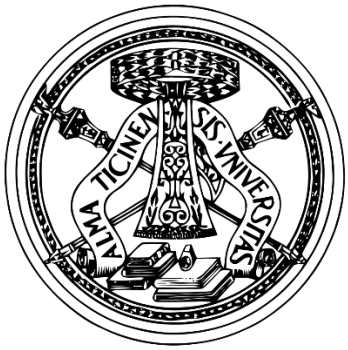

UNIVERSITA' DEGLI STUDI DI PAVIA

Department of Economics and Management

Master Program in International Business and Entrepreneurship
–
Digital Management

THE DIGITALIZATION AND THE SUSTAINABILITY IN THE ITALIAN FARINACEOUS FOOD INDUSTRY

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Index

Abstract

This thesis explores the intersection of digitalization and sustainability within the Italian farinaceous food industry, a sector encompassing products like pasta, bread, and other wheat-based foods. As consumer demand for sustainable products grows, and digital technologies continue to reshape traditional industries, this research aims to investigate how these trends are influencing production processes, supply chain management, and environmental impact in Italy's globally recognized food sector.

The study begins by analyzing the current state of digital transformation within the industry, focusing on the adoption of technologies such as the Internet of Things (IoT), data analytics, and automation in improving efficiency and reducing waste. Additionally, it evaluates the sustainability practices adopted by Italian manufacturers, including the use of renewable energy, sustainable sourcing of raw materials, and efforts to reduce carbon footprints.

Through a combination of interviews and analysis of sustainability reports, the research highlights the challenges and opportunities that arise from integrating digital technologies with sustainability goals. The findings demonstrate how digital tools can enhance sustainability efforts, drive innovation, and support long-term competitiveness in a rapidly evolving global market.

This thesis contributes to the broader understanding of how traditional food industries can embrace modern technology to achieve sustainability, offering insights that are relevant not only to Italy but to similar food sectors worldwide.

Sustainability, meanwhile, has become a central theme in the industry, driven by regulatory pressures and global initiatives, but also by a desire to preserve Italy’s agricultural and culinary heritage. Key strategies, such as the adoption of renewable energy, sustainable farming practices, and eco-friendly packaging, demonstrate the industry's commitment to reducing its environmental impact

while maintaining high-quality standards. However, the full potential of these practices can only be realized with the integration of digital solutions, as they allow for more precise monitoring, measurement, and management of sustainability efforts.

In conclusion, the Italian farinaceous food industry stands at a pivotal moment where embracing digitalization and sustainability is not just an option but a necessity for its future success. By harmonizing these two forces, the industry can enhance its global competitiveness, meet evolving consumer demands, and contribute to broader environmental goals. This research underscores the importance of continued investment in technological innovation and sustainable practices, and its findings offer a framework for the industry to balance tradition with modernity, ensuring its continued growth and relevance in a rapidly changing world.

Introduction

In this thesis, I am going to explore the complex relationship between the technology and the sustainability applied in the Italian food industry. In fact, this thesis will explore the integration of technology 4.0 within the food industry and its implications for sustainability. With the advent of industry 4.0 there was a big implementation and fusion of digital technologies with the traditional manufacturing ones that saw a significant transformation in the food industry. This intersection has become increasingly well-known in both academic discourse and practical applications.

The rapid development and adoption of Internet and digital technologies dramatically changed business processes, leading to a disruptive digital transformation of the whole industry value chain. The so-called Industry 4.0 refers to a complex evolution of the entire industrial sector that includes technological advances in production equipment (i.e. Additive Manufacturing), IoT, data tools and analytics, involving activities and stakeholders at all levels. Therefore, companies need to completely redesign their business processes and models in order to achieve the important benefits disclosed by these new settings. Even though there are some potential advantages, only a limited number of companies has already made rapid advances by developing high digital capabilities necessary to obtain a competitive advantage (Savastano, Amendola, & D'Ascenzo, 2018).

This thesis will analyze and investigate how technologies such as Internet of Things (IoT), robotics and Artificial Intelligence are reshaping some operations in the food industry and how they lead to enhance transparency, traceability, and efficiency. Incorporating digitalization into the food bakery sector offers a groundbreaking chance to improve sustainability efforts by streamlining production methods, refining supply chain operations, and engaging consumers

effectively. This not only reduces environmental harm but also meets the growing demand for environmentally friendly products among consumers. Furthermore, it examines how these technological advancements contribute to fostering sustainability with the food industry, addressing concerns related to food waste reduction, resource optimization, environmental conservation, and ethical sourcing practices. So, this thesis will provide insights about the potential of Technology 4.0 to drive sustainable practices in the food industry.

In the last years, it has been vitally important to focus a significant attention on the role of technology in addressing environmental challenges. “Companies are trying to achieve the growth sustainable objectives that are insert in the Agenda 2030. In fact, It refers to a global action plan whose official title is “2030 Agenda for Sustainable Development” that was adopted by the United Nations (UN) in September 2015” (Nations United, 2015).

“It is a framework in which there are some goals, targets, and indicators aimed at addressing pressing global challenges and achieving sustainable development by the year 2030. The centerpiece of the Agenda 2030 is the set of Sustainable Development Goals (SDGs), that consist of 17 goals and 169 targets. These goals cover a wide range of issues, including poverty eradication, zero hunger, good health and well-being, quality education, clean water and sanitation, affordable and clean energy, decent work and economic growth, gender equality, industry innovation and infrastructure, reduced inequalities, sustainable cities and communities, responsible consumption and production, climate action, life below water, life on land, peace, justice and strong institutions, and partnerships for the goals” (Sustainable development goals).

“They build on the success and lessons learned from the Millennium Development Goals (MDGs), but they are more comprehensive and universal,

applying to all countries regardless of their level of development. The Sustainable Development Goals are guided by the principles of People, Planet, Prosperity, Peace, and Partnership, often referred to as the “Five PS”. People ensure that they can fulfill their potential and enjoy a decent standard of living” (Woodbridge , 2015).

Planet refers to protecting it from degradation, including through sustainable consumption and production, conservation of ecosystems, and combating climate change.
Prosperity means promoting inclusive and sustainable economic growth, decent work for all, and reducing inequalities within and among countries.

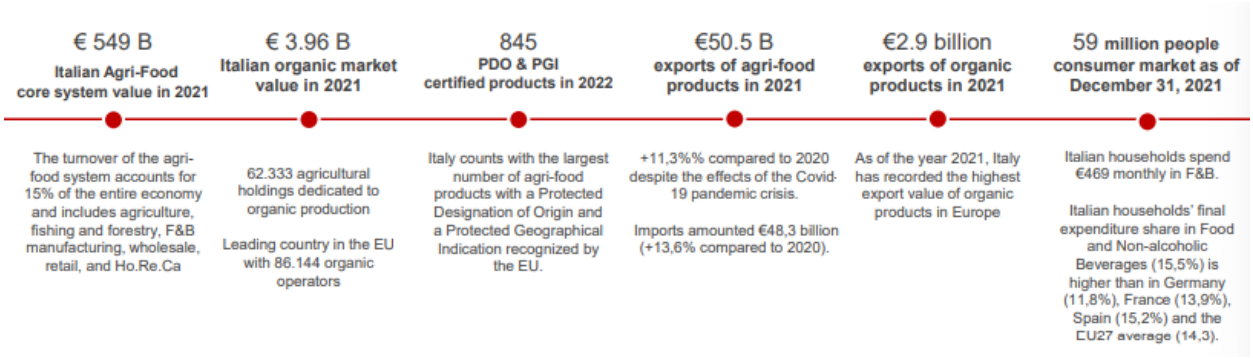
Peace because it fosters peaceful, just, and inclusive societies that are free from violence and provide access to justice for all.

At least, *partnership* that is about mobilizing global solidarity and cooperation to achieve the Sustainable Development Goals thought partnership between governments, civil society, the private sector, and other stakeholders.

It represents a shared commitment by the international community to work towards a more sustainable, equitable, and resilient future for people and for the planet. Also, it provides a roadmap that includes a transformative change, guiding policy, and decision-making efforts toward achieving sustainable development by the year 2030. It emphasizes the importance of mobilizing financial resources, technology transfer, capacity-building, trade, and data monitoring to support Sustainable Development Goals implementation.
The agenda also calls for strengthened global partnerships and cooperation at all levels, including international, regional, national, and local.

Chapter 1

1.1- Overview of the Italian Farinaceous Food Industry



The evolution of the Italian food system 1.1

"Italy is renowned world leader in the agri-food industry distinguished by its long-standing food-based culture and traditional vocation for food safety and quality" (Invitalia, 2023).

I decided to analyze this market because the Italian farinaceous (flour-based) industry has a very significant global influence. Italy has a long-standing tradition in producing and consuming farinaceous products, like pasta, bread, and pastries. This is a deep cultural integration that provides a rich context for study and business opportunities. Also, Italian cuisine, with its high-quality ingredients and traditional preparation methods, is renowned worldwide. Italy is also considered one of the world's largest producers and exporters of pasta and the country's brand are synonymous with quality, making Italian products highly required in the international markets. There is a growing focus on sustainability within this industry from the organic farming methods to eco-friendly packaging, reflecting global trends and consumer demand. The interest in healthy eating is growing, influenced by the lifestyle changes. After Covid-19, there is a major awareness of the relationship between diet, health and the environmental impact

of food choices is increasing, together with interest in food experiences linked to tradition.

Here there are some numbers showing: Italians prefer the supermarkets to buy dairy products (77%), fruit and vegetables (70%), but for products such as bread the 89% choose to go to the bakery. The consumption trends are the attention to sustainability, increasingly shorter supply chains, greater consumption of natural foods and sustainable cuisines. The 82% of the sample selected in this article, composed of 2,872 customers aged between 25 and 64 years old, prefer artisan foods, 89% ops for anti-waste purchasing formulas and 66% choose organic products. (The food sector in Italy. Consumption trends and chanllenges between innovation and the fight against counterfeiting). Taking a look at exports in 2022, Italian exports reached a record 28,5 billion euros, with an increase of +21% compared to 2021, overtaking Germany and France in the European Union. Not only that, but the Italian food industry has also reached a historical record of 60 billion euros in turnover, with an increase of 14.7% compared to 2021, with Germany the main outlet market, followed by United States and France. The sector has changed in the recent years to respond to changes in consumer behavior such as the search for healthy and sustainable food. Companies are therefore investing more and more in research to develop healthier products, promoting sustainable and allergen-free foods.

In Italy, the food industry stands out as the leading manufacturing sector in terms of turnover, second in the number of companies and workers, and also in export value. Annually, it generates 179 billion euros in turnover, encompasses 60 thousand enterprises, employs 64 thousand workers, and export over 50 billion euros worth of products. Over the past decade, these figures have increased by 24.7%, 12.2% and 60.3% respectively.

The industry's significance extends beyond economic impact, playing a crucial role in the psychophysical well-being and quality of life of Italians, underscoring its high social value. It forms a vital component of the Italian food supply chain,

which has an overall value of 607 billion euros, with 1.3 million enterprises and 3.6 million workers. The food industry accounts for 16.6% of total domestic expenditure, which is comparable to Spain and higher than in France, the Netherlands, Germany, and the EU average of 16.1%.

The Italian food industry enjoys a high social reputation, with 86.4% of Italians expressing trust in it. This confidence spans generations, with 93.8% of the elderly, 84.2% of adults, and 81.6% of young people trusting the industry. Additionally, 80% of Italians believe the sector provides more benefits than costs. The local and national focus of the industry is appreciated by 78.3% of respondents, who see it as a source of income and employment. Italian food is seen as a symbol of national identity and pride, blending tradition with modernity and maintaining strong ties to local regions while promoting the Italian spirit globally.

Regarding food preferences, 92.7% of Italians eat a varied diet without specific restrictions, while 7.1% are vegetarian and 4.3% vegan. Eating habits vary, with 42.1% being creatures of habit, 20.5% innovators, 9.2% health-conscious, 7% food enthusiasts, 6.3% exclusively eating Italian products, 5.8% viewing food as a social activity, and 4.4% seeking pleasure in their meals.

Ethical and social values significantly influence Italians' food choices. The majority are willing to forgo products that could harm their health (66.7%), do not meet food safety standards (52.6%), are environmentally unfriendly (43.3%), or do not protect workers' and suppliers' rights (35.6%).

The Italian food industry's diverse offerings positively impact people's well-being, according to 90.7% of Italians. Its affordable quality ensures inclusive food consumption, benefiting even vulnerable social groups. Despite budget constraints, 63.4% of Italians prioritize quality for certain foods, and 79% appreciate new products in stores, reflecting the complexity of Italian food demand.

Modern consumers are well-informed and cautious, often using smartphones to evaluate whether products and companies align with their values, especially regarding food safety, a priority heightened by the Covid-19 pandemic.

“Exporting Italian food is not just about selling products but also about sharing food styles, cultural values, and the Italian lifestyle. The agri-food sector is recognized globally for its quality, and it is essential to further promote Italy's unique biodiversity and variety of food and wine. When importing necessary raw materials or semi-finished products, partnering with economies within Italy's sphere of influence will strengthen ties with European, Anglo-Saxon, and Mediterranean countries, helping Italy remain resilient amid changing geopolitical contexts” (The economic and social value of the Italian food industry, 2024).

The food industries that are going to be analyzed in this thesis are the Italian’s bakery, pasta, and flour-based product that plays a significant role in our rich culinary tradition and in our economy. The Italian farinaceous food industry is a major contributor to the national economy. Italy is one of the world’s largest producers and exporters of pasta, with brands like Barilla, De Cecco, Bauli, and others leading the global market. It is the second manufacturing sector that covers thirteen percent of the National industrial production. The industry also encompasses numerous small-medium-sized enterprises that maintain traditional methods and cater to niche markets.

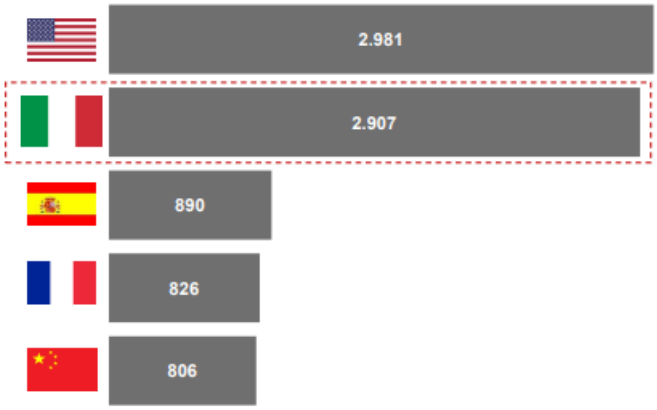
Recent market trends show a growing demand for organic and gluten-free products, reflecting broader consumer preferences for health-conscious and sustainable options. Additionally, there is an increasing interest in high-quality, artisanal products that highlight Italy’s culinary heritage.

Italy’s rich agricultural tradition, particularly in wheat cultivation, has laid the foundation for its renowned farinaceous food industry. The history of pasta dates

to ancient times, with early references found in Roman texts. Over centuries, pasta has evolved into a symbol of Italian culinary excellence, with countless regional variations and recipes.

In the bakery products we can include a wide range of goods, including bread which we have different varieties like focaccia and different types of bread like ciabatta, pane di Altamura, and pizza and sweets that have products like panettone and biscotti. The Italian pasta products are famous globally, with different categories like dry pasta that is made from durum wheat semolina, including spaghetti, penne, and fusilli. Then we can find fresh pasta such as tagliatelle, tortellini and ravioli that are often enriched with eggs and specially pasta that includes regional specialties like orecchiette, pappardelle and trofie.
Italy is well-known for its export growth, in fact it is a leading exporter of pasta, bakery, and flour-based products, with significant markets in Europe, North America, and Asia. The demand for authentic Italian products continues to grow globally. There is a strong demand for artisanal and premium products that emphasize high-quality ingredients, and unique flavors.
Farinaceous foods are products made primarily from grains and other starchy ingredients. In the Italian context, this includes a variety of staple foods such as pasta, bread, pizza and various baked goods. These products are central to Italian cuisine and hold significant cultural and economic importance.

“This sector is renowned worldwide for its high-quality products and innovative recipes. It included a mix of large-scale manufacturers, but also small and medium-sized enterprises (SMEs), and artisan producers” (L.Bravi, 2021).



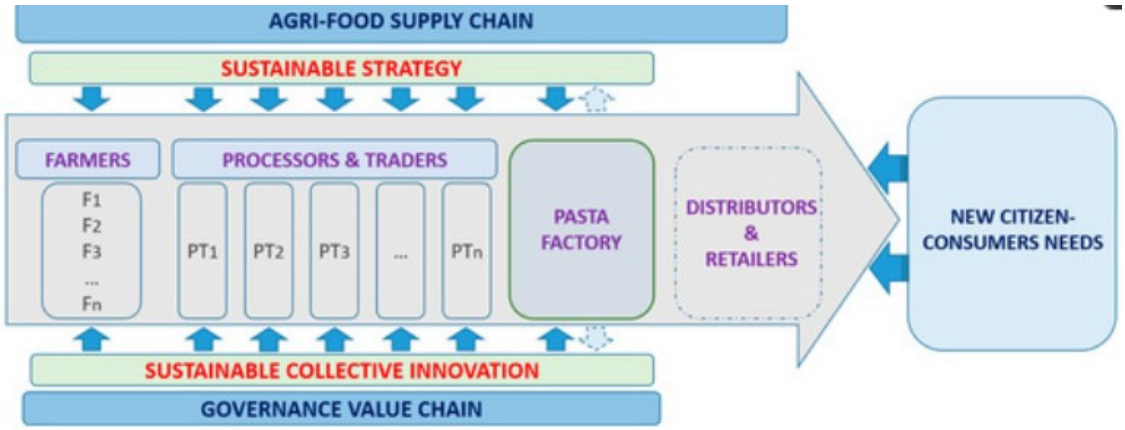
The exporters of organic product 1.2

"Here there are some numbers linked to the exporters of organic products worldwide expressed in million euros. Made in Italy organic products registered an export value of €2.9 billion, confirming the Italian leadership in Europe and positioning and the second top exporter of organic products in the food industry worldwide. The exportation of these products have steadily increased over +156% from 2010 to 2021" (Invitalia, 2023).

"The global food market is substantial and has been steadily expanding over the years. According to the Food and Agriculture Organization (FAO), the global food import value reached USD 1,755 billion in 2021. Fruits and vegetables accounted for the largest share of global food imports at 18.4%, followed by cereals and related products at 14.6%. Both meat and fish represented over 10% each, while animal and vegetable oils made up 8.6% of the total. Projections for 2023 anticipate a 13% increase in food import value, bringing it to approximately USD 2,000 billion. Notably, the most significant increases are expected in sugar, cereals, oilseeds, and dairy products, with growth rates exceeding 20%" (Coriglioni & Algieri, 2024).

In this sector there are thousands of bakeries, pasta producers, flour-based product, and related business, contributing significantly to Italy's GDP ("Gross

Domestic Product"). The major production core is spread across Italy, with regions like Emilia-Romagna, Tuscany, and Campania that are prominent for pasta production, while Lombardy, Veneto, and Sicily are known for their bakery products.



The sustainable practices 1.3

Another important aspect is sustainability because the industry is seeing a push towards sustainable practices, including the use of locally sourced ingredients, eco-friendly packaging, and energy efficient production processes.

The Italian bakery and pasta industry faces intense competition both domestically and internationally. So, maintaining a competitive edge requires continuous innovation and quality improvement. In this sector there are stringent food safety, and quality standards set by both Italian and international authorities.

This includes compliance with labeling, hygiene, and traceability regulations.

Also, increasing costs of raw materials, energy, and labor pose challenges for producers, particularly smaller artisan businesses that operate on thinner margins.

Adopting new technologies for production efficiency, supply chain management, and digital marketing is crucial but can be a significant investment, especially for small and medium sized enterprises.

This sector is facing big changes that are in progress nowadays and for the future: the need for a major sustainability in the products and processes but also the advent of the Fourth Industrial Revolution with the introduction of the new technologies.

