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Shaping food systems towards improved nutrition: a case study on Tuscan Bread Protected Designation of Origin

CASE STUDY

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Abstract

The concern for the quality of food, its composition and contribution towards nutrition and health is widespread among public and private food system actors. The increasing interest in locally integrated supply chains leads to reconsider the configuration of the food system in relation to sustainability and health outcomes. This article focuses on the relationship between processing practices and nutritional value in the wheat-to-bread sector, illustrated by a case study on the Tuscan Bread Protected Designation of Origin (PDO). By adopting a food system perspective, the case study shows how the different actors have mobilized to respond to multiple drivers of change. A mixed research method approach is adopted to illustrate the relationship between processing practices and nutritional value outcomes: practice-based indicators for each step of the chain are complemented with performance-based indicators of the chemical, physical and sensorial profile of Tuscan Bread PDO. Furthermore, the implications on food system governance of a differentiation strategy based on territorial origin and enhanced nutrition are discussed.

Keywords: food system, wheat-to-bread chain, nutrition, territoriality, governance
JEL code: Q1, Q13, Q18, Q02

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1. Introduction

A concern for nutritional qualities of food, composition and contribution towards physical health and well-being, is widely spread among academics, policy, health professionals and practitioners. The increase of non-communicable diseases – including obesity, type II diabetes and a range of cardiovascular diseases – is recognized as being strongly related to diets of poor nutritional quality. Diseases related to unbalanced nutrition and, more broadly, unsustainable diets, raise concerns also in relation to the impacts on public healthcare costs (Popkin, 2006; Stuckler and Nestle, 2017; Wang *et al.*, 2011).

Improving nutrition and enhancing sustainability is the core of several Sustainable Development Goals (SDGs), to which United Nations have recently committed. Specifically, SDG 2 calls for 'ending hunger, achieve food security and improve nutrition, and promote sustainable agriculture'. The global transition towards more nutritionally balanced and higher quality diets is a basic requirement for food systems' sustainability (see Auestad and Fulgoni, 2105 for a review). The concerns on the healthiness of diets and nutritional value of food has driven food producers to adapt processing technologies to compete over food's health attributes (Nestle, 2013) although it has been noted that this does not necessarily result in improved healthiness of marketed products (Golan and Unnevehr, 2008). Nutritional information has also become a terrain of competition on the market (Mancino *et al.*, 2008; Verbeke, 2008). Authors indicate that investments and actions on the production side should be coupled with parallel investments on the demand side to increase the requests for nutrient-dense food (Jones and Ejeta, 2016).

A productive, diverse, ecologically and socially sustainable agricultural system has been recognized as crucial for shaping healthy diets and improving human nutrition (Jones and Ejeta, 2016). Agriculture plays an essential role in providing a diversity of nutrient dense foods to meet dietary recommendations for health. The agricultural sector is increasingly considered in relation to the wider food system's upstream and downstream activities, such as input supply, transformation, packaging and storage, logistics and retail (Venturi *et al.*, 2016a). There is an increasing need for integration between the various stages of the supply chain, both to encounter the demand side pressure for healthier food and to reduce the risks on raw material supply, associated with different shocks and stresses (e.g. prices, quantities, sanitary requirements). A food system approach to food and nutrition security has contributed to broaden the view on the links among actors, resources and on capturing food systems' multiple outcomes (Ericksen, 2008; Ingram, 2011). The objectives of different categories of food systems' stakeholders may be divergent in relation to food and nutrition security and sustainability outcomes (Galli *et al.*, 2016). It occurs that agricultural systems have achieved increased productivity to the detriment of the safeguard food nutritional value and sustainability (Mozaffarian and Ludwig, 2010).

Recently, the spread of locally integrated – and shorter – supply chains has raised public attention on the origin of the raw material, as well as on the ingredients and processing methods in relation to food's nutritional value (Aprile *et al.*, 2016; Brunori *et al.*, 2016). Moreover, longer transportation and storage times are perceived as negatively affecting the nutritional content of food (Caputo *et al.*, 2013). Despite the perception that local, or shorter chains, have a supposed ability to benefit consumers with healthier foods – compared to mainstream food chains – the relationship between the configuration of the food system and the contribution to health is still widely debated, especially in socio-economic analysis (Bogomolova *et al.,* in press; Brunori and Galli, 2016).

This paper addresses the relationship between food system and nutritional outcomes by focusing on the following research questions: how can the supply chain mobilize to pursue improved nutritional value, compared to conventional processes? And, what are the implications for food system actors?

To address such wide questions, we adopt an inter-disciplinary approach to understand the interplays among changes in product quality, nutritional value, agri-food chain and rural development. A case study on the wheat-to-bread sector illustrates the method adopted.

Bread holds a central role in diets worldwide, wheat is traded globally and bread manufacturing often develops locally. Furthermore, bread and cereal products are at the center of a contrasted debate on sustainability and on nutritional value more specifically (see Galli *et al.*, 2015 for a review). Cereals are staple foods, that provide a major source of carbohydrates, proteins, B-vitamins and minerals[1]. A growing body of evidence suggests that regular consumption of cereals may have a role in the prevention of chronic diseases[2]. At the same time, cereal processed products contribute to a considerable proportion of sodium intake; therefore, manufacturers are encouraged to reduce the sodium content of foods, such as breakfast cereals and breads (McKevith, 2004). The mechanisms by which cereals convey beneficial effects on health are multifactorial and are related to, among other indicators, the micronutrient and fiber content and their glycemic index.

There is mixed evidence in the literature on the relationship between the supply chain practices and the nutritional value of cereal bread. During all steps of bread making, complex biochemical and physical transformations occur, affect and are affected by the flour constituents and different substances are used in processing to optimize their functionality (Venturi *et al.*, 2013a, 2016b). The quality of component cereals, storage, processing and conservation impact on the nutritional value of bread (Dewettinck *et al.*, 2008). As with other food processing, the challenge in fermenting cereals lies in the ability to combine good sensory quality with demonstrated nutritional and health benefits (Jones *et al.*, 2015; McKevith, 2004; Venturi *et al.*, 2013b). Consumer's perception of bread quality is, to some extent, determined by sensory and health attributes and the perception about nutrition and health can be influenced by written information (Dewettinck *et al.*, 2008; Hellyer *et al.*, 2012; Mancino *et al.*, 2008; Pohjanheimo *et al.*, 2010). The wheat-to-bread sector is rather opaque as grains provenance is often unknown, whereas traceability and communication to the consumer imply a shift towards higher quality and identity preservation of wheat (i.e. varietal traceability) (Barling *et al.*, 2009). Traceability systems that track physical entities along the chain are increasingly used to meet a range of regulatory and commercial objectives, including growing ethical concerns on the content and nutritional value of 'mass-produced' bread and specific health risks for humans (e.g. the danger from mycotoxins, fungal infections of grain, etc.). Other studies reinforce the recognition among stakeholders about a public anxiety on the healthiness of bread (Sharpe *et al.*, 2008; Jones *et al.*, 2015)[3].

