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Climate Change and its effect on Prosciutto di Parma PDO production. The point of view of key informants

Supervisor

Prof. Francesco Pagliacci

Submitted by

Panicheva Yulia

Student n. 2050824

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Abstract

In the face of developing agricultural systems, understanding the influence of climate change on the production quality of Parma Ham is a key factor.

The products protected with the collective marks PDO (protected designation of origin, DOP in Italian) and PGI (typical geographical identification, IGP in Italian) and TSG (traditional specialty guaranteed, STG in Italian) are crucial in the Italian agri-food business. Understanding how climate change affects high-quality regional products, Geographical Indications, has a primary importance for both producers and consumers.

Through in-depth interviews with Parma Ham producers and members of the Consorzio del Prosciutto di Parma, this thesis seeks to study the possible influence of climate change on the production of Prosciutto di Parma, namely one of the most important Geographical Indications, by turnover. Prosciutto di Parma is made in Emilia-Romagna Region, located in the Northern part of Italy.

To achieve this primary objective, the study based on the literature review focused on the understanding the Geographical Indications system in Europe and, in particular in Italy; analyzing Italian agriculture and pork industry data; examining climate change observations with the occurrence of extreme weather and their subsequent possible impacts on Parma Ham quality.

Based on the gathered data, the study anticipates evaluating the overall impact of climate change on the Prosciutto di Parma PDO production. The findings demonstrate that climatic conditions have already changed in the Parma region. Nevertheless, since the conditions in the processing areas are constantly checked and changed to preserve the product, producers are able to maintain and potentially enhance the Parma Ham quality.

The research underlines the significance of industry collaboration, innovation, and continual monitoring in order to maintain the quality and reputation of the Prosciutto di Parma PDO product.

Keywords: climate change, Prosciutto di Parma DOP, Parma region, quality, interview-based study, producers, Consortium of the Parma Ham

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1. Introduction

Climate change is having a variety of effects on Europe's environment and population. Extreme weather events such as heatwaves, storm surges, droughts, and floods have the most impact. The primary variables impacting changes in crop growth and output have been recognized as rising temperatures and water shortages. Forecasts predict higher temperatures and lower moisture levels in the future. (European Commission, 2023).

The Mediterranean region is especially vulnerable to climate change: rising average temperatures, heat waves, limited rainfall, melting glaciers degrading water sources, abrupt floods or excessive rainfall compound the effect on already vulnerable land. Climate change is expected to have a significant influence on water supply in Mediterranean nations by aggravating drought conditions and water shortages. (European Environment Agency, 2006).

For example, during the summer of 2022**,** Italy had an extraordinary event defined by unusually high temperatures and a lengthy period of insufficient rainfall, hence by prolonged droughts. Northern Italy has been impacted by high-pressure conditions and African storms, both of which have favored strong temperature anomalies. 2021 was one of the hottest years, with an average anomaly of +0.23C relative to the thirty-year period 1991-2020. The spring was especially chilly, the coldest since 2005, while the summer was the sixth hottest since 1961. (Fioravanti et al., 2022)

When it comes to climate change, the agricultural sector is the most vulnerable. It will bear the majority of the adverse effects of changing climatic trends, worsening global food security worries. (Li et al., 2022).

Climate change can have both direct and indirect impacts on agricultural production. Changes in phenology and growing seasons, shifts in agricultural areas and soil erosion, changes in water availability and irrigation are the examples of direct impacts. As a result of these direct effects, indirect impacts (Increased pest and disease pressure, harsh weather conditions such as high winds, hailstorms, heatwaves, and frosts) develop which can further harm agricultural productivity. (Jacobs et al., 2019).

Crops are susceptible to increased atmospheric CO2 concentrations and other effects of climate change, such as variations in temperature and precipitation. (Zhao et al., 2017). As a result, higher temperatures can hasten crop maturity, lowering nutritional content and diminishing yields. (Hatfield and Prueger, 2015). In consequence, shifting precipitation patterns lead to more frequent and

prolonged droughts, resulting in increased agricultural and animal water scarcity. Flooding, planting disruption, and soil erosion are all caused by increased rainfall intensity. (European Commission, 2023).

Climate change's linked effects on agro-ecosystems and agricultural output have an impact on product pricing, quantity and quality, trade patterns, agricultural revenue, and food prices. (Jacobs et al., 2019).

Despite the fact that the entire global agri-food industry is vulnerable to climate change, agri-food Geographical Indications are significantly more vulnerable due to the relationship between their specific terroirs and changing climatic conditions. Indeed changed climatic conditions impact several critical terroir characteristics such as rainfall, water availability, soil quality, and temperature. These consequences, in the context of climate change, raise issues about the concept of terroir and current standards that establish the uniqueness of Geographical Indications (GIs) (Clark and Kerr, 2017).

The European Union protects the high-quality traditionally produced goods by collective marks, GIs, such as PDO- Protected designation of origin, PGI - Protected geographical indication, TSG - Traditional speciality guaranteed. These products are based on the concept of terroir. This French term distinguishes products by the climate, soil type, and manufacturing methods of the particular territory where they were produced. These certificates elevate products and countries of origin while assuring consumers of the origin and conformity with quality requirements. (European Commission, 2023).

Prosciutto di Parma is an example of a collective mark, possessing PDO denomination. The name Parma Ham is reserved exclusively for hams produced in Parma in accordance with the strict rules defined by the Consorzio's specifications, which are based on the ancient tradition of its place of origin. (Consorzio del Prosciutto di Parma, 2023).

For a variety of reasons, analyzing the impact of climate change on Prosciutto di Parma PDO production is crucial. Firstly, climate change is already causing rising air temperatures and precipitation levels, as well as more frequent extreme weather events such as heat waves, droughts, floods, and storms in the area of production of Prosciutto di Parma PDO. Climate forecasts show significant changes in the intensity and frequency of atmospheric events, which are expected to worsen in the future. Warmer temperatures and changes in rainfall patterns can have an impact on

pig growth and curing. As a result, climate change has the potential to diminish Parma pig production by directly causing heat stress, which causes malnutrition, poor fat formation, and increases the animal's susceptibility to numerous illnesses, leading in lower end product value and economic losses for farmers and the industry.

This thesis is based on the following research questions. Firstly, I am going to understand how has the climate changed in recent years in Europe, and, in particular in Italy, and how climate change affects GIs production. Secondly, I am going to analyze pork industry and Prosciutto di Parma PDO case study.

Throughout conducting interviews, I am expecting to examine the possible impact of climate change on the Prosciutto di Parma PDO production taking into account the point of view of key informants, such as Consorzio del Prosciutto di Parma, Parma Ham producing companies. In this work I aim to investigate if climate change affected the climatic conditions of the Parma region, and consequently if it affected the production techniques, production costs as well as consumer demand of the Prosciutto di Parma PDO product.

The rest of this thesis is structured as it follows. Chapter 2 includes a theoretical review of the main literature concerning GIs and the impact of climate change on agricultural products. Chapter 3is a Material and Data section, which includes data on Italian agriculture and pig industry, GIs system in Italy, Prosciutto di Parma case study, and climate change observations in EU and Italy. Chapter 4 describes the adopted methodology and the characteristics of the interviews. Chapter 5 presents the main qualitative results and it discusses them. Lastly, Chapter 6 concludes the thesis.

2. Theoretical review

2.1 Geographical Indications and their main characteristics

According to the official website of the European Union, Geographical Indication (GI) is a distinguishing mark used to identify a product whose quality, reputation, or other attributes are related to its geographical origin. (European Commission, 2023)

GI status ensures authenticity, quality, and distinctiveness linked to origin for customers while protecting producers ('GI users') from competitors attempting to abuse their reputation and know-how developed to manufacture genuine high-quality products. (European Commission, 2023). Agricultural items, foodstuffs, wine and spirit beverages, handicrafts, and industrial products are common uses for geographical indicators.

The EU's trade agenda prioritizes adequate protection and enforcement of geographical indications (GIs) at the international level. The EU is working at the global and bilateral levels to strengthen geographical indication protection and intellectual property (IP) enforcement regimes to avoid usurpation and misuse of EU GIs around the world. (European Commission, 2023). The EU quality strategy seeks to protect specific product names in order to promote their distinctive features relating to geographical origin and traditional capabilities.

According to the European Commission (2023) Product names that have a specific link to the place of production may benefit from a «geographical indication» (GI). Consumers can trust and discern quality products with «GI» accreditation. Simultaneously, the GI system assists producers to promote their products and sell them on the market. Products that are being tested or have received "IG" recognition are noted in quality product registers. The registries must also include information on each product's production parameters and geographical indications.

GI, which are recognized as intellectual property, are becoming increasingly relevant in trade negotiations between the EU and other nations. Other EU quality schemes emphasize traditional manufacturing processes or items made in tough natural locations such as mountains or islands. (European Commission, 2023)

A GI right allows individuals who have the right to use the indication to restrict a third party from using it if their product does not meet the appropriate criteria. A protected geographical indication, on the other hand, does not allow the holder to restrict someone from producing a product using the

same processes as those specified in the standards for that indication. A GI is often protected by gaining a claim over the sign that forms the indication. (Wipo, 2023).

GIs provide the right to exclusive use to those producers within the defined zone who comply with the production standards through a certification procedure. The GI certification process converts the resources that give rise to the specific features of the product into "collective intellectual property." (Bramley, 2011).

The capacity of GIs to provide place-based distinctiveness stems from the GI product's close relationship with the area of production. The GI system collects local resources, changing territory into an attribute. (Belletti, 2007).

From this statement an attribute is considered as a concept of terroir that is connected to the distinctive biophysical qualities of certain areas, such as altitude, microclimate, local plant species, and soil type, and GI systems that prioritize terroir can be developed to safeguard these resources, which are viewed as crucial to the product's originality. (Berard, 2006).

Bowen (2009) states that terroir is also related with the cultural activities that have preserved these ecological riches throughout centuries.

Watson (2016) suggests that the so-called terroir—the relationship between place and quality—is an objective construct of traditional culture. The concept of terroir—that there is a vital link between a product's qualities and the region it was made—is at the core of Europe's approach to GI protection. (Watson, 2016).

Summing up this French term terroir involves four important factors: soil, terrain, climate, traditions. This concept is crucial for geographical indications to be safeguarded.

GIs provide intellectual property rights for specific items whose attributes are specifically tied to the region of production. In particular, it is possible to distinguish between:

- PDO Protected Designation of Origin (food and wine).
- PGI stands for protected geographical indicator (food and wine).
- GI Geographical indication of spirit drinks
- TSG Traditional speciality guaranteed

In the context of quality schemes for this sector, including GIs and guaranteed traditional specialties, the legislation specifies how to use logos for each scheme, clarifies how the schemes are applied, and addresses labeling guidelines for agri-food products containing PDO or PGI ingredients.

For example:

1. Regulation (EU) No 1151/2012 on quality schemes for agricultural products and foodstuffs

This regulation is intended to assist producers of agricultural products and food in conveying to buyers the characteristics of products and farm attributes of these products and food, thereby ensuring:

- fair competition for farmers and producers of agricultural products and food products with value-added characteristics;
- availability to consumers of reliable information related to such products;
- respect for intellectual property rights;
- the integrity of the internal market.

2. Commission Delegated Regulation (EU) No 664/2014 on logos to be used for PDO, PGI and TSG

This regulation supplements Regulation (EU) No 1151/2012 of the European Parliament and of the Council with regard to the definition of Union symbols for protected designations of origin, protected geographical indications, and guaranteed traditional specialties, as well as certain provenance rules, procedural rules, and additional transitional rules.

3. Commission Implementing Regulation (EU) No 668/2014 on detailed rules for the application of Regulation (EU) No 1151/2012 on quality schemes for agricultural products and foodstuffs

It includes specific rules for the use of linguistic characters for EU GIs, the definition of the geographical area, the obligation to include detailed rules on the origin and quality of feed in product specifications of products of animal origin, packaging, specific rules for a name, proof of

origin, procedural requirements for registration applications, and specific rules for the description of the product and the manufacturing method.

The EU GIs system protects the names of products originating in specified regions and holding specific traits or a reputation linked to the manufacturing territory. The distinctions between PDO and PGI represents that the PDO indication only certifies goods that were completely made and packed in the specified region, on the other hand, the PGI indications refer to the goods where not all manufacturing steps were tied to a specific area, but just the most important production steps that give the product its distinct character. GI is reserved for spirit drinks. (European Commission, 2023)

PDO Protected Designation of Origin

The names of PDO-registered products are those having the deepest ties to the region from whence they originate.

Products: Food, agricultural products and wines.

Specifications: Each stage of the manufacturing, processing, and preparation must take place in the designated region. For wines, this means that the grapes must come from the same geographical area where the wine is made.

Labeling is required for food and agricultural products. However, it is optional for wine. (Figure 1).

Figure 1. Protected Designation of Origin (PDO)

PGI - Protected Geographical Indication

When a distinctive quality, reputation, or other unique trait is largely due to geographical origin, the PGI stresses the relationship between the specific geographical place and the name of the product.

Products: Food, agricultural products and wines.

Specifications: At least one stage of production, processing, or preparation must take place in the region for most items. For wines, this means that at least 85% of the grapes used must come from the same geographical location where the wine is made.

Labeling is required for food and agricultural products. However, it is optional for wine. (Figure 2).

Figure 2. Protected geographical indication (PGI)

GI - Geographical indication for spirit drinks and flavoured wines.

The GI preserves the name of a spirit drink or flavoured wine originating in a nation, area when the product's quality, reputation, or other attributes are primarily related to its geographical origin.

Products: Spirit drinks and flavored wines.

Specifications: At least one of the distillation or preparation procedures for most products must take place in the region. However, raw materials do not have to be sourced within the region.

For all products, a label is optional. (Figure 3).

Figure 3. Geographical indication of spirit drinks (GI)

TSG - The traditional Speciality Guaranteed

The traditional Speciality Guaranteed (TSG) emphasizes traditional elements such as the method of production or the composition of the product without being tied to a specific geographical place. A product that is registered as a TSG safeguards its name from forgery and misuse.

Products: Food and agricultural products.

Label: Mandatory for all products. (Figure 4)

Figure 4. Traditional speciality guaranteed (TSG)

2.2 Climate change impact on agriculture (agriculture and livestock)

Agriculture in Europe plays a crucial role in generating various food, feed, and residual biomass items, while also serving additional significant purposes like landscape management, rural development, and tourism. Agricultural production can be classified into three distinct groups (Gurría, 2017):

1. Crop cultivation, which includes grains, roots, fruits, and tubers, along with the byproducts such as straw, chaff, husks, and similar residues.