In conclusion, the Italian bakery, pasta, and flour-based product industry is a vital part of Italy's cultural and economic fabric. It combines traditional craftsmanship with modern innovation to meet changing consumer demands. While the industry faces challenges such as competition, regulatory compliance, and rising costs, its commitment to quality, sustainability, and authenticity continues to drive its success both domestically and internally.

1.2- Key challenges facing the industry and emerging opportunities

"Despite its strengths, there are some challenges that this industry is facing nowadays. Both domestical and international *competition* is intense, with producers from other countries striving to capture market share. There are also some *regulatory pressures* in terms of stringent safety and quality standards, along with adapting to new regulations regarding sustainability and environmental impact. Also, some supply chain issues mean ensuring a reliable and sustainable supply of high-quality raw materials, particularly wheat, in the face of global market fluctuations and climate change" (Porter, 1990).

"The food industry has undergone significant changes over recent decades, but it still faces various challenges and opportunities in the 21st century. These include changing consumer preferences toward healthier and more sustainable food options, advancements in food production and distribution technologies, and growing concerns around food safety, waste, and social equity. Food demand is closely tied to factors such as global population, quality of life, and lifestyle

habits, which vary between countries. Studies predict that the global population will increase by 26% between 2019 and 2050, reaching approximately 9.7 billion people, with food demand expected to rise by 56% compared to 2010 levels. According to research by Alexandratos and Bruinsma, the annual per capita food consumption in 2050 is estimated to include about 160 kg of cereals, 16 kg of oil equivalents, 49 kg of meat, and 100 kg of dairy products. This relationship between population growth and food demand is especially significant in developing countries, where population growth is higher, and food access is often more limited. As people move out of poverty and into the middle class, their consumption of meat and processed foods typically increases, placing additional pressure on the food supply chain. Furthermore, in developed countries, improved quality of life and fast-paced daily routines have driven higher food demand over the years, with interconnected, energy-intensive activities becoming more common. Research also highlights the connection between water, energy, and food (WEF) systems and their relationship with GDP. Studies involving over 175 countries have shown a strong correlation between GDP and the WEF nexus, confirming previous observations" (Coriglioni & Algieri, 2024).

There are several opportunities for growth and innovation within the industry. There are some *health trends* like the increasing awareness about the health and nutrition that is driving demand for whole-grain, organic, and gluten-free farinaceous products. Consumers are increasingly seeking organic pasta and bread options. This trend is driven by a desire for products free from synthetic pesticides and fertilizers. Organic certifications have become important marketing tools, with producers highlighting their commitment to sustainable and health-conscious farming practices. There is a rise in awareness of gluten intolerance and celiac disease that has led to a significant increase in the availability and variety of gluten-free farinaceous products. Other dietary trends, such as low-carb, keto, and plant-based diets, have spurred innovation in the creation of alternative flours and pasta made from legumes, quinoa, and other

non-traditional ingredients. There is a growing market for pasta and bread enriched with additional nutrients, such as fiber, protein, and vitamins. These products cater to health-conscious consumers looking to maximize the nutritional value of their meals. Producers are experimenting with ingredients like whole grains, ancient grains (e.g., spelt, farro), and seeds to enhance the nutritional profile of their products.

Sustainability and environmental impact have led to innovations in packaging. Many companies are adopting biodegradable, recyclable, or reduced-plastic packaging solutions to meet consumer demand for environmentally friendly products. Brands are increasingly highlighting their sustainability credentials on packaging to attract eco-conscious consumers. There are also some sustainable production practices in which companies are investigating such as crop rotation, reduced waste usage, and organic farming methods, to ensure the long-term viability of their raw material supply. Energy efficient production processes and waste reduction initiatives are becoming standard practices in the industry to minimize environmental impact.

Consumers are demanding greater transparency about the origin of their food. This has led to the adoption of blockchain technology and other traceability systems that provide detailed information about the supply chain, from farm to table. Certifications and labels, and organic certifications, are becoming more prevalent as consumers seek to make informed purchasing decisions.

Italian pasta and other farinaceous foods continue to enjoy high demand worldwide, providing opportunities for export growth, so a high global demand. The adoption of digital technologies can enhance production efficiency, improve quality control, and support the development of new products. The Italian farinaceous food industry is dynamically evolving, driven by health and wellness trends, sustainability initiatives, technological advancements, and the expanding

global market. By staying attuned to these trends, companies can continue to thrive and meet the changing demands of consumers both domestically and internationally.

The food industry is a cornerstone of the global economy, supporting millions of jobs and generating substantial revenue annually. As the world's population rises, the demand for food is surging, necessitating major investments in agriculture, infrastructure, and distribution systems. It's essential to manage the environmental consequences of this increased demand while promoting sustainability. The close relationship between energy, water, and waste in food production emphasizes the importance of minimizing waste, improving energy use, and making better use of resources throughout the entire supply chain.

In developed countries, consumers often lack awareness of the resources required to produce their food, leading to a disconnect and lack of responsibility for the environmental impacts of their food choices. The "throwaway" culture, prioritization of convenience over sustainability, and normalization of high food production and consumption levels exacerbate these issues. Social and cultural factors significantly influence energy consumption and waste generation in the food industry, with many studies focusing on these topics. Household behavior and knowledge of food waste also play a crucial role, with studies indicating that a lack of knowledge about food storage, poor planning, and disregard for food value contribute to household food waste. Educational campaigns and technology to improve household food management are effective strategies to address these issues.

Meeting the growing demand for food will require substantial investments in agricultural productivity, infrastructure, and improvements in food distribution and access. This will be a key challenge for governments and the private sector, as they balance the need for food security and quality with concerns about sustainability, environmental impact, health, and nutrition. At the same time, the

food industry is experiencing significant technological advancements, such as precision agriculture, big data analytics, and smart and connected technologies. The sector is also subject to increasingly stringent regulations and standards aimed at ensuring food safety, quality, and sustainability. Energy consumption varies significantly across different food-processing sectors, depending on the specific products and production methods. Reducing energy consumption, cutting costs, and lowering greenhouse gas emissions have become essential goals, especially in the context of global challenges like climate change and population growth. Prioritizing waste reduction and improving resource efficiency across the entire supply chain, from production to consumption, is increasingly important.

In 2007, European Union (EU) leaders set a target to reduce annual energy consumption by 20% by 2020. This was followed by the 2018 Clean Energy for All Europeans package, which set a more ambitious target of a 32.5% reduction by 2030. Further updates proposed even higher targets, aiming to reduce greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels, and achieve climate neutrality by 2050. The new EU Energy Efficiency Directive (EU 2023/1791), published in September 2023, emphasizes "energy efficiency first" as a key principle, setting an additional target of an 11.7% reduction in energy consumption by 2030. The industrial sector plays a crucial role in achieving these energy savings.

“Implementing effective strategies and practices in the food industry can help achieve these goals. Improvements in process control, product design, packaging optimization, and better utilization of energy, water, and other resources are examples of best practices. Embracing renewable energy and adopting circular economy principles, such as recycling and reuse, are additional measures that can significantly reduce the environmental impact of the food sector. Collaborative efforts between government, industry, and consumers are essential for promoting sustainable practices and driving meaningful change” (Coriglioni & Algieri, 2024).

1.3-Importance of digitalization to address sustainability challenges

There are some important aspects to consider in the importance of sustainability and digitalization in the modern industries, overall, in the Italian farinaceous food ones. “First, industries are significant contributors to environmental issues like pollution and resource depletion. Sustainable practices can help reduce the carbon footprint, manage waste effectively, and conserve natural resources, ensuring long-term ecological balance. Governments and international bodies are increasingly implementing environmental regulations. Adopting sustainable practices helps industries comply with these regulations, avoiding legal penalties and enhancing their reputation. There is also a growing preference for environmentally friendly and ethically produced products. Industries that prioritize sustainability can attract and retain customers, leading to increased market share and customer loyalty. Sustainable practices often lead to cost savings through improved efficiency, reduced waste, and lower energy consumption. For example, optimizing resource use and recycling can significantly cut operational costs. Companies are expected to operate responsibly and contribute positively to society. Sustainability initiatives are integral to CSR, enhancing the company’s image and building trust with stakeholders” (Geissdoerfer, Vladimirova, & Evans, 2018).

Digital technologies streamline operations, reduce manual errors, increase productivity, automation, data analytics, and IoT (Internet of Things) enable real-time monitoring and optimization of processes. Digital tools enable personalized marketing, better customer service, and improved product offerings. E-commerce platforms, mobile apps, and social media enhance customer engagement and satisfaction. Embracing digitalization fosters innovation, allowing industries to develop new products and services. Staying ahead in technology adoption for maintaining competitiveness in a rapidly evolving market. “Digital transformation enables industries to respond quickly to market changes and

disruptions. Cloud computing, flexible production systems, and digital supply chains enhance the ability to adapt and scale operations" (Reischauer, 2018).

"There is an important relationship between the digital technologies and sustainability that are used nowadays in the Italian food bakery, pasta, and flour-based products because it is essential for advancing global efforts toward a more inclusive, resilient, and environmentally sustainable future" (Faggini, Cosimato, & Parziale, 2021).

Today, there are lots of international guiding lines that are inviting the companies to calculate and reduce the environmental impact in the processes, products, and packaging along the entire lifecycle to create substantial opportunities to enhance sustainability..

"On the other hand, the coming of the new technologies known as Industry 4.0 is transforming the ways of production, creating challenges and opportunities" (Javaid, Maleem, Singh, Suman, & Gonzalez, 2022).

Furthermore, in the food industry there is the challenge of the company to transform the sector into more friendly, socially responsible, and economically viable practices. This relationship is multifaceted, involving improvements in efficiency, traceability, waste reduction, and consumer engagement.

"First, there will be a *resource efficiency* in which digital technologies can enable precision agriculture techniques, such as sensors and satellite imaging, that can help the farm's resources. Also, it could be helpful for soil conditions, water levels, and crop health, reducing environmental impact and maximizing fields but also minimizing the use of water, fertilizers, and pesticides. Sustainable practices help in optimizing the use of resources like water, soil, energy, and raw materials. This is crucial in grain and flour production, where resource-intensive processes can lead to significant environmental degradation.

Another important aspect is the *reduction of food waste* in which the digital solution can help minimize the food waste at the different stages of the supply chain, which are the production, the processing, and the packaging. By forecasting demand, optimizing storage, and transportation, and implementing dynamic pricing strategies, businesses can reduce losses, conserving resources and reducing greenhouse gas emissions" (Reischauer, 2018).

There are also some certification schemes that can help with meal planning and waste reduction tools, digital technologies can provide resources to promote ethical, healthy, and environmentally friendly food systems. Moreover, there is an emergence of technologies such as vertical farming, aquaponics and lab-grown that can offer significant and innovative solutions to enhance food production sustainability.

These technologies can help reduce land and water requirements, minimize greenhouse gas emissions and improve resource efficiency. This is the process known as *innovation* in *food production.*
Overall, the introduction and integration of digital technologies into the food industry drives sustainable practices, improve efficiency, enhance transparency, and empower stakeholders across the supply chain.

Another important aspect during the delivery in the production phase is the use of *sustainable packaging.* Innovations are in the packaging materials, such as biodegradable and compostable in alternative to plastic ones, that can help to reduce the pollution in the environment and resource consumption.
Additionally, we can add that there are new technologies such as intelligent packaging with sensors that can monitor if a food is fresh, and it has high quality reducing the waste. Also, blockchain enhances transparency and traceability

across the supply chain. It allows every ingredient to be tracked from its source to the final product, ensuring authenticity and adherence to sustainability standards.

This helps in verifying organic or fair-trade certifications, reducing fraud, and promoting sustainable sourcing practices. The use of smart sensors and automated systems in production lines help monitor and optimize energy usage.. By reducing energy consumption and improving efficiency, these manufacturers can lower their carbon footprint.

“Digital energy management systems enable the integration of renewable energy sources, such as solar and wind, that are used in the production processes. These systems monitor energy usage and manage the switch between renewable and conventional energy sources to maximize sustainability” (Reischauer, 2018).

For what concerns the e-commerce and digital marketing, there are some tools that can educate consumers about the sustainability initiatives of these types of manufacturers. Furthermore, digital tools collect and analyze customer feedback helping companies to understand consumer preferences and concerns regarding sustainability.

There are some certifications and standards like *Digital Certification Systems* in which the platforms manage, and control verify certifications (organic, fair-trade) streamline the process and enhance credibility. These systems ensure that sustainable practices are documented and recognized, promoting adherence to high standards. The synergies between digital technologies and sustainability in the Italian Bakery, food and flour-based product industries is driving significant advancements. Digital tools enhance efficiency, reduce waste, ensure traceability, and engage consumers, all of which contribute to more sustainable practices.

As these technologies continue to evolve, their impact on sustainability will likely grow, fostering a more responsible and eco-friendly food production landscape.

This is a starting point for the food industries that can play a significant role in advancing the sustainability goals and building a more sustainable, resilient, and equitable food system for the next and future generations.

1.4-Historical Context: Evolution of the Farinaceous Food Industry in Italy

The farinaceous food industry in Italy, encompassing products made from flour such as pasta, bread, and pastries, has a rich and storied history. Its evolution reflects broader social, economic, and technological changes over centuries.

In ancient Rome, bread was central to the Roman diet, and there were different types, used and consumed by different social classes. Also, pasta had a different form, like “lagane”, that was a precursor to lasagna but was different from the modern ones, unleavened and baked rather than boiled. In the Middle Ages, there was a rise of guilds in cities regulated the production and the sale of bread, and other farinaceous products, ensuring quality and standardization.

Lagane in the ancient Rome 1.5

In the 18th Century, the recipes for pasta and pastries became more sophisticated, reflecting the influence of wealthy patrons and the exchange of ideas within Europe. In this age, there was a phase known as “The age of Exploration” in which there were brought new ingredients to Italy, like sugar which transforms the baking and the pastry industry. This was a period of proliferation in which pasta had become a popular staple in Italy, with regional variations and specialized production techniques emerging. In the 19th century, the Industrial Revolution brought significant changes, with the mechanization of flour mills and the introduction of pasta and other farinaceous foods, making them more accessible to a broader population. In this period, there was a significant urbanization in which the growth of cities created larger markets for bread, pasta, and pastries. Bakeries and pasta factories flourished in urban centers. There was also an improvement in transportation networks that facilitated the distribution of wheat and farinaceous products across Italy and beyond.

The 20th century saw the introduction of modern milling technologies that produce high-quality, refined flour. Advances in pasta production technology, including extrusion and drying techniques, standardized and scaled up the production process. In this period, Italy became leading exporter of pasta and other farinaceous products, renowned for their quality and variety. Also, Italian cuisine, particularly pasta, gained international popularity, influencing culinary practices worldwide. There has been a growing emphasis on organic farming, sustainable production practices, and the use of local ingredients. Modern technologies, including digital tools for supply chain management and quality control, have further optimized production processes.

The evolution of the farinaceous food industry in Italy is a testament to the country’s ability to adapt and innovate while maintaining a deep connection to its culinary traditions. From ancient milling techniques to modern industrial production, the industry has continually evolved, reflecting broader historical

trends and technological advancements. Today, it stands as a symbol of Italian cultural heritage and a key player in the global food industry.

“Italian cuisine, recently, has become famous all over the world for its variety, authenticity, but also for its delicious recipes and it was included in the UNESCO list of intangible cultural heritage. This is a social and cultural expression around the world, making it a big tradition for our country. The Italian cuisine is not just recipes and ingredients, but it is also practice, expertise, and values that has been reached over many centuries. It has been passed from generation to generation, preserving some techniques and secrets making it unique. Every region of Italy has its own distinctive dishes, based on fresh, high-quality ingredients, often based on local resources. For this reason, it is considered a cultural heritage site, and the UNESCO will help to preserve and protect this unique cultural identity. At the same time, it is considered very important to help to preserve the cultural methods, sustainable agriculture and ancient production methods for artisan food that are closely connected to Italian cuisine. Also, this inclusion is having a significant impact on the country’s tourism and economy. This could be helpful to develop the businesses connected to restaurants, agritourism locations, food tours, generating opportunities for local communities. This is also a recognition of good Italian food promoting the Mediterranean diet around the world as a healthy diet, encouraging a balanced lifestyle based on fresh ingredients, such as olive oil, wholegrain cereals, vegetables and fruit” (The most precious treasure of Italian culture? Our culinary art, 2023).

“Pasta and pizza are the two most iconic creations that have become beloved around the world. These dishes show the creativity of the Italian cuisine but also the unity and conviviality. Making pasta by hands or creating the perfect pizza are skills that are passed through generations” (Italian cuisine's candidacy for UNESCO heritage status, 2023).

1.5-Challenges Facing the Italian Farinaceous Food Industry

The Italian farinaceous food industry today is facing significant challenges that arise are from economic pressures, environmental concerns, social changes, and technological demands.

There are some *economic challenges* regarding market competition because Italian producers are up against competitors from other countries who often sell at lower prices, which can attract cost-conscious consumers even if it means sacrificing some quality. There are also some economic downturns that can affect how much consumers are willing to spend on food, making it critical for Italian producers to balance price and quality. For what that concern the supply chain issues, the price of high-quality wheat and other raw materials can fluctuate, impacting the overall cost of production. Efficiently transporting products, especially for export, is essential to maintain quality. Disruptions in logistics can lead to delays and higher costs.

The *environmental challenges* regarding managing resources like water and energy efficiently are crucial for sustainability but can require significant investment in new technologies and practices. Climate change affects what production, leading to potential shortages or variability in the quality of raw materials. Reducing waste during production is important for environmental sustainability. Finding ways to repurpose by-products effectively is challenging. This industry should also drive towards net-zero emissions while also considering larger environmental and social effects.

The *social* and *cultural challenges* face the increasing demand for healthier, gluten-free, and organic products requires adapting traditional recipes while maintaining the quality that Italian products are known for. Trends like reduced

carbohydrate intake can decrease the demand for traditional pasta and bread. There is a delicate balance in maintaining traditional production methods and recipes and innovating to meet modern consumer demands. In this industry there is a challenge to develop its offers due to changing the tastes of consumers for healthier and sustainable food options, such as organic, vegan, and plant-based and alternative proteins. The product creation must strategically change to meet the needs of environmentally concerned consumers and health-sensitive consumers. The development of goods that meet these customer demands through the use of cutting-edge food technology, sustainable sourcing practices, and innovative ingredients is made possible by investigating research and development.

Technological challenge means modernizing the production with new technologies, but this could be an expensive cost of implementation. There is a need for a workforce skilled in operating advanced machinery and digital tools. Some issues regard integration because incorporating digital tools into traditional processes can be difficult, especially for smaller producers. Ensuring digital systems are secure from cyber threats protecting data production and processes. Also, there are some benefits of data processing, artificial intelligence (AI), and automation in improving productivity, reducing waste, and supporting supply chain management. Predictive AI and cutting-edge technologies enhance quality assurance, risk assessment, and traceability, enabling a digital transformation that maximizes production and decision-making producers. To fully utilize technology, the sector must manage the line that separates it from augmenting rather than replacing human labor with automation.

There are also some challenges considering the creation of new products that should align with modern consumer preferences while maintaining traditional quality standards. Continuous investment in research and development should be made to keep up with trends and technological advancements. Another important

aspect is the differentiation in which the Italian should emphasize the quality and heritage of their products because they stand out in a crowded market that requires some strategies to reach it.

“The Italian farinaceous food industry faces a complex array of challenges, from maintaining its cultural heritage and high quality in the face of global competition to adopting new technologies and sustainable practices. Balancing these demands could be crucial for the industry’s continued success and growth” (Woodward, 2024).

In summary, this industry is facing a number of obstacles, including supply chain interruptions, problems with safety and quality, complicated regulations, shifting customer preferences, and the effects of climate challenges. Artificial intelligence, blockchain, automation, and other technologies provide solutions to improve supply chain management, guarantee food safety, adhere to legal requirements, and satisfy changing customer preferences. Overcoming these obstacles requires not only a focus on sustainability and innovation but also an efficient use of technology. Building resilience and keeping competitiveness will require merging strategic planning with technical developments as the business develops. This strategy will not only solve the problems of today, but also open the door to a feature that is more adaptable, and customer focused.