This contribution draws from such contested debate to address how practices along the wheat to bread chain shape nutritional value of bread, by illustrating a case study. The Tuscan Bread Protected Designation of Origin[4] (PDO) supply chain shows how integration, localization and the enhancement of nutritional value can be prioritized as a basis for differentiation on the market.

The background in Section 2 introduces the food system concept which highlights the opportunities and implications for improving or worsening food and nutrition security. Materials and methods (Section 3)

[1] Nutrient composition of bread cereals is 50-80% carbohydrate, proteins (8-12%), lipids (1.5-7.0%) and micronutrients, and a range of phytochemicals beneficial to health (McKevith, 2004). The composition of the dry matter of wheat varies depending on soil, climate and genetic variations between wheat types. Components of the wheat grain include bran and germ. Bran, the outer coating or 'shell', is rich in B-vitamins and minerals. Cereals are rich in phosphorus, calcium, magnesium, potassium, zinc and copper, while the level of sodium – before processing – is relatively low. Vitamins such as thiamine (B1), riboflavin (B2), pantothenic acid, inosotol, P-aminobenzoic acid, folic acid and vitamin B6 are also distributed throughout the wheat grain.

[2] Epidemiological studies indicate a strong correlation between the consumption of whole grain cereals and the decrease of diseases like cardiovascular disease, type-2 diabetes, obesity, metabolic syndrome as well as some types of cancer (Larsson *et al*., 2005; Mellen *et al*., 2008). This evidence encouraged the Food and Drug Administration to approve the first health claim for whole grains in 1997 and since then, countries and organizations around the globe are increasingly including them in their dietary recommendations.

[3] A recent social media current – particularly strong in the USA – poses grain staples, especially wheat, under attack in popular press books (e.g. protein intensive Paleo Diets, in the book by Cordain (2010)) and drives to reduce the consumption of gluten by eliminating wheat, grains and in certain cases carbohydrates. Beyond the concern on overweight and obesity related to an excessive amount of cereals in the diet, the other widespread issue is related to the allergenic potential of wheat. It should be recalled that the spread of extreme conceptions of 'healthy food' fail to recognize the importance of calories intake and balance within the diet and encourage the – sometimes unnecessary – exclusion of whole food groups without appropriate support and professional advice (Jones, 2015).

[4] Designations of origin are names that identify a product from a given territory, testifying a link between a quality, reputation or characteristic of the product and its geographical origin. Protected Denominations of Origin entails the name of a region, a specific place or, in exceptional cases, a country, used to describe an agricultural product or a foodstuff: (1) originating in that region, specific place or country; (2) possessing quality or characteristics which are essentially or exclusively due to a particular geographical environment with its inherent natural and human factors; and (3) the production, processing and preparation of which take place in the defined geographical area.

indicates how the case study analysis was developed. The cast study described in Section 4 articulates three sub-sections: the first presents the drivers of change, the second gives an overview of the activities developed at different levels of the food system, and the third focuses on the performance aspects. A discussion follows in Section 5, to highlight the implications for actors and the interplays between changes in product quality, nutritional value, agri-food chain practices and rural development.

2. Theoretical background: a food system approach

Agriculture and food studies have progressively shifted towards systemic approaches, which allow to widen the scope from supply chains linear links to the complex relations among actors and resources, including food systems' main outcomes (Cordell *et al.*, 2009; Ericksen, 2008; Garnett, 2013; Hammond and Dubé, 2012; Ingram, 2011). A food system approach allows to identify opportunities and implications for improving or worsening food security including nutrition. Moreover, it offers a lens to gain a more comprehensive understanding of the factors of change impacting upon the food system (within and beyond the food chain), the multiplicity of actor that may contribute to achieving outcomes, and to increase awareness on the dynamics and the effects of actions, for the anticipation of possible unexpected consequences.

Figure 1 presents the key elements and activities of the food system, based on Ingram, (2011) and Ericksen, (2008).

Food systems comprise natural and human made assets (i.e. environment, infrastructures, etc.), institutions (i.e. cognitive, normative and regulative) and activities (from input provision to consumption and disposal), that deliver outcomes (i.e. food and nutrition security, health, socio-economic growth and equity and environmental sustainability) (HLPE, 2014; UNEP, 2016).

The bottom part of Figure 1 indicates that there is a bi-directional relationship between food system's activities and outcomes. On one side, food systems influence consumers' choices, collective dietary patterns and this has implications for health: for example, food processing, storage and logistics determine food safety conditions, and this increases or decreases exposure to illness. The way food system activities affect the

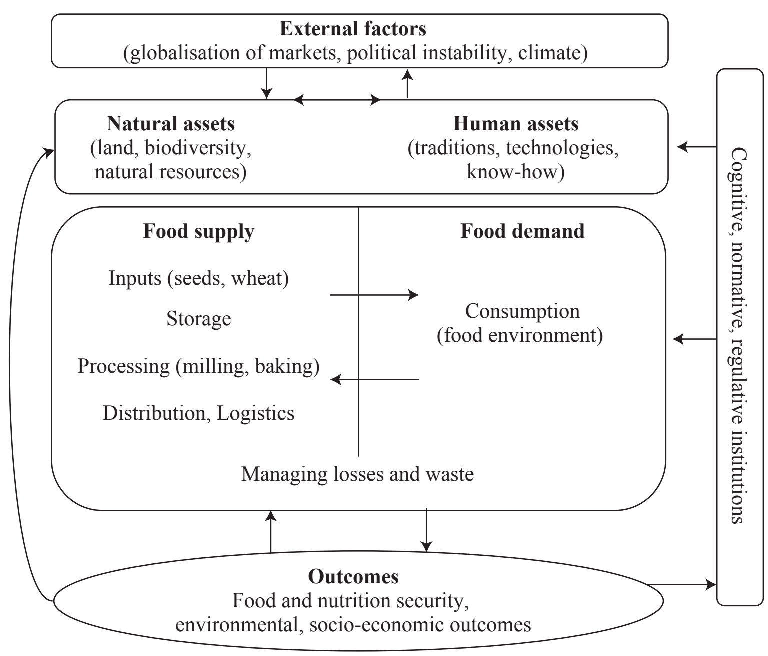

Figure 1. Food systems' elements (adapted from Ingram (2011) and Ericksen (2008)).

nutritional quality of foods, their affordability, accessibility and acceptability within the 'food environment', is the focus of increasing research (Downs and Fanzo, 2016; Hawkes *et al.*, 2012; Waterlander *et al.,* in press).