2. Grazed biomass that serves as fodder for livestock. This biomass is obtained from various sources such as harvested crops, crop residues, grazed biomass, and imports of agricultural products. These imports encompass live plants and animals, food items derived from animals and plants, and other processed products originating from agriculture (e.g., leather products).

3. Livestock rearing and production.

According to the Eurostat data EU farms used 161 million hectares of land for agricultural production in 2020, 38 % of the total land area of the EU. However, the share of utilized agricultural area differs considerably among EU Member States. The Utilised Agricultural Area (abbreviated as

UAA) describes the area used for farming. Thus, France occupies 28.6 million hectares and Spain covers 24.4 million hectares, while Portugal and Ireland encompass 3.9-4.3 million hectares respectively. Italy, in turn, occupies an average position and covers 12.9 million hectares of utilized agricultural area. (Figure 5).

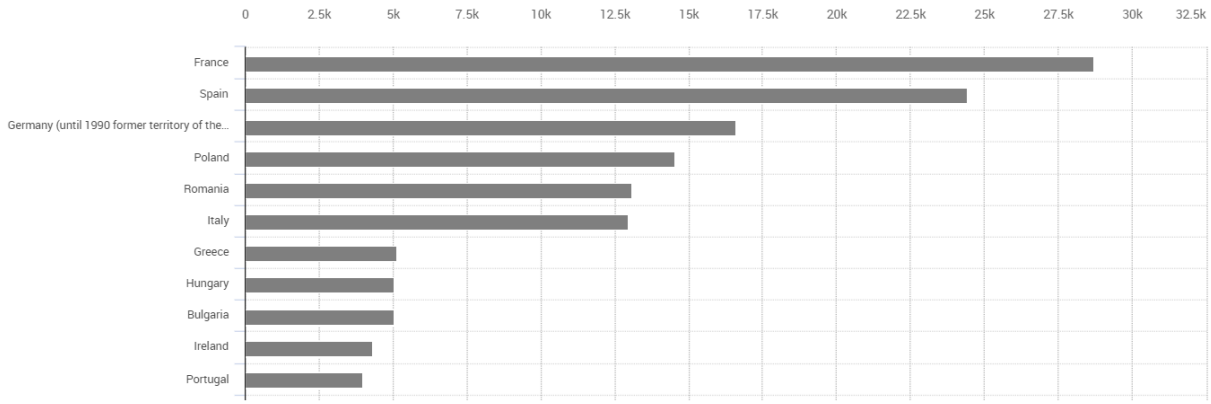

Figure 5. Utilized agricultural area, Annual, Main area (1000 ha), 2021.

However, Eurostat data show that, in addition to greater production, farm sizes have increased across the EU, while the number of farms has decreased. Small farm holdings dominate Europe's agriculture sector: «The number of farms in the EU has been declining sharply, but the amount of land used for production has remained stable». (Eurostat)

The impact of changing mean temperature and precipitation, along with weather and climate extremes, is already evident in Europe, affecting both crop yields and livestock productivity. Agriculture also plays a role in climate change by emitting greenhouse gases and air pollutants. According to reports from the European Environment Agency (2016), the observed and projected climate change impacts for the main biogeographical regions in Europe can be classified into seven regions: Atlantic, Arctic, Boreal, Continental, Mountain, Coastal, and Mediterranean regions (see Figure 6). The Arctic region has experienced notable climate change observations, including an increase in heavy precipitation events, river flow, the risk of river and coastal flooding, damage risk from winter storms, and multiple climatic hazards. The Boreal and Atlantic regions also exhibit indicators of climate change, such as an increase in heavy precipitation events and an elevated risk of damage from winter storms. Coastal zones, on the other hand, face the risk of sea-level rise and intrusion of saltwater. Mountain regions are characterized by the upward shift of plant and animal species, the risk of hail and frost, while the continental region experiences an increase in heat extremes and the risk of river floods, along with a decrease in summer precipitation. Specifically, the

Mediterranean region is significantly impacted by climate change factors, including a substantial increase in heat extremes, the risk of droughts, the risk of biodiversity loss, higher water demand for agriculture, risks to livestock production, a decrease in precipitation, and reduced crop yields.

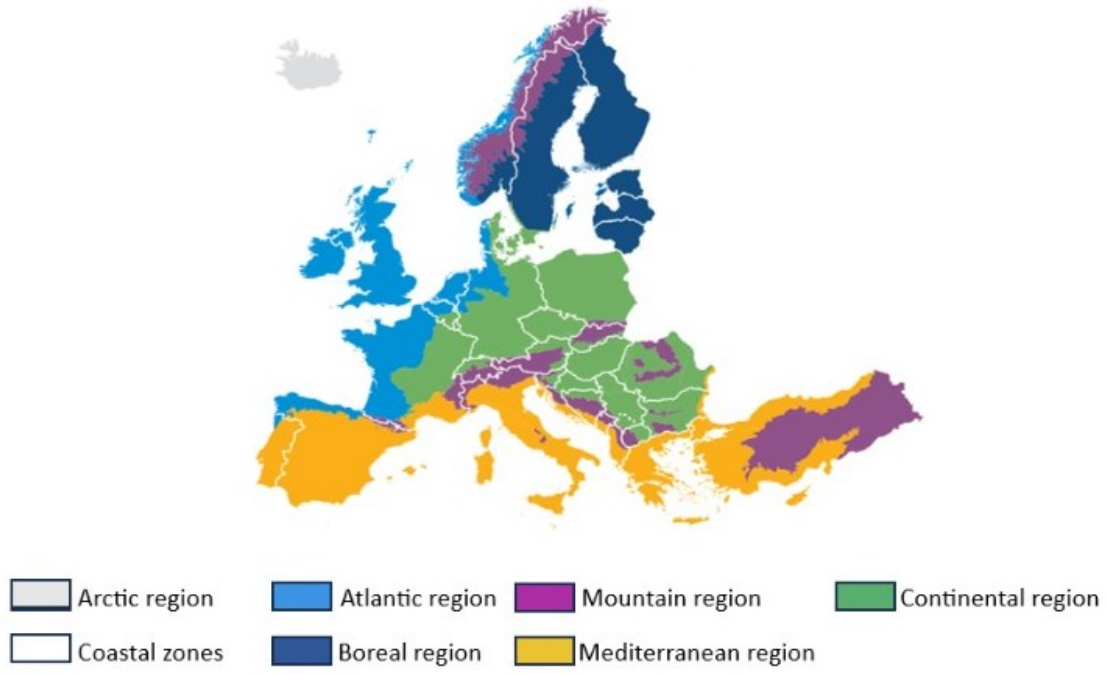

Figure 6. Main climate change impacts on the agriculture sector for the main biogeographical regions in Europe. (Source: European Environment Agency, 2016)

The agricultural sector is the most susceptible industry when confronted with climate change. It will endure the most substantial adverse consequences resulting from shifts in climate patterns, ultimately exacerbating global food security concerns. (Li et al., 2022). According to climate projections, a majority of European regions are anticipated to experience higher levels of warming compared to the global average. The combined impacts of temperature, rainfall, and atmospheric CO2 concentration changes have varying effects on crop yields across them.

Climate change can have both direct and indirect impacts on agricultural production and the underlying agro-ecosystems. Direct impacts encompass changes in phenology and growing seasons, shifts in cultivation areas and soil erosion, alterations in water availability and irrigation demands, as well as the direct effects of elevated CO2 levels on plant growth. Indirect effects occur as a result of these direct impacts, which can further negatively affect agricultural production. Examples include increased pest and disease pressure, the spread of invasive species, and the occurrence of extreme events like strong winds, hailstorms, heatwaves, and frosts. The consequences for agricultural

production extend beyond the farm level, impacting livelihoods, food security, and the broader economy and society. The interconnected impacts of climate change on agro-ecosystems and agricultural production subsequently influence product prices, quantity and quality, trade patterns, agricultural income, and food prices. (Jacobs et al., 2019)

The relationship between agriculture and climate change is intricate and interconnected. The agricultural industry is a significant contributor to greenhouse gas emissions, which in turn influence the climate. The escalation of greenhouse gas concentrations in the atmosphere, along with rising temperatures and alterations in precipitation patterns, have far-reaching effects on the quantity, quality, and sustainability of agricultural and livestock production. Additionally, these changes impact the surrounding natural environment where agriculture takes place. Overall, alterations in atmospheric CO2 concentrations and rising temperatures are causing modifications in the characteristics and structure of crops, as well as impacting the prevalence of indigenous and invasive pests and diseases. These changes have the potential to impact both livestock and, consequently, humans, alongside crops. Furthermore, the escalation of ozone levels associated with climate change is expected to have notable adverse effects on agriculture, particularly in the northern mid-latitudes. (Lavalle, 2009). Based on scientific research analyzing the influence of rising temperatures on four significant crops (wheat, rice, maize, and soybean), various approaches consistently demonstrated detrimental effects on crop production worldwide. (Zhao et al., 2017). Without the benefits of CO2 fertilization, effective adaptation strategies, and genetic enhancements, a one-degree Celsius rise in the global mean temperature would, on average, lead to a reduction in global yields: wheat by 6.0%, rice by 3.2%, maize by 7.4%, and soybean by 3.1%.

However, the impact of climate change on agricultural yields varies depending on the country and the specific crop involved. Certain regions may experience positive effects due to specific aspects of climate change, such as cooler countries benefitting from rising temperatures or experiencing "carbon fertilization effects." However, other countries may suffer significant negative consequences, such as water stress and reduced crop productivity. In many countries, a combination of these various impacts can exacerbate vulnerabilities. Crop production in northern temperate latitude sites would benefit from higher spring/summer air temperatures as it would extend the length of the growing season. However, in regions where summer temperature and water availability already impose limitations, warmer temperatures during crop development could actually decrease yields. For instance, the effect of increasing temperatures on agricultural yields can be both positive and negative, depending on the country's characteristics. Nevertheless, a substantial rise in temperature leads to water scarcity, which

can severely worsen agricultural systems in all countries, particularly in semi-arid regions like Southern European countries. Furthermore, while increased precipitation may benefit semi-arid areas by enhancing soil moisture, it can exacerbate issues in regions already facing water excess problems. (Agovino, 2019)

Crop cultivation is acknowledged as a vulnerable component of the food and feed production sector, susceptible to the impacts of climate change. However, it is important to note that livestock production can also be significantly influenced. Climate change has implications for various aspects of food safety, including the consequences on livestock production and the occurrence of livestock diseases. (Godde et al., 2021).

The effects of climate change on livestock can be direct, with stress factors affecting the appetite of animals. Indirect influences are also observed, such as the need to modify the quantity and quality of forages from grasslands and the supply of concentrates. Additionally, changes in temperature can impact the production efficiency of livestock. Estimates indicate negative effects of heat waves during the summer, but these may be counterbalanced by the positive effects of warmer winters. Similar to crops, climate change can have both detrimental and beneficial effects on livestock, depending on the specific area and circumstances. For instance, altered seasonal temperatures can adversely impact productivity if higher temperatures lead to reduced animal product output (e.g., milk, meat) in the summer. However, they may also result in improved conditions for livestock keeping and production during winter. (Miraglia et al., 2009)

Climate change is characterized by rising temperatures, greater variation in precipitation, and more frequent severe weather events. These changes have been observed to have significant effects on livestock and the production of crops and forage for livestock. These impacts can be categorized as direct and indirect effects. Direct effects include feed intake, immune system functioning, and overall production. Indirect effects, on the other hand, encompass climate's impact on crop and forage production, water availability, and the presence of pests and pathogens that affect livestock. (Cheng et al., 2022). For a concise overview of these impacts refer to Table 1.

Impact type	Observed impacts	The main influencing factors
	Decrease in feed intake	

Direct impact	Change in quality and composition of animal milk and meat production	Heat stress
	Decline in reproductive efficiency	
	Decreased immune system	
	Increased mortality rate	
Indirect impact	Occurrence of pathogens and parasites	Temperature rise and change in the precipitation pattern
	Decrease in crop and forage quality	Temperature rise and CO2 level
	Change in the quality of water and increased water consumption	Increased temperature
	Increased disease	Temperature rise and precipitation change

Table 1. Direct and inderect effects of the ckimate change on livestock (Source: Cheng et al., 2022)

The thermal environment plays a crucial role in influencing animal production, encompassing factors such as air temperature, humidity, and air movement. The ideal combination of these factors is commonly known as the thermal comfort zone, within which animals demonstrate optimal performance and minimize energy expenditure. However, when the environmental conditions exceed this comfort zone, additional energy is needed to regulate body temperature, leading to decreased efficiency in production processes. Animals experience thermal stress when the ambient temperature falls outside the boundaries of the thermal comfort zone. (Collier et al., 2019).

Heat stress arises when animals are unable to adequately dissipate heat to maintain a stable body temperature. Consequently, this condition has been observed to cause elevated respiration, pulse, and heart rates, as well as increased body temperatures in animals. (Nardone et al., 2010). As a result, various negative impacts can occur, including reduced feed intake, decreased milk

production, lower reproductive efficiency, and alterations in mortality rates and immune system function.

High environmental temperatures can lead to a decrease in feed intake. In particular, ruminant animals can experience reduced appetite, gut motility, and rumination when exposed to heightened heat stress. Lactating dairy cows, for example, demonstrate a reduction in feed intake when ambient temperatures surpass 25–26 °C, with even more pronounced declines observed above 30 °C. Goats, on the other hand, are generally less susceptible to heat stress compared to other ruminants. However, their voluntary feed intake still declines when the ambient temperature exceeds their thermal comfort zone by more than 10 °C. (Yadav et al., 2013).

Heat stress has an impact on both the composition and quantity of goat milk. During hot seasons, lactating goats activate a mechanism that reduces water loss through urine in order to prioritize milk production when water resources are limited. Additionally, exposure to high temperatures adversely affects buffalo milk production as it disrupts the physiological functions of the animals, including pulse rate, respiration rate, and rectal temperature. (Seerapu et al., 2015). As a consequence, the increased production of metabolic heat caused by heat stress leads to a decline in milk production.

Rojas-Downing (2017) claims beef cattle that have higher weights, thicker coats, and darker colors are more susceptible to the effects of warming. Global warming has the potential to decrease body size, carcass weight, and fat thickness in ruminants. This trend is also observed in pig production, where larger pigs experience more significant reductions in growth, carcass weight, and feed intake. The survival rate of piglets may decrease due to a decline in the sows' feed intake during suckling periods when temperatures exceed 25 °C, leading to a reduction in milk yield.

The poultry industry may face challenges with low production levels when temperatures surpass 30 °C. Heat stress in birds results in reduced body weight gain, decreased feed intake, lower carcass weight, and a decline in protein and muscle calorie content. Hens exposed to heat stress experience reduced reproductive efficiency, leading to decreased egg production due to lower feed intake and disruptions in ovulation. Additionally, hotter conditions can have negative impacts on egg quality, including reductions in egg weight, shell weight, and shell thickness. (Rojas-Downing et al., 2017).