1.6-The impact of unsustainable practices

The Italian food industry, in particular the ones concerning the farinaceous (grain-based) products, has faced various unsustainable practices. These issues can be categorized into: first of all, in the intensive agriculture there are some monoculture practices in which the large-scale monoculture farming of grains like wheat can lead to soil degradation, reduced biodiversity, and increased

vulnerability to pests and diseases, the excessive use of pesticides and fertilizers contaminates soil and water sources, harming ecosystems and potentially impacting human health. Grain farming is water-intensive, and in some regions, this has led to the depletion of local water resources and contributed to the lowering of water tables. Even the cultivation and processing of grains contribute significantly to greenhouse gas emissions, through both direct (e.g., methane from rice paddies) and indirect means (e.g., fossil fuels used in farming machinery) and transporting raw grains and finished farinaceous products across Italy and for export contributes to carbon emissions. Another important problem is that the expansion of agricultural land for grain production can lead to the destruction of natural habitats, affecting local flora and fauna and the focus on high-yield grain varieties can lead to a reduction in genetic diversity, making crops more susceptible to diseases and climate changes. Overall, the processing of grains products like pasta, bread, and pastries is energy-intensive, often relying on non-renewable energy sources and some excessive and non-recyclable packaging for farinaceous products adds to the environmental footprint. The inefficiencies in the supply chain, from production to consumption, lead to significant food waste, contributing to environmental degradation.

Unsustainable practices in the Italian farinaceous food industry have significant and multifaced impacts that extend beyond the immediate production environment. These impacts affect the economy, environment, social dynamics, and the industry’s long-term viability.

An environmental impact regards the depletion of natural resources such as the water usage that can affect the ecosystem and the communities because of the depletion of local water resources in the phase of the production. Furthermore, high energy consumption in processing and transportation exacerbates the industry’s carbon footprint.

As an economic impact there is an increase in costs due to the resource scarcity that drives up costs for water, energy, and raw materials, affecting the profitability. Consumers are increasingly aware of sustainability issues and companies known for unsustainable practices may face boycotts and loss of market share that can damage their reputation. Environmental degradation can lead to supply chain disruptions, as the availability of high-quality raw materials becomes inconsistent.

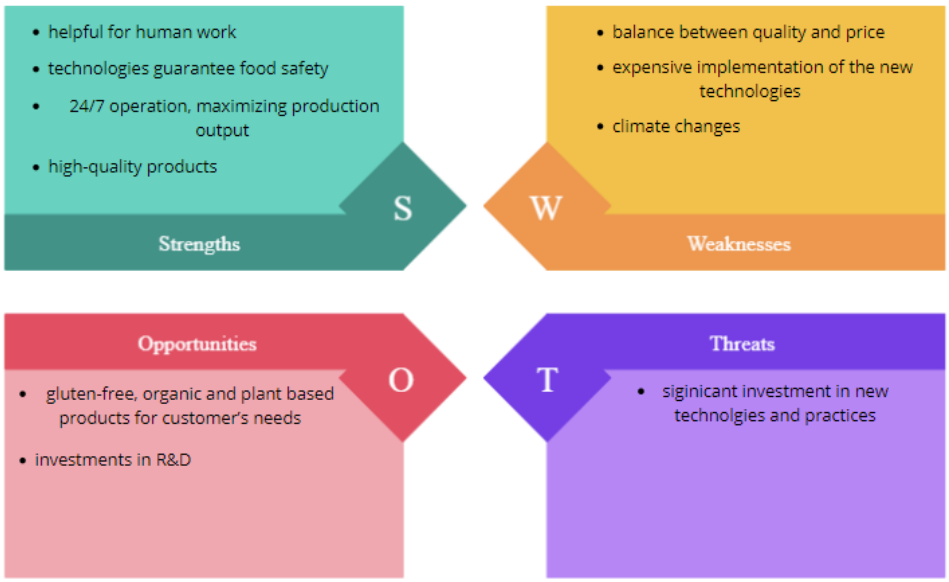
As a social impact there are some factors affecting the health of the community like pollution in the use of chemical fertilizers and pesticides that can contaminate local water supplies, leading to health problems in nearby communities but also air quality because of the emissions that can degrade air quality, posing respiratory health risks.

Unsustainable practices in the Italian farinaceous food industry have far-reaching negative impacts on the environment, economy, society, and the industry's long-term viability. By prioritizing sustainability, industry can protect natural resources, improve community well-being, and maintain its global reputation for high-quality products.

"Sustainability, internationalization, and digitalization are three key growth paths for firms. First, firms based in Western economies, like Europe, are encouraged to expand abroad. Second, the digital revolution increasingly calls small-medium-sized enterprises to pursue technological innovation like artificial intelligence as well as to adhere to environmental sustainability goals. Third, internationalization and technological progress are often considered potentially threatening for the environment, due to issues related to pollution or the

excessive usage of the planet's resources" (Denicolai, Zucchella, & Magnani, 2021).

Efforts to address these issues involve promoting sustainable agricultural practices, such as crop rotation, organic farming, and integrations pest management. There is also a push for reducing water and energy consumption, improving waste management, and enhancing the biodiversity of agricultural landscapes. Additionally, consumer awareness and demand for sustainability produced food products can drive industry changes towards more eco-friendly practices.



The SWOT 1.6

1.7- Digitalization gaps and opportunities

The Italian farinaceous food industry, renowned for its traditional methods and high-quality products, faces both significant challenges and opportunities as it navigates the digital age. Previous studies has shown that digitalization can lead

to improved efficiency, better product quality, and enhanced customer satisfaction. IoT can help utilized for real-time monitoring of production processes and supply chain management, Big Data Analytics employed for demand forecasting, quality control, and consumer insights, blockchain is applied for ensuring traceability and authenticity of products, AI and Machine learning are used for process optimization and predictive maintenance.

“Digitalization is one of the most easily suitable and available options for small-medium-sized enterprises to innovate and to grow because of the broad range of creative solutions that it offers across the industries, the possibility to easily access virtual global environments, and the decreasing costs associated with applications like artificial intelligence or cloud computing” (Denicolai, Zucchella, & Magnani, 2021).

There are some gaps in digitalization, first in the technological infrastructure in which many small to medium enterprises (SMEs) in the farinaceous food industry still rely on fragmented and outdated IT systems and these systems need an integration of new digital tools and technologies. (Raihan, 2024). There is a significant gap in digital skills among workers in this sector because traditional skills dominate, and there is a lack of training programs focused on digital competencies such as data analytics. Many businesses, especially smaller ones, do not have solid cybersecurity measures in place, making them vulnerable to cyber threats and there are complex data privacy regulations, such as the GDPR, that presents challenges for companies that lack the necessary digital infrastructure and expertise.

“Also, there are some high initial investments like the cost of digital infrastructure that can be prohibitive, especially for SMEs, there is a shortage of skilled workers who can operate and maintain advanced digital systems, regulatory challenges like compliance with food safety and data protection

regulations that can complicate digital integration, and cultural resistance like traditional mindsets and resistance to change slow down the adoption of new technologies" (Gazzola, Greghi, & Colombo, 2019).

The opportunities of digitalization are operational efficiency because implementing automation in production processes can enhance efficiency, reduce costs, and improve product consistency. Digital technologies can streamline operations, reduce waste, and enhance productivity. For example, IoT sensors can provide real-time data on equipment performance, enabling predictive maintenance and reducing downtime. Big Data analytics can optimize supply chain operations, ensuring timely delivery and reducing inventory costs. Digital tools can optimize supply chain management, from sourcing raw materials to distributing finished products, ensuring better inventory control and reducing waste. Data analytics and Artificial Intelligence ca drive production innovation by identifying emerging consumer trends and preferences. Digital platforms can facilitate international trade, allowing Italian farinaceous food products to reach new markets globally, as a market expansion. These technologies can improve traceability and food safety. "Blockchain technology offers a robust solution for traceability, allowing consumers to verify the origin and quality of products. This transparency can enhance brand trust and comply with stringent food safety regulations" (Azucar & De Bernardi, 2020).

Digital Technology 4.0 often is referred to as Industry 4.0, and it represents the fourth industrial revolution, characterized by the integration of digital technologies into various aspects of industrial processes to improve efficiency, productivity, and flexibility. It was born at the dawn of the industrial age, and it represents the great leap in technology.

It forced the companies to adapt the way to operate in the first stage, the industry 1.0, also called classic age of the Industrial Revolution, was the work that results from the human endeavor in the workplace.
The second stage, industry 2.0, was characterized by using electricity and led to the use of some modern techniques of mass production.
In industry 3.0, there was the outcome of computer power in production, with machines and robots replacing the workers on the assembly lines.

Industry 4.0 brings together computers driven by machine-learning algorithms in an entirely new and connected way that allows a transformation of the manufacturing process. Thanks to that, there were an increase in productivity in order to operate more efficiently and produce more, a reduction of the costs due to this continuous process of automation, the delivery brings profitability increase, more quickly respond that is aligned with the changing of the customers' demands, but also embrace new ways of working and partner with their employees to create new jobs through the upskilling of their workforce.

This type of technology allows companies to make people's jobs easier.
When it is applied to the food industry, it brings about significant transformations across the entire food supply chain, from production and processing to distribution and consumption. It can help the company to take a new approach in its business because it can bring the success of envisaging the future, greater integration of processes, and a great need for clarity around outcomes and how a firm is going to achieve them.

This will help food manufacturers comprehend the complete range of opportunities available and the types of investments or modifications to current processes required to capitalize on them. It also explores what constitutes 'best practice' and helps businesses understand some of the more technical aspects of

these concepts. Crucially, food manufacturers must establish new partnerships across various industries and seek new collaborators to successfully navigate this evolving landscape.

“The digital technology refers to digital devices, systems, and resources that help create, store, and manage data, in real time, to inform the decision making but also to analyze it more swiftly. An important aspect of digital technology is information technology (IT) which refers to the use of computers to process data and information” (Schwab, 2016).

One of the advantages of technology is limitless communication, so companies can extend their reach beyond domestic boundaries and access millions of customers worldwide. Most of the firms automate their processes because digital technology is not just important, but it is also a requirement for all modern businesses. Most of them, nowadays, use digital technology to manage operations and processes to enhance the customer journey.
Companies adopt digital technologies to increase their profitability.
Firms that refuse to make this change will lose their competitive advantage.
There are lots of incentives that allow the companies to digitalize.
For example, production will run fast since machines are replacing humans in repetitive tasks. So, the coordination of corporate data is just one system that allows everyone to work together more seamlessly.
In some companies there is this use of information in order to maximize the supply chain efficiency that allows the company to keep better track of all the orders.
It can instantly tell companies how much inventory they have and how it can be deployed. That also increased the visibility that can have an important role in helping solve some issues in the production and enable the manufactures to make smart decisions at early stages. An operator can also pull the data from a machine

and put it into the Cloud, allowing for far greater analysis than was ever possible before. The data can also be used to create algorithms to make decisions and predictions, helping a company to make the most of its equipment by reducing downtime to a minimum. In the meantime, there is this “Such Predictive Maintenance” in which you know if a machine is about malfunctioning and you can build in downtime by moving the production to other machines which may have more capacity, and you can save money and cutting down on the time a machine that is idle.

From the aggregation of some pieces of data, it is possible to gather insights into how a machine is performing. Industry 4.0 enables the companies to a new way of thinking but also to be agile and to partner with other businesses; not every firm can be an expert in every area. “Companies can partner, connect each other with the workforce necessary to manage it efficiently, engage to ensure that they are ready to respond to the potential changes that the Industry 4.0 brings, analyze the data to make smart decisions and decide the strategies to adapt” (Schwab, The Fourth Industrial Revolution, 2016).

Thinking of these stages, we can think that this industry demonstrates to its customers and customers that they understand how the world is changing and to follow the need to adopt these guidelines. There are some technologies that can be applied in industries, where there is no greater collaboration between machines and humans. They can control physical activities, and data can be shared from one system to another in real-time.

Digital technologies can be a driver for firms’ international expansion and can provide smaller ventures with new instruments and approaches to reach and serve global customers, as well as new ways to organize economic activities and business operations.

The digital technologies most used in the food industry are: IoT, Big Data, robotics, and artificial intelligence. Overall, the application of Digital technology 4.0 in the food industry is revolutionizing traditional practices and enabling greater efficiency, transparency, and traceability throughout the food supply chain. By harnessing the power of Internet of Things, Artificial Intelligence, Robotics, and blockchain, food producers, manufacturers, and retailers can improve food safety, reduce waste, and meet the growing demands of a globalized and digitally connected market.

IoT

"The Internet of Things (IoT) refers to a network of physical objects or "things" embedded with sensors, software, and other technologies to connect and exchange data with other devices and systems over the Internet. These "things" can range from everyday household items to sophisticated industrial tools. The primary purpose of IoT is to enable objects to communicate, collect, and share data without human intervention, thereby increasing efficiency, accuracy, and economic benefit" (Lakhani & Iansiti, 2020).

The key components of IoT are *sensors* and *devices*. Sensors are devices that detect and measure changes in the environment, such as temperature, motion, moisture, light, and more. Devices are objects embedded with sensors that gather data (e.g., smart thermostats, fitness trackers).

There are networks that enable devices to connect and communicate data with each other and with central servers. Common connectivity options include Wi-Fi, Bluetooth, cellular networks, and other protocols. Local or cloud-based systems that analyze the data collected by IoT devices. Data processing can involve

simple data aggregation or more complex analytics and machine learning algorithms.

The Internet of Things (IoT) provides a seamless connection between the production process and operators to share critical data about operations. IoT can monitor temperature, humidity, and food safety data points, trace and track packaged food, increase visibility within the food supply chain, alert operators to equipment maintenance needs, and more.
The use of sensors, Radio Frequency Identification (RFID), and GPS can give manufacturers important insights into a segment of their operations or about the entire process, improving food quality and safety and boosting production efficiency. IoT enables the connection of physical devices and sensors to the internet, allowing real-time monitoring and control of various processes in the food industry. In food processing and manufacturing, IoT devices can monitor equipment performance, track inventory levels, and ensure compliance with quality and safety standards.

The benefits that IoT can bring are improving the efficiency with the automation and real-time data analysis streamline process and reducing waste, cost savings because predictive maintenance and optimized resource use lower operational costs, enhancing decision-making with data-driven insights that support more informed and strategic decisions but also better quality of life due to the convenience and improved services in everyday life and professional sectors.

The Internet of Things is transforming various industries by providing enhanced connectivity and intelligent data-driven decision-making capabilities. While it presents numerous benefits, it also poses significant challenges that need to be addressed to realize its full potential.

Big Data

"Big Data refers to extremely large and complex data sets that are difficult to process and analyze using traditional data processing tools and techniques. These datasets are characterized by their volume, velocity, and variety, which collectively are known as the "3 Vs" of Big Data. The primary goal of Big Data is to extract meaningful insights and information from these vast amounts of data to aid decision-making, optimize operations, and create new opportunities" (Sadiku, Ashadlu, Ajayi-Majebi, & Musa, 2020).

The three Vs of Big Data are: the *volume* refers to the massive amount of data generated every second from various sources such as social media, sensors, transactions, and more. This can range from terabytes to petabytes of data. "The *velocity* refers to the rapid rate at which data is generated and needs to be processed. This includes real-time data streams and the need for quick analysis and action. The *variety* refers to the diverse nature of data formats, including structured data (databases), semi-structured data (XML, JSON), unstructured data (text, images, videos), and more" (Robinson & Gillis, 2023).

There is also some additional "V" that we can include that have other characteristics, such as: the *veracity* that ensure that data is accurate and reliable and *value* that emphasizes the importance of extracting valuable insights from data to drive business decisions.

"Some researchers applied Big Data within food manufacturing to obtain demand and yield forecast. Another study explored the application of Big Data in order to reduce food waste, while others studied its application in food logistics to show the application of Big Data in the food sector" (The future of jobs report, 2018).

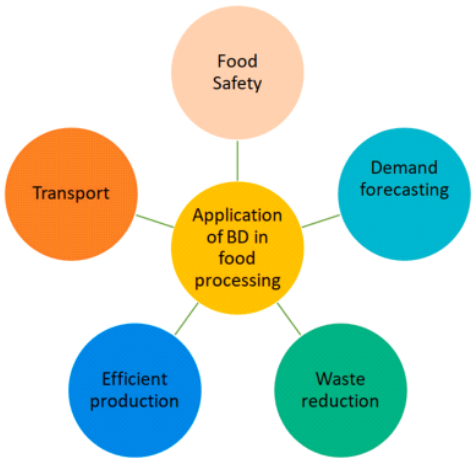
For what concerns the food waste, Big Data technologies are being implemented in the food production that analyze the data generated from smartphones, social media, IoT, and multimedia. Moreover, it can be used to provide transparency, traceability, and predictive insights into various activities.

It helps make real-time decisions and develops monitoring and sampling strategies for safety evaluation. Big Data analytics technology can provide greater predictability for food production operations for foodborne diseases and thwart a potential outbreak in its early stages. Furthermore, this data allows the identification and verification of certain practices or actions that are robust in preventing outbreaks. Similarly, accurate prediction of food products' shelf life would be easier as it could be used to determine the exact spoilage of product.

In demand forecasting Big Data can support food production operations with new abilities such as demand forecasting. For instance, IBM supported bakeries by using It to analyze weather data to estimate the demand of certain products based on the amount of sunshine, temperature, and consumer preference. This also leads to optimized food operations, less food wastage, better planning, and improved resource utilization. For the efficiency of the production, Tzounis in 2017 proposed that the application of Big Data can automate processes, predict situations, and improve food production activities in real-time. It can act as a decision-making tool to provide suggestions, early warnings, and control situations. It can help in maintaining and preserving product quality.

It can delve into historical production parameters and identify the optimal settings for a production line. Also, it can reduce the time and cost of launching a new product with minimum impact on product facilities or logistics.

Big Data is revolutionizing various sectors by enabling organizations to harness vast amounts of data for strategic advantage. However, it also presents significant challenges that need to be managed through advanced technologies, skilled personnel, and robust data governance practices.



Big Data in food processes 1.7

Robotics

Robotics is an interdisciplinary field of science and engineering dedicated to the design, construction, operation, and use of robots. Robots are programmable machines capable of carrying out a series of actions autonomously or semi-autonomously. The goal of robotics is to develop systems that can assist humans in various tasks, from industrial manufacturing to exploring hazardous environments, enhancing capabilities, and improving efficiency and safety.

Robots can be outfitted with grippers, vision sensors that are devices that detect and measure physical properties such as light, sound, temperature, distance, and movement, providing robots with information about their surroundings, and other attachments to add value to the production process. They can work independently or alongside human operators on dangerous tasks or those requiring extreme precision, while manufacturers predominantly use robots for picking, packing,

and palletizing operations, they are also increasingly harnessing robots for actual food preparation, cutting or processing hot or raw/potentially hazardous foods, and much more.

Robotics technology is increasingly used in food production and processing facilities to automate repetitive tasks such as sorting, packaging, and quality inspection. They are Industrial Robots designed for precision, speed, and strength. It can move materials and products throughout the production facility, reducing manual handling and improving safety. They can help in automating repetitive and hazardous tasks, improving efficiency and precision but also automating warehousing, transportation, and delivery services.

The benefits that Robotics can bring are the increasing of the efficiency performing tasks faster and more accurately than humans, enhancing safety because robots can handle dangerous tasks, reducing the risk to human workers. Also, cost savings because automation can lead to long-term cost reductions in various industries, consistency and precision providing consistent performance with high precision, reducing errors and waste and scalability because robots can be scaled up or down based on demand and operational needs.

Robotics is a rapidly evolving field that combines multiple disciplines to create machines capable of performing a wide range of tasks. As technology advances, robots are becoming more capable and integrated into various aspects of human life, offering significant benefits while also presenting challenges that need to be addressed.