On the other side, nutrition and health outcomes, (that depend on dietary choices and consumer purchases), may drive the way food production, processing, storage, trade and retailing are developed.

The 'food environment' concept is central in this regard: it encompasses the physical, economic, political and socio-cultural surroundings, the opportunities and conditions that influence food choices and nutritional status, mediated through food preferences and knowledge (Swinburn *et al.*, 2014). Information affects consumers' knowledge, attitudes, food choices and, ultimately, dietary behavior. Food choice can be influenced by a wide range of factors, among which health nutritional labeling, sensory features, ethical concerns and affordability. The actual drivers of purchase behavior and their effects on dietary patterns are still widely debated (Campos *et al.*, 2011; Cowburn and Stockley, 2005; Grunert and Wills, 2007).

The central section of Figure 1 shows the supply chains' activities that shape how foods are produced, processed, distributed and marketed, consumed and disposed of. The way food is processed along the chain can affect nutrition and diets both positively and negatively by creating both 'entry' and 'exit' points for nutrition (Hawkes *et al.*, 2012). Food chains processes can help preserve existing nutritional value (e.g. safe handling conditions of food) or can contribute to improving the nutritional value being by introducing micronutrients (e.g. through fortification) or can lead to decreasing nutrients, by removal from the original raw material (e.g. grain germ, which contains several nutrients, is generally removed from white flour as it is highly perishable) or by adding substances partly associated with diet-related non-communicable diseases (e.g. sodium or preservatives) (Augustin *et al.*, 2016; Mozaffarian *et al.*, 2016). Value chains represent a potential way to leverage agriculture to improve nutrition, particularly regarding traditional value chains for micronutrient rich foods (Gelli *et al.*, 2015).

Normative and regulative institutions impact on food systems (right hand side of Figure 1) and play a key role in balancing supply and demand for nutritious food. Institutions have the responsibility to address the several factors of change (top of Figure 1) that challenge contemporary food systems, including the survival of the agricultural sector. Agriculture, which contributes critically to the nutritional value of food, is increasingly facing land abandonment and urbanization trends, environmental degradation, retailing markets concentration, price transmission along the chains and, not least, policy developments (including agricultural policy) (FAO, 2017).

Public involvement in nutrition outcomes can be broadly distinguished in three categories: (1) interventions to increase food supply of nutritious food, (particularly where availability is lacking); (2) interventions to change food demand (particularly where nutritious food is available, but is not consumed); and (3) interventions to enhance value chain organization and performance, when both demand and supply for nutritious food exist. In the last case, public action may focus on optimizing the nutrient flow along the value chain (Allen *et al.*, 2016). This leads to considering the role of policy in supporting valorization strategies developed by private food chain actors, through different instruments and incentives. Private actors in food value chains range from vertically integrated multinational corporations to farmers, individual entrepreneurs that transport, store, aggregate or sell food, whose incentives and goals should be aligned. Because goals for nutrition, sustainability, and economic development will not always be complementary, interventions will need to manage trade-offs and constraints to meet the multiple goals.

3. Materials and methods

The research was designed as a case study. According to Yin (2003: 2) 'the distinctive need for case studies arises out of the desire to understand complex social phenomena' such as organizational processes, for example. Case studies are indicated as a preferred strategy when 'how' or 'why' questions are posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within a real-life context (Yin, 1981:59, 2003: 2). The Tuscan Bread PDO case is rich in information and data is readily available from multiple sources. For this reason, the research questions are addressed by integrating a qualitative phase and quantitative evidence (Eisenhardt, 1989: 534-535) to develop a mixed research, conducted by inter-disciplinary teams, in which multiple skills are exploited (Paluck, 2010; Starr, 2004).

The first part of the work consists in analyzing the challenges affecting the wheat-to-bread chain (i.e. factors of change), framing the context in which the strategies undertaken by food system actors, take place. The analysis integrates desk based data and grey literature, participation to public events, a set of in depth interviews to key informants and a focus group. The key informants addressed were food system stakeholders covering, but not limited to, all stages of the supply chain: the agricultural consortium responsible for collecting wheat, a wheat genetics' professor that contributed to developing the PDO specification, the milling company, three bakers, the director of the PDO consortium, a quality manager of a large retailing company, a regional policy maker responsible for managing the 'integrated supply chain' project and providing funding based on Rural Development Program. These have been interviewed repeatedly, between September 2014 and December 2016. A focus group in March 2015 was organized to discuss the performance of the Tuscan Bread PDO chain, compared to other more local and global bread chains (Galli *et al.*, 2016).

The second part of the work focuses on the linkage between food system activities and nutritional outcomes, assessed by developing performance based indicators and practice based indicators. As defined in the Sustainability Assessment for Food and Agriculture 'performance based indicators focus on the results of compliance with an objective and measure the performance of an operation, identify trends and communicate results; practice based indicators focus on prescribing the necessary tools and systems required for best practices to be in place. The latter indicators are process rather than outcome oriented' (FAO, 2013:48).

3.1 Practice based indicators

For each stage of the supply chain a set of practices that impact on the nutritional value of wheat, flour and bread are identified and discussed. The Tuscan Bread PDO practices are compared and benchmarked in relation to a comparable conventional industrial bread. The relationships between the phases of the bread production chain and the nutritional value were investigated based on academic literature analysis, grey literature and in-depth interviews with stakeholders and experts.

3.2 Performance based indicators

The characterization of nutritional parameters for Tuscan Bread PDO is developed through chemical and sensorial analysis. As done for practice based indicators, the empirical data from chemical and sensory analysis of the Tuscan Bread PDO is compared to a generic white bread (Supplementary Materials S1). The chemical analysis entails: (1) in laboratory sourdough bread production by using flour according to the PDO specification; (2) chemical characterization of sourdough and conventional bread, by calculating concentrations of the main fermentative metabolites produced in the sourdough during the storage time and in the bread samples, after cooking; (3) sensorial analysis of bread (crust and crumb). For details see Zinnai *et al.* (2013) for industrial white bread and Venturi *et al.* (2013a) for Sourdough Tuscan Bread; and (4) Statistical analysis, to evaluate the statistical significance of the data obtained.