Heat stress can have an impact on the reproductive efficiency of both male and female livestock. In cows and pigs, heat stress can disrupt oocyte growth and quality, impair embryo development, and lower pregnancy rates. (Ross et al., 2017). While heat stress also affects poultry reproduction, there

may be differences in performance compared to mammals. Male broiler chickens, for example, are reported to be more susceptible to heat-induced infertility compared to female broiler chickens. (Nawab et al., 2018).

During acute stress, the production of cortisol serves as a stimulus for the immune system. However, under chronic stress conditions, the secretion of cortisol has been linked to immune suppression. This suppression of the immune system leaves animals more susceptible to diseases and immune challenges. Heat stress can adversely affect immune functions through both cell-mediated and humoral immune responses. Consequently, periods of hot weather can increase livestock's vulnerability to diseases and raise the occurrence of specific ailments, such as mastitis. (Bagath et al., 2019). The research of Dahl G. E (Dahl et al., 2020) provides compelling evidence that heat stress during the dry period has substantial adverse effects on the innate and adaptive immune functions of both the mother and her offspring. These effects influence the morbidity and mortality rates of cows and calves during the early lactation period, spanning from birth to first calving. Heat stress also directly impacts the passive and cell-mediated immunity of newborn calves, which may account for the increased mortality observed in calves during the summer season.

Concurrently, rising temperatures and changes in precipitation patterns can expedite the occurrence of pathogens and parasites. This heightened susceptibility to diseases raises the potential for increased morbidity and mortality among the animals, and subsequent economic losses. Mortality is a crucial consequence of heat stress and carries substantial economic implications. (Dahl et al., 2020).

Regarding indirect impacts, climate changes can affect crop quality through elevated temperatures and drought conditions. These factors can lead to fluctuations in the concentrations of water-soluble carbohydrates and nitrogen in crops. (Hopkins and Del Prado, 2007). In addition, as temperatures rise, the nutritional value of forage decreases, resulting in reduced protein content. (Lee at al., 2017).

The quality of water plays a crucial role in agricultural irrigation. Water is employed for various purposes in the livestock industry, including animal consumption, the growth of feed crops, and the processing of products. (Gosling and Arnell, 2016). The rising temperature concern is expected to rise water use and consumption. Another problem is connected with water salinity which represents a complex issue influenced by multiple factors, such as river flow, tidal surges, rainfall, groundwater extraction, as well as the impact of sea-level rise. (Vineis at al., 2011)

Climate change has the potential to modify the seasonal models and variance of resources, crop yields, and livestock production. While certain breeds, such as smaller and lighter-colored animals, may be less affected by heat stress, the increased frequency and duration of heat waves will still subject animals to additional stress. (Polsky and von Keyserlingk, 2017). Furthermore, alterations in the seasonal patterns of forage availability may present subsequent challenges for livestock management.

2.2.1 The impact of climate change on Geographical Indications

Climate change is already having a deep influence on PDOs and PGIs, since it impacts critical characteristics of terroir, such as: rainfall, water availability, soil quality, and temperature. These consequences raise concerns about the definition of terroir and the existing standards that define the identity of GIs in the face of climate change. Terroir, which refers to the unique interplay between soil, moisture, sunshine, and other natural variables that give a product its distinct characteristics, is critical to comprehending the possible issues climate change provides for GIs (Clark and Kerr, 2017). If climate change alters these parameters, established terroirs may not sustain agricultural enterprises properly. As a result, there may be pressure to change the legal definition of terroir.

Climate change is anticipated to disrupt the majority of the attributes of terroirs, lowering the production and profitability of farms relying on GIs (Salpina and Pagliacci, 2022). Farmers who adopt GI schemes, especially, are projected to face the main burden of climate change and its attendant economic, environmental, and social impacts. (Soubry et al., 2020).

Based on the research of Salpina and Pagliacci (2022), crop GIs are especially vulnerable to temperature increases, water stress, high precipitation, floods, severe winds, and seasonal changes. In contrast, animal-based GIs are sensitive to high precipitation, floods, heat, and water stress, which damage cattle and fodder.

For instance, animal-based GIs are primarily concerned excessive rainfalls, which have severely impacted feed supply in defined production regions in recent years. Heavy rainfalls are followed by severe winds, storms, and even floods in the case of cheese GIs made in mountain locations. (Pagliacci and Salpina, 2022).

Another example based on this research shows that rainfall that lasts for 4 or 5 days during the ripening season of GI cherries usually results in cracking of the fruits and «loss of prestige», thus a decline in product quality. Similarly, for annual crop GIs, prolonged precipitation during harvesting

appears to significantly restrict agricultural field accessibility, resulting in output losses and delays (Pagliacci and Salpina, 2022).

As an illustration from the Veneto Region, Radicchio GIs' harvesting time is limited. As a result, frost is a serious concern in the context of climate change. Radicchio is also quite demanding in terms of soil conditions, necessitating moderately drained soils with an elevated pH level. (Thompson and Duncan, 1997).

Also, numerous works document an advance of phenological phases of olive trees due to temperature increase, which affects their productivity in the Mediterranean region (Sousa et al., 2020). It means that temperature increase for these GIs could potentially require to change production processes compromising products' quality.

In the context of climate change, the idea of vulnerability is critical. The adjective vulnerable is defined as "exposed to the possibility of being attacked or harmed" by the Oxford Dictionary of English (Wolf et al., 2013). Two key notions of vulnerability in the context of climate change may be presented. Outcome vulnerability is based on natural science and considers several possibilities of climate change by looking at a system's ability to adapt. On the other hand, contextual vulnerability is grounded on social science and emphasizes a system's current incapacity to adapt to a changing climate (O'Brien et al., 2007).

GIs are additionally vulnerable because of the climatic conditions. Terroirs, in particular, can be a source of vulnerability: any changes in average annual temperature or water availability can reduce productivity, and thus farm profitability, of GI farms, which are not eligible to relocate their production to a more suitable location (Pagliacci and Salpina 2022).

GIs, on the other hand, are projected to be disproportionately endangered by the consequences of climate change due to their features. The increased frequency and intensity of climate change-induced events is increasing crop losses all across the world (Salpina and Pagliacci, 2022), lowering agricultural product quality, particularly in places where traditional farming practices are widely used.

Climate change is anticipated to result in a more active hydrological cycle, with higher overall rainfall and more frequent high intensity rainfall events in alternation with prolonged droughts (Caretta et al., 2022). Adapting to climate change in GI agro-food products may cause production declines which consequently may impact livelihoods. The consequences of climate change, on the

other hand, will not be consistent among all farmers within the defined area. As result, the requirement for adaptability will differ among various agricultural operations, perhaps causing tension within the organization that holds the GI goods. Consequently, both the GI requirements and the organization must account for climate change adaptation. (Clark and Kerr, 2017).

To summarize, although the entire global agri-food industry is vulnerable to climate change, agri-food GIs are significantly more vulnerable due to the relation between the concept of terroir and changing climatic conditions.

3. Material and data

3.1. Data on Italian agriculture

The agricultural industry and agri-food system in Italy are significant contributors to the country's economy, accounting for around 2% and 15% of GDP, respectively. Italian agriculture is a one-of-a-kind blend of climates, soils, and terrain, resulting in one of the most diverse agricultural outputs in the EU. (Marras et al., 2021)

As a result, the northern parts of Italy produce largely cereals, soybeans, meat, and dairy products, while the southern regions specialize in fruits, vegetables, olive oil, wine, and durum wheat. Therefore, the country is one of the EU's top agricultural producers and food processors. Italy also possesses the most agri-food products with Protected Designations of Origin and Protected Geographical Indications recognized by the EU, and it is the world's top wine producer in terms of volume. (European Commission, 2023)

Italy has over 1.1 million farms covering approximately 12.6 million hectares of agricultural land. More than half of all agricultural land is classed as mountainous or subject to natural restrictions. Agriculture and forestry are key economic drivers for 53% of the Italian population, which lives in rural or intermediate areas. (European Commission, 2023).

Because Italy's territory stretches across a wide latitude, its soil and climate features are exceptionally diverse, which has favored the development of highly diversified agricultural methods, resulting in notably specialized agri-food items. Because of Italy's geographical diversity and its influence on agricultural methods, the previously described geographical elements led to the creation of several types of land, each ideal for unique agricultural objectives. Therefore, there are 3 types of land used for agriculture in Italy. (Figure 7).

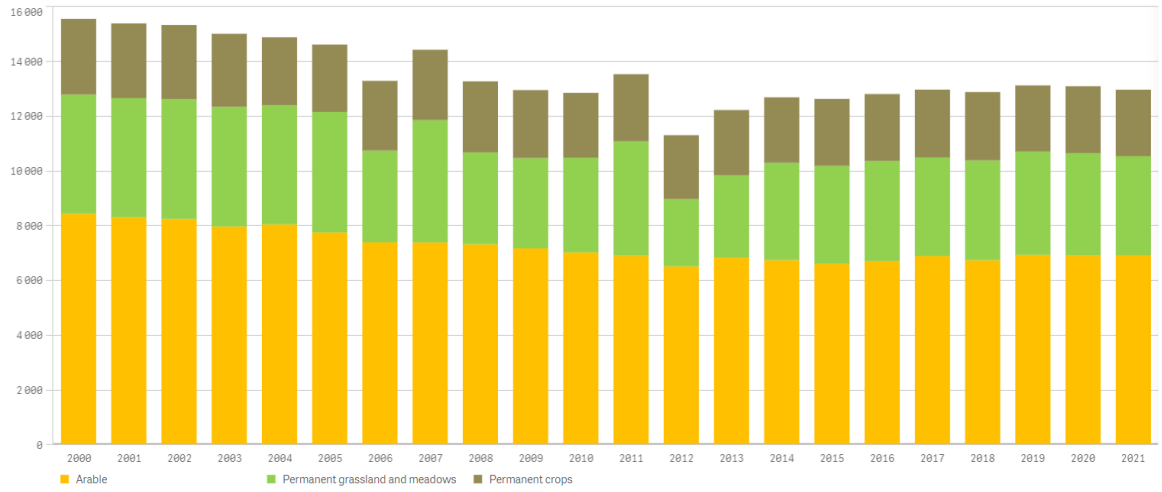

Figure 7. Land used for agriculture by type in 1000 hectares in Italy. (Source: EUROSTAT)

Agricultural output per sector

Crops accounted for over half of the entire value of the EU's agricultural production, with vegetables, horticultural plants, and cereals being the most valued crops. Animals and animal products accounted for around two-fifths of overall output, with milk and pigs accounting for the vast majority. (see Figure 8).

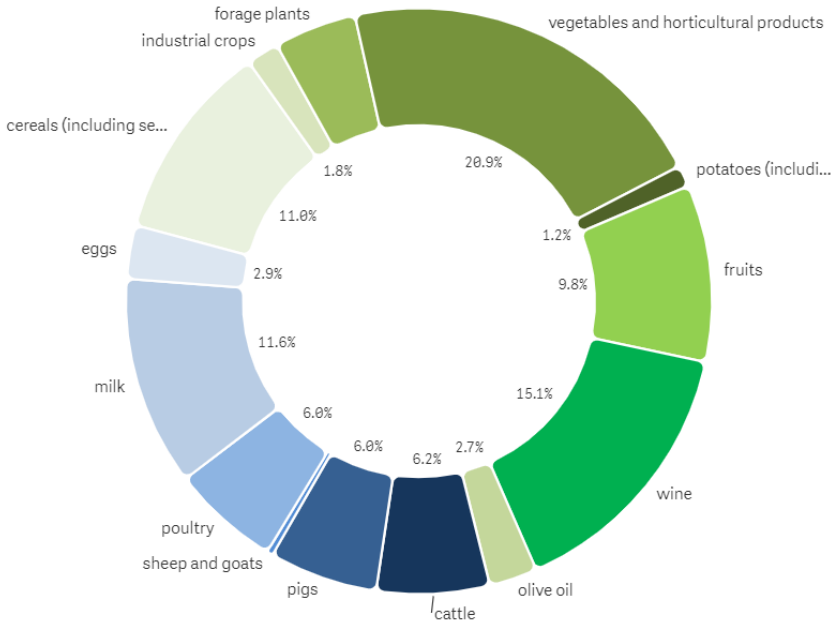

Figure 8. Agricultural output per sector in Italy, 2022. (Source: Eurostat)

3.1.1 Data on pork industry

The European Union's pork industry accounts for almost half of the total meat production in the region. This sector is marked by significant diversity, evident in the varying approaches to pig rearing and the range of farm sizes among the EU Member States, spanning from small-scale, localized farming to large-scale industrial facilities housing thousands of animals. (European Parliamentary Research Service, 2020).

The pork industry in Italy holds a prominent position within the country's agricultural and food sectors. Within the swine production process, the act of slaughtering animals holds significant role due to its influence on aspects such as animal well-being, the food security, and the overall sustainability of the agricultural and food chain.

According to Eurostat, in 2022 the total pig population in European Union numbered 134 thousand heads (Figure 9). Spain accounted 34 thousand heads, followed by Germany (21 thousand heads), France (12 thousand heads), Denmark (11 thousand heads), Netherlands (10 thousand heads), and Poland (9 thousand heads). Italy ranked 7th position with 8 thousand heads.

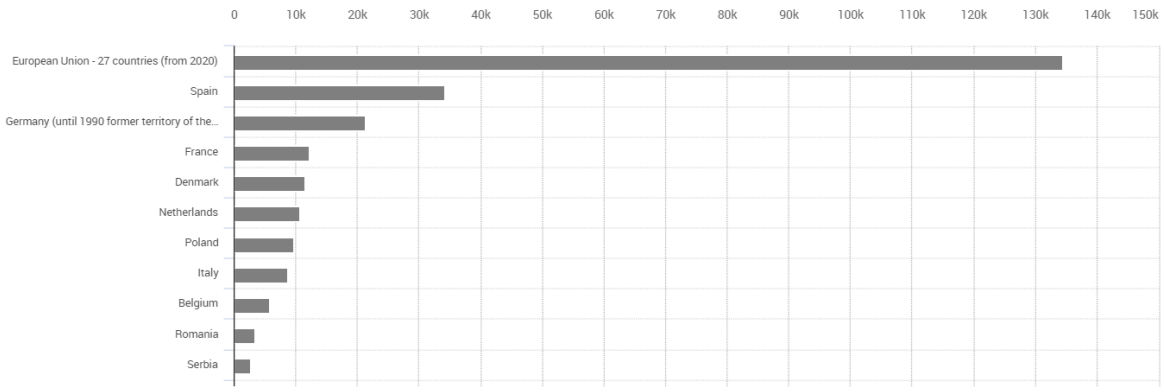

Figure 9. Pig population, thousands heads. (Sourse: Eurostat)

The Italian pork industry encompasses a wide range of participants involved in both the agricultural phase and the subsequent industrial transformation process. The slaughtering activities play a crucial role in ensuring the sustainability of the agricultural and food chain by monitoring the origin and quality of agri-food production at a significant node within the production chain. As a result, they ensure the traceability of production, thereby maintaining the standards and transparency of the entire process. (Bonazzi, 2021).