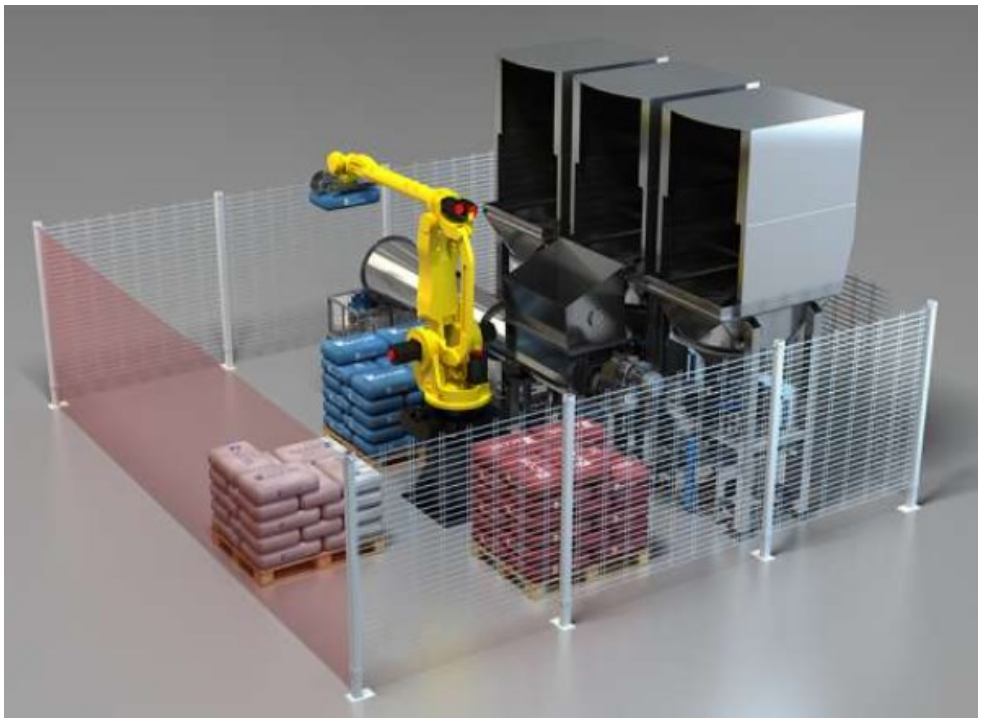
Robotics means maximizing productivity, elevating quality, and minimize waste. Robots are considered a good investment in today’s global market where companies need to be competitive. This means focusing on keeping costs down,

making high-quality products, and getting things done quickly. They can help with all of this.

Robots can help in speed and accuracy because they are fast and precise which means that they can get tasks done quickly and consistently, improve the quality because they can maintain a high level of quality throughout production, reducing errors, and waste, increase the productivity because robots can work tirelessly, freeing up human workers to focus on more complex tasks, fast payback because the initial investment in robots can be recovered quickly through the savings they generate in labor and improved production, multiple tasks because a single robot can be programmed to perform various tasks, reducing overall production time and increasing flexibility. At the same time, there are 24/7 operation, this means that robots can work around the clock, maximizing production output.

There are some disadvantages and challenges in the implementation of these robots, like the high initial investment because investing in them is costly. When you decide on adopting this technology, you should take into consideration all costs of industrial robots including initial price, installation, configuration, and maintenance, as well as costs related to keeping your robots safe from cyber threats. Another problem could be the scarcity of experts because automation is a fairly new technology in the industry. Finding people to take care of maintenance and programming can be challenging. Therefore, you need to consider that you should employ such expertise. There is also an understandable social concern that robots are stealing job from humans. “Robots require humans to operate but they are certainly replacing a big deal of what working force, forecasting losses of 20 million manufacturing jobs by 2030” (Rise of robotics in the food industry: pros, cons, and application, 2024).

Robots in food industry 1.8



The robotics applied in food industry 1.9

The robotic systems are more and more use for bags picking, cutting, and emptying, avoiding the manual handling of toxic and noxious substances.

Fertilizer production requires and involves the extensive use of acids, bases, and generally toxic/noxious products. Recipes in this way are typically prepared by dosing raw materials from bags. These robots can pick bags from different pallets, open them, empty them automatically, and then dose the contents directly into a dissolve.

The benefits are improving the safety, enhanced the efficiency, reducing the costs, and greater consistency.

Artificial Intelligence

Artificial Intelligence (AI) is a branch of computer science focused on creating systems or machines that can perform tasks typically requiring human intelligence. These tasks include learning, reasoning, problem-solving, perception, understanding natural language, and making decisions. AI aims to simulate human cognitive processes through algorithms, data, and computational power, enabling machines to operate autonomously or assist humans in various activities.

Artificial intelligence (AI) enhances food production from the very beginning of the process, with AI-driven farm equipment that can plant and harvest food. During production, Artificial Intelligence algorithms can collect food safety, supply chain, and other critical data to improve product quality and even tap into new food trends. Machine learning algorithms and Artificial Intelligence can also help manufacturers maintain quality and identify debris or contaminants in food production operations.

The benefits that AI can generate are the automation of routine tasks because It can handle repetitive tasks, freeing up human workers for more complex activities, improving decision-making because AI provides data-driven insights

and predictions, enhancing decision-making processes, increasing efficiency and productivity operating continuously and handle large volumes of data quickly, improving overall efficiency. At least It can enhance the customer experience personalizing interactions and support through chatbots, recommendation, systems, and more.

The previous digital technologies were the main ones that I am going to analyze in the food industry because they are the most used. Obviously, there are other technologies that are less applied but that concern the technologies of the industry 4.0. In food production, Ai can predict crop yields, identify potential disease outbreaks in livestock, and optimize food processing parameters to maximize efficiency and quality. In supply chain management, Artificial Intelligence algorithms can forecast demand, optimize inventory levels, and improve logistics and distribution routes, reducing food waste and ensuring timely delivery to consumers. Artificial Intelligence is used to analyze large volumes of data collected from sensors, cameras, and other sources to optimize production processes and improve decision-making.

Cloud Manufacturing

"Cloud Manufacturing (CMfg) is a modern manufacturing paradigm that leverages cloud computing technologies to enable the dynamic and efficient allocation of manufacturing resources and capabilities. It transforms traditional manufacturing systems into a network of shared, scalable, and on-demand resources that can be accessed and utilized over the Internet. This model facilitates collaboration, flexibility, and efficiency in the manufacturing process by integrating distributed resources and services" (Ichhhuda, 2021).

Cloud Manufacturing entails the application to manufacturing cloud technologies, with widespread access, and easy and on-demand IT services—

infrastructure, platform, or application—to support production processes and supply chain management. Cloud manufacturing ranges from the virtualization of physical resources necessary for factory equipment, to application data and processes across platforms and execution-and-collaboration tools, hosted in the Cloud.

Cloud Manufacturing represents a transformative approach to modernizing the manufacturing industry by leveraging cloud technologies to create flexible, efficient, and collaborative production environments. While it offers significant benefits, It also presents challenges that need to be addressed to fully realize its potential.

Additive manufacturing

Additive Manufacturing, also known as 3D Printing, is a process of creating three-dimensional objects from a digital model by successively adding material layer by layer. Unlike traditional subtractive manufacturing methods, which remove material from a solid block, additive manufacturing builds objects by adding material only where needed, thus reducing waste and allowing for more complex geometries.

It finds application in the prototyping to support the product development process, static simulation, wind tunnel, etc., manufacturing (direct production of products), maintenance and repair and modelling phases.

Additive manufacturing is a transformative technology that offers significant advantages in terms of freedom of design, customization, and waste reduction. It is increasingly being adopted across various industries for prototyping, production, and customization of complex parts. However, challenges such as

material limitations, production speed, and costs need to be addressed to fully leverage its potential.

Augmented reality

Augmented reality (AR) is a technology that overlays digital information, such as images, videos, sounds, and other data, onto the real-world environment in real-time. This integration enhances the user's perception and interaction with the physical world by adding computer-generated elements to their sensory experience. AR is achieved through devices such as smartphones, tablets, AR glasses, and headsets, which use cameras and sensors to detect the user's surroundings and superimpose the virtual content accordingly.

Augmented reality allows us to improve the visual perception of the real world. The application of augmented reality to the carcasses cutting operation has resulted in an increase in the production yield; however, the staff require training in order to benefit fully from the efficiency and capability of the Augmented Reality application rather than implementing the standard procedure of verbal communication of instructions. The Augmented Reality platform, called ARGA (Augmented Reality Grading App), enables faster, more consistent, and more accurate meat grading while taking full advantage of the experience and capabilities of the industry's meat graders. It is widely used in training the staff as well as guiding step-by-step maintenance or operating procedures.

Augmented Reality is a transformative technology that enriches the real world with digital enhancements, offering numerous applications across various industries. While it presents significant benefits in terms of user engagement, learning, and operational efficiency, It also faces challenges related to technology, cost, and user acceptance that need to be addressed for widespread adoption.

The benefits of using these technologies are different. For example, *error reduction* in which manual activities are vital and the most used in food processing however they are prone to errors and laxity. Relying on human decisions creates a platform for mistakes that results from human errors caused by factors like tiredness, distraction, pressure due to limited time, lack of motivation, human emotions, and limitations of recognizing and accessing complex relationships. Digitalization offers solutions that help to prevent and eradicate errors. Digitization also complements manual practices and human logic, intervention, and decision-making. Implementing Industry 4.0 and digitalization will improve production methods, quantity, and quality and enable more accurate control of processes.

Another important aspect could be the *production efficiency* that means the introduction of sophisticated technologies that are made possible by Industry 4.0 and digitization has already brought outstanding achievements to several companies. For example, a traditional SME bakery upgraded its mechanical controls with sensors that monitor software to reduce losses, variability, and the need for frequent checks. The automation of the processes helped the company achieve uniformity in the weight of the bread and quality improvement. Automating the production process in the company also enabled the company to save on costs while increasing its production by 5%. The monitoring system collected data within seconds while the line operated and produced information for the management. The information that the management received helped responsible parties investigate any defects, determine the origin, and implement measures to avoid recurrence. Digital solutions will help the food industries achieve several other benefits: improved working conditions, improved food safety, optimized production, reduced waste, enabling flexible and prompt change to consumer needs, and providing new career opportunities.

In the end, we can add the *automation* because industry 4.0 will enable this sector to be more responsive to rapid changes that are inevitable, unpredictable, and detrimental to the success of any business. Looking at the performance of already digitized companies, it is evident that companies will achieve more benefits with digital transformation aside from being capable of adapting to change. Automation facilitates supply and demand.

For instance, big data predicts consumers' actual demands when employed with computational tools. The benefits of automation are extensive for companies to access, analyze, and predict consumer dynamics enabling them to make suitable and timely decisions. In addition, smart sensor systems and big data enhance production, making machine processes more efficient, and reducing the number of raw materials used, energy consumption, and emission of greenhouse gasses. Also, industry 4.0 enables us to collect more data, in real time, to inform decision making, and analyze it more swiftly.

Blockchain technology

Blockchain technology is a decentralized, distributed ledger system that records transactions across multiple computers in such a way that the registered transactions cannot be altered retroactively. This technology is the foundation of cryptocurrencies like Bitcoin but has applications far beyond digital currencies. Blockchain ensures transparency, security, and integrity of data by using cryptographic techniques.

Blockchain technology provides a decentralized and transparent ledger system that enables secure and traceable transactions across the food supply chain. In food traceability, blockchain can track the journey of food products from farm to fork, providing consumers with information about the origin, product methods, and handling practices. Blockchain can also help prevent food fraud and ensure

authenticity of organic, fair trade, and other certified products by verifying the integrity of supply chain data.

Blockchain technology offers a revolutionary approach to recording and verifying transactions, providing unparalleled security, transparency, and efficiency. Its applications span numerous industries, from finance and supply chain management to healthcare and real estate. However, challenges such as scalability, energy consumption and regulatory issues need to be addressed to fully realize the potential of this transformative technology.

The digitalization of the Italian farinaceous food industry presents a compelling opportunity to enhance competitiveness, efficiency, and sustainability. By addressing the identified gaps and leveraging the outlined opportunities, the sector can thrive in the digital age, preserving its rich heritage while embracing innovation.

1.8- Analyzing the current state of sustainability practices

Food has been the most important requirement of humanity throughout the history of
the world and is a critical component of the world economy. The increase in the world
population and globalization have led to the global distribution of food. The need for
food and nutrition in modern times has led to the formation of a large food industry. With the increasing population and development of the economy and industry, discussions about the use of resources and food safety are also on the agenda. Food is influenced by the world's ecosystems and human intervention, and is a fundamental issue in academic research, especially in terms of sustainability.

All of the companies involved in producing food, from farm to fork, make up the food industry. “The term food industry can also refer to the food supply chain. A large number of global and local companies are active in the food industry, where activities such as farming, food processing, packaging, transport, sales, and customer service take place” (Simsek, Kara, Kalipci, & Eren, 2024).

Analyzing the current state of sustainability practices involves assessing how various industries, organizations, and individuals are adopting environmentally friendly practices to mitigate their impact on the planet. Many businesses are integrating sustainability into their core strategies, for example implementing renewable energy sources or adopting circular economy principles or promoting sustainable supply chain practices.

Sustainability in the food industry is increasingly critical, driven by environmental concerns, regulatory pressures, and changing consumer preferences. This industry in Italy is a vital part of the national economy and cultural identity. However, the sector faces significant sustainability challenges, including resource-intensive production processes, waste management issues, and the need to reduce its carbon footprint.

Sustainable sourcing is critical in reducing the environmental impact of raw material production. Italian farinaceous food producers are increasingly adopting practices such as: sourcing grains from organic farms that use no synthetic pesticides or fertilizers, reducing transportation emissions by sourcing raw materials locally, and ensuring fair labor practices and equitable trade conditions for suppliers (Altieri, 2018). Also, energy consumption is a significant concern in the farinaceous food industry. Practices to improve energy efficiency can include to invest in solar, wind, and other renewable energy sources to power production facilities, to implement advanced systems to monitor and optimize energy use, and to upgrade equipment and processes to reduce energy consumption. For what

concerns the waste reduction, this means to reuse by-products and waste materials in other production processes, converting organic waste into compost or bioenergy, developing biodegradable and recyclable packaging materials to reduce plastic waste. Reducing greenhouse gas emissions is a key objective for the industry, like measuring and tracking carbon emissions across the supply chain, setting and achieving specific targets for emission reductions, and investing in projects that offset carbon emissions (reforestation). Social sustainability practices ensure that the industry's growth benefits all stakeholders ensuring safe and fair working conditions for all employee, supporting local communities through various social initiatives, and informing consumers about the sustainability of products and encouraging sustainable consumption. The several challenges regards high initial investment costs for sustainable technologies and practices, navigating complex and sometimes inconsistent regulations, limited availability of advanced sustainable technologies, and resistance to change within traditional production methods (P. Pradhan, 2015). Reducing wastefulness through more efficient utilization of natural capital has to be at the core of any sustainability initiative. Consequently, it stands to reason that pollution prevention strategies that improve efficiency by eliminating waste at its source should also be a guiding strategy for sustainable development.

The Italian farinaceous food industry has made significant strides in adopting sustainable practices, but there is still considerable room for improvement. By addressing the identified challenges and leveraging the opportunities, the sector can enhance its sustainability performance, contributing to environmental conservation and social well-being while maintaining its tradition of quality.

The food industry is at a critical juncture where sustainable practices are essential for the long-term well-being of humanity and the planet. "The study suggests that future research should focus on sustainable food chains, the impact of sustainable diets, and the relationships among agri-food systems, sustainable agriculture, and the overall sustainability of the food chain. The researchers call for a concerted

effort to develop a more inclusive and equitable food system that benefits all members of society" (Simsek, Kara, Kalipci, & Eren, 2024).

1.9- Identifying barriers and enablers for sustainable digital transformation

Sustainable digitalization involves encouraging the development and use of technologies with sustainability considerations in mind (for example sustainability by design). This ensures that technological advancements prioritize ethical considerations and environmental sustainability throughout their lifecycle. "Sustainable digitalization is the compass that guides us toward a future where technology empowers society while minimizing its environmental footprint. By embracing sustainable practices in our digital endeavors, we can ensure a more equitable distribution of benefits and reduce our impact on the planet, ultimately leading to a better quality of life for all. The key facts about digital sustainability regards environmental impact, carbon footprint, e-waste, and dual impact of digitalization" (Sustainable Digitalization, 2024).

"Sustainability and digitalization are big topics these days. Digital transformation is the form that IT development is taking nowadays that goes beyond digitizing information processing but includes a transformation of the organization, for instance new digital services or new business models. Digital transformation projects are therefore in a unique position to realize the sustainable development agenda" (Gils & Weigand, 2020).

Sustainable digital transformation involves integrating digital technologies in a manner that enhances sustainability across various aspects of the business. For the Italian farinaceous food industry, achieving this transformation requires overcoming specific barriers and leveraging enablers.

For example, many small and medium-sized enterprises might lack the necessary digital skills and knowledge to implement new technologies. Also, the upfront

investment required for digital transformation, including hardware, software, and training, can be expensive for smaller businesses.

“Barriers to sustainable digital transformation are advanced technologies such as IoT, artificial intelligence, and blockchain involve significant upfront costs, which can be prohibitive for small and medium-sized enterprises (SMEs), and uncertainty regarding the ROI of digital transformation projects can deter investment, especially when short-term financial pressures are intense” (Denicolai, Zucchella, & Magnani, 2021). There is also a shortage of professionals with the necessary skills to implement and manage digital technologies in the food industry, and employees accustomed to traditional methods may resist adopting new technologies, fearing job displacement or increased complexity in their work routines. “Increasing consumers demand for transparency and traceability in food production pushes companies to adopt blockchain and other traceability solutions, and growing consumer and market expectations for sustainability drive companies to implement digital solutions and enhance environmental performance” (Mckinsey & Company, 2019).

Another important aspect is the transformation of the industry ecosystems in cities and regions under the influence of digital and green transition. The problem concerns the pathways of industrial transformation linked to digital and green transitions. these pathways can connect digital and green technologies enabling a twin transition, produce system innovation leading to a radical change of routines, and transform economic activities and industry ecosystems. Such pathways can connect digital and green technologies, and they allow the current transformation of industrial activities and ecosystem to be mastered. The three instances of this pathway are: the *prioritization* that allows the potential for system change in the most important industries to be assessed, while maintaining a high level of granularity and detail, the *ecosystem identification* that delineate the change at the level of industry groups rather than individual companies,

maximizing the impact and ensuring the public character of innovation policy, and in the end *platform-based smart and green transition* strengthens the ecosystem perspective with technologies and solutions over which many organizations can build complementary products and services.

“Two reasons justify the orientation of this approach: first, the widely accepted principle of smart specialization for a place-specific innovation strategy or “one-size-does-not-fit-all”, which suggests that theoretical predictions about future growth should be assessed and validated with place-specific data; second, the probability of finding innovative smart/green solutions in less expected activities, a trend outlined in many aspects of the innovation theory, such as the probabilistic and nondeterministic character of innovation, serendipity in innovation, and innovation outcomes by chaotic systemic combinations” (Komninos, 2022).

Chapter 2

2.1- Definition of sustainability and theoretical frameworks

Sustainability from the Latin word “sustinere” means “take care, support, defense, preserve, and encourage” and we have not to consider it as a status or an immutable vision but like a continuous process. In fact, the sustainable development was defined in 1987 in “Brutland Report” as a condition that can ensure the needs satisfaction of the present generation without compromising the possibility for the future generations to realize theirs”.

Achieving sustainability requires a holistic and integrated approach that considers the interconnections between environmental, social, and economic factors. It involves balancing competing interests and trade-offs to achieve long-term resilience and well-being for both current and future generations.
In practice, sustainability is often pursued though various strategies and initiatives, including: adopting sustainable practices and technologies in industries such as agriculture, energy, transportation, and manufacturing, implementing policies and regulations that promote sustainability and address environmental, social, and economic challenges, encouraging public and private sector collaboration, stakeholder engagement, and community participation in decision-making processes and investing in education, research, and capacity-building to raise awareness, build skills, and foster innovation for sustainable development. Ultimately, sustainability is a collective responsibility that requires cooperation and commitment from individuals, communities, businesses, governments, and international organizations to create a more equitable, resilient, and thriving world for present and future generations.