4. Case study: Tuscan Bread Protected Designation of Origin

4.1 Context: the challenges and the drivers of change

Despite the cereals market being complex and highly globalized, due to the supply variations in the main production areas worldwide, overall production yields have increased over the past decades in many countries of the world, including Italy (FAO Stat, 2015). The steady increase in productivity has guaranteed production being higher than consumption, driving grain prices steadily downward. At the global level supply is greater than demand, while this does not hold for Italy, where national production is insufficient for processing needs. Italy is among the largest importers from Canada, France, East Europe, USA.

The Tuscan Bread PDO case study develops in Tuscany, whose regional (and national) cereal market is affected by economic, social and environmental crisis. The cereal sector in Tuscany (in central Italy) is suffering increased price volatility on international markets, and the recent changes in the Common Agricultural Policy support (namely the transition from coupled payments to single farm payments, which aim to orient farmers' business decisions to market signals). The economic sustainability of cereal farms is at risk, as the prices on the market hardly cover the production costs. The sharp contraction in the number of farms and cultivated areas over time clearly documents such crisis[5].

Looking at downstream phases of the wheat-to-bread chain, wheat storage represents another weakness in the region, because it is fragmented on the territory and not conducive to product differentiation, resulting in increased operation and transportation costs. The milling of soft wheat in Tuscany is generally done by small-medium firms, fragmented over the territory. Regional transformation is not closely linked to supplies from Tuscany, although there are established links between some mills and their territorial supply basins. The reasons for the use of supplies from outside the region are linked to price convenience and uniformity of batches, in relation to the requirements on the quality of raw material for baking purposes. In the current context, producer organizations and consortia play a key role in increasing the level of integration with the other actors of the chain (mills, pasta factories, bakeries, feed mills, etc.) and to pursue the valorization of a regional product, both through the concentration of the supply in qualitative homogeneous lots and by exploiting the peculiarities of the regional production system.

Industrially produced bread necessitates of specific standard characteristics of flour, made of grain blends whose provenance is often unknown (either national or continental, but also global) to the detriment of transparency within the supply chains. Moreover, the bread market in Italy is undergoing a deep process of change. At demand level, bread and pasta real prices have undergone a reversal over time: up to 1970s pasta's price was higher than bread price per kg, while in the following years bread's price became higher (3 euro for bread versus 1.5 of pasta, on average per kg). Despite the overall decline in bread consumption, the baking industry has resisted the crisis in different ways among the market segments: consumption of 'table bread', which refers to traditional freshly baked bread, is generally decreasing. The sector of bread substitutes, (i.e. dry breads and breadsticks, sandwich bread, unleavened bread and the segment of gluten free) has recently shown the highest increase rates.

In recent years, a re-localization trend has spread across Italy, as a possible strategy to revitalize the cereal sector through the enhancement of authenticity, quality and traceability of wheat. Bread is an important part of the cultural and social fabric associated with Tuscan territory, agriculture, gastronomy, and bread recipes reflect the specific culinary tradition of each Tuscan province. Over time, Tuscan Bread has maintained the characteristic of being baked without salt, to the point that this is now one of its distinctive features, and produced with sourdough (a dough containing a lactobacillus culture in symbiotic combination with yeasts) as a fermenting agent, which gives the final product a special aroma and flavor (Malandrin *et al.*, 2015).

The proliferation of spontaneous initiatives promoting local baking, as well as the establishment of PDO and Protected Geographical Indications (PGI) for bread are indications the re-localization process developed by bridging the gap between producers, processors and consumers[6]. However, the protection of the integrity of traditional products does not prevent traditional food producers from the necessity to innovate (Vanhonacker *et al.*, 2013). Moreover the effectiveness of PDO and PGI labels have been questioned, also by academic

[5] In 2010, the Italian census of agriculture recorded 16,571 farms (23% of total number in Tuscany) active in grain production, about a half compared to the previous decade, while the contraction of cultivated areas is about one-third. The average area per farm dedicated to cereals is about 10.5 hectares, rising to 13.32 for durum wheat and dropping to just over 5 hectares for soft wheat.

[6] Seven different Italian bread types, including Tuscan Bread PDO, are registered in the PDO/PGI catalogue, indicating the variety of traditional recipes and the linkage between wheat production, milling, bread baking and territorial specificities.

literature (Carbone *et al.*, 2014). Innovation is a strategic task especially for small and medium enterprises: in the bread sector, the most interesting dynamics concern the ability to offer the right balance between taste, authenticity, healthiness, and at the same time adaptability to new lifestyles (including packaging).

4.2 Actions by food system actors

The process of recognition of Tuscan Bread as a PDO (according to Regulation 510/2006 (EC, 2006)) started in 2002, thanks to the initiative of a group of bakers, farmers' associations, a milling industry and other local stakeholders, whilst the financial support was provided by the regional administration on agricultural policy funds. The aim was to promote and protect Tuscan Bread, codifying the original recipe and its related product specifications, including the use of varieties of wheat traditionally grown within the region. Product specifications strictly determine processing and features of the final product. Some crucial aspects differentiate a PDO bread supply chain from a conventional one: (1) wheat cultivated in Tuscany must belong to a set of soft wheat varieties, allowed in specific proportions; (2) flour must include the wheat germ; (3) sourdough leavening is compulsory; (4) no salt can be included in the recipe; (5) the final weight has to range between 0.45 and 1.10 kg; and (6) the Consortium packaging must be used. Product specifications strictly determine processing and features of the final product (see Figure 2 for an image of bread as available on the consortium website).

A 'Consortium of Promotion for the Valorization of Sourdough Tuscan Bread' was established in 2004 aiming to obtain the PDO recognition. The process lasted 13 years, and was completed in 2016. The nutritional 'premium', (further examined in the following paragraphs) was among the crucial aspects, together with the link to the regional pedo-climatic conditions, that allowed for the PDO recognition.

Figure 2. Tuscan Bread Protected Designation of Origin.