The majority of pig breeding in Italy is concentrated in the northern regions, with Lombardy alone accounting for 50% of the animals. When considering the northern regions as a whole, including Lombardy, Piedmont, Emilia Romagna, and Veneto, they collectively house 89% of the total pig population in Italy.

3.2. Geographical Indications system in Italy

Italy is the European country with the largest number of agri-food products with a designation of origin and geographical indication recognized by the European Union. According to the Ministry of agriculture, food sovereignty and forestry data, there are now 578 PDOs in Italy, with 170 for agri-food items and 408 for wine and spirits. PGIs include 257 goods, specifically 139 agri-food products and 118 wine and spirits. There are presently three Traditional Specialities Guaranteed: Mozzarella, the Pizza Napoletana and the Traditional Amatriciana. (Ministry of agriculture, food sovereignty and forestry, 2023).

There are a total of 43 high-quality agri-food products derived from pigs, out of which 21 are PDO and 22 are PGI. In 2018, the certified production of meat-based products in Italy exceeded 200 thousand tons, generating a turnover of over 2 billion euros. (Bonazzi, 2021).

The distinguished characteristic of heavy pig breeding in Italy is the concept of terroir and the unsurpassed quality associated with it. This quality is characterized by PDO (Protected Designation of Origin) and PGI (Protected Geographical Indication) labels. The production of these labels must adhere to precise requirements regarding age, weight, genetic origin, and feed intake.

According to PDO/PGI portal (2023), Geographical Indications improve the quality of manufacturing in Italy's territory. The major goal is to reward producers for their efforts in delivering a diverse range of high-quality products. GIs have a positive impact on the regional and national economies.

GIs protection necessitates a collaborative effort of networking within the Italy System. The Ministry of agriculture, food sovereignty and forestry collaborates with regional and European administrations, as well as supply chain participants.

GIs are awarded as a consequence of collaboration between commercial and public actors and serve as a guarantee to consumers of excellent product quality and value in terms of PDO, PGI, and TSG. (PDO/PGI portal, 2023).

3.3. PDO pork industry and Prosciutto di Parma PDO

For the production of the Italian heavy pig to obtain high-quality meat from heavy cuts, it is obligatory to slaughter animals that are at least 9 months old and weigh 160 kg live weight. The specific breeds used for this purpose are the Italian Large White and Landrace, which have been carefully selected based on factors like the loss experienced during the first salting of the ham. Additionally, crosses between these breeds are also utilized in the production process. (Bosi and Russo, 2004)

The feeding regime for Italian heavy pigs aims to achieve mature animals within a specific weight range, which involves restricting feed and energy intake in their diet. Throughout the entire growing-fattening phase, which spans approximately six months, pigs are traditionally provided with liquid feed twice a day. This liquid feed is prepared by combining commercial feed with either water or milk whey. In the northern and northeastern regions of Italy, the historical presence of whey as a by-product of cheese production, such as Parmigiano Reggiano and Grana Padano, has contributed to the widespread adoption of liquid feeding due to its relatively affordable cost. (Vitali, 2021). Additionally, during the growing phase pigs are supposed to use different areas for resting, feeding, defecating, and urinating purposes. Also, The European legislation on pig welfare establishes minimum requirements for environmental illumination, mandating a minimum of 40 lux of light intensity for at least 8 hours per day. (European Commission Council directive 2008/120/EC of 18 December 2008). This regulation recognizes the importance of providing pigs with adequate levels of light in terms of both intensity and duration. By meeting these requirements, it enables pigs to engage in their explorative and social activities, fulfilling their inherent needs.

The pig farming sector is subject to numerous EU legislative acts that encompass a wide range of areas, including environmental protection, food safety, public health, organic production, and animal health and welfare. However, there is evidence indicating a failure to comply with EU regulations regarding pig welfare, and the continuation of harmful routine practices. (Marie-Laure Augère-Granier, 2020). As part of the common agricultural policy (CAP), the pig meat sector falls under the common organization of markets, which oversees trade and offers assistance in times of sectoral crises. Additionally, farmers have the opportunity to secure rural development funding through the CAP's second pillar, enabling them to make essential investments in their farms.

The Italian pig industry is distinguished by a multitude of participants engaged in both the agricultural stage and the subsequent industrial transformation process. What unites these two

sectors of the pig production chain in Italy is the activity of slaughterhouses. These entities hold a significant role in upholding the sustainability of the agricultural and food supply chain. They serve as a crucial checkpoint in the production chain, specifically at the juncture where agricultural production transitions into industrial processing. This role ensures the traceability of production, food safety, and, consequently, transparency within the consumer market. (Van Ittersum et al., 2007).

In 2023, 2,623 million pigs were slaughtered in Italy (10,347 million pigs in 2022), according to the data from ISTAT (Data Slaughterhouse Sector in Italy). There are 56 slaughterhouses recognized for the slaughter of pigs for production with the denomination of origin, 82% of which are in Northern Italy, specifically in the regions of Lombardy and Emilia-Romagna, and specifically in the provinces of Cremona, Mantova, Parma, and Modena, which account for approximately 70% of total slaughter activities in Italy. (Bonazzi, 2021).

The value chain of Italy's pork industry occupies a prominent position in the country's agricultural and food sector. It forms an intricate network of activities and participants responsible for the cultivation, processing, and distribution of pork and its associated products.

Bonazzi (2021) claims the Italian pork industry's value chain encompasses four primary stages, representing a sequence of interconnected processes, individuals, and businesses involved in the transportation and transformation of raw materials from initial producers to ultimate consumers. The process commences with livestock farming, where breeders adhere to Production Specifications and oversee animal welfare, ensuring their well-being from birth to maturity, a period of at least nine months. The subsequent stage involves abattoirs, responsible for verifying that the received animals originate from farms within the PDO network. These facilities assess, categorize, and disassemble carcasses in strict accordance with the PDO Product Specifications. Fresh pork legs are promptly sent to the prosciutto production plant, typically within 48 hours of slaughter.

The production process that follows encompasses various activities, including preparation, curing, slicing, packaging, and labeling with PDO certifications. The adherence to Production Specifications is certified by the independent control body, IFCQ Certificazioni (2023), which operates under the supervision of the Ministry of Agricultural, Food, and Forestry Policies. This body conducts specific checks to ensure that the pork legs meet the Production Specifications' requirements, certifying only those that satisfy all criteria. These certified products are labeled with the PDO designation on the rind, which includes the producer's identification code, serving as both proof of certification and a guarantee of quality.

The final stage involves sales and distribution, with products reaching stores, supermarket chains, and ultimately, the plates of consumers not only in Italy but also around the world.

In 2021, the Prosciutto di Parma Consortium (2023) initiated an exemplary supply chain project. This endeavor involves the direct collaboration of the protection Consortium, a select group of supply chain stakeholders, including producers, breeders, and slaughterhouses, and also benefits from the support of additional technical and scientific partners, such as the University of Milan.

This project offers a model of excellence to all segments within the Parma Ham production chain, with the primary goal of encouraging them to adhere to higher sustainability standards than those currently mandated by existing regulations. These elevated standards pertain to various aspects, including animal welfare, the responsible use of medications, and biosecurity.

Particular emphasis is placed on the initial stages of the supply chain, namely breeding and slaughtering. In these early links, the project aims to identify, develop, and promote concrete metrics and practices that will lead to the creation of an increasingly eco-friendly Parma Ham. This approach aligns with the preferences of contemporary consumers who are increasingly concerned about the sustainability of the production process and the food products they purchase (Consortium for Parma Ham Prosciutto di Parma, 2023).

The Italian pig industry is comprised of numerous agencies and organizations that play critical roles in regulating, promoting, and supervising various sectors of the business.

For example, the Ministry of Agricultural, Food and Forestry Policies (MIPAAF, 2023) is in charge of conducting of inspections, controls and sanctions, which make it possible to guarantee consumers high quality products. The Ministry promotes and supports, through transparent selection and allocation procedures, research and innovation activities in the agricultural sector. It serves an important role in the supervision and management of agricultural aspects of the pig sector, including quality criteria and production requirements (the Ministry of Agricultural, Food and Forestry Policies (MIPAAF)).

The Central Inspectorate for the Protection of Quality and the Prevention of Fraud in Agri-Food Products (hereinafter ICQRF), founded in 1986, is the official control body of the Italian Ministry of Agricultural and Forestry Policies, operating throughout the national territory and is one of the largest European agri-food control bodies. Through the fight against food fraud and, more broadly, through activities to prevent and combat offenses, the ICQRF plays a critical role in protecting

consumers, food safety, and producers from unfair competition. Controls on quality, recognition of control and certification structures, and supervisory roles on control structures working in the field of regulated quality production in the pork sector are the major activities. (The Central Inspectorate for the Protection of Quality and the Prevention of Fraud in Agri-Food Products, 2023)

The Italian Pig Breeders Association (Associazione Nazionale Allevatori Suini – ANAS, 2023) is a non-profit organization that operates throughout the national territory and aims to promote and implement all efforts that can help to improve, conserve, enhance, and disseminate breeding pig breeds and products derived from them. Ordinary members of ANAS are pig breeders registered in the Herd Book's Breeding Register or users of the outcomes of ANAS genetic programs. ANAS supporting members are entities and companies active in the pig industry with tasks that fall within the Association's institutional aims. Overall, The Italian Pig Breeders Association is linked to breed improvement, genetic selection, and promoting pig breeders' interests. (The Italian Pig Breeders Association, 2023).

Another agency involved represent academic and research institutions, such as the University of Parma, which conduct research and provide expertise related to pig health and production.

Ifcq Certificazioni Srl was founded as a regulatory body for the "Prosciutto di San Daniele" and its manufacturing chain. Today, IFCQ certifies 25 agri-food products from Northern to Central Italy with PDO and PGI designations. The IFCQ team conducts its activities with objectivity and competence, instilling trust in all parties, from the producer to the final consumer, encouraging companies to improve the quality of their products and, as a result, their competitiveness in a constantly changing economic and social environment. The activity's pillars are quality, efficiency, transparency, and environmental stewardship. (Ifcq Certificazioni Srl, 2023).

3.4 Prosciutto di Parma case study

According to eAmbrosia, Parma ham, also known as Prosciutto di Parma, is specifically designated for ham that carries a distinctive permanent marking. It is sourced from the fresh hind legs of pigs that are born, raised, and slaughtered within specific regions outlined in the EAmbrosia specification. The production adheres to all relevant legal and regulatory requirements, and the ham is aged for a minimum of 12 months in the traditional production area after being salted.

Parma Ham can only be used to refer to hams produced in Parma and meeting the rigorous standards established by the Consorzio (Parma Ham Consortium, 2023). These standards are deeply rooted in

the longstanding customs of the region. In 1996, Parma Ham became one of the first meat products to be granted the esteemed Designation of Protected Origin, acknowledging its genuine nature and specific place of origin.

The designated production region for Parma Ham encompasses the province of Parma in the Emilia-Romagna region of Italy. It is situated south of the Emilia Road (Via Emilia), at a minimum distance of 5 km, and stretches up to a maximum altitude of 900 meters. The eastern boundary is marked by the River Enza, while the Stirone stream delineates the western boundary of the production area.

This area benefits from exceptional ecological, climatic, and environmental conditions. It is the exclusive location where the distinct and crucial breeze, responsible for the gentle and unparalleled "drying" of Parma Ham, occurs. The plant's large windows facilitate the circulation of air, which significantly contributes to the enzymatic and biochemical processes necessary for the development of Parma Ham. (eAmbrosia «Prosciutto di Parma», 2023).

For centuries, the exceptional circumstances of the Parma region have allowed the production of top-notch hams that have been cherished by connoisseurs since the time of the Romans. The word "prosciutto" derives from the Latin term "perexsuctum," meaning "dried," highlighting the authentic and time-honored nature of Parma Ham production.

The pig farms responsible for supplying the legs utilized in the production of Parma Ham, as well as the authorized slaughterhouses for their preparation, the processing facilities (ham curing plants), and the facilities for slicing and packaging, must all be situated within the specified area. Hams produced in the same region but failing to meet the Consorzio's standards cannot be labeled with the official certification mark, the Parma Crown. (Figure 13) They are not allowed to be referred to as Parma Ham, even if they originate from the Parma area.

Figure 10. Official certification mark, the Parma Crown (source: Parma Ham Consortium, 2023)

Parma Ham possesses distinct characteristics (eAmbrosia «Prosciutto di Parma», 2023), which can be described as follows:

a) External Appearance: The ham has a curved shape and does not include the distal part, or trotter. It should be free from any visible flaws that could affect the overall quality, with the exposed muscular portion above the femur head (best end) limited to 6 centimeters through trimming.

b) Weight: Generally, the ham weighs between eight and ten kilograms, but it should not be less than seven kilograms.

c) Sliced Color: When sliced, the ham displays a uniform range of hues, transitioning from pink to red, with marbling of white fat.

d) Aroma and Flavor: The taste of Parma Ham is characterized by a mild and delicate flavor. It carries a slight saltiness, complemented by a fragrant and distinct aroma.

e) Compliance with Analytical Parameters: The ham meets specific predetermined analytical criteria, ensuring its quality and adherence to established standards.

The selection of qualitative parameters is determined by considering both sensory qualities and chemical measurements such as salt, moisture, and soluble nitrogen content (proteolysis index). It is widely recognized that superior ham should have low levels of sodium chloride and moisture, while a high proteolysis index negatively impacts the texture of the lean meat. (eAmbrosia «Prosciutto di Parma», 2023)

The ranges for the above parameters are:

- Moisture: 59.0% - 63.5%;
- Salt: 4.2% - 6.2%;
- Proteolysis index: 24.0% - 31.0%.

The fresh pork legs used in the production of Parma Ham possess specific characteristics outlined as follows (eAmbrosia «Prosciutto di Parma», 2023):

- Fat consistency: The evaluation of fat consistency involves measuring the iodine number and/or the linoleic acid content in both the inner and outer fat layers of the subcutaneous panniculus adiposus of the leg. The iodine number should not exceed 70, and the linoleic acid content should not exceed 15% for each sample.