In the Italian farinaceous food industry, known for its production of pasta, bread, and other flour-based products, integrates several theoretical frameworks to

enhance sustainability. These frameworks provide structured approaches to achieve and measure sustainability goals. Large companies have the legal requirement to present a sustainability report that is available, and it can be found on the Internet.

The first one is the *triple bottom line (TBL),* that focuses on three performance areas: people, planet, and profit, encourages business to consider social and environmental impacts alongside financial performance, and in this context this might involve sourcing wheat from sustainable farms, ensuring fair wages and working conditions for employees, and reducing waste in production processes.

Then, *life cycle assessment (LCA),* that analyzes the environmental impacts of a product from cradle to grave (production, distribution, consumption, and disposal), help identify critical points where environmental impact can be reduced and for pasta production, life cycle assessment might examine the energy and waste usage in wheat cultivation, emissions from transportation, and waste management practices.

Circular economy aims to eliminate waste and promote the continual use of resources, encourages redesigning products and processes to ensure materials are reused, repaired, or recycled, and this could involve using by-products from wheat milling as bioenergy, and designing packaging that is recyclable or compostable.

*Sustainable supply chain management (SSCM)***,** integrates sustainability into the supply chain, ensuring that each step, from raw material sourcing to product delivery, is environmentally and socially responsible, focuses on transparency, traceability, and collaboration with suppliers and stakeholders, and this might

involve working with farmers to adopt sustainable agricultural practices and ensuring suppliers adhere to ethical labor standards.

At the end *Corporate social responsibility (CSR),* encourages businesses to operate in a socially responsible manner, involves voluntary actions by companies to improve social and environmental conditions, and corporate social responsibility initiatives could include community engagement programs, supporting local economies, and investing in sustainable technologies.

The Italian farinaceous food industry, with its deep cultural roots and global influence, has the potential to be a leader in sustainability (Barilla, Sustainability Report: our journey towards a sustainable future, 2020). By adopting and integrating various theoretical frameworks, the industry can address environmental, social, and economic challenges, ensuring a sustainable future for generations to come.

There are some applications in the production processes like implementing energy-efficient technologies in milling and pasta production, reducing water usage and recycling wastewater in production facilities. Also, in packaging and distribution using biodegradable or recyclable packaging materials, optimizing logistics to reduce carbon emissions from transportation, innovation and research is important investing in research to develop new, sustainable products and production methods, collaborating with universities and research institutions to advance sustainable practices in the industry.

2.2- Key principles of sustainability

There is a wide range of interpretations regarding what sustainability truly entails and how it should be achieved. There are three such “sustainable principles,”

drawing from well-established pollution prevention techniques. These principles emphasize the development and implementation of more efficient systems that minimize waste by enhancing the quality of products, processes, and systems. By adhering to these principles, we can optimize the use of resources throughout the entire life cycle of systems, thereby enhancing the sustainability of our ecosystems, production capabilities, community resources, and human resources.

The key principles of sustainability guide practices and policies to ensure long-term viability and well-being for both the environment and human societies.

Technologies 4.0 seems to have the potential to growth the economic, environmental, and social sustainability. Talking about sustainability we can distinguish between three different "pillars": *economical sustainability, social sustainability,* and *environmental sustainability* (Geissdoerfer, Vladimirova, & Evans, 2018).

The *economic sustainability* is the activity or practice that helps to support long-term financial growth keeping the environment, community, and social factors in mind. It is the production and the maintenance, internally the environment, of favorable conditions for the economic growth throughout a correct and efficient exploitation of the resources. The main goal is to create a balance between economic growth and the development of positive change for the environment and humanity. There are some factors that affect the economic sustainability including the responsible managing resources, the capacity for efficiency and innovation of economic systems and enterprises, financial stability at the macro-level, the level of equity and social inclusion, corporate responsibility.

The *social sustainability* involves a focus on the well-being of people and communities, promoting equity, human rights, access to education and health care that is equally distributed to the community. To achieve It, It is necessary to overcome poverty and socioeconomic inequality promoting equal access to

opportunities and resources for all individuals and addressing social injustices and reducing inequalities within and between communities, discrimination, prejudice and social exclusion, so respecting and preserving cultural heritage and diversity, integrating cultural heritage and diversity but also integrating cultural considerations into sustainable development practices, lack of access to resources, insecurity and conflict and poor governance. Social sustainability means also improving the quality of life enhancing the well-being and health of individuals and communities, ensuring access to essential services such as education, healthcare, and housing.

The *environmental sustainability* is the ability to preserve and protect the natural environment over time through appropriate practices and policies, meeting present needs without compromising the availability of resources in the future (air, water and soil pollution, climate change, loss of biodiversity, overexploitation of natural resources). There should be an awareness of the natural resources, trying to preserve the functions of the environment as resource provider and waste receptor, promoting renewable energy sources. The goal is to reduce greenhouse emissions, increasing the use of energy from renewable sources, implementing policies to conserve biodiversity, adopting sustainable practices in agriculture and the food chain such as agrivoltaics and regenerative agriculture, raising the awareness and engaging communities on the issue of environmental sustainability, promotion of the circular economy.

There are also some integrated principles such as recognizing the interconnectedness of environmental, economic, and social systems, addressing sustainability challenges in a comprehensive and integrated manner, building systems and communities that are resilient to environmental, economic and social shocks, promoting adaptive management and flexibility to respond to changing conditions. It is important that the needs of the present and future generations are

met by avoiding actions that compromise the ability of future generations to meet their own needs.

These key principles of sustainability provide a comprehensive framework for achieving a balanced and enduring approach to development. By integrating these principles into policies, practices, and everyday decisions, societies can work towards a more sustainable and equitable future.

Natural capital is depleted in two main ways: through consumption and through degradation. Consumption involves using raw materials like water, metals, chemicals, paint, plastic, and wood in products, which eventually exit the value chain as unusable waste. It also includes the use of non-renewable energy sources—once fossil fuels are burned for energy, they are gone forever. Degradation refers to the resources consumed to manage waste, such as landfills, and the pollution released into the environment. As pollutants accumulate in water, air, soil, and living organisms, they degrade these resources, diminishing their value as essential components of natural capital. Society also squanders natural capital through degradation caused by neglect and overuse in several areas:

Ecosystems: excessive use of national parks and wilderness areas has led to significant degradation, diminishing these cherished resources for both present and future generations.

Production capabilities (factories, farms, etc.): when factories are closed in the American industrial sector, the natural capital invested in these facilities is lost. Similarly, unsustainable farming practices degrade topsoil and pollute water bodies, reducing their potential value for current and future generations.

Community resources: Urban decay diminishes the value of existing infrastructure, wasting the natural capital that was originally invested in it.

Human resources: The deterioration of ecosystems, production capabilities, and community resources lowers the quality of life for both current and future

generations, thus squandering their potential. Severe wastefulness can lead to shortages of essential goods, potentially causing social unrest and even conflict. As Lozano (2008) observed, “When individuals and societies are unable to meet their basic needs, the long-term protection of the environment becomes a lower priority, at least in the short term” (Lindsey, 2011).

Reducing wastefulness through more efficient utilization of natural capital has to be at the core of any sustainability initiative. Consequently, it stands to reason that pollution prevention strategies that improve efficiency by eliminating waste at its source should also be a guiding strategy for sustainable development. Reducing waste is a central focus in nearly every quality improvement program in today’s business environment. Waste is essentially the outcome of a flawed product, process, or system. Therefore, eliminating defects and waste through quality improvement is a logical approach to conserving natural capital and enhancing sustainability. Historically, from the first industrial revolution up until World War II, the prevailing business mindset was that quality and productivity were inherently in conflict. This belief was debunked by innovators like Deming (1982), who demonstrated that both quality and productivity could be improved simultaneously by preventing defects and waste. The modern sustainability movement builds on this idea, suggesting that if we can boost productivity and quality by reducing defects and waste, we can also enhance sustainability and quality of life by preventing waste and pollution. “Quality assurance programs like "LEAN" or "Six Sigma" often highlight seven major types of waste that can significantly hinder an organization’s efficiency” (Womack and Jones, 2003). These includes: over-production, waiting, transport, processing, inventory, motion and rejects.

2.3- Global trends and case studies in sustainable food practices

Balancing food supply and demand in a sustainable way that ensures the long-term survival of humanity will be one of the most critical challenges in the coming decades. The rapid population growth over the past few centuries, combined with the demands of industrialization, has made food production and processing a pressing issue. This challenge is expected to intensify in the next 50 years as the global population surpasses 9 billion. Environmental concerns related to food production, such as land use changes, significant biodiversity loss, aquatic eutrophication from excessive use of nitrogen and phosphorus fertilizers, climate change, water shortages from irrigation, ecotoxicity, and the human health impacts of pesticides, are key issues that need to be addressed. This review highlights key points from the recent book "Green Technologies in Food Production and Processing," which offers a thorough overview of the current state of agriculture and the agri-food industry in terms of environmental sustainability and resource management. The book also provides strategies for industries to adopt more eco-friendly technologies in food production and processing. Food is a fundamental part of life and essential for human survival. Throughout history, people have relied on food for sustenance. In ancient times, when the human population was much smaller, resources were plentiful, and there was little need for advanced food processing or storage methods. However, as populations grew, limited food processing and storage capabilities meant that many people had to spend significant amounts of time each day gathering food through harvesting and hunting to feed themselves and their families. The advent of industrialization caused a large portion of the population to shift toward various other activities, which created a demand for an industrialized food sector to support the growing number of urban residents. Since the Industrial Revolution, global food production has seen a substantial increase, but this growth has not kept pace with the rapidly expanding population. The result has been significant waste and inefficient resource distribution. Currently, 3 billion

people worldwide are malnourished, with 2 billion suffering from iron deficiency and nearly 800 million affected by protein and calorie shortages. Meanwhile, most land and aquatic resources are being overexploited, and shockingly, 30–50% of the food produced is wasted. Some of the most pressing environmental issues we face today include changes in land use, drastic reductions in biodiversity, aquatic eutrophication caused by excessive nitrogen from fertilizers, global warming driven by enteric fermentation and fossil fuel use, water shortages due to irrigation, ecotoxicity, and the harmful effects of pesticides on human health. Green technology, as defined by Wikipedia, is the "application of one or more of environmental science, green chemistry, environmental monitoring, and electronic devices to monitor, model, and conserve the natural environment and resources, and to curb the negative impacts of human involvement" http://en.wikipedia.org/ (Boye & Arcand, 2013).

“Global trends in sustainable food practices reflect growing awareness and efforts to address the environmental, social, and economic impacts of food production and consumption. These trends are driven by consumer demand, technological advancements, policy changes, and a greater understanding of the need for sustainability in the food sector” (FAO, 2018).

For example, *plant-based diets and alternative proteins* that means increasing consumer preference for plant-based diets to reduce environmental impact and improve the wealth, growth of plant-based meat and dairy alternatives, such as products made from soy, pea protein, and oats, develop and commercialize of law-grown (cultured) meat as sustainable protein alternatives and invest in research and innovation to make these products more affordable and accessible.

Also*, reduction of food waste,* meaning implementing technologies and practices to reduce food loss during production, transportation and storage, better inventory management and improved logistics to minimize waste in retail and foodservice sectors. Food loss and waste (FLW) in one of the most serious social, economic and environmental issues undermining our planet’s sustainability, and

by reducing it some UN Sustainable Development Goals may be achieved. “Reducing food and loss waste is also beneficial for company economic sustainability since it was observed that for every dollar invested in reducing it there is a saving of 14 dollars in operating costs” (Principato, Ruini, Guidi, & Secondi, 2019).

Sustainable packaging, using eco-friendly materials, shifting from single-use plastics to biodegradable, compostable, and recyclable packaging materials, innovations in edible packaging and minimal packaging design, making initiatives in circular economy promoting the reusage and refill of the models, such as bulk bins and returnable containers, developing infrastructure to support recycling and composting at scale.

Consumer demand for transparency, for example traceability and transparency, growing consumer demand for information about the origin, production methods, and environmental impact of food products, the use of blockchain and other technologies to provide transparency and traceability in the food supply chain.

Use of *sustainable ingredients*, increasing grains grown using organic and regenerative methods, practicing rotation, reduced tillage, and covering cropping to enhance soil health and biodiversity.

Reduction of the environmental impact like water conservation, implementing water-saving technologies and practices in wheat cultivation and pasta production, recycling and reusing water in production processes. But also, upgrading production facilities to reduce energy consumption, such as using energy-efficient ovens and drying processes, adoption of renewable energy sources like solar and wind power to reduce carbon footprints.

Product innovation and health focus, developing and promoting whole grain enriched pasta products that offer higher nutritional value, adding functional ingredients such as legumes, vegetables, and fiber to pasta and bread to cater to health-conscious consumers. For gluten-free and specialty products means

expanding the range of gluten-free options to cater to consumers with dietary restrictions and innovating with alternative flours like chickpea, lentil, and quinoa flours.

These global trends in sustainable food practices reflect a shift towards more responsible and mindful food production and consumption. By adopting these practices, the food industry can reduce its environmental footprint, enhance social equity, and ensure economic viability, contributing to a more sustainable and resilient global food system.

2.4-Definition of digitalization and theoretical frameworks

Digitalization refers to the integration of digital technologies into everyday life and business processes. It involves transforming analog processes and systems into digital ones, resulting in improved efficiency, enhanced capabilities, and the creation of new value propositions. “Digitalization goes beyond mere digitization (converting analog data into digital format) by fundamentally altering how businesses operate and deliver value to customers” (Dieffenbacher, 2024).
The digitalization is defined as the process of leveraging digital technologies to transform a business model, creating new revenue streams and value-producing opportunities. This involves integrating digital tools and systems into various aspects of a business’s operations, from management and communication to production and customer service. It enables organizations to adapt to rapidly changing market conditions, meet customer expectations, and optimize their processes for greater efficiency and productivity. It makes processes easier and more efficient especially in today’s tech-driven world where it is crucial to adopt a digital culture in order to survive and succeed

The rapid rise and development of digital technologies, and their widespread adoption across various industries, products, services, and supply chains within

and between organizations, have made it increasingly important for small businesses to embrace digitalization. Generally, digitalization refers to the use of digital technologies to transform value-creating processes and business models. Related terms such as the fourth industrial revolution, Industry 4.0, the Internet of Things (IoT), and other information systems (IS) concepts are often used interchangeably to describe this phenomenon. There is broad consensus that micro, small, and medium enterprises (SMEs) play a crucial role in sustaining economic growth and creating jobs at both national and global levels, as well as in developing and deploying digital technologies. These firms, which constitute the vast majority of businesses and contribute 50–60% of value added, are collectively referred to as SMEs. The concept of 'smallness' has been debated among scholars for decades, with various criteria proposed to distinguish SMEs from large enterprises, such as ownership structure, industry sector, revenue, and assets. Despite their smaller size, SMEs often maintain close relationships with suppliers and customers and exhibit flexible, agile structures and processes that are crucial for digital transformation. However, the investments and capabilities needed to embark on the digital journey and gain a competitive edge are often more accessible to large enterprises. This disparity in the use of digital solutions to boost productivity between small and large corporations is often referred to as the business digital divide. Unlike born-digital firms, whose business models are built around digital technologies many traditional small enterprises remain uncertain about the benefits of digitalization, as well as how, when, and to what extent they should adopt digital technologies. Research on how organizations can plan for digitalization has primarily focused on large enterprises, particularly in manufacturing, through frameworks like ‘maturity models’ and ‘digital readiness’ assessments. However, relatively little attention has been paid to whether these approaches are suitable for SMEs, leaving the digitalization of SMEs an underexplored area. “Recent criticism has emerged due to the failure to consider the unique contexts of SMEs, with digitalization often being treated as a ‘black box’ that companies must simply adapt to. There is a clear gap in understanding

how digitalization impacts SMEs' structures, processes, and business development, necessitating further research" (Meier, 2023).

The industrial world is facing rapidly changing challenges, including geopolitical tensions, technological changes, shifts in global markets, and the impact of climate change. The most widely used classification, based on European Union regulations (2003), categorizes businesses with up to 10 employees and less than 2 million euros in turnover as micro firms, those with up to 49 employees and less than 10 million euros in turnover as small enterprises, and those with 50 to 250 employees and an annual turnover not exceeding 50 million euros as medium-sized enterprises. In the context of global digitalization, these firms face increasing pressure from an evolving ecosystem while also grappling with limited time and resources.

Digitalization and automation are the game changers to meet these challenges. It is essential to collect, understand and use the massive amount of data created in the Industrial Internet of Things (IoT). Combining the real and the digital worlds makes it possible to seamlessly integrate the entire value chain from design to realization, while optimizing with a continuous flow of data.

Digital technologies can be a driver for firms' international expansion and can provide smaller ventures with new instruments and approaches to reach and serve global customers, as well as new ways to organize economic activities and business operations. Over the last years, manufacturing companies have had to face several challenges, mainly related to the volatility of the demand and the continuously changing requirements, both from customers and suppliers. In the meantime, new technological roadmaps and suggested interventions in manufacturing systems have been implemented. These solutions aim to exploit the high innovation and communication technology (ICT) in industry (M. Demartini, 2018). Industry 4.0 is a complex and flexible system that presents

types of challenges and opportunities, for example the introduction and integration of new technologies in order to improve quality, efficiency and competitiveness. Specifically, the food industry has recently changed from a supply-based approach to a demand-based approach, the so called “chain reversal”, in which the customers tell producers what they want to eat. Production will be tailored to customer demand.

Digital innovation has garnered substantial interest recently in both academic and practical realms. Despite this growing attention, it remains an emerging field, not yet fully established as a distinct area of research. This nascent domain draws from various social science disciplines, striving for theoretical and conceptual coherence to better inform both research and practice. The digitization of innovation challenges traditional notions of value creation necessitating new theoretical developments and alternative conceptualizations. Digital innovation involves using digital technology during innovation processes or as innovation outcomes. Traditional industries face challenges in digitizing products and offering digital services. Unlike traditional value chain structures, digital innovation creates value through more dynamic and interconnected processes. “The three key challenges in digital innovation research are: developing explanations of digital innovation that recognize the intricate interactions between social and material elements, creating theories that incorporate the unique characteristics of digital technologies. And developing theories that oscillate between detailed, specific insights and broader, general principles” (Holmstrom, 2018).

The theoretical frameworks of digitalization are different: *sociotechnical systems theory* in which it emphasizes the interdependence between social and technical systems. “Digitalization is seen as a process that involves both technological innovation and social change. It focuses on how digital technologies are integrated into organizational processes and how they interact with social

elements such as culture, work practices, and human behavior" (Mumford, 2006). "*Resource-based view (RBV)* that looks at digitalization in terms of a firm's resources and capabilities. It posits that digital technologies can provide firms with unique resources that can lead to competitive advantages. The focus is on leveraging digital assets (e.g., data, software, digital platforms) to enhance business performance and create new value" (Barney, 1991). "*Dynamic capabilities framework* that extends the RBV by emphasizing the need for firms to continuously adapt, integrate, and reconfigure their resources in response to rapidly changing digital environments. Dynamic capabilities include sensing opportunities and threats, seizing opportunities, and transforming organizational resources to address these changes" (D. J. Teece, 1997). "*Digital business ecosystems* view digitalization as a phenomenon that transcends individual firms, focusing instead on the broader ecosystem of interconnected businesses, technologies, and stakeholders. Digital ecosystems are characterized by complex interactions and interdependencies among various actors, facilitated by digital platforms and infrastructures*"* (M. Iansiti, 2004). *"Disruption theory* examines how digital technologies disrupt existing markets and business models. It explores how incumbents are challenged by new entrants that leverage digital innovations to offer superior value propositions. This framework helps in understanding the transformative impact of digitalization on industries and competitive dynamics" (Christensen, 1997). "*Institutional theory* considers the role of institutional forces (e.g., regulations, norms, standards) in shaping the digitalization process. It looks at how digital technologies are adopted and diffused within organizations and industries in response to institutional pressures and how they conform to or challenge existing institutional structures" (Scott, 2008).