Instrumental to the success of the initiative, was an 'integrated supply chain project' submitted and granted by Tuscany Regional Administration (within the Rural Development Plan (RDP), 2006-2012) to enhance regional wheat production. The project, championed by a milling company as 'channel captain', establishes a formal relationship among actors of the regional supply chain, above all to encourage farmers recovering the production of traditional and native soft wheat varieties (in line with the requirements of the PDO specifications). The RDP measures included farm investment support to update technologies to the requirements of the agronomic protocol. The protocol defines the agronomic planning of farming operations and inputs that must be used to ensure homogeneity and quality of soft wheat. Funding for research and development was granted to the Universities of Pisa and Florence, to develop respectively innovative bread making technologies and agronomic protocols to facilitate and consolidate the manufacturing process based on objective parameters (such as markers or identifiers of chemical composition of bread). The commercial agreement defines production quantities and premium price ranges for farmers and coordinates stakeholders to the common aim of ensuring the quality of the final product, a prerequisite of the commercial and economic success of the initiative.

Figure 3 identifies the main actors involved in the Tuscan Bread PDO project, which mirrors the structure of the regional integrated supply chain. The project joins around 60 farmers: in 2016, out of 80,000 tons of soft wheat produced overall in Tuscany, 5,000 tons of soft wheat for PDO bread were planted, using certified seeds for traceability purposes. Price of wheat is anchored to the reference commodity market price (which is currently 180 euro per ton on the Bologna market (ISMEA, 2017)), to which a premium price is added (a range of minimum, average and maximum prices is set in the supply chain contract). For example, in 2016, soft wheat was paid 270 euro per ton (250 euro in 2015) to the consortium, (which retains approximately 30 euro per ton and then pays the farmers). 5,000 tons of wheat allow to produce 5,000 tons of bread (15% is lost in milling and 15% is recovered in baking, approximately). The integrated supply chain project ends in 2016, however the contract can be renovated year by year.

Collection and storage centers involved in the project invested in the expansion of storage capacity, endowment of equipment necessary to detect the quality of the wheat stored and the adoption of conservation techniques to ensure a healthier product. The farmers involved in the project stock their product at a Consortium (located in center of Tuscany, in Siena), which also provides extension services. Recently a second storage center in the north of Tuscany joined the Consortium.

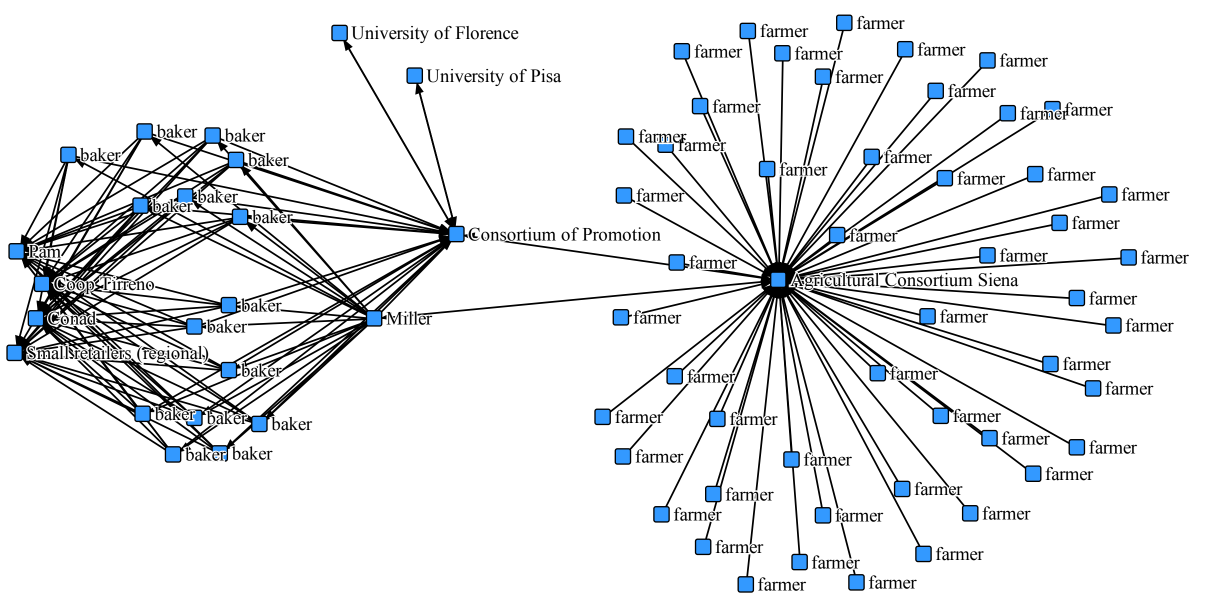

Figure 3. The Tuscan Bread Protected Designation of Origin integrated supply chain project members.

The Integrated Supply Chain Project encompasses one milling company, that's also the project leader and among the promoters of the PDO recognition. After the PDO success, two other milling plants have joined the Consortium. The average price of flour for PDO bread purposes is approximately 500 euro per ton, which is higher than average price of white flour for baking (390 euro per ton (ISMEA, 2017)).

Twenty-five bakeries located all over Tuscany, mostly medium scale, are also included in the project. Bakers joining the Consortium have changed through the years, as not all of them were willing to follow such a long term and uncertain project. Moreover, the baking process for Tuscan Bread PDO determines higher costs of production with respect to more conventional bread, discouraging some of the bakers. Although these costs are hardly quantifiable, they are linked to longer baking times, which impact on labor, and to the organization of spaces for the sourdough leavening process, which impact on structures. All these conditions have led to a self-selection of larger size bakers, able to comply with PDO specifications, with the very small and artisanal farmers leaving the Consortium over the years. It should be noted that the Tuscan Bread PDO chain is defined as 'industrial' and as such it can exploit the economies of scale to afford the costs related to the search of quality, harder to achieve by small and artisanal production.

Because the larger size bakers remained involved through the PDO recognition process, large scale distribution represents the main market channel for Tuscan Bread PDO. The Consortium was able to bargain specific bread surplus management agreements. Normally, large scale distribution returns the unsold, left over bread, to the reference bakeries, at the end of the day: this has strong impact on the price of bread and the competitiveness of the sector, the profitability of bakers and not least, on waste. The Consortium activated ad hoc agreements with the main large distributors, by setting the rule that Tuscan Bread PDO should not be returned to bakers, relieving them from disposal of surplus bread.