- Subcutaneous fat layer: The outer portion of trimmed fresh legs should have a vertical thickness of approximately 20 millimeters for Parma Hams weighing between 7 and 9 kilograms, and around 30 millimeters for Parma Hams weighing over 9 kilograms.

- Weight of fresh legs: Ideally, the trimmed fresh legs should weigh between 12 and 14 kilograms, but under no circumstances should they weigh less than 10 kilograms.

- Meat quality: Fresh legs of pigs affected by significant myopathies (such as PSE, DFD, evidence of inflammatory or traumatic conditions, etc.) that have been verified by a veterinarian at the slaughterhouse are excluded from protected production.

- Except for refrigeration, no preservation treatments, including freezing, should be applied to the fresh legs. Refrigeration involves storing and transporting the legs at a core temperature ranging from -1°C to +4°C.

- Legs from pigs slaughtered less than 24 hours or more than 120 hours before use shall not be utilized. (Prosciutto di Parma (Parma Ham) Protected Designation of Origin Specifications).

In order to participate in the protected production process, breeders must receive prior authorization and be assigned a unique code by the Certification Body. Each approved breeder is required to apply an indelible tattoo, displaying their identification code, on the hind legs of every piglet within thirty days of their birth.

The different breeding phases are defined as follows:

- Suckling: The initial four weeks during which the piglets are nursed by the sow.

- Weaning: From the 5th to the 12th week, when the piglets are separated from the sow and transition to solid food.

- Piglet fattening: The stage from 30 to 80 kilograms of weight, during which the piglets are raised and nourished to reach a specific weight.

- Fattening: From 80 to 160 kilograms of weight and beyond, encompassing the further growth and development of the pigs until they reach their desired weight. (Consortium for Parma Ham Prosciutto di Parma).

The breeding methods focus on producing large-sized pigs, which is accomplished by ensuring consistent daily weight gains. To achieve this goal, feed is provided in measured portions, preferably in liquid or mashed form, traditionally supplemented with whey. (see Figure 14).

Corn	d.m.:	up to 55% of the d.m. in the ration
Kernel and/or corncob mash	d.m.:	up to 55% of the d.m. in the ration
Sorghum	d.m.:	up to 40% of the d.m. in the ration
Barley	d.m.:	up to 40% of the d.m. in the ration
Wheat	d.m.:	up to 25% of the d.m. in the ration
Triticale	d.m.:	up to 25% of the d.m. in the ration
Oats	d.m.:	up to 25% of the d.m. in the ration
Minor grains	d.m.:	up to 25% of the d.m. in the ration
Bran and other by-products of wheat processing	d.m.:	up to 20% of the d.m. in the ration
Dehydrated potato***	d.m.:	up to 15% of the d.m. in the ration
Cassava***	d.m.:	up to 5% of the d.m. in the ration
Pressed beet pulp silage	d.m.:	up to 15% of the d.m. in the ration
Expeller pressed flax	d.m.:	up to 2% of the d.m. in the ration
Dried exhausted beet pulp	d.m.:	up to 4% of the d.m. in the ration
Apple and pear residue; grape and tomato skins as supplement carriers	d.m.:	up to 2% of the d.m. in the ration
Whey*	d.m.:	up to a maximum of 15 ltrs head/day
Buttermilk*	d.m.:	up to a maximum intake of dry matter of 250 grams head/day
Dehydrated aflalfa meal	d.m.:	up to 2% of the d.m. in the ration
Molasses**	d.m.:	up to 5% of the d.m. in the ration
Soybean extraction meal	d.m.:	up to 15% of the d.m. in the ration
Sunflower extraction meal	d.m.:	up to 8% of the d.m. in the ration
Sesame extraction meal	d.m.:	up to 3% of the d.m. in the ration
Coconut extraction meal	d.m.:	up to 5% of the d.m. in the ration
Corn germ meal	d.m.:	up to 5% of the d.m. in the ration
Peas and/or other leguminous seeds	d.m.:	up to 5% of the d.m. in the ration
Brewer's and/or torula yeast	d.m.:	up to 2% of the d.m. in the ration
Lipids with a melting point higher than 40 C°	d.m.:	up to 2% of the ration

*d.m. = dry matter

Figure 11. Feed admitted during the fattening phase (eAmbrosia «Prosciutto di Parma», 2023)

The production of Parma Ham includes the following 9 stages (eAmbrosia «Prosciutto di Parma», 2023):

1. Separation: Prior to slaughter, the pig must be in good health, well-rested, and have abstained from eating for 15 hours. Once these requirements are met, the legs are separated from the sides.
2. Cooling: The hams are then placed in specialized cold rooms for 24 hours, serving two purposes: to lower the temperature of the pork legs from 40°C to 0°C and to facilitate the trimming process by firming up the meat at lower temperatures. During the cooling stage, the hams experience a weight loss of approximately 1%.

3. Trimming: The next step involves trimming, which involves the removal of fat and rind to give the ham its characteristic round shape resembling a "chicken leg." Trimming serves both aesthetic and technical purposes, particularly to enhance the salting process. Hams with even the slightest imperfections are discarded during this stage. After trimming, the hams can lose up to 24% of their weight in fat and muscle. Apart from refrigeration, no other preservation treatments, including freezing, are permitted for the pork legs used in the production of Parma Ham.
4. Salting: Refrigerated and trimmed pork legs are transported from the abattoirs to salting plants. The rind is treated with wet salt, while the lean portions are sprinkled with dry salt. No chemicals, preservatives, or additives are used, and smoking is not applied to the hams. The hams are stored in cold rooms at a temperature ranging from 1°C to 4°C with approximately 80% humidity. After around 6-7 days in the first salting rooms, the hams are taken out, excess salt is removed, and the pork legs are lightly salted again. The hams are then placed back into another cold room, known as the second salting room, where they remain for 15 to 18 days, depending on their weight. During this period, the hams gradually absorb salt and lose some moisture. By the end of the salting period, the weight loss amounts to approximately 3.5-4%.
5. Resting: following the removal of any remaining salt, the hams are transferred to designated resting rooms, where they are stored for a period ranging from 60 to 90 days. These rooms maintain a humidity level of about 75% and temperatures between 1°C and 5°C. During the resting phase, the hams experience a weight loss of approximately 8-10%.
6. Washing – Drying: The hams undergo a washing process using lukewarm water, followed by the scraping of the rind to eliminate any residual salt or impurities. On dry and breezy sunny days, the hams are naturally dried, while on other occasions they are dried in specialized drying rooms.
7. Pre-maturation – Trimming: Pre-maturation occurs in spacious rooms with opposing windows, where the hams hang on traditional racks called "scalere." Following the pre-maturation phase, the hams are beaten to achieve their distinctive rounded shape. During this stage, the weight loss is around 8-10%.
8. Smearing: A layer of smear, consisting of ground pork fat mixed with a small amount of salt, ground pepper, and sometimes rice flour, is applied to the hollow areas around the best end, exposed muscular parts, and any cracks. Smearing serves to soften the surface muscular

layers, preventing them from drying too rapidly compared to the inner layers and allowing for further moisture loss.

9. Sampling – Maturation: After the application of the smear and reaching the age of seven months, the hams are transferred to the "cellars," which provide cooler temperatures and less ventilation compared to the pre-maturation rooms. Before the transfer, an essential stage known as sampling takes place in the life of the hams. During this phase, experts utilize a specialized needle made of horse bone, which possesses the unique ability to swiftly absorb and release the aroma of the product. The needle is inserted into various points of the muscular tissue, and the experts with exceptional olfactory capabilities evaluate the progress of the curing process based on the sniffed aroma. It is during the maturation phase that significant biochemical and enzymatic transformations occur, resulting in the distinct aroma and flavor of the ham. Throughout maturation, the hams experience a weight loss of approximately 5%. When the hams reach the age of 12 months and pass various inspections conducted by the Certification Body's inspectors, the "Ducal Crown" firebrand is affixed as a mark of authentication.

EAmbrosia «Prosciutto di Parma» (2023) claims the distinguishing feature of Parma Ham is its elevated protein content, which contributes to its overall digestibility. The curing processes also result in a substantial presence of free amino acids, further enhancing its digestibility. In terms of lipids, Parma Ham contains a higher proportion of unsaturated fats (64.9%) compared to saturated fats (35.1%). Notably, it is rich in oleic acid (45.8%), while the levels of saturated lipids and cholesterol are minimal in the fat of Parma Ham.

Parma Ham is also abundant in vitamins, particularly B1, B6, B12, and PP, allowing for significant portions of the recommended daily intake to be met. Likewise, it contains substantial amounts of essential mineral salts such as phosphorus, zinc, iron, and selenium.

An additional noteworthy aspect is the absence of artificial coloring agents or preservatives, including nitrites and nitrates commonly found in other meat-based products. The Production Specifications strictly permit only pork and salt as ingredients in Parma Ham.

The exclusive use of the name "Parma Ham" is reserved for hams that bear the distinctive Ducal Crown brand. This firebrand, affixed to the hams at the conclusion of the maturation period, signifies that they have undergone the required inspections and meet all the specified product and quality criteria. The presence of the "Ducal Crown" serves as an identifier and authentication mark

for Parma Ham, distinguishing it from other dry-cured hams and providing assurance that it has successfully passed through all the essential production stages, as outlined by the relevant authorities.

The complete journey of each Parma Ham leg can be traced through various means such as seals, brands, and tattoos imprinted on its skin. As part of the process, every authorized breeder is required to apply an enduring tattoo displaying their unique identification code on the hind legs of each piglet before the thirtieth day following its birth. This practice enables the identification and tracking of each leg's origin and history.

Seal: It consists of a ring imprinted with the acronym "CPP" and the date marking the commencement of the curing process. The date includes the month indicated by the first three letters of its name and the year represented by the last two digits in Arabic numerals.

Firebrand: Applied by the abattoir, it comprises a standard base featuring the acronym "PP" and an alphanumeric code consisting of one letter and two digits. This code identifies one of the 37 authorized abattoirs. When fresh pork legs from recognized breeding farms, accompanied by the appropriate certificates of origin and conformity with the production regulations for the breeding stage and quality requirements for fresh pork legs intended for protected production, arrive at the abattoir, the abattoir affixes its firebrand on these legs. (eAmbrosia «Prosciutto di Parma», 2023)

The Consorzio del Prosciutto di Parma was established in 1963 by 23 producers who aimed to protect the authenticity of the product, preserve its traditional methods, and uphold the reputation associated with the name "Parma." Currently, the Consortium consists of 134 producers of Parma Ham, working together to maintain the quality and heritage of this renowned delicacy. (Consortium for Parma Ham Prosciutto di Parma)

The Parma Ham Consortium is responsible for a variety of activities and functions, including the management and protection of production regulations, the management of economic policy, and the design of strategies, trends, and macroeconomic policies for Parma Ham. Another purpose is general supervision of the right observance of legal and regulatory laws at breeding farms, slaughterhouses, producers, and traders at all levels; full-time inspectors serve as Judiciary Police Agents. These inspectors are authorized to do any type of verification, inspection, or control on anyone who manufactures, packages, keeps, or sells hams in any type of institution. Any wrong processes recorded will be penalized administratively, civilly, or criminally. The international protection of the

designation "Parma Ham" and the related trademark (Ducal Crown) is critical in the manufacturing of Prosciutto di Parma. The Consortium defends the use of the term "Parma Ham" and its related brands, stamps, and identification seals, as well as the suppression of any illegal use of the term or any unfair competition. To do this, the Consortium may take any appropriate action, including legal action, particularly in countries where the product is widely advertised. Last but not least, there is the definition of Quality Control Schedules in terms of the amount of salt, degree of humidity, and level of proteolysis, as well as promoting and improving the product, and the marketing support to improve the image of Parma Ham internationally. (Consortium for Parma Ham Prosciutto di Parma (Parma Ham) Protected Designation of Origin).

The specifications for Parma Ham encompass various aspects, including:

- Age and weight of pigs: Pigs used for Parma Ham production should be over 9 months old and have an average body weight per batch of 160 ± 10% kilograms. This requirement necessitates the castration of males to ensure meat quality.

- Genetics: Pigs must originate from specific genotypes outlined in the production specifications. These genotypes include breeds such as Italian Large White, Italian Landrace, Italian Duroc crossbreeds, and hybrids resulting from cross-breeding programs aligned with the objectives of the Italian Herd Book for heavy pig production.

- Approved feedstuffs: The specifications detail the types and quantities of feed allowed at different stages of the production cycle. The permissible raw materials and inclusion levels are explicitly listed. The requirements for minimum slaughter age and maximum weight per batch necessitate controlled weight gains, leading to rationed feeding.

- Quality of raw thighs ("green hams") and meat processing techniques: The specifications address the quality standards for the initial raw thighs and the methods employed in their preparation and curing. These factors play a significant role in determining the key qualitative parameters of the final Parma Ham product.

- Traceability: The specifications emphasize the importance of traceability throughout the entire production cycle, ensuring that the origin and journey of each Parma Ham can be accurately traced and monitored.

Export and sales data

Parma Ham is famous well-known product sold worldwide.

Prosciutto di Parma is exported to extra European destinations, such as African, Asian, and Central and South American nations, with Brazil being the largest market. According to the Consortium data (Consorzio Del Prosciutto Di Parma, 2023), 1.581 Parma Hams (10.134 kg) were sold to Africa in 2021, including Mauritius, Congo, Reunion, Kenya, Malawi, Ethiopia, and Ghana. In terms of Asian nations (Japan, China, Hong Kong, Singapore, South Korea, Thailand, Vietnam) 164.965 Parma Hams (1.085.944 kgs) were exported.

Concerning North American continent, The United States is the first Parma Ham export market; 757.000 Parma Hams were sent to the United States in 2021 (5.269.575 kgs). The trademark "Parma Ham" in Canada is owned by "Maple Leaf," a Canadian corporation that has the right to market its local products with the name Parma. In 2021, the export of the Parma Hams was 68.806 (465.192 kg).

Parma Ham is sold to practically every country in Europe, with the biggest European markets outside of the EU being the United Kingdom, Switzerland, and Norway.

The EU accounts for 48% (1.372.717 hams) of Parma Ham export, with presliced products accounting for 56% of sales; Germany, France, and Belgium being the primary markets. In any EU Member State, Prosciutto di Parma is protected and guaranteed as a Protected Designation of Origin.

Overall, 33% of Parma Ham is exported, with 67% sold in Italy. (Figure 15). 7.850.000 Parma Ham branded in 2022. Prosciutto di Parma is transported to approximately 94 countries, with export turnover of 290 million euros, 2021. It now represents 134 Parma Ham producers who use and protect the traditional processing method. The proportion of EU pigs bearing the Parma Crown shows 1.79%. (Consortium of Prosciutto di Parma, 2023).