Digitalization is a multifaceted phenomenon that involves the integration of digital technologies into all aspects of life and business. The theoretical frameworks discussed provide various lenses to understand and analyze

digitalization, each highlighting different aspects such as sociotechnical interactions, resource capabilities, dynamic adaptation, ecosystem interdependencies, market disruption, and institutional influences. Understanding these frameworks helps in comprehensively grasping the complexities and opportunities presented by digitalization.

2.5- Global trends and case studies in food industry digitalization

In contemporary society, digitalization and sustainability are prominent and often-discussed concepts. The ongoing economic challenges stemming from the 2008 financial crisis continue to impact the global economy, exacerbating social inequalities. Simultaneously, environmental issues such as global warming and pollution are severely affecting the well-being and productivity of nations and damaging the planet's biodiversity.

Digitalization, recognized as a mega-trend, is being increasingly adopted by companies aiming to innovate and seize new opportunities in the digital era. This scenario prompts a critical question among scholars, governments, and businesses: can digitalization drive or align the world towards sustainable development?

The results indicate that blockchain technology can impact sustainability across all dimensions. "The iterative information-gathering process of the framework highlighted significant sources of impact. Positive impacts include support for small farmers, reduction in food waste, smart contracts, combating illegal practices, reduced intermediary roles, and promoting equality in design. Conversely, negative impacts are associated with high energy consumption, digital divide issues, and potential monopolies in service provision" (Delpero, 2019).

“The global trends in digitalization are profoundly influencing the Italian farinaceous food industry, which includes pasta, bread, and other flour-based products. These trends encompass the adoption of advanced technologies, sustainability practices, and consumer engagement strategies” (Aagaard).

The global trends in digitalization are Internet of Things and smart sensors that are increasingly used to monitor and optimize production processes, from farming to manufacturing. These technologies help in tracking real-time data on environmental conditions, machinery performance, and supply chain logistics. Artificial intelligence and machine learning are used to analyze large datasets, predict consumer behavior, and optimize production schedules. These technologies enable companies to improve efficiency, reduce waste, and personalize product offerings. Blockchain for supply chain transparency provides a secure and transparent way to trace the origin and journey of raw materials and finished products. This ensures authenticity, sustainability, and ethical sourcing, which are increasingly important to consumers. “Sustainable and circular economy practices are facilitating the shift towards circular economy models, where waste is minimized, and materials are reused. Companies are adopting practices such as recycling, upcycling, and sustainable sourcing, supported by digital tracking and management systems” (Hess).

The Italian farinaceous food industry is experiencing significant transformations driven by global digitalization trends. Companies like Barilla, and De Cecco, are at the forefront, leveraging digital technologies to enhance efficiency, ensure sustainability, and engage consumers. Through precision agriculture, blockchain for supply chain transparency, smart manufacturing, and sustainable practices, these companies are setting benchmarks for the industry. As digitalization continues to evolve, the synergies between digital technologies and sustainability

will play a crucial role in shaping the future of the Italian farinaceous food industry.

Several emerging trends are set to shape how people consume food in the coming years. Numerous studies in the literature highlight key issues and tendencies influencing the food market, offering valuable insights into how consumers, businesses, and policymakers are adapting to these changes. Some of the most significant trends include:

Plant-based foods: the popularity of plant-based foods is expected to continue rising as more individuals embrace vegan and vegetarian diets or aim to cut back on meat consumption. This trend is leading to a greater variety and availability of plant-based products, including meat substitutes, dairy alternatives, and plant-based snacks.

Sustainable and regenerative agriculture: increasing consumer awareness of the environmental impact of food production is driving demand for products that come from sustainable and regenerative agricultural practices. Techniques like organic farming, crop rotation, and regenerative grazing contribute to soil health restoration and lower carbon emissions.

Functional foods: there is a growing interest in foods that provide health benefits beyond basic nutrition. This has fueled the development of functional foods, which include ingredients like probiotics, prebiotics, and antioxidants that support digestive health, enhance immunity, and reduce inflammation.
Personalization: advances in technology and data analytics are enabling more personalized food options tailored to individual preferences and needs. This includes customized meal plans, DNA-based diets, and personalized nutrition advice based on factors such as age, gender, and lifestyle.

Convenience: the demand for convenient and easy-to-prepare food options is increasing, driven by busy lifestyles. This trend is evident in the popularity of pre-packaged meals, meal delivery services, and grab-and-go snacks, which cater to the need for quick and effortless meal solutions.

“These trends highlight a growing consumer preference for healthier, more sustainable, and personalized food options that align with evolving needs and lifestyles” (Coriglioni & Algieri, 2024).

The food market is a dynamic and complex industry. As consumer preferences and behaviors continue to evolve, companies must adapt and innovate to stay competitive and meet shifting market demands. Several key factors drive the growth, profitability, and sustainability of the food industry:

*Technological advancements and innovation**:*** the food industry is in a constant state of evolution, with new technologies reshaping how food is produced, processed, and distributed. Innovations such as precision agriculture, robotics, and smart technologies are at the forefront of this transformation.

Environmental and sustainability challenges: the food industry faces growing pressure to address environmental and sustainability issues, including reducing greenhouse gas emissions, conserving water, and minimizing food waste. As a result, sustainable farming practices and circular economy models are becoming increasingly popular.

Food safety and quality standards: the industry is subject to increasingly stringent regulations to ensure the safety and quality of food products, aiming to prevent contamination and product recalls.

Consumer trends and preferences: shifts in consumer tastes and preferences significantly influence the food industry. There is a growing demand for healthier, more sustainable food options, including plant-based and alternative protein sources.

Economic and political influences: trade agreements and government policies play a crucial role in the food industry. “Factors like tariffs and trade barriers can affect the cost and availability of imported food products” (Coriglioni & Algieri, 2024).

2.6- Synergies between digitalization and sustainability

The Sustainable Development Goals (SDGs) of the United Nations 2030 Agenda emerged in 2015, becoming a global compass for navigating extant sustainability challenges. The field of digitalization and sustainability is still emerging and faces uncertainties and complexities. Despite the promising interplay between digitalization and sustainability, there's limited evidence on how digital paradigms genuinely contribute to sustainability and address SDGs research gaps. Sustainability and digitalization are major trends that have the potential to transform the economy and society. The intersection of these domains presents significant opportunities for sustainable development, yet challenges persist, and the field remains underexplored. “Digitalization, particularly through Big Data and Artificial Intelligence (AI), is seen as a promising avenue for advancing sustainability and achieving the SDGs. However, the field is nascent and faces various technological and non-technological challenges, including ethical, social, and environmental controversies” (Del Rio Castro, Camino Gonzalez Fernandez, & Uruburu Colsa, 2021).

“Digitalization and sustainability are two of the most influential trends shaping modern economies and societies. While digitalization refers to the integration of

digital technologies into everyday life and business processes, sustainability focuses on meeting present needs without compromising the ability of future generations to meet theirs. The synergy between these two fields can foster substantial advancements towards a more sustainable future" (Osburg & Lohrmann, 2017).

"IoT devices and smart sensors enable real-time monitoring of production processes, energy usage, and resource consumption. This leads to optimized operations and significant reductions in waste and predictive maintenance, powered by IoT, allows for timely maintenance of equipment, preventing unexpected breakdowns and extending the lifespan of machinery. This reduces waste and improves resource efficiency" (Seele, 2016). Advanced data analytics and AI algorithms can analyze vast amounts of data to identify inefficiencies and optimize production processes. This results in lower energy consumption and minimized waste and AI-driven demand forecasting improves inventory management by aligning production with actual demand, reducing surplus and minimizing food waste. Blockchain ensures complete traceability of products from origin to consumer, enhancing transparency and accountability in supply chains. This can help verify sustainable practices and reduce fraud and it can secure and streamline the verification process for sustainability certifications, ensuring authenticity and boosting consumer trust. Digital supply chain management systems optimize logistics and transportation routes, reducing fuel consumption and greenhouse gas emissions and they facilitate better collaboration with suppliers, ensuring compliance with sustainability standards and improving overall supply chain sustainability. Advanced weather forecasting models help farmers plan their activities more effectively, reducing crop damage and enhancing yields and data analytics support efficient resource management, promoting sustainable land use and conservation practices. Digital technologies facilitate the development and testing of eco-friendly packaging solutions, reducing plastic use and promoting recyclability and digital tools enable

comprehensive lifecycle assessments, helping companies design products with minimal environmental impact.

Sustainability is a multifaceted concept with various interrelated elements that do not always work together harmoniously. Assessing the impact of cross-cutting factors, such as digitalization, can be challenging, as achieving certain goals might unintentionally impede progress on others. There is a strong correlation between composite indices for digitalization (IDI Development Index), sustainability (SDG Index), and economic growth (GCI and GDP). However, a closer look at more granular indicators paints a more mixed picture. Specifically, two sustainability goals and 22% of the sustainability indicators in the SDG "Index showed negative relationships with digitalization. This suggests that while there are synergies in areas related to economic and social sustainability, there are trade-offs in environmental protection aspects such as climate change, resource depletion, and waste generation, which are negatively associated with current economic development models. Recognizing and managing these structural challenges is crucial for achieving balanced and effective progress towards sustainability" (Perez-Martinez, Hernandez-Gil, San Miguel, Ruiz, & Arredondo, 2023).

Digitalization is increasingly seen as a powerful force for advancing sustainable development. However, aligning digitalization efforts with the globally recognized Sustainable Development Goals (SDGs) is essential for achieving comprehensive and inclusive sustainability in the digital age. Despite its potential, the SDGs currently offer limited guidance on leveraging digital capabilities. Moreover, research on how digitalization affects the SDGs is fragmented and sparse. Few studies have thoroughly examined and categorized the impact of digitalization on sustainable development. There is the introduction of the Digitainability Assessment Framework (DAF), a new tool designed to evaluate how digital interventions impact the SDGs in a practical and context-

aware manner. The DAF enables a detailed analysis of various technical, social, ethical, and environmental aspects of digital interventions by examining their effects on SDG indicators. This framework adapts concepts from the Theory of Change (ToC) and aims to assist developers, users, and policymakers by offering a comprehensive view of digital services or products and suggesting potential improvements. Digitalization, particularly artificial intelligence (AI), plays a crucial role in accelerating progress towards the SDGs. As Tegmark highlights, "the more intelligent and powerful machines get, the more important it becomes that their goals are aligned with ours," referring to the SDGs in this context. Digitalization encompasses the widespread adoption of technologies that generate, process, and transfer information. It is vital to explore how digital interventions can align with sustainable development goals, considering the specific objectives of the 2030 Agenda. A mindful approach to digitalization involves understanding where we are in the development process and how to use digital tools effectively within a sustainability framework. This approach helps avoid uncritical optimism or systematic pessimism, ensuring that technology is applied in ways that support sustainable development. It is important to assess why digital interventions are used, what problems they address, who is responsible, when they produce results, and how they function in practice. Digitalization is widely seen as a crucial driver of sustainable change. The rapid adoption of digital technologies highlights their versatility and power, enabling them to perform tasks that traditionally required extensive human effort. Despite various challenges, there is increasing momentum in using digital interventions (DIs) to address Sustainable Development Goals (SDGs) and their targets. Recent studies have explored how DIs contribute to monitoring SDG indicators within specific "for good" projects. However, these studies have often focused narrowly and have not sufficiently addressed the potential negative impacts of digitalization on the broader goals of Agenda 2030. There has been limited research on the overall relationship between DIs and the SDGs. Our work aims to bridge this gap by providing a framework to assess the impact of DIs on the

SDGs in a comprehensive and integrated way. This framework also helps identify gaps in knowledge that hinder the effective use of digitalization for sustainable development.

When evaluating the impact of digital interventions on sustainability, it is essential to consider three key dimensions. First, the inherent complexity of the SDG framework must be acknowledged, including both synergies and trade-offs. Digital interventions may enhance certain indicators while potentially conflicting with others. Second, the impact of a digital intervention can vary depending on the context; for instance, its effects might differ between industrialized and non-industrialized settings. Third, the role of stakeholders—such as providers and users—affects how a digital intervention functions, based on their intentions and preferences. Each of these dimensions plays a critical role in providing a comprehensive assessment of digital interventions' impact on sustainable development.

he core idea behind the Digitainability Assessment Framework (DAF) is to methodically evaluate how a digital intervention (DI) influences the indicators that support the Sustainable Development Goals (SDGs). The DAF utilizes concepts from the Theory of Change (ToC), which outlines causal pathways connecting changes brought about by activities to their impacts. ToC is used here to focus on how DIs affect SDG indicators, rather than on how the DIs themselves could be improved. While the DAF's assessments may provide insights into potential improvements for DIs, the framework itself is not designed for this purpose. The Theory of Change is not a rigid methodology but rather a flexible approach for goal-oriented planning. It helps simplify and address the complexities involved in assessing how DIs contribute to or hinder progress towards the SDGs. ToC is recognized for its practical application in evaluating program theories and development practices, and its adaptability makes it suitable for various contexts. In the DAF, ToC elements are integrated to assess the impact of DIs on SDGs based on scientific evidence, rather than evaluating or enhancing the DIs themselves.

ToC typically includes five key components: Inputs, Activities, Outputs, Outcomes, and Impact. These components allow for a combination of quantitative and qualitative criteria to explain the change process and address multiple aspects such as social, governance, and security perspectives. When applying ToC, it is crucial to define appropriate boundaries, scope, and complexity. For the DAF, ToC is adapted to focus specifically on how DIs impact SDG indicators. This adaptation helps capture the various levels of change brought about by a DI, presenting them in a logical connection to relevant SDG indicators and identifying key information convergence.

"In the DAF, the ToC elements are mapped into the following segments:

- *Digitalization Intervention*: corresponding to Inputs and Activities in ToC.
- *Purpose:* corresponding to Outputs and Outcomes in ToC.
- *Impact:* covering both the desired and undesired effects of the DI." (Rhyner, 2022)

The synergy between digitalization and sustainability in the Italian farinaceous food industry is driving improvements in operational efficiency, supply chain transparency, and sustainable practices. By leveraging digital technologies like IoT, blockchain, AI, and advanced analytics, the industry can address current challenges and future demands, positioning itself as a leader in sustainable innovation. As companies like Barilla and De Cecco demonstrate, integrating digitalization with sustainability fosters a more sustainable and resilient future.

2.7- Case studies of successful integration of sustainability and digitalization in the food industry

The Italian farinaceous food industry has seen notable successes in integrating sustainability with digitalization.

Barilla, one of Italy's leading pasta producers, has made significant strides in integrating digitalization with sustainability, particularly in its agricultural practices. Barilla collaborates with farmers to implement precision agriculture techniques. Using IoT sensors and satellite imagery, they monitor soil health, weather conditions, and crop growth. This data helps optimize water usage, reduce the application of fertilizers and pesticides, and increase crop yields, promoting more sustainable farming. Barilla uses blockchain technology to enhance supply chain transparency. Consumers can scan QR codes on pasta packaging to access detailed information about the origin and journey of the ingredients used. This ensures accountability and builds consumer trust. Thanks to the availability of always up-to-date data, enable efficient and effective management of all the company's main Quality and Food Safety Process, example by accurately assessing compliance with regulations and certification standards and providing evidence of this to the relevant authorities and third-party certification bodies, as well as making timely decisions for the continuous improvement of processes and products. Also, paperless digital tools, thanks to the immediate availability and centralization of data, help manufacturing plants to manage key Quality and Food Safety processes such as the evaluation and management of product non-conformities, audit programs and the monitoring of critical control points in the HACCP process, as well as to remove large amounts of paper from the plants for the benefit of the company's sustainability program. It has also developed four power BI- based analytical digital tools that contain data, integrated from different sources, presented in synthetic views that allow for high-level or granular, global, or local perspectives. Data sources are automatically verified, validated, and updated. It is easier to check compliance of indicators, correct deviations from standards, define actions for continuous product improvement and better manage investments (Barilla, 2022).

In this way there is a significant reduction in water usage and chemical inputs, promoting biodiversity and soil health as an environmental impact. An

improvement in crop yields and resources efficiency lead to cost savings and increased profitability in the economic impact. And at the end it enhances transparency fosters consumer trust and promotes responsible consumption in the social impact.

Bauli adopted IoT technologies during the processes of production to achieve and analyze in a short while the data, to improve the performance of the production lines, food waste reduction, reinforcing the security of the website. Adoption of the software system: SCADA (Supervisory Control and Data Acquisition) and MES (Manufacturing Execution System) to control the supervisor activities from a remote or local point of view interacting with the existing ERP to improve the process of production (Bauli, 2022).

De Cecco applied Totem in the production's departments in order to easily teach how to carry out a work and easily internally communicate more effectively, flow and pervasive (De Cecco, 2022). De Cecco has equipped its production lines with IoT devices and automation technologies. These systems monitor machinery performance in real-time, optimizing operations and minimizing downtime. Automated processes ensure consistent product quality and reduce waste. The company employs digital twin technology to create virtual replicas of its manufacturing processes. These digital models help identify inefficiencies, test process changes, and implement improvements without disrupting actual production. It uses digital tools to track and manage packaging materials, ensuring they meet sustainability standards. They have also transitioned to using recyclable and biodegradable packaging.

The environmental impact reduced waste and energy consumption through optimized manufacturing processes. The increasing in the operational efficiency and reduced costs associated with production downtime and waste is considered as an economic impact and the social ones is the commitment to sustainable packaging resonates with environmentally conscious consumers.

By leveraging advanced technologies such as IoT, blockchain, and digital twins, these companies have optimized their operations, reduced environmental impact, and promoted transparency and trust among consumers. These initiatives not only contribute to the companies' economic success but also align with broader sustainability goals, showcasing a path forward for the industry. These are considered a successful integration of digitalization and sustainability in the Italian farinaceous food industry.

Chapter 3

3.1-The qualitative vs. quantitative approaches

There are two approaches guiding the methodology of a research study that design, collect the data, and process the analysis. The choice is between a qualitative and a quantitative method that depends on the nature of the research question, the objective of the study, and the type of data required to achieve those objectives.

The first one to be analyzed is the *qualitative research approach* that is an explanatory approach that seeks to understand phenomena through the collection and analysis of non-numerical data. It is often used when the researcher aims to gain deep insights into a particular context, behavior, or experience. The primary characteristics of qualitative research include: the subjectivity because the research is often interpretative, with the researcher playing an active role in understanding the meanings and perspective of participants, the flexibility because the research design is often emergent, allowing the study to evolve as new insights are gained, rich and descriptive data because data is typically collected through methods such as interviews, focus groups, observations, and document analysis, resulting in detailed, narrative data, contextual understanding because qualitative research is often conducted in natural settings, providing a holistic view of the phenomenon within its real-world context.

The advantages of using this approach are a depth of understanding because the qualitative methods allow for an in-depth exploration of complex issues, capturing the nuances of participants' experiences and perspectives, the flexibility because the open-ended nature allows for adjustments during the study, accommodating emerging themes or unexpected findings, and contextual

insights for the emphasis on context that enables researchers to understand the conditions under which certain behaviors or phenomena occur.

The *quantitative research approach* is a systematic approach that seeks to quantify phenomena and establish patterns, relationships, or causal links through the use of numerical data. Key characteristics of quantitative research include: objectivity because the emphasis is placed on maintaining objectivity and minimizing researcher bias, with structured methodologies that are replicable, there is a structured design because research design is typically predetermined, with specific hypotheses, variables, and methods outlined before data collection begins, statistical analysis in which the data is collected using instruments such as surveys, experiments, or secondary data, and analyzed using statistical techniques to identify trends, correlations, or causal relationships, and large sample sizes because quantitative studies often involve large, random samples to ensure that findings are statistically significant and generalizable.

“The advantages of this quantitative approach are: the objectivity and reality because quantitative methods are often considered more objective, reducing the influence of researcher bias and enhancing the reliability of the findings, generalizability because of the use of large, random samples and statistical analysis allows for findings to be generalized to a broader population, and precision because quantitative research provides precise, quantifiable data that can be used to measure the extent of a phenomenon or the strength of relationships between variables” (Creswell & Creswell).