Tuscan Bread PDO is currently sold on the market with the Consortium label at a minimum price of 3.5 euro per kilo compared to a regional average price of 1.94 euro per kilo of fresh bread (ranging between 1 and 4 euros, data from Italian Ministry of Economic Development, June 2015). Bestsellers' products are large loaves, baked in wood ovens, and cut over the counter, where the customer can actually see the PDO label.

Traceability contributes to the prevention of contamination and adulteration, but it is not intended specifically for the end user. Full traceability of the Tuscan Bread PDO supply chain requires certification of seeds, dedicated storage structures for wheat and flour, to ensure wheat separation and identity preservation. Traceability implementation entails the adoption of an IT-system by companies involved in the project, which allows to collect and centrally manage data on incoming raw materials and outgoing products for each operator involved in the production chain. The PDO quality label contributes by definition to the transparency towards consumers and enables farmers and producers to communicate about origin (the geographical distance between the supply chain stages within Tuscany regional borders is at maximum 100 km) and other features, irrespective of the number of intermediaries in the supply chain. Beyond delivering a message on the value-added quality of the production process, the ingredients and the baking processes, the PDO guarantees that an official control over the supply chain is implemented by one of the bodies recognized by the Italian Ministry of Agriculture. The marketing strategy of the Consortium is strongly pushing, beyond territoriality, on the nutritional qualities of the product, (i.e. low gluten, sourdough leavening, and preservation of organoleptic features).

4.3 Outcomes

- *Performance and practice based indicators of Tuscan Bread Protected Designation of Origin*

Table 1 presents parameters related to the chemical-physical characterization of Tuscan Bread PDO in comparison to a widespread industrial white bread obtained through a fast leavening process. Additional data, referring to mold spoilage, staling process as well as nutritional value of both sourdough bread and industrial white bread, are shown in Table 1.

Table 1. Performance parameters of Sourdough Tuscan Bread and generic industrial bread.

Parameters	Sourdough Tuscan Bread	Generic industrial bread
pH	3.4-4.6	5.3-5.8
Lactic acid	0.4-0.8%	0.005-0.040%
Acetic acid	0.1-0.3%	0.005-0.040%
• Mold spoilage[1]	Protected from deterioration due to the antimicrobial substances produced by lactic acid bacteria	Sensitive to contamination by molds and bacteria
• Staling[1]	Slower, because the acidifying lactic acid slows down the starch retrogradation	Faster because of the reduced concentration of lactic acid
• Nutritional value[1]	• Reduced glycemic index: GI=50. • Production of exopolysaccharides (EPS) with probiotic action. • No salt. • Increased bioavailability of amino acids. • Degradation of phytic acid which forms complexes with certain ions difficult to assimilate. • Increased solubility of the fibers. • Good tolerance by celiac towards sourdough products.	• Glycemic index: GI=100. • Reduced production of EPS with probiotic action. • Presence of salt: 0.8 g/100g. • Reduced bioavailability of amino acids. • Presence of phytic acid. • Reduced solubility of fibers.
Flavor and taste	Production of D/L-lactic and acetic acids and secondary products (aldehydes, ketones, esters, etc.)	Reduced flavor complexity and savoriness

[1] Secondary data, adapted from Venturi *et al.* (2013a, 2016b).

Tuscan Bread PDO is characterized by a lower pH and a higher concentration of lactic and acetic acid than the industrial white bread. In this context, we can also explain the reduced mold spoilage as well as the slower staling process generally observed in sourdough bread, compared to industrial white bread. As reported in previous papers (Venturi *et al.*, 2013a, 2016b), the PDO bread is characterized by a significantly higher production of secondary products that allow to obtain an enhanced flavor complexity and a higher savoriness than a widespread industrial white bread.

Table 2 identifies a set of practices of the bread making process that have potential implications on the whole quality as well as on the nutritional value of bread, and illustrates them with the Tuscan Bread PDO chain compared to the ones commonly adopted in standard white bread supply chains.

Table 2. Supply chain practices and impact on nutrition.

Supply chain stage	Practice	Tuscan Bread PDO[1]	Standard industrial white bread
1. Seed and wheat cultivation	Choice of soft wheat varieties	Old/ancient wheat varieties traditionally harvested in Tuscany	No limitation about flour origin and composition
2. Milling	Choice of flour	Flour includes wheat germ	White flour without inclusion of wheat germ
3. Mixing, fermentation and baking	Choice of leavening method	Sourdough leavening	Use of improvers
4. Distribution	Communication strategy and transparency all along the chain	Full traceability of bread along the wheat to bread chain	Provenance and quality of grains and flour often unknown

[1] PDO = Protected Designation of Origin.

■ *Seed and wheat cultivation*

The suitability of a variety of wheat for breadmaking is determined mainly by its genetic make-up. A wheat variety is more suitable for bread-making when the ability of its proteins to form the dimensional networks of gluten during kneading is greater. Environmental factors, such as nitrogen fertilization, water and temperature influence protein content. By contrast, protein quality is largely under genetic control (Callejo *et al.*, 2015).

The choice of wheat varieties to be utilized for bread-making greatly influence the bread quality as well as its nutritional value. It has been recognized that ancient varieties of wheat have a higher genetic variability, thus contributing to enhance biodiversity (Dinelli *et al.*, 2009). In Italy, old landraces and varieties, which underwent intensive breeding programs at the beginning of the twentieth century, were replaced after the Second World War with the modern semi-dwarf and high-yielding cultivars (Rascio *et al.*, 2015).

Current interest in the health benefit of grain consumption has led to an increased focus on the phytochemical content of different grains and grain varieties. Ancient wheats have been recognized to offer unique nutraceutical values for their peculiar content in health-beneficial phytochemicals (Dinelli *et al.*, 2009). Although no significant differences among investigated cultivars were detected in relation to the amounts of total phenolic and flavonoid compounds, the qualitative phytochemical profile between old and modern varieties was remarkably diverse. The peculiar and varied phytochemical profile of investigated old wheat genotypes confirmed that ancient grains may represent a rich source of genetic diversity, especially with regard to functional properties (Dinelli *et al.*, 2009).

As regards the indication of wheat varieties admitted for Tuscan bread PDO production, the selected ones by 'Consortium of Tuscan Bread Sourdough' represent wheat varieties traditionally harvested in Tuscany, to guarantee a strong linkage between the Tuscan bread and its territory of origin[7]. These can be mixed with more recent varieties to obtain a flour characterized by the needed technological features.