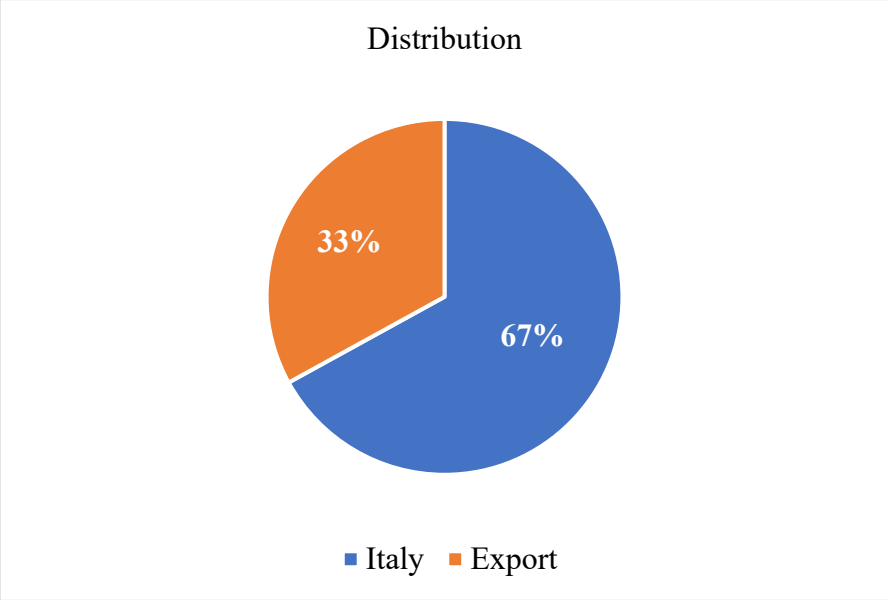

Figure 12. Distribution of the Parma Ham, % (source: Consortium of Prosciutto di Parma, 2023)

Parma Ham branch represents 3600 pig farms with 84 abattoirs, 3000 processing workers in the sector, and 50.000 employees in the whole branch.

Within the category of certified cured meats, Prosciutto di Parma PDO holds the leading position, with a production of 85,400 tons, accounting for 41.9% of the total, which consists 800 million euros of production value. It also contributes significantly to the sector's revenue (1.600 million euros revenue from consumer sales), with a turnover of 824 million euros, representing 40.8% of the total. (Bonazzi, 2021)

According to the Consortium interviewee, Parma Ham production in 2023 is 7,330,000 pieces, with a production value of 770 Mln €. The consumption value is estimated at 1,600 Mln €. In terms of employment, the 133 Parma Ham production plants associated to the Consortium (all located in typical area) employ about 3,000 people.

3.5 Climate change observations in EU and Italy

3.5.1 Climate change observations in EU

The study of Beniston (2007) indicated that for Europe, the warming of the regional surface will result in heatwaves becoming more frequent, intense, and lasting for longer durations. Specifically, by the end of the 21st century, countries in central Europe are projected to have a comparable

number of hot days as currently experienced in the southern parts of the continent. Mediterranean droughts are expected to commence earlier in the year and persist for longer durations. Winter storms are characterized by extreme wind speeds. These changes are attributed to reductions in mean sea-level pressure, leading to an increased occurrence of North Sea storms and subsequently higher storm surges along the coastal regions of Holland, Germany, and Denmark.

According to the analysis conducted by Vitali (2015), it was found that the summer months may witness extreme and lengthened heat waves. These heat waves have been linked to a heightened risk of mortality in dairy cows, with the risk continuing for a few days following the conclusion of the heat waves. Furthermore, older cows were found to be particularly susceptible to death during heat waves.

The Mediterranean area is particularly subject to climate risk: rising average temperature, heat waves, low rainfall, melting glaciers are eroding water reserves, sudden floods or copious rainfall multiply the effect on the territory already at risk.

3.5.2 Climate change observations in Italy

Italy experiences significant impacts from climate change and climate variability, and it exhibits considerable diversity in climatic conditions throughout its regions. From the northern to the southern parts, Italy displays marked variations in climate, accompanied by differences in soil, topography, and structural characteristics of the agricultural sector. (Coderoni and Pagliacci, 2023). The northern region is characterized by a humid subtropical climate, whereas the southern region features a hot-summer Mediterranean climate.

The ISPRA Report "Climate indicators in Italy" illustrates the trend of the climate during 2021 and updates the estimate of climatic variations in recent decades in Italy. (Fioravanti et al., 2022).

Northern Italy has been affected by frequent high-pressure conditions and African hurricanes, which have favored intense thermal anomalies. 2021 was one of the warmest years, reaching an average anomaly compared to the thirty-year period 1991-2020 of +0.23C. (Figure 13) Spring was particularly cold, the coldest since 2005, while summer was the sixth warmest since 1961.

2021 was marked by an annual precipitation anomaly national average lower than the climate 1991-2020, with monthly rainfall mainly less than normal. Especially spring 2021 was characterized by negative thermal anomalies on all Italian regions, often associated with low rainfall laying the foundation for the establishment of conditions of intense drought. Almost all the months of 2021

were drier than the norm (Figure 14,15). Although January and November months were particularly rainy. A tropical cyclone located on the Mediterranean dumped rains extremely intense in southern Italy; on eastern Sicily the hourly intensity reached the value highest ever recorded in the region, and heavy rains caused widespread flooding and flooding of rivers and canals.

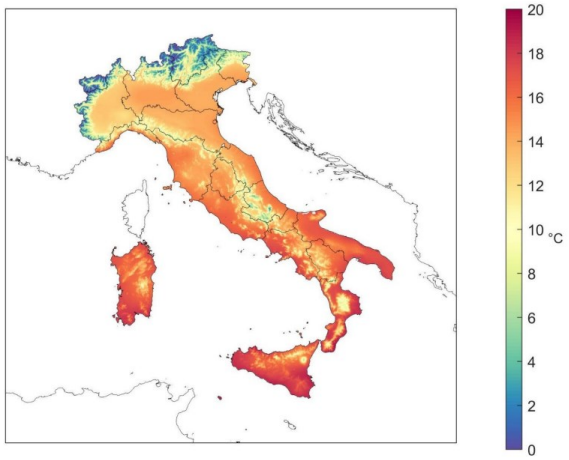

Figure 13. Average annual temperature in Italy. (Source: Fioravanti et al., 2022)

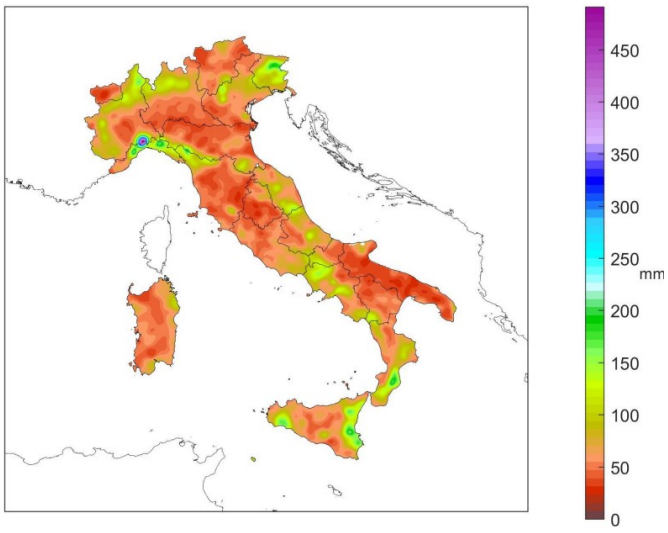

Figure 14. Maximum daily precipitation. (Source: Fioravanti et al., 2022)

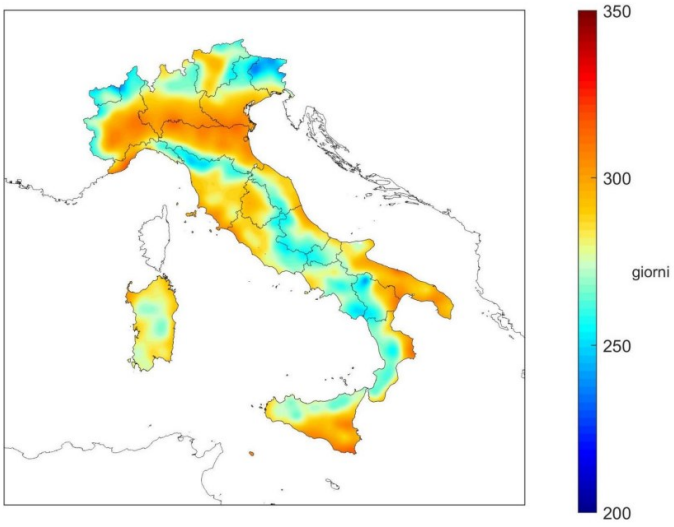

Figure 15. Dry days. (Source: Fioravanti et al., 2022)

Northeast Italy stands as one of Europe's most industrially developed and agriculturally productive regions. In recent years, it was one of the Italian areas mainly affected by drought. The Po River basin, its Delta, and much of Northern Italy were deeply affected. Po River suffered a drastic reduction in its flow rate with the occurrence of an extreme process of saltwater intrusion inland. Drought caused severe damage to agriculture, which in some areas resulted in the total loss of production (e.g., rice yield dropped by >30%). (Cammalleri et al., 2020). High surface temperatures affected a large part of the lowlands, posing a significant hazard for thousands of hectares of farmlands. Particularly severe were the temperatures recorded along the Adriatic coast. Hot areas extended north and south affecting portions of the Alps and Apennines (Straffelini and Tarolli, 2023). These consequences create a ripple effect, impacting various aspects of the economy and society. They introduce a series of additional risks at the agricultural and household levels, including diminished income levels and instability, as they directly influence productivity.

3.5.3 Climate change observations in Parma region

Increasing atmospheric temperatures and rainfall levels, as well as more frequent extreme weather events such as heat waves, droughts, floods, and storms, are already being caused by climate change. Climate projections reveal considerable changes in the severity and frequency of atmospheric occurrences, which are predicted to intensify in the future. (United States Environmental Protection Agency, 2023).

As a result, the figures below (Figures 16 and 17) depict both the yearly temperature change and the yearly change in rainfall patterns, in the Province of Parma.

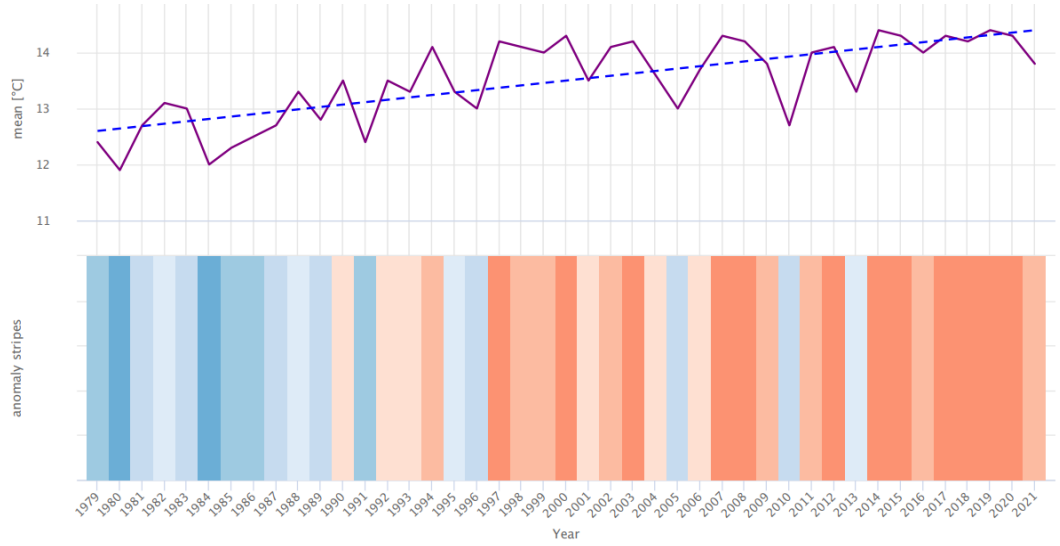

Figure 16. Yearly Temperature Change of Parma Province, 1979-2021. Source: Meteoblue, 2023

According to the chart (Table 2), the annual temperature changes significantly over the years. The dashed blue line is the linear climate change trend. In the lower part the graph shows the so called warming stripes. Each colored stripe represents the average temperature for a year - blue for colder and red for warmer years. From 1979 till 2021 the trend line is going up from left to right, last years represent red colored stripes, thus the temperature trend is positive and it is getting warmer in Parma due to climate change.

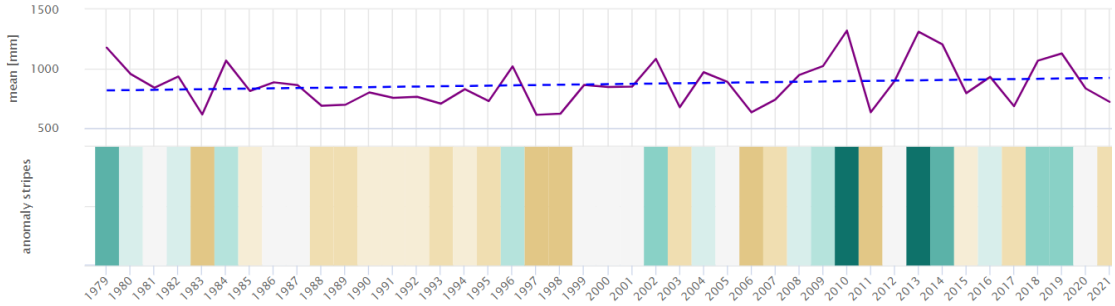

Figure 17. Yearly change in rainfall patterns of Parma Province, 1979-2021. Source: Meteoblue, 2023

The top graph shows an estimate of total precipitation for the region of Parma (Table 3). The dashed blue line is the linear climate change trend. In the lower part the graph shows the so called precipitation stripes. Each coloured stripe represents the total precipitation of a year - green for

wetter and brown for drier years. As indicated in the graph the trend line is gradually going up from left to right, hence the precipitation trend is positive and it is getting wetter in Parma due to climate change. However, a drought occurred in recent years.

Chapter 4. Method and Interviews

4.1 Method

Firstly, to examine the observations of climate change and its perceived impacts on the production of Prosciutto di Parma PDO a review of the main literature on the topic was conducted. This part concerned the analysis of the GI system in EU and in Italy in particular, also addressing the impact of climate change on agriculture, livestock, as well as the effects of climate change on GI products (PDOs and PGIs). Then Prosciutto di Parma case study was implemented, including the examination of organoleptic characteristics, production steps and process, marketing and sales data.