3.2-Justification for the chosen methodology

In this study the choice between qualitative and quantitative methods was guided by the research questions and objectives.

The methodology used for this thesis is a qualitative approach in which the phenomena were understood in depth, aided by subjective analysis. The subject of digitalization and sustainability in the Italian farinaceous food industry is likely to be complex, involving various stakeholders, processes, and practices that are deeply embedded in cultural, economic, and social contexts. Qualitative methods are particularly well-suited to exploring such complexities, allowing the researcher to gain a nuanced understanding of how digitalization and sustainability are perceived, implemented, and experienced within the industry.

Qualitative research is valuable for capturing the perspectives of various stakeholders, including business owners, production managers, technology providers, and sustainability experts. Through interviews, focus groups, or case studies, qualitative methods can uncover the motivations, challenges, and contextual factors that influence how digitalization and sustainability initiatives are adopted and integrated into production processes.
For instance, understanding why certain companies may resist or embrace digitalization, or how traditional production methods are being modified to align with sustainability goals, requires in-depth exploration that quantitative methods might not fully capture.

The Italian farinaceous food industry is likely characterized by unique cultural and organizational dynamics, especially given the importance of tradition in Italian food production. Qualitative methods can help explore how these dynamics influence the adoption of digital technologies and sustainability practices. For example, interviews can reveal how cultural values related to food quality and heritage impact decisions regarding modernization and sustainability.

Digitalization and sustainability are rapidly evolving fields, with new practices and trends emerging regularly. A qualitative approach allows the researcher to

investigate these emerging trends in real-time, gathering detailed accounts of innovative practices, pilot projects, or experimental approaches being tested within the industry. For example, there are some small and medium enterprises that are leveraging digital tools to improve sustainability or how industry leaders are interpreting the concept of sustainability in their operations.

Digitalization and sustainability often involve significant changes in how production processes are managed and executed. Qualitative research is well-suited to examining these processes and understanding the nature of change within organizations. Through methods like case studies, the research can track how specific companies or sectors within the industry have evolved, identifying the key drivers and barriers to change.

The approach took is based on the information of the different companies that were taken on the public “Sustainability Report” in order to understand the type of technologies and sustainability used in the internal organizational work and processes of the different industries.

The research is based on the type of technologies 4.0 and the type of the sustainability adapted in the major companies in order to understand how the firms are evolving at the same level of the technologies, how they are answering to these changes and how they could see the future transforming. Also, for the sustainability point of view there were some changes that should be done in order to adapt to our environment that is going to have significant transformations, and how the companies are adjusting their processes during the production processes but also how to manage the internal activities, how to run the deliveries of the products, how to analyze the data, how to service and to maintain.

Analyzing the report of sustainability of the years 2022 of the major companies, makes understanding the sustainability and technological approach used but there were some information missing above all from the technological point of view.

In conclusion, a qualitative methodology is justified for this thesis because it allows for an in-depth exploration of the complex and context-dependent processes involved in the digitalization and sustainability of production in the Italian farinaceous food industry. The qualitative approach will enable the researcher to capture the nuanced perspectives of various stakeholders, understand the cultural and organizational dynamics at play, and provide a detailed account of how digitalization and sustainability are being integrated into traditional production processes. This approach is essential for generating the rich, descriptive insights necessary to understand these emerging phenomena in a rapidly evolving industry.

3.3-Primary data collection: the case studies

The primary data collection methods used in this study investigate the sustainability and digitalization of the Italian farinaceous food industry. The research utilized cases studies to gather detailed insights from key stakeholders within the industry. These methods were chosen to explore the complexities of digitalization and sustainability practices and to provide a comprehensive understanding of the challenges and opportunities faced by the industry.

Case studies were conducted to provide a detailed examination of how digitalization and sustainability are being implemented in specific organizations within the industry. This method allowed for an in-depth exploration of the processes, challenges, and outcomes associated with these initiatives.

The data were collected through a combination of document analysis and observations. This included on-site visits to observe production processes and the application of digital technologies and the review of internal reports, sustainability assessments, and digitalization project documentation.

The case study data was analyzed through cross-case synthesis, comparing and contrasting the findings across the organizations. Throughout the data collection process, ethical considerations were carefully managed.

The case studies provided a robust methodological approach for exploring the digitalization and sustainability of the Italian farinaceous food industry. These methods allowed for a comprehensive examination of both the broad trends and the intricate details of how these initiatives are being implemented.

3.4- Secondary data collection: literature, industry reports, government publications

The secondary data collection methods utilized in this study are focused on existing literature, industry reports, and government publications relevant to the digitalization and sustainability of the Italian farinaceous food industry. The secondary data provided a foundation for understanding the current state of the industry, identifying key trends, and contextualizing the primary data collected through interviews, surveys, and case studies.

The literature review aimed to synthesize existing academic research on digitalization and sustainability, particularly as these concepts apply to food production and, more specifically, to the Italian farinaceous food industry. This review served to identify gaps in the current knowledge, inform the development of the research questions, and provide a theoretical framework for the study. The literature was sourced from a variety of academic databases, including Google Scholar. Keywords used in the search included "Digitalization in farinaceous food industry," "Sustainability in Italian farinaceous food production," "Italian food industry," "Farinaceous products," and "Industrial processes." The literature review focused on peer-reviewed journal articles, books, and conference papers published within the last decade to ensure relevance to contemporary industry practices.

There are some key themes that emerged from the literature, including the role of the digital technologies in enhancing efficiency, sustainability practices in food production, challenges of digital transformation, and the intersection of digitalization and sustainability. Studies examine how digital tools such as IoT, blockchain, and AI are being integrated into food production processes to improve efficiency, traceability, and quality control. Research explores sustainable practices include resource management, waste reduction, and the impact of sustainability certifications on consumer behavior. Literature highlights the barriers to digital adoption, such as costs, technological infrastructure, and resistance to change within traditional industries and in the end papers discuss how digitalization can be leveraged to achieve sustainability goals, such as reducing carbon footprints and improving resource efficiency. The analysis of the literature provided a comprehensive understanding of how digitalization and sustainability are currently understood and implemented within the food industry. This review also identified specific challenges and opportunities within the Italian context, offering insights into the cultural and economic factors influencing these trends in the farinaceous food sector.

Industry reports were used to gather data on the current state of digitalization and sustainability practices within the Italian farinaceous food industry. These reports provided quantitative data, market trends, and expert analyses that complemented the qualitative findings from primary data collection. These reports offered insights into market dynamics, technology adoption rates, consumer trends, and competitive analysis within the Italian food industry and are found on the Internet because they are public and accessible.

The industry reports highlighted several important trends such as digital adoption rates, sustainability initiatives, market trends, and economic impact. There are some data on the adoption of digital technologies within the Italian food sector, including the extent to which these technologies are used in production, supply chain management, and marketing, Information on the sustainability initiatives

undertaken by leading companies in the farinaceous food industry, including efforts to reduce energy consumption, manage waste, and source sustainable ingredients, analysis of consumer demand for sustainably produced and digitally traceable food products, reflecting growing interest in transparency and ethical production, and reports on the economic impact of digitalization and sustainability initiatives on the Italian food industry, including case studies of successful implementations.

The secondary data collection, encompassing literature, industry reports, and government publications, played a critical role in this research by providing a solid foundation of existing knowledge and contextual insights. This chapter has detailed the sources and key findings from these secondary data types, setting the stage for the analysis of primary data in the following chapters. The integration of secondary and primary data will enable a comprehensive understanding of how digitalization and sustainability are shaping the future of the Italian farinaceous food industry.

3.5-The sampling

The population for this study includes all entities involved in the production of farinaceous food products in Italy. This includes large-scale producers, small and medium enterprises (SMEs). The study also considers key stakeholders such as industry experts, sustainability officers, and technology providers who are directly involved in or knowledgeable about digitalization and sustainability practices in the industry.

The entities and individuals selected for this study are companies or individuals must be actively involved in the production or supply chain of farinaceous food products in Italy, participants must have experience or knowledge related to the

adoption of digital technologies and/or sustainability practices within the industry. Companies must be located within Italy, with a preference for a range of regions to capture geographical diversity. The sample includes entities of varying sizes, from large-scale producers to SMEs to ensure a comprehensive view of the industry.

The sampling techniques used are purposive sampling because this technique was used to select the case studies. The goal was to choose companies that are particularly knowledgeable or influential in the areas of digitalization and sustainability. This method ensures that the sample includes key players who can provide in-depth insights into the industry's practices. Also, stratified random sampling used to ensure that the sample is representative of the entire industry. The population was divided into strata based on factors such as company size (large, medium, small), type of production (industrial vs. artisanal), and geographical location. “Random samples were then drawn from each stratum to ensure diversity and representation across different segments of the industry” (Lincoln & Denzin, 2017).

The case studies were conducted, each focusing on a different type of producer like large-scale or SME. This selection allowed for a detailed examination of the practices and challenges faced by different segments of the industry. Companies for case studies were selected based on their prominence in the industry and their known involvement in digitalization and sustainability initiatives. Site visits were arranged for data collection.

The sampling strategy for this study was designed to provide a comprehensive and representative view of digitalization and sustainability practices within the Italian farinaceous food industry. Purposive sampling for qualitative data was able to capture both depth and breadth in its findings. This approach ensured that the research could effectively address the complex and multifaceted nature of the industry, providing valuable insights for both academic and practical applications.

Chapter 4: Findings and discussion

4.1-Analysis of primary data

This research aimed to explore the technologies 4.0 that are being used in the companies that are being analyzed and what are the benefits that they found using these technologies. Also, another important aspect that has been highlighted is how these companies define their industries sustainable.
Going more in depth, the questions made to the following interviewees were:

1) The name of the company
2) The name of the interviewee
3) The position of the interviewee
4) What are the technologies 4.0 used in your company?
5) What benefits do you think that the integration of 4.0 technologies could lead to?
6) How does sustainability translate into your organization?

The companies, the interviewers and the job positions of those I decided to analyze are the following:

Company	Interviewee	Job position
Bertagni 1882 SPA	Sergio Sandri	Technical Manager
Enrico Giotti SPA-McCormick Group	Carlo Bonavia	Site SC&Operations Manager
Gardapan SRL	Leonardo Montresor	QA Manager
Abaribi SRL	Chiara Abaribi	Direction/RAQ

Interviewers' table 1.10

What are the technologies 4.0 used in your company?

The technologies 4.0 adopted in the previous companies are a production lines created since 2018 that have been built with Industry 4.0 technologies, a total of eight lined with a combined production capacity of about 4200 kg/h, a data exchange between the machines themselves and the company's management system but also everything is tracked and stored in relational databases. Another company decided not to implement 4.0 technologies. The last one answer was that they had some plants interconnected with the factory management system. Another interviewer answered that they adopted a 4.0 production equipment like dosing machines, mixers, proofing cells, shuttle carts, and packaging lines.

What benefits do you think that the integration of 4.0 technologies could lead to?

The first company answered that the benefits they recognized were real-time control of process data, the increasing od the process efficiency, the reduction of decision-making time and the improvement of the process of standardization. The second company didn't adopt the 4.0 technologies, but they recognized as benefits the ability to monitor the Lines/Machines live on your computer and consequently analyze the data. The other company identified as benefits the constant monitoring of process parameters and optimization of production but also crucial in the event of issues with the finished product to understand the causes that have led to negative alterations. The last company answered that the benefits are the production process control and the real-time relevance of the information.

How does sustainability translate into your organization?

The fist company translated the sustainability in its company as energy diagnosis, measurement and reporting of all water, electricity, and fuel consumption, annual improvement plans for reducing consumption and carbon footprint, photovoltaic systems installed for 0.8 MW and cogeneration plants producing 10% of electricity needs and 7% of thermal energy needs. The second interviewer answered that from a sustainable perspective they have a PLP plan, invests to reduce gas and electricity consumption and collaborate with local organizations through the D&I group. Thanks to the adoption of next-generation equipment, the third company has made significant strides in energy efficiency, significantly reducing our environmental impact. This is just one of many aspects of their journey toward a more sustainable future. The search for sustainable raw materials is a constant commitment: they are carefully selecting suppliers and materials that meet the highest environmental standards. Moreover, they are actively engaged in the development of new, increasingly eco-friendly packaging materials to further reduce our impact on the planet. The last company is developing the sustainability in order to undertake consistent and feasible actions. At the moment, they have only solar panels.

4.2-Analysis of secondary data

There are some concrete cases that are inserted in the public Report of sustainability of some of the major Italian companies working on the farinaceous sector. These reports are easily found on the Internet. These following are some examples concerning how they are becoming more sustainable in their internal processes through the years:

In *Colussi*, for example they talk about environmental, social and economic sustainability in which in the first one they are referring to the food waste, pollution, water, soil pollution reduction, but also about the substitution of fossil sources with renewable ones. In the second one they refers to the promotion of health products, promotions of job security culture, working conditions, consumer nutrition education, and discrimination. In the third and last one they talk about development of professional skills, innovation in the process of production and products, occupation, and development of professional skills. (Colussi, 2022)

In *Morato Pane*, environmental sustainability means the participation of the project "Programma per la valutazione dell'impronta Ambientale" in which the company wants to reduce the impact of the Carbon Footprint of its products, and it is the first Italian company that is developing a sustainable industrial bread, using a certificate and transparency approach, use of natural and organic materials, responsibility in the use of the waste raw materials. In the economical sustainability Morato Pane works everyday trying to ensure economic performances in order to safeguard and improve the value of the company and of the activities, the attention to the innovation and the understanding of the evolution of the market that makes the company continue its business (Morato Pane, 2022).

In *Barilla*, they talk about environmental sustainability as paperless (Barilla, 2022), in *Bauli* environmental sustainability means energy efficiency and recyclability index, food waste during the process phase, paper packaging with the reduction of the usage of the plastic (Bauli, 2022). *Rana* for environmental sustainability refers to the circular economy during the creation and the design of the packaging, reduction of the impact in the environment during the production, circular economy in which the waste is regained, and it is not source of pollution (Rana, 2022). *Galbusera* for environmental sustainability means to respect the

environment improving the use of technical measures that can help to reduce the emission of waste material and to improve the use of the technologies during the process of production like minimizing the acoustic impact in the external environment, optimizing the water and energy consumption. Social sustainability for them means a safety and saving workplace, safety, and hygiene rules. They want to reduce the number of accidents in the workplace, improving the condition and safety of the work, welfare of the employees, quality of the products trying to satisfy the customers' needs (Galbusera, 2022).

De Cecco in his report talks about environmental sustainability in which the level of emissions produced during their processes is equal to one tenth of the threshold of 50 mg/Nmc that is reported in the legislation, a purification plan that is organic, sized for double the real inflow of waste water discharged and provided for, regarding the use of fuels pollutants, to be replaced with the use of methane gas eliminating fuel oil whose emissions have a significant impact on the environment (De Cecco, 2022).

Forno D'Asolo has both social and environmental sustainability in which in the first one It takes care about resources and initiatives for the welfare of the employees from the new born of a child to the graduation and the second one regards eco sustainable agriculture, utilization of raw materials that have a lower impact on the environment, and safety regulations and insurance for what that concern the quality of the food (Forno D'Asolo, 2022).

For Divella, sustainability means social ones for ethical and behavioral codes with suppliers and customers during the entire supply chain, with specific and training courses in order to teach them the social responsibility, welfare for the employees and environmental means reduction of the waste and recycle of the trash applying the rule of the four R: reduce, reuse, recycle and regain, improving

the industrial process, reduction in the maintenance costs, reduction of electrical, gas and water consumption (Divella, 2022).

Loacker talks about environmental sustainability because their mission is to use sustainable packaging using the 7 Rs (rethink, refuse, reduce, repurpose, reuse, repair and recycle), reducing the greenhouse emissions. Social sustainability in the promotion of the professional and personal development of people in the company and invest in creating a healthy and safe working environment (Loacker, 2022). *Balocco* for social sustainability refers to the best quality of the product for the customers and for environmental they are strongly supporting the environment trying to reduce the waste in the environment with some activities like “Too Good to Go” and “Banco Alimentare del Piemonte”, a correct disposal of the packaging of the products (Balocco, 2022). *Pasta Berruto* uses renewable energy ensuring a strong sensibility over the environment (Berruto, 2022). *Grissin Bon* ensure high quality and safety products for the customers, security for the employees during their job in the social sustainability while in the environmental ones new technologies that can reduce the use of water, energy and gas consumption, reduction of the impact in the environment from the production to the final phase in which the product is sold to the customers (Grissin Bon, 2022).

Also, few companies declare how they are organizing their internal processes utilizing technologies 4.0:

Barilla is using IoT digital tools, thanks to the availability of always up-to-date data, enable efficient and effective management of all the company’s main Quality and Food Safety Process, example by accurately assessing compliance with regulations and certification standards and providing evidence of this to the relevant authorities and third-party certification bodies, as well as making timely

decisions fir the continuous improvement of processes and products. Also, It is applying IoT for paperless digital tools, thanks to the immediate availability and centralization of data, help manufacturing plants to manage Key Quality and Food Safety processes such as the evaluation and management of product non-conformities, audit programs and the monitoring of critical control points in the HACCP process, as well as to remove large amounts of paper from the plants for the benefit of the company's sustainability program. It has also developed fur power BI-based analytical digital tools that contain data, integrated from different sources, presented in synthetic views that allow for high level or granular, local, or global perspectives. Data sources are automatically verified, validated, and updated. It is easier to check compliance of indicators, correct deviations from standards, define actions for continuous product improvement and better manage investments (Barilla, 2022).

Bauli is adopting IoT technologies during the processes of production to achieve and analyze in a short while the data, to improve the performance of the production lines, food waste reduction, and reinforce the security of the website. Adoption of the software system: SCADA (Supervisory Control and Data Acquisition) and MES (Manufacturing Execution System) to control the supervisor activities from a remote or local point of view interacting with the existing ERP to improve the process of production (Bauli, 2022).

De Cecco is using IoT for the application of Totem in the production's departments in order to easily teach how to carry out a work and easily internally communicate more effectively, flow, and pervasive (De Cecco, 2022).