■ *Milling*

The milling of grain to produce white flours reduces the levels of phytates as well as the levels of many nutrients present in different parts of the wheat kernel. The wheat germ, is a rich source of B-vitamins, oil, vitamin E and lipids, composed of essential fatty acids, mainly palmitic and linoleic acids. However, germ is discarded during industrial milling because the fat is liable to become rancid during storage. Eventually, the re-addition of wheat germ into the white flour allows to recover part of the nutrients lost. Wheat germ is a high nutritive by-product of the flour industry (Gomez *et al.*, 2012). It is characterized by a high protein content, mainly in the form of albumins and globulins, and a balanced amino acid composition, which repairs the defects of cereal proteins. The germ also provides six times more minerals, seven times more fat and fifteen times more sugars than does white flour without germ. Antioxidants in wheat germ are useful to prevent cardiovascular diseases and cancer. Therefore, wheat germ offers an appropriate medium to convey these benefits to human diet (Gomez *et al.*, 2012).

Generally, wheat germ has a considerable fat content of around 10 g/100 g, and a significant quantity of bioactive molecules related to its role as part of the embryo of a new plant (Gomez *et al.*, 2012). Among these bioactive molecules, the lipases and the lipoxygenases can hydrolyze lipids and initiate the oxidative rancidity process. This fact and the high unsaturated fatty acid content of wheat germ lead to the very short shelf-life of raw germ (Sjovall *et al.*, 2000) or even flours with germ. Because of the limited shelf life, the utilization of flour including wheat germ is generally avoided to produce widespread industrial white bread.

[7] The selected varieties are listed as: red wheat varieties (≤80% of total): Centauro, Bilancia, Serio, Verna and Pandas. White wheat varieties (≤50% of total): Mieti, Mec, Marzotto and Bolero.

Based on the indications provided by Tuscan Bread PDO Consortium, the flour utilized for bread production must be white flour including wheat germ, in order to obtain a foodstuff characterized by a sensorial expression strongly linked to the bread traditionally produced in Tuscany, but showing an increased nutritional value. This is allowed by the technological facilities of the milling plant involved in the integrated supply chain project, which extracts the germ from the kernel at the beginning of the process and re-adds it subsequently.

■ *Mixing, fermentation and baking*

Sourdough is a mixture of flour (mainly wheat or rye) and water, fermented with lactic acid bacteria and yeasts, which are responsible for its capacity to leaven a dough, while contemporarily and unavoidably acidifying it (De Vuyst *et al.*, 2014). In the modern bakery technology, sourdough represents an alternative to the use of baker's yeast (although bakers often use a combination of both leavening agents) to manufacture a variety of products (Minervini *et al.*, 2014) such as bread, crackers, snacks, pizza and sweet baked goods, because it offers many advantages over baker's yeast: enhanced flavor, prolonged shelf-life, improved dough structure and increased nutritional value of the leavened baked good (Arendt *et al.*, 2007; Katina *et al.*, 2005).

Sourdough processes can be used to modify levels of bioactive compounds, however, not much data is available (Katina *et al.*, 2005). Sourdough fermentation has been reported to increase folate content, decrease tocopherol and tocotrienol content, and decrease or increase thiamin content depending on the process (Katina *et al.*, 2005). Thus, sourdough fermentation can both increase or decrease the levels of bioactive compounds depending on the nature of the compound and the type of the sourdough process. The presence of yeast seems to favor the formation of folates and thiamin. Formation of acidity can both increase levels of bioactive compounds (such as total amount of phenolic compounds) or decrease levels of some compounds (such as thiamin, ferulic acid dehydrodimers, tocopherols and tocotrienols). The degradation of phytate, already discussed above, has repeatedly been reported in sourdough processes (Katina *et al.*, 2005).

Phytates can chelate and bind minerals, resulting in insoluble complexes that may lead to a decrease in mineral absorption and bioavailability, and therefore the removal of phytates from baked goods has long been considered desirable. Evidence demonstrating a diverse range of benefits to health and wellbeing is now accumulating. Sourdough fermentation has been shown to decrease the amount of phytate in wholegrain cereals. Many studies have indicated that phytate hydrolysis during dough fermentation significantly enhances the bioavailability of minerals including calcium, copper, magnesium, zinc and iron. The results reported by Buddrick *et al.* (2014), indicate that the proving time had the most significant impact on the phytate reduction which might enhance mineral bioavailability of the final products.

According to the indications provided by Consortium, sourdough leavening is compulsory in Tuscan Bread production. The operating conditions related to the sourdough utilization and storage have been defined and bakers must readapt the organization of the production process to be able to comply with such operating conditions. This represents a challenge for those bakers who rely only on bakers' yeast fermentation, which allows standard leavening, flavor and shorter production times. Comparing to the industrial bread production, it is worth noticing that mechanization, large scale production and increased consumer demand for high quality, convenience and longer shelf life have created the need for functional food additives such as emulsifiers and anti-staling agents to achieve desired quality in bread. Addition of emulsifiers is particularly important for large scale, industrial bread baking as these impart greater dough strength to withstand machine handling, improve rate of hydration, improve crumb structure, improve slicing characteristic, improve gas holding capacity and extend shelf life (Moayedallaie *et al.*, 2010; Mondal *et al.*, 2008).

■ *Storage and distribution*

The use of sourdough has been reported to have positive effects on bread staling, thanks to the role of lactic acid bacteria (Arendt *et al.*, 2007). One such effect is an improvement in loaf specific volume, which is associated with a reduction in the rate of staling, as has been demonstrated by a reduction in crumb softness loss for sourdough breads during storage. A decrease in the staling rate as measured by differential scanning calorimetry has also been reported for breads containing sourdough[8].

In traditional bread making processes, such as that indicated for Tuscan Bread Sourdough, the use of sourdough appears as the main step in order to allow to extend the product shelf life in a 'natural' way, despite the operating conditions required for sourdough leavening being quite expensive in terms of time and labor.

The breadmaking industry has undergone important changes in the last decades because of mechanization for increasing production and consumer demands. The mechanization of the breadmaking process involves dough rheology changes and the frozen technologies also require recipe modification for reducing the freezing damage. Consumers demand products of better quality and longer shelf-life. The search for solutions to meet those requirements has been parallel to the development of different additives and technological aids that modify dough rheology and improve bread quality. Additives and technological aids are extensively used in the baking industry for improving dough machinability in the case of emulsifiers and enzymes, bread characteristics by using enzymes, hydrocolloids, emulsifiers and to extend the shelf life of the resulting products (Gomez *et al.*, 2004).