In the more empirical part of this work, I conduct a qualitative analysis through in-depth interviews with key informants in Parma Ham Consortium and among some Prosciutto di Parma producers (see 4.2). The main goal is to investigate and comprehend their viewpoints, experiences, and observations about how climate change affects Prosciutto di Parma production.

I will closely examine the outcome of the interviews to identify specific issues such as temperature fluctuations, changes in climatic conditions and any possible changes in the production process. This examination may help to better understand the problems faced by prosciutto di Parma producers as a result of climate change.

In this analysis, some Parma Ham producers and some members of the Parma Ham Consortium are interviewed in order to compare their answers and identify common features and differences. This method strengthens the findings' robustness and enables for a more detailed analysis of how the effects of climate change may vary from producer to producer.

4.2 Interviews

To analyze climate change observations and perceived effects on Prosciutto di Parma production and, therefore responses of the agents involved in the production of this GI product, the interviews were conducted, according to the description shown in the Table 2.

Interviewee	**Type of Entity**	**Type of the Interview**

Veterinary doctor and a manager of the Research and quality department	Consortium	email interview
Manager-producer	Producer	phone call
Manager in the Quality Control and Development department	Producer	phone call
Sales manager	Producer	phone call

Table 2. Characteristics of the interviews

Two types of entities were taken into account, namely the Consortium (Consorzio del Prosciutto di Parma) and Producer, as they are aware about the current situation on the Parma Ham market, production practices and any possible challenges faced by manufactures due to climate change in the Parma region, as well as potential instruments to be used to adapt to shifting climatic conditions.

Participant selection for the interviews was based on the working position in the company, company's location. In particular, veterinary doctor was contacted because of his awareness of the current health situation of the pigs and possible correlation of the pigs' diseases with the climate changing conditions. Managers were approached due to his deep understanding of the Parma Ham manufacturing process and corporate decision-making function. Research and Quality managers were reached out since they play significant roles in supporting the production processes of both product development and general quality assurance.

The interviews were conducted via email and phone calls since It was not possible to meet in person because of logistical concerns and time inconvenience. All the interviews were conducted in the months between October and December 2023. The date and time of the phone call interviews were agreed according to working schedule and availability of the interviewees. Each phone call interview lasted between 20 and 25 minutes on average. The email interview was conducted with a

veterinary doctor and a manager of the Research and quality department, with the support of colleagues from the Consortium. This interview was carried out by answering the questions by the Consortium members. In the period of three weeks between late November 2023 and early December 2023, all clarifications were provided to the interviewees and any misunderstandings resolved.

The email interview was performed in English, while the phone call interviews were conducted in Italian, digitally recorded and manually translated into English and eventually transcribed.

The goal of the interviews was pointing out the following aspects related to the production of Parma Prosciutto di Parma PDO: Parma region's climate situation, climate change in the area, changes in the production costs and in consumer demand parameters, due to climate change; characteristics of the Parma ham, and possible climate change adaptation techniques (if any).

In line with these objectives, the interview guide was structured according to the following ten questions (Table 3)

Number of the question	**Type of the question**	**Description**
1	What is your main role in the company?	The company's working position was asked
2	How long have you been working in this company and in ham production in general?	The overall working experience was taken into account, as the working experience at the current position, as well as the total working experience in the industry
3	What are the main characteristics of your Prosciutto di Parma PDO product?	These characteristics include organoleptic and sensory traits (color, taste, aroma), as well as nutritional value and production volume

4	In your opinion, how has the climate in the Parma region changed in recent years?	Climate change observations and personal opinion about this issue were asked
5	What impact has the climate change had on the production of Prosciutto di Parma PDO?	The possible perceived effects of the climate change on Prosciutto di Parma production were asked (changes in taste, aroma, or color)
6	Has climate change affected the cost of production of the Prosciutto di Parma PDO? If yes, how?	Any changes in the production cost of the Parma ham were asked
7	Has climate change affected consumer demand for Prosciutto di Parma PDO? If yes, how?	Any changes in the production cost of the Parma ham were asked
8	What challenges do you face due to climate change?	Possible climate challenges during the production process of the Prosciutto di Parma were asked (If any)
9	What strategies and techniques have been implemented to mitigate the influence of climate change on the production of Prosciutto di Parma PDO, and how effective are they?	Possible strategies and techniques have been asked (If any)
10	What are your thoughts on the future of Prosciutto di Parma production?	Personal opinion about the future of the Parma Ham was taken into account

Table 3. Characteristics of the interview questions

A structured method was used throughout the interviews, allowing for open-ended conversations concerning the producers' observations and experiences about the influence of climate change on Parma Ham production. However, following a preliminary examination of the company organization's website and brochures, the questions were slightly modified to each interview.

Chapter 5. Results and Discussion

5.1 Climate change observations of the Parma region and their impact on Parma ham production

The aim of this study is to investigate if climate change affected the Parma Ham production. In this subchapter the results of the conducted interviews are presented. Interview outcomes of the following organizations are described: Consortium of the Prosciutto di Parma, Martini Alimentare SRL, La Felinese Salumi S.P.A., Leoporati Prosciutti Langhirano S.P.A.

Consortium of the Prosciutto di Parma

The interviewees were represented by a Veterinary doctor and a Manager at Food Safety and Research Office at the Consorzio del Prosciutto di Parma. They have been working there for five years on average.

The Parma Ham Consortium was created in 1963 with the goal of providing high-quality goods to consumers. Since then, the Consortium has assured manufacturing standards compliance while also taking part in additional efforts vital to the product's preservation and promotion in Italy and across the world:

- Management and production safety requirements were filed to the European Union for the "Parma Ham" Denomination of Origin;
- Economic policy administration;
- Worldwide protection of the phrase "Parma Ham" and the accompanying trademark (Ducal Crown);
- Supervision of the proper implementation of legislative requirements, as well as promotion and improvement of the product through regulations;
- Assistance to associated companies.

It presently constitutes 133 manufacturers who use and defend traditional manufacturing practices. (Consortium of the Prosciutto di Parma, 2023).

Martini Alimentare SRL

The second interview was dedicated to the Prosciutto di Parma PDO production at the Martini Alimentare SRL company. The main role of the interviewee is being a commercial manager/producer of the area cured hams and cold cuts. The interviewee has been working in this company for 25 years in total but on the current position he has a 4-year experience in the maturation sector.

The Martini Group is a huge corporation that owns labs, research facilities, and plants for selecting and producing the best pigs, chickens, and rabbits for meat. It also follows the slaughtering and the processing of the meat. The Martini Group includes two distinct but complementary divisions: one dedicated to animal husbandry and the other to the food industry. Because of their traditions and natural inclination toward innovation, they provide the market with the finest quality at all levels. Today, the Martini Group has consolidated its leadership position in production and safety. (Martini Alimentare website).

According to the interviewee, Martini Alimentare SRL is a company that was born in the world of feed 100 years ago. Then slowly and ' evaluated to go from feed to breeding, then from breeding to slaughter, and from slaughter to curing the hams. A prosciuttificio was developed fifteen years ago in Langhirano Sala Baganza which is now the part of the Consortium of Parma.

They produce within the Consortium of Parma about 5000-6000 pigs per week from what about 2000 are aged. This prosciuttoficio runs more or less with 200.000 hams per year. Normally the producers manage seasoned hams that go up to 16-18 months, for a small quota, they reach 24 months, a product of the great reserve.

La Felinese Salumi S.P.A.

The third interview was conducted with a Manager in the Quality Control and Development department with seven years working experience.

This company was established in 1963. Nowadays in the province of Parma, in the heart of the food valley, the Felinese activity is organized in five factories in which the entire range of Italian delicatessen is produced. Felinese exports to more than 30 countries including the USA, Canada, Japan and all European states (La Felinese Salumi S.P.A. website).

Leoporati Prosciutti Langhirano S.P.A.

The fourth interview was represented by a sales manager who is a family member of Leoporati Prosciutti group. The interviewee since 2005 has been working full-time for the family business. He has never had work experience outside of this company and therefore not even outside the industry.

Since 1969, the Leporati family has been producing high-quality Parma Ham. Three generations have carried on the family business with the same enthusiasm that their grandpa instilled, all with the goal of providing the client and, ultimately, the end consumer with a high-quality product. The best fresh legs of Italian pork carefully chosen by expert "master salters", the use of little salt and a slow and long maturation. (Leoporati Prosciutti website).

5.1.1 Parma Ham characteristics: overview of the interviewees

All the interviewees described the main characteristics of the Prosciutto di Parma product as a well-balanced combination of very high quality organoleptic and sensory traits, as well as nutritious attributes.

The Prosciutto di Parma PDO product is distinguished as a sweet ham with delicate and fragrant aroma. The fatty part of the pork, which is lard, is produced from a mixture applied to the exposed part, that of the meat, to give it a minimal covering safety.

Because of its low content of fats, plentiful mineral salts and vitamins, and easily digestible proteins, Parma Ham is an ideal product for everyone. Because of its high protein content and the natural proteolysis that happens during curing (the breakdown of proteins into smaller molecules and individual amino acids), it is also a highly digestible product.

Parma Ham is also a great diet for resisting and suppressing the activity of free radicals, the principal cause of aging and degenerative disorders, as well as restoring the physiological equilibrium of the body, due to the presence of natural antioxidants such as vitamin E and selenium. (Consorzio del Prosciutto di Parma, 2023). The total lipid component is also of good quality, thanks to the high amount of unsaturated fatty acids (64.9%), which are beneficial fats for health, such as oleic acid (45.8%), a monounsaturated fat found in olive oil that protects against cardiovascular disease.

Eating Parma Ham helps to satisfy RDAs for group B vitamins while also providing a significant amount of important minerals that are highly bioavailable, meaning they are easy for the body to absorb, such as iron.

5.1.2 Climate change observations and its impact on the production of the Parma ham

Parma Ham Consortium interviewees noted that over the past 40 years there has been an increase in average temperature in the region of Parma. Confirmation of his perception comes from meteoblue website which reports the annual temperature change in Parma. The data indicate that from 1979 to 2022 there has been an average annual temperature increase of about 2°C. The site also indicates that there have been no substantial changes in average precipitation, but monthly anomalies, both in temperature and precipitation, have increased in recent years.

The interviewees expressed personal and professional opinions about the impact of the climate change on the production of the Prosciutto di Parma PDO. They noticed that abnormally intense heat spikes can affect the quality of the raw material because they cause stressful situations (in the farm, during transport and at the slaughterhouse) that can affect the metabolism of organs and muscles. However, as a veterinary doctor mentioned the email interview, Parma Ham production, on the other hand, has not been affected by climate change because the conditions in the processing environments are continuously monitored and adjusted to keep the products in optimal conditions. The Specifications of production provide for humidity and temperature ranges that must be always respected and that guarantee constant quality in the final product.

Besides, the Martini Alimentare SRL interviewee expressed his personal opinion about climate change in the Parma region in recent years. He started his narration with a history of the Prosciutto di Parma production. According to him, the Parma ham is born with the famous characteristics of the windows left open for the eventual sea breeze that came up from the ground. It created a particular microclimate (they would leave the windows open or close them depending on the moment). It refers to the practice of leaving windows open as an important aspect of the traditional manufacturing process. Producers enable the natural sea breeze to enter the curing rooms by leaving the windows open. This has two effects: it aids in the drying of ham, and it imparts distinctive taste and flavor, including factors like as humidity, air movement, and other environmental conditions that aid in the curing process.

According to the Martini Alimentare SRL interviewee, today this more traditional technique no longer exists, due to the increase in the use of technology. The conditions that exist inside the prosciuttificio (ham factories) practically are all forced, in the sense that there are spaces of color and refrigeration depends on the moment at the time of the prosciutto preparation.

A manager mentioned that the Parma Consortium believes that the microclimate has changed, like all microclimates these days, in the sense that something has changed with climate change. But this does not affect the attitude towards the Parma ham quality. Moreover, the interviewee stated that the climate change had no impact on the production of Prosciutto di Parma PDO since, as he mentioned before, today 99% of ham factories have forced air, the particular microclimate created internally in the ham factories.

The respondent from La Felinese Salumi S.P.A. expressed roughly similar opinions about climate change observations in the Parma area. Interviewee stated that certainly like all over the world, the climate has also changed in the Parma region. Winter temperatures are less severe and much less prolonged than a few years ago, summer temperatures are definitely on the rise. In addition to the rising and lower temperatures, there is also the length of the season (for example, summer is extended until October, and winter begins later).

Referring to the impact of climate change on the production of Prosciutto di Parma PDO, La Felinese Salumi S.P.A. manager, however, believes this depends on the technical system that is used in the company. For example, La Felinese Salumi S.P.A. corporation has the production level of Parma, that is, the plant where they produce it, is average. She stated that, fortunately, they have technical systems that do not allow to have this great influence on the external climate because they are automated. In this case, only the company can decide the temperature and the humidity for the production process of Parma Ham, as also Martini Alimentare SRL company stated. So, according to La Felinese Salumi S.P.A. manager view, surely it is much less impactful than in the past when the producers of Parma Ham opened the seasoning windows to get the sea air. And so there is not this big impact of climate change on the production of Prosciutto di Parma PDO thanks to the technology of the plants they use.

Leoporati Prosciutti Langhirano S.P.A. interviewee had the same view about climate change situation in Parma region. He noted climate has changed compared to many years ago, now fog is more frequent and winters are less harsh. He added that climate change does not greatly affect the characteristics of the product because thanks to technology (like La Felinese, Parma Consortium,

and Martini Alimentare companies stated) for many years now it has been possible to produce hams even without opening the windows (a typical method that characterizes the drying and seasoning of pork legs). Nevertheless, according to the Leoporati Prosciutti Langhirano S.P.A. interviewee opinion, without this step a traditional and artisan technique is missing that gives a different aroma and flavor to hams. However, when the climate allows, they continue to open the windows and let the natural air into the seasoning rooms, so as to differentiate the aroma of their hams from others.

5.1.3 Cost of production and consumer demand

The Parma Ham Consortium interviewees stated that the increase in average temperature can definitely affect production costs. The steps that influence processing cost the most are the salting and resting phases, which must be conducted in cells with a temperature between 0 and 4°C and last at least 90 days, averaging 120-130 days. An increase in outside temperature means more work and energy consumption for the cooling equipment in the salting and resting cells. On the contrary, the interviewees affirmed that climate change has not dramatically affected consumer demand for Prosciutto di Parma PDO product.

Conversely, The Martini Alimentare SRL manager affirmed that according to his personal experience climate change did not affect much the cost of production and consumer demand for the Prosciutto di Parma PDO.

La Felinese Salumi S.P.A. interviewee noted that certainly the investments that have been made at the company's level have influenced the production costs of Prosciutto di Parma PDO. However, those investments are not directly related to climate change, but simply to organization's development. Moreover, she also added that climate change did not affect the consumer demand for the Prosciutto di Parma PDO.