Company	Description	Year of foundation	Location	Turnover
Colussi	The company was founded in 1911 in Venice by Angelo Colussi, who came from a family of bakers originally from Pianaz in the Val di Zoldo (Belluno). Founded initially as a simple bakery for producing bread and biscuits, Colussi expanded into an industrial-scale operation in the 1930s, thanks to Angelo's three sons: Alessandro, Giacomo, and Alberto.	1911	Milano	The total amount of turnover is around 226 million of Euros
Morato Pane	For generations, we have brought the goodness of bread to the tables of millions of people with taste and passion. Our products tell a long story of innovation and quality.	1970	Altavilla Vicentina, Vicenza	The total amount of turnover is around 66 million of Euros
Barilla	Barilla G. e R. Fratelli S.p.A., commonly known simply as Barilla, is an Italian multinational corporation in the food industry. It operates primarily in the markets for dry pasta, ready-made sauces, baked goods, flour, and bread.	1877	Parma	The total amount of turnover is around 4,9 billion of Euros
Bauli	Bauli S.p.A. is an Italian bakery company known for its production of baked goods, including pandoro, panettone, colomba (Italian Easter cake), and croissants. Founded in Verona in 1922 by pastry chef Ruggero Bauli, it has grown into one of the largest companies in its sector. The company is headquartered in Castel d'Azzano, near Verona, and is recognized as a leading player in the Italian baked goods industry.	1922	Castel D'Azzano, Verona	The total amount of turnover is around 634 million of Euros

Pastificio Rana	It's 1960, and Italy is in the midst of an economic boom, leading to a rise in wealth, consumer spending, and employment, including for women. This last factor, in particular, sparks the idea of a new business venture."If young brides no longer have time to make tortellini, I'll make them for them!" Giovanni Rana must have thought, before purchasing the iconic used Guzzino for 18,000 lire, which he uses to personally deliver tortellini to his first customer families. And this is how homemade fresh pasta transforms into the fresh pasta that Giovanni Rana brings right to your door.	1960	Vigano, Milano	The total amount of turnover is around 900 million of Euros
Galbusera	Galbusera S.p.A. is an Italian food company that produces biscuits, crackers, and snacks, operating both in Italy and abroad. It was founded by Mario and Enea Galbusera in Morbegno in 1938, with its headquarters in Cosio Valtellino.	1938	Morbegno, Sondrio	The total amount of turnover is around 278 million of Euros
De Cecco	De Cecco is an Italian company producing dried pasta, flour and other related food products. It is the third-largest manufacturer of pasta in the world.	1886	Fara San Martino, Chieti	The total amount of turnover is around 32 million of Euros
Forno D'Asolo	Nestled among the rolling hills of Asolo, with its gentle rhythms and rich memories, Forno d'Asolo crafts its specialties. This enchanting place is where, five generations ago, a small bakery was founded, destined to carry the name of Asolo across the globe.	1985	Rodano, Milano	The total amount of turnover is around 189 million of Euros

	Forno d'Asolo has since become renowned for its high-quality baked goods, reflecting both the traditions of the region and the expertise passed down through generations. Their commitment to excellence has made them a significant name in the culinary world. For more information, you can check the details on their official site or related articles about the bakery's history and products			
Divella	F. Divella S.p.A. is an Italian company operating in the food sector, founded in 1890 in Rutigliano, located in the metropolitan city of Bari. The company specializes in producing a variety of food products, including durum wheat semolina pasta, biscuits, vinegar, olive oil, rice, ready-made sauces, and more.	1890	Rutigliano, Bari	The total amount of turnover is around 370 million of Euros
Loacker	Loacker S.p.A. is an Italian confectionery company that produces wafers, chocolate, and related products, headquartered in South Tyrol.	1925	Bolzano	The total amount of turnover is around 435 million of Euros
Balocco	Balocco S.p.A. is an Italian confectionery company specializing in the production of baked sweets, headquartered in Fossano (CN).	1927	Fossano, Cuneo	The total amount of turnover is around 204 million of Euros

Pasta Berruto	We are a Piedmontese company recognized worldwide for the production of durum wheat semolina pasta. We carefully select the best raw materials, mixing them with water, passion, and care. Our pasta-making process involves meticulous shaping, following traditional methods. The drying phase adheres to strict standards, and finally, the pasta is always inspected to ensure the highest quality.We keep our long-standing history alive, valuing the territory and the people who contribute to our craft.	1881	Carmagnola, Torino	The total amount of turnover is around 64 million of Euros
Grissin Bon	From a small dream, a great brand is born. An Italian company, a family business; for three generations, Grissin Bon has been a national leader in baked goods, bringing our values to your tables.	1950	Calerno, Reggio Emilia	The total amount of turnover is around 72 million of Euros

Companies' information 1.11

4.3-Discussion

The Italian farinaceous industry is a cornerstone of the country's culinary heritage and economic fabric, stands at the intersection of two transformative trends: digitalization and sustainability. Throughout this thesis, there is an exploration of how these two forces are reshaping the industry, affecting everything from the production processes and supply chain management to consumer engagement and environmental stewardship. This conclusion

synthesizes the critical insights, discuss the implications for the industry, and suggest some avenues for the future research.

Digitalization has permeated various facets of the Italian farinaceous industry, introducing efficiency and innovation in several ways. The adoption of digital technologies, such as data exchange between the machines and the company's management system, and the fact that everything is tracked and stored in relational databases has enabled producers to optimize their operations. The use of blockchain technology and plants interconnected with the factory management system for traceability like the case of Gardapan SRL, has also gained traction, allowing for greater transparency in the supply chain and providing consumers with detailed information about the origin and journey of their products. Digital tools like packaging lines in Abaribi SRL have facilitated more efficient supply chain management by improving logistics, reducing waste, and enabling real-time tracking of inventory levels and shipments. These improvements have helped producers respond more effectively to market demands and disruptions, particularly in the wake of the COVID-19 pandemic.

The sustainability movement has prompted the Italian farinaceous industry to re-evaluate its practices and adopt more environmentally friendly approaches. Producers have increasingly prioritized the use of sustainable raw materials and eco-friendly production methods to further reduce the impact on the planet like in Gardapan SRL. This includes sourcing locally grown, organic wheat, reducing water and energy consumption, and minimizing waste throughout the production process. Measures such as carbon footprint reduction, photovoltaic systems, cogeneration plants and the measurement and reporting of all water, electricity, and fuel consumption have been implemented to enhance the industry's sustainability profile in Bertagni 1882 SPA. Beyond environmental considerations, the industry has also addressed social and economic dimensions of sustainability. This includes fair labor practices, support for local communities

through the D&I group like in Enrico Giotti SPA-McCormick Group, and initiatives to ensure economic viability for small-scale producers.

The benefits they gain through the adoption of the technologies 4.0 is about real-time control of process data, the increase of the process efficiency, the reduction of decision-making time, and the improvement of the process standardization in Bertagni 1882 SPA. Another important aspect that was considered important for Enrico Giotti SPA-McCormick Group is the possibility to monitor the lines and the machines live on the computer and consequently analyze the data. Gardapan SRL thinks it is crucial in the vent of issues with the finished product to understand the causes that have lead to negative alterations.

The integration of digitalization and sustainability presents both opportunities and challenges for the Italian farinaceous industry. On the one hand, digital tools can enhance the efficiency and effectiveness of sustainability initiatives by providing data-driven insights, facilitating resource optimization, and enabling more transparent reporting. On the other hand, the successful integration of these trends requires significant investment in technology and skills development, as well as a cultural shift towards embracing innovation and sustainability as core business values. The growing consumer demand for sustainable and digitally connected food products offers a significant market opportunity for the Italian farinaceous industry. Producers who can effectively communicate their sustainability credentials and engage with consumers through digital platforms are likely to gain a competitive advantage. However, meeting these expectations requires a deep understanding of consumer preferences and the ability to adapt quickly to changing market conditions. The industry's transition towards digitalization and sustainability is also influenced by policy and regulatory frameworks. Governments and industry bodies play a crucial role in setting standards, providing incentives, and creating an enabling environment for innovation. Policies that support investment in digital infrastructure, promote sustainable agriculture practices, and facilitate access to international markets can

help the industry navigate the challenges and seize the opportunities presented by these trends.

4.4-Limitation of the study: potential constraints and challenges, scope and delimitations

In this study, there are some constraints and challenges that can impact the research outcomes and interpretations. For example, some sensitive information are not publicly available or shared. Some data cannot be accurate due to rapid changes in the market dynamics, consumer preferences, and technological advancements.

The study is limited to certain regions of Italy, leading some lack of comprehensive understanding of the industry at a national level.

Also, the fluctuations in market conditions, such as prices of raw materials or changes in consumer demand, can impact on the study's findings.

Stringent food safety and labeling regulations may affect the production and distribution of farinaceous products.

There are some challenges in logistics and transportation, especially during global crises (e.g., pandemics, wars), which can affect the availability of products. Changes in weather patterns and environmental conditions can affect the production and quality of raw materials.

There is an increasing consumer demand for sustainable and environmentally friendly products that may require the industry to adopt new practices and technologies and an important shift in consumer preferences towards healthier or alternative diets such as gluten-free, low-carb that can affect the demand for traditional farinaceous products. As well as the rise of alternative food products, for example the plant-based or non-traditional grains that may pose challenges to the traditional farinaceous industry.

The cultural importance of farinaceous foods in Italian cuisine may limit the willingness of producers and consumers to adopt changes. Social trends, such as urbanization and lifestyle changes, can influence the consumption patterns of farinaceous products.

Identifying and addressing the limitations, constraints, and scope of a study on the Italian farinaceous food industry is crucial for producing accurate and relevant findings. By acknowledging these factors, researchers can provide a more comprehensive and nuanced understanding of the industry and its challenges.

4.5-Practical implications

Based on the research findings, there are some recommendations that should be done to the industry to navigate the digitalization and the sustainability landscape. To fully leverage the benefits of digitalization, producers should invest in state-of-the-art technologies and the development of digital skills among their workforce. This includes training programs, partnerships with technology providers, and collaborations with research institutions to stay abreast of the latest developments and best practices in the field, the collaboration between different stakeholders, including producers, suppliers, technology companies, and policymakers, is essential for driving innovation and achieving sustainability goals. Industry associations and clusters can facilitate knowledge sharing, joint research and development initiatives, and the dissemination of best practices. Producers should prioritize transparency in their operations and actively engage with consumers to build trust and loyalty. This includes providing clear and accurate information about their products' origins, production methods, and sustainability credentials. Digital platforms and tools can be leveraged to facilitate direct communication with consumers and gather feedback to inform product development and marketing strategies. Sustainability efforts

should encompass environmental, social, and economic dimensions. Producers should adopt a holistic approach that considers the entire lifecycle of their products, from sourcing and production to distribution and consumption. This includes exploring innovative solutions for reducing environmental impact, promoting social equity, and ensuring economic viability for all stakeholders.

4.6-Future research direction

The suggestions for future researches can be the potential emerging of new technologies, such as blockchain, artificial intelligence, and the Internet of Things on the industry's sustainability efforts and market dynamics. This includes assessing the feasibility and scalability of these technologies in different production settings and their implications for consumer behavior and supply chain management. It is also important understand the consumer perceptions and behavior towards sustainable and digitally connected farinaceous products that is critical for developing effective marketing strategies and product innovations. Future studies could examine the factors influencing consumer choices, the effectiveness of different communication channels and messages, and the role of digital tools in shaping consumer preferences.

Conclusions

The thesis concludes that the Italian farinaceous industry finds itself at a critical intersection between digitalization and sustainability. This alignment offers promising opportunities to modernize operations, address evolving consumer expectations, and enhance environmental responsibility. Through the adoption of innovative digital solutions, such as IoT and blockchain for transparency and efficiency, the industry can support sustainable development goals, foster consumer trust, and improve competitiveness. A collaborative approach among stakeholders, including producers, suppliers, and policymakers, is essential to drive this transformation effectively.

Moreover, this shift promises benefits beyond the operational level, positioning Italian brands as global leaders in quality and responsibility, aligned with the principles of the 2030 Sustainable Development Goals. However, fully realizing this potential requires overcoming several challenges. Investment in training and infrastructure, addressing regulatory complexities, and fostering a culture open to digital and sustainable practices are key steps forward. Collaboration among stakeholders like producers, governments, and technology providers is essential to balance tradition with innovation, leveraging Italy's renowned heritage to meet the modern demands of a global, sustainability-conscious market.

Ultimately, by championing digital transformation alongside environmental stewardship, Italy's farinaceous food industry has the potential to set a powerful example for traditional sectors worldwide, showcasing how heritage and technology can unite to address the pressing challenges of our era.

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Appendix

Transcription

	Italian		English
Azienda 1	Bertagni 1882 SPA	**Company 1**	Bertagni 1882 SPA
Intervistato	Sergio Sandri	**Interviewee**	Sergio Sandri
Ruolo in azienda	Responsabile tecnico	**Job position**	Technical Manager
Quali sono le tecnologie 4.0 che vengono adottate nella sua azienda?	Bertagni opera nel settore alimentare come produttore di pasta fresca ripiena. Tutte le linee produttive realizzate a partire dal 2018 sono state realizzate con tecnologie INDUSTRIA 4.0 – Un totale di 8 linee con una capacità produttiva complessiva di circa 4200 kg/h. La tecnologia che abbiamo sviluppato prevede la totale integrazione di tutte le macchine che compongono il processo produttivo attraverso uno scambio dati tra le macchine stesse ed il gestionale aziendale. Questo significa che ogni fase del processo acquisisce informazioni dalla parte a monte e trasferisce informazioni alla parte a valle, inoltre tutto viene tracciato ed archiviato su DB relazionali che consento tracciabilità di tutte le materie prime utilizzate. Le informazioni sono inoltre utilizzate per rendicontare in tempo reale l'efficienza di linea attraverso OEE e per	**What are the technologies 4.0 used in your company?**	Bertagni operates in the food sector as a producer of fresh filled pasta. All production lines built since 2018 have been built with INDUSTRY 4.0 technologies – A total of 8 lines with a total production capacity of about 4200 kg/h. The technology we have developed provides for the total integration of all the machines that make up the production process through a data exchange between the machines themselves and the company management system. This means that each phase of the process acquires information from the upstream part and transfers information to the downstream part, moreover everything is tracked and stored on relational DBs that allow traceability of all the raw materials used. The information is also used to report line efficiency in real time through OEE and to analyze machine downtime that is automatically detected by the system.

	analizzare i fermi macchina che vengono automaticamente rilevati dal sistema.		
Quali sono i benefici che riscontra nell'utilizzo di quest'ultime?	I principali benefici sono: • controllo dei dati di processo in tempo reale • aumento delle efficienze di processo • riduzione dei tempi decisionali • riduzione degli errori umani • migliore standardizzazione di processo	**What benefits do you think that the integration of 4.0 technologies could lead to?**	• real-time control of process data • increased process efficiency • reduced decision-making time • reduction of human errors • improved process standardization
In quale modo la sua azienda può essere definita sostenibile?	• Diagnosi energetica • Misura e rendicontazione di tutti i consumi idrici, elettrici e combustibile • Piani annuali di miglioramento sul contenimento dei consumi e carbon footprint • Impianti fotovoltaici installati per 0.8 MW • Impianti di cogenerazione con produzione del 10% del fabbisogno elettrico ed il 7% del fabbisogno termico	**How does sustainability translate into your organization?**	• Energy diagnosis • Measurement and reporting of all water, electricity, and fuel consumption • reducing consumption and carbon footprint • Photovoltaic systems installed for 0.8 MW • Cogeneration plants with production of 10% of electricity demand and 7% of heat demand

Azienda 2	Enrico Giotti SPA-McCormick Groups	**Company 2**	Enrico Giotti SPA-McCormick Groups
Intervistato	Carlo Bonavia	**Interviewee**	Carlo Bonavia
Ruolo in azienda	Site SC&Operations Manager	**Job position**	Site SC&Operations Manager
Quali sono le tecnologie 4.0 che vengono adottate nella sua azienda?	Per ora non abbiamo implementato tecnologie 4.0 o meglio NON abbiamo mai sfruttato il beneficio economico legato a questa possibilità per la complessità IT del nostro sistema (cybersecurity, etcc…).	**What are the technologies 4.0 used in your company?**	For now, we have not implemented 4.0 technologies or rather we have NEVER exploited the economic benefit linked to this possibility due to the IT complexity of our system (cybersecurity, etc ...).
Quali sono i benefici che riscontra nell'utilizzo di quest'ultime?	Per ora niente ovviamente ma immagino che il più grande beneficio possa essere il controllo delle Linee/Macchine in diretta sul tuo computer e conseguente possibile analisi dei dati.	**What benefits do you think that the integration of 4.0 technologies could lead to?**	For now nothing of course but I imagine that the biggest benefit could be the control of the Lines/Machines live on your computer and consequent possible data analysis.
In quale modo la sua azienda può essere definita sostenibile?	Da un punto di vista di sostenibilità abbiamo un importante piano PLP per essere più sostenibili (soprattutto a livello della corporate). Nel nostro piccolo abbiamo un grande focus sulla parte ambientale (non ti nego anche legata all'aspetto economico) dove abbiamo fatto notevoli investimenti per ridurre consumi di GAS e anche Energia Elettrica. Da un punto di vista di Sostenibilità sociale stiamo cercando di collaborare con enti locali con il gruppo di D&I (partecipiamo a mense sociali, supportiamo orti sociali, etc…)	**How does sustainability translate into your organization?**	From a sustainability point of view, we have an important PLP plan to be more sustainable (especially at the corporate level). In our own small way, we have a great focus on the environmental part (I won't deny that it is also linked to the economic aspect) where we have made significant investments to reduce GAS consumption and also electricity. From a social sustainability point of view, we are trying to collaborate with local authorities with the D&I group (we participate in social canteens, we support social gardens, etc...)
Azienda 3	Gardapan SRL	**Company 3**	Gardapan SRL
Intervistato	Leonardo Montresor	**Interviewee**	Leonardo Montresor

Ruolo in azienda	QA Manager	**Job position**	QA Manager
Quali sono le tecnologie 4.0 che vengono adottate nella sua azienda?	Ormai tutti gli impianti nello stabilimento sono interconnessi con il sistema gestionale di fabbrica. Nello specifico tramite gestionale vengono inviati ai singoli impianti gli ordini di produzione (o bolle di lavoro) e al termine delle lavorazioni le macchine restituiscono i dati logistici di lavorazione (es. inizio/fine produzione, numero di pezzi processati, tempi impasto, lievitazione, cottura e raffreddamento). I dati ricevuti vengono archiviati nel gestionale ed utilizzati per monitoraggio e generazione di report di produzione.	**What are the technologies 4.0 used in your company?**	By now all the plants in the plant are interconnected with the factory management system. Specifically, production orders (or work notes) are sent to the individual plants through the management system and at the end of the processing, the machines return the logistical processing data (e.g. start/end of production, number of pieces processed, kneading times, leavening, baking and cooling). The data received are stored in the management system and used for monitoring and generating production reports.
Quali sono i benefici che riscontra nell'utilizzo di quest'ultime?	Lo storico dei dati presenti in azienda permette il controllo costante dei parametri di processo e l'ottimizzazione delle produzioni. È altresì fondamentale in caso di problemi sul prodotto finito per capire le cause che hanno portato ad alterazioni negative.	**What benefits do you think that the integration of 4.0 technologies could lead to?**	The historical data present in the company allows constant control of process parameters and the optimization of production. It is also essential in the event of problems with the finished product to understand the causes that have led to negative alterations.
In quale modo la sua azienda può essere definita sostenibile?	Grazie all'adozione di impianti di ultima generazione, la nostra azienda ha compiuto importanti passi avanti nell'efficientamento energetico, riducendo in modo significativo il nostro impatto ambientale. Questo è solo uno dei tanti aspetti del nostro percorso verso un futuro più sostenibile. La ricerca di materie prime sostenibili è	**How does sustainability translate into your organization?**	Thanks to the adoption of the latest generation systems, our company has made important steps forward in energy efficiency, significantly reducing our environmental impact. This is just one of the many aspects of our journey towards a more sustainable future. The search for sustainable raw materials is a

	un impegno costante per Gardapan: selezioniamo con cura fornitori e materiali che rispettino i più alti standard ambientali. Inoltre, siamo attivamente impegnati nello sviluppo di nuovi materiali di imballaggio, sempre più ecosostenibili, per ridurre ulteriormente il nostro impatto sul pianeta.		constant commitment for Gardapan: we carefully select suppliers and materials that comply with the highest environmental standards. In addition, we are actively engaged in the development of new, increasingly environmentally sustainable packaging materials to further reduce our impact on the planet.
Azienda 4	Abaribi SRL	**Company 4**	Araribi SRL
Intervistato	Chiara Abaribi	**Interviewee**	Chiara Abaribi
Ruolo in azienda	Direzione/RAQ	**Job position**	Direction/RAQ
Quali sono le tecnologie 4.0 che vengono adottate nella sua azienda?	Impianti di produzione – dosatrici, impastatrici, celle di lievitazione, carrellatori, linee di confezionamento	**What are the technologies 4.0 used in your company?**	Production equipment (dosing machines, mixers, proofing cells, shuttle carts, packaging lines)
Quali sono i benefici che riscontra nell'utilizzo di quest'ultime?	controllo del processo produttivo, informazioni in time rilevanti così come in caso di fermo	**What benefits do you think that the integration of 4.0 technologies could lead to?**	• Production process control • real-time relevant information
In quale modo la sua azienda può essere definita sostenibile?	al momento il piano di sviluppo della sostenibilità (intesa come insieme di azioni da attuare da parte dell'impresa per migliorare il benessere della persona e del pianeta) e in corso di sviluppo al fine di intraprendere azioni coerenti e percorribili. Al momento possediamo solo dei pannelli solari.	**How does sustainability translate into your organization?**	At the moment, the Sustainability Development Plan (understood as a set of actions to be implemented by the company to improve the well-being of the person and the planet) is being developed in order to take coherent and viable actions. At the moment we only have solar panels.

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