5. Discussion

The cases study shows that a quality differentiation process – based on the valorization of traditions and territory, coupled with the improvement of nutritional value – does not concern isolated actors but activates the food system at different levels, leading to systemic changes. The crisis of the regional cereal sector has acted as a driving force towards the innovation of the wheat-to-bread chain, supported by the policy maker, who has enabled structural investments, remuneration of farmers, and higher quality and nutrition for consumers.

Coordination and governance of the food chain are key aspects in relation to outcomes, including nutrition: integrating the supply chain by establishing an explicit connection (i.e. a contract) among partners has led to a change in the overall governance structure.

According to literature on the governance of global value chains, 'internal' governance is referred to the relations within the chain. Governance as 'drivenness' is the process of organizing activities, allocating resources and distribution of gains, and determining inclusion or exclusion of other firms (Gereffi, 1994; Wilkinson, 2006). The leading role of the Consortium is crucial in the organization of the Tuscan Bread PDO chain, since the beginning to the end of a very lengthy PDO recognition process. The Consortium also plays a power rebalancing role, for example when it engages in the negotiation with retailers, (i.e. to avoid surplus bread return as a responsibility of bakers).

Other governance approaches refer to coordination (Gereffi, 2005; Gibbon *et al.*, 2008) and normalization*,* as a process of re-aligning a given practice to follow a norm (Gibbon and Ponte, 2008). Drawing from conventions theory, 'quality conventions' are mutual expectations that include, but are not limited to, institutions (Ponte, 2009): when price alone cannot evaluate quality, economic actors adopt other conventions to assess quality (i.e. trust, reputation, certification, etc.). Conventions of quality thus become instruments of coordination of the supply chain, as they provide the necessary knowledge base and determine the behavior of actors. A quality convention based on health and regional identity helps to set standards that regulate the stability of raw material and information flows, preserves the territorial identity of a product, avoids the exploitation of local resources, and fairly distributes costs and benefits among involved stakeholders (Brunori *et al.*, 2016).

[8] It has been noted, however, that the anti-staling effect found for sourdough is dependent from the particular strain performing the fermentation, and that this effect involves dynamics other than those associated with the degree of acidification. Starch molecules can be affected by enzymes produced by lactic acid bacteria, causing a variation in the retrogradation properties of the starch. This in turn slows the rate of staling. Additionally, proteolysis of gluten subunits has also been proposed. Additionally, proteases aid the liberation of water associated with the protein network thus allowing for an increased alpha amylase activity. The acidic conditions and proteases associated with sourdough play a role in reducing the staling rate of bread (Arendt *et al*., 2007).

'External' governance refers to the distribution of duties and rights between the firms and stakeholders in a broader sense (i.e. including civil society and institutions) (Sacconi, 2006). When considering performance in relation to nutrition, 'extended' governance assumes a key role. Public administrations, producers' consortia, third party certifiers and research actors all contribute to the definition of the regulatory context, enforce quality controls and can exert pressure on firms to frame competition on nutrition performance.

Governance change can be interpreted by referring to the analytics of governmentality, suggested in relation to sustainability by Spence and Rinaldi (2014) and Dean (2009). In the Tuscan PDO case, transformation and appraisal of its consequences do not take place just within one organization, but across the organizational boundaries of the supply chain and the wider food system. Overall, the analytics (fields of visibility, techne, episteme) contribute to the 'identity formation' of the different stakeholders of the chain (Spence and Rinaldi, 2014: 43). The 'field of visibility', as a condition to competitiveness and reputation building, develops around the link to territory, improved nutritional value and increased transparency for the consumer. The field of visibility corresponds to distinctive practices along the chain with economic and technological implications (i.e. 'techne' of governmentality). The most striking example is the sourdough leavening process, which improves nutrition and requires the re-organization of the production process, and impacts on labor working hours and structures. Similarly, the inclusion of the wheat germ into flour, which enhances sensorial expression and maintains part of the nutritional value contained into the wheat kernel, needs a technological adaptation of industrial facilities of the milling plant, and the management of stocks for the optimal and safe conservation of flour. In relation to transparency, full traceability is a necessary tool which envisages the design and development of an information system to support companies involved in the project, to collect and centrally manage data on incoming raw materials and outgoing products for each operator involved in the supply chain and identification of any chemical identifiers (i.e. markers) capable of distinguishing unambiguously the finished product.

Furthermore, the PDO specifications, that codify quality among producers and convey a message on the origin, expresses at once the plans and the know-how, codified and made available to a community (i.e. the 'episteme') (Spence and Rinaldi, 2014: 43). The PDO specification also represents a challenge, in relation the know-how required to re-discover and uptake traditional production practices that have been lost, due to modern continuous baking processes (which led to the removal of sourdough leavening for bread for example). A training for bakers is currently being organized by the Consortium, as a necessary action to allow the compliance with PDO specifications, by an increasing number of bakeries in the region. This training addresses particularly the handling and management of sourdough in accordance to PDO specifications, and with the support of research institutions.

6. Conclusions

The Consortium of Tuscan Bread has embarked on a long-term process of innovation to compete with conventional industrial white bread: the territorial differentiation, gained through the PDO labelling, is reinforced by enhancing nutritional value. This process is not linear and addresses multiple levels of the food system, aiming at delivering a healthier bread and encountering consumers' preference for localness and traditional products.

The food system perspective adopted enables to shed light on the multiple levels involved in the transition towards an improved nutrition: the revitalization of the soft wheat sector, triggered by supply chain actors and supported by policy that allows farmers to receive a higher price for wheat; the recognition of the differential quality to processors, through a tool as the PDO label; the increased transparency in a very opaque market, through traceability.

The success of the differentiation strategy adopted by the stakeholders relies on the integration of the supply chain stakeholders and requires a change in the governance. This allows the realization of an interplay among price, taste and nutritional value which would not take place without an explicit supply chain agreement.

The regional scale provides a favorable context to balance territorial identity, artisanal know-how and industrial scale. It is a sort of 'laboratory' to experiment with standardization of 'artisanal' practices for the attainment of economies of scale and eventually reach wider markets (e.g. standardization of the sourdough leavening process).

The Tuscan Bread PDO enhancement potential will be fully visible after some time from the recent PDO recognition. Only then, a complete assessment of the sustainability of the initiative will be possible.

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Supplementary material

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Materials S1. Chemical analysis.

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