Leoporati Prosciutti Langhirano S.P.A. sales manager agreed with an opinion of the Parma Ham Consortium and affirmed the external climate influences the production costs. In colder periods, they need to keep the rooms at a certain temperature and therefore they use the heat (produced with co-condensing boiler). Conversely, during the hottest months of the year, they have to cool the rooms and therefore they are forced to use a cooling system. In recent years, with warmer winters than usual or in any case with summers that last longer (interviewee noted this year October and

November were relatively warm months) they have to use the cooling systems for longer, so in this sense the production costs increase a little.

According to the impact of climate change on the consumer demand for Prosciutto di Parma PDO, Leoporati Prosciutti Langhirano S.P.A. sales manager stated it has not been affected by climate change, it has been negatively affected by inflation and the increase in all costs and selling prices.

5.1.4 Strategies and technologies implemented for mitigating the impacts of climate change

Consortium interviewees think that Parma Ham production has not been largely affected by climate change, because the conditions in the processing environments are continuously monitored. From their side, they invest in minimizing the impact of the production process on climate change. They mentioned about their production establishments that are making production systems more efficient, especially in terms of energy efficiency and recycling of production waste materials. The recovery of waste materials is concerned by the use of "fondelli" (the final part of the bricks sliced industrially for the production of pre-sliced Parma Ham) to produce stuffed pasta, tortellini, with Prosciutto di Parma as well as the recovery of exhausted salt (salt collected after the end of the first and second salt phases) used in winter on the roads as antifreeze.

Consortium interviewees stated there are 133 production plants of Parma Ham, and each of them is responsible for its own plant; the Consortium cannot suggest one solution rather than another. Examples of energy efficiency performed by their plants include the installation of photovoltaic panels or the recovery of heat from cooling cell motors used to heat part of the plant.

On the other hand, the Martini Alimentare SRL company’s view is focused on sustainability, animal welfare, and on things not related to Parma Ham production but related to what else the company produces: chickens, plastic recycle, and packaging modification. So, they are paying attention to different aspects except climate change influence. In this case, no particular strategies and techniques have been implemented to mitigate the influence of climate change on the production of Prosciutto di Parma PDO.

For La Felinese Salumi S.P.A. company technology development is crucial to address climate change issue. They have a program of sustainability and energy saving. They also have voluntary certificates regarding the environment and food safety aspect. In addition, they have a small internal program where they propose long-term goals. They installed the purifier to purify water that is

discarded from production processes. They intend to put solar panels all over the plant, to develop technologies that allow energy savings at the water level, recirculation, and heating level.

Leoporati Prosciutti Langhirano S.P.A. sales manager, however, considers that, rather than adopting specific techniques to mitigate the influence of climate change, it is important to make supply chain more sustainable, so as not to further worse climate changing patterns. From their part, they installed solar panels, condensing boilers that consume less than the previous ones, enthalpy systems, which are external probes that detect temperature and humidity and that automatically open the windows (if the values are those set by the company) in the seasoning rooms to save on energy costs. To sum up, it is crucial to address the issue of sustainability, which concerns the entire supply chain and not only producers.

5.1.5 Future expectations of the Parma ham PDO production

The Consortium interviewee's opinion is that future production depends on the availability of raw materials (pork sector). In the short term, a reduction in the production level of Parma Ham is expected. In the longer term, it is much more difficult to make predictions, also due to the current situation of great uncertainty at both national and global level.

The Martini Alimentare SRL manager wishes there are many ham factories but, unfortunately, the problem is that the 2023 figures speak of a 7-8% production fall. He believes that with changes in sustainability, on animal welfare logically will be fewer farms. Breeding is a big problem for the discharges and emissions and therefore If at least the regions from where there can be a pig slaughtering are not expanded from specifications, he does not see the possibility of the production increasing.

La Felinese Salumi S.P.A. agrees with Consortium opinion and supposes the cost of the raw material impacts a lot on the future of Parma Ham, which is certainly fluctuating. So, less farms are expected.

Also Leoporati Prosciutti Langhirano S.P.A. sales manager believes that in the upcoming years there will be a decline in production due to the shortage of raw material (fresh thighs of pigs born, reared and slaughtered in Italy) and a consequent increase in the selling price of the seasoned product. He considers that it will be necessary to make efforts for a greater collaboration between all the operators of the supply chain, both in terms of sustainability and market performance.

5.2 Discussion

5.2.1 Climate change observations and its impact on the production of the Parma ham

Changes in average temperature and precipitation, as well as the occurrence of weather extreme events, have been already started affecting agricultural yields and livestock productivity across Europe. (European Environment Agency, 2016). Climate change factors have a significant impact on the Mediterranean region, including an increase in heat extremes, the risk of droughts, the risk of biodiversity loss, increased water demand for agriculture, risks to livestock production, a decrease in precipitation, and reduced crop yields.

The ISPRA Report "Climate Indicators in Italy" depicts the climate trend until 2021 and updates estimates of climatic variances in recent decades in Italy. Northern Italy has been impacted by high-pressure conditions and African storms, both of which have favored strong temperature anomalies. The year 2021 was one of the hottest, with an average anomaly of +0.23C relative to the 1991-2020 period. (Fioravanti et al., 2022). The Parma Ham interviewees had the same idea about climate changing conditions: they mentioned the average temperature has risen by nearly 2°C over the last forty years. This opinion was supported by Parma Ham producers, mentioning also about prolonged seasons, mild winters, and frequent smog.

Climate change has implications for various aspects of food safety, including the consequences on livestock production and the occurrence of livestock diseases. The effects of climate change on livestock can be caused by stress factors affecting the appetite of animals (Miraglia et al., 2009). The interviewee from Consortium of Parma Ham found that excessively severe heat spikes might impair raw material quality because they create stressful circumstances on the farm, during transit, and at the slaughterhouse, which can alter organ and muscle metabolism. Other effects of climate change include the need to vary the quantity and quality of forages from grasslands, as well as the availability of concentrates (Miraglia et al., 2009).

These effects might be classified as direct or indirect. Feed intake, immune system function, and total production are all affected directly. Climate's impact on crop and pasture production, water availability, and the prevalence of pests and diseases that harm livestock are examples of indirect impacts (Cheng et al., 2022).

The consequences of the climate change may influence livelihoods, food security, and the broader economy and society, exacerbating global food security concerns (Li et al., 2022). However, as a

veterinary doctor noted during the interview, climate change has had no effect on Parma Ham production since the conditions in the processing areas are constantly checked and changed to preserve the product in excellent condition. The production specifications include humidity and temperature parameters that must be followed at all times to ensure consistent quality in the final product.

In this regard, Leoporati Prosciutti Langhirano S.P.A. interviewee affirmed that climate change does not greatly affect the characteristics of the product because of the technology used. Also the manager of the Martini Alimentare SRL company stated that climate change did not affect the Parma ham quality.

Moreover, based on respondents conclusions climate change might not has affected other PDO hams production quality since, as previously stated, most of the ham factories now have forced air, a specific microclimate established internally in the ham factories.

However, La Felinese Salumi S.P.A. manager believes that climate change impact on the Parma Ham production (and other PDO hams production respectively) depends on the company's size, so technical system used internally in the organization or the possibility to implement new technology.

5.2.2 Cost of production and consumer demand

The occurrence of some specific weather circumstances make GIs even more susceptible. The link with a specific terroirs, in particular, can represent a source of additional vulnerability: fluctuations in average yearly temperature or water availability can affect productivity, and consequently farm profitability, of GI farms that are unable to transfer their production to a more suited area. Climate change is expected to disrupt the majority of terroir qualities, decreasing the output and profitability of farms that rely on GIs. (Pagliacci and Salpina 2022).

According to the Parma Ham Consortium interviewee, a rise in average temperature might affect production costs. The salting and resting stages, which must be performed in cells with temperatures ranging from 0 to 4°C and last at least 90 days, with an average of 120-130 days, have the greatest impact on processing costs.

In addition, Leoporati Prosciutti Langhirano S.P.A. organization believes that also external climate influences the production costs. During colder months, they must maintain a specific temperature in

the rooms, therefore they utilize heat (generated with a co-condensing boiler). Conversely, they are compelled to employ a cooling system during the warmer months in order to cool the rooms. They have had to utilize the cooling systems for longer in recent years due to warmer than typical winters or prolonged summers (the respondent mentioned that October and November were particularly warm this year). As a result, manufacturing costs increased.

However, in the La Felinese Salumi S.P.A. case, the production costs of Prosciutto di Parma PDO are increased only due to organization's development strategy and investments made, not related to the changing climatic conditions.

Soubry (2020) also affirmed that farmers who use GI systems, in particular, are expected to bear the brunt of the economic, environmental, and social consequences of climate change. The Consortium Veterinary doctor noted as the outside temperature rises, the cooling equipment in the salting and resting cells must work harder and consume more energy.

The interconnected impacts of climate change on agro-ecosystems and agricultural production subsequently influence product prices, quantity and quality, trade patterns, agricultural income, and food prices. (Jacobs et al., 2019). However, in the case of Prosciutto di Parma PDO all respondents stated that consumer demand wasn't affected by climate change. The Leoporati Prosciutti Langhirano S.P.A. sales manager mentioned that consumer demand for Parma Ham product was influenced by inflation and consequent rise in all costs and selling prices.

5.2.3 Climate change strategies and technologies used in case of the Prosciutto di Parma PDO

Climate change is already having an impact on PDO and PGI quality since it affects essential terroir characteristics such as precipitations, water availability, soil quality, and temperature. (Clark and Kerr, 2017).

Nonetheless, according to a Consortium responder, climate change has had no effect on Parma Ham quality since the conditions in the processing areas are constantly checked. From their side, they invest in reducing the impact of the manufacturing process on climate change. The Consortium is improving the efficiency of production systems, particularly in terms of energy efficiency and the recycling of industrial waste materials (recovery of exhausted salt for road antifreeze use, utilize of "fondelli" for Parma Ham tortellini). Examples of energy efficiency performed by their plants

include the installation of photovoltaic panels or the recovery of heat from cooling cell motors used to heat part of the plant.

Additionally, in order to solve the issue of climate change, La Felinese Salumi S.P.A. believes that technical development is essential. Because of its automated technological processes, the Parma Ham production is unable to alter by the external climate. This company has an energy-saving and sustainable initiative that involves installing a purifier to clean water waste from manufacturing activities. In addition to developing technology that enable energy savings at the water level, recirculation level, and heating level, they aim to install solar panels throughout the facility.

From the Leoporati Prosciutti Langhirano part, they installed solar panels, energy-efficient condensing boilers, and enthalpy systems - external probes that measure temperature and humidity and automatically open the seasoning rooms' windows if the values match those set by the company.

However, the Martini Alimentare SRL manager stated no particular strategies and technologies used in case of the Prosciutto di Parma PDO production, except controlled internal microclimate. The company's perspective is focused on sustainability and animal welfare, currently they are paying attention to different aspects not related to climate change influence on the Parma Ham making.

To sum up, Leoporati Prosciutti Langhirano S.P.A.'s sales manager believes that rather than implementing strategies to lessen the effects of climate change, we should work to improve the sustainability of the supply chain in order to prevent the patterns of climate change from getting worse. In conclusion, it is crucial to address the sustainability issue, which affects not just manufacturers but the whole supply chain.

5.2.4 Future expectations of the Parma ham PDO production

All interviewees stated the decline of the Parma Ham PDO production in a short-term perspective. The first reason includes the availability and cost of raw materials (fresh thighs of pigs born, reared and slaughtered in Italy). The second reason mentioned by the Martini Alimentare manager is the limited area of pig slaughtering, if this zone is not expanded from specifications, he does not see the possibility of the production increasing.

In the long term perspective it was difficult to make any predictions.

6. Conclusions

This study conducted a thorough investigation to better understand the link between climate change and the prestigious Prosciutto di Parma PDO product. The findings demonstrate the climate change observations in European Union, Italy, and in particular in the Parma region, and its possible influence on the Parma Ham production.

According to Beniston's (2007) research, warming of the regional surface would result in more frequent, severe, and longer-lasting heatwaves across Europe. Specifically, by the end of the twenty-first century, countries in central Europe are expected to have a comparable number of hot days as those now experienced in the continent's southern regions.

The summer of 2022 in Italy was marked by exceptionally high temperatures and a prolonged period of little rainfall. Northern Italy has been hit by high-pressure systems and African storms, both of which have encouraged large temperature swings.

The average temperature in the Parma region has increased during the last 40 years. According to the statistics, the average yearly temperature rised by nearly 2°C between 1979 and 2022. Monthly temperature and precipitation anomalies have grown in recent years.

Geographical indication (GI) is a distinguishing symbol used to identify a product whose quality, reputation, or other features are connected to its geographical origin. (European Commission, 2023). In addition, the Geographical Indications system enables customers, distributors, etc. to differentiate between original products and their countless imitations.

The Parma Ham is a PDO product with rigorous production criteria. The whole process of obtaining the «Prosciutto di Parma» denomination must take place inside the province of Parma's extremely limited boundaries. Only at this region can the ideal drying conditions, notably the natural curing that gives Parma Ham its sweetness and taste, occur (Parma Ham Consortium, 2023). Being Protected Denomination of Origin, Parma Ham is expected to be at risk influenced by the climate change since animal-based GIs are vulnerable to heavy precipitation, flooding, heat, and water stress, all of which harm cattle and fodder. (Salpina and Pagliacci, 2022).

However, according to the conducted interviews, Prosciutto di Parma PDO wasn’t influenced by climate changing conditions since the conditions in the processing areas are constantly checked and changed to preserve the product in excellent condition. Thanks to automated technologies, there are

external probes in the companies that measure temperature and humidity and automatically open the seasoning rooms' windows.

The organization’s view is focused on sustainability and animal welfare. In particular, the Consortium is increasing production systems' efficiency, especially with regard to energy efficiency and the recycling of waste products from industry. Producers install solar panels, purifiers for water cleaning waste from manufacturing activities, and energy-efficient condensing boilers.

With continuous climate changing conditions, high production costs are possible to maintain acceptable levels of humidity and temperature set by Parma Ham specifications. As the outside temperature rises, the cooling equipment in the salting and resting cells must work harder and consume more energy.

Future expectations of the Parma ham PDO production are adverse. Soon the decline is expected due to the availability and cost of raw material.

Despite the findings, this study has certain limitations. Although the small sample size of interviews is informative, it may not cover the entire range of knowledge and issues experienced by all producers. Extending the breadth of interviews and embracing a broader range of opinions may improve the thoroughness of future research.

Future studies on the influence of the climate change on the Parma Ham production are recommended, considering the possible long-term effects of shifting climatic patterns on the quality of Parma ham.

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