sustainability

MDPI

Article

Improvement of Certified Artisan Cheese Production through Systemic Analysis—*Serra da Estrela* PDO

Denis A. Coelho [1,*], Tiago E. P. Carrola [1] and Ana F. Couvinhas [2]

1 Human Technology Group, Department of Electromechanical Engineering and Centre for Mechanical and Aerospace Science and Technology, Universidade da Beira Interior, 6201-001 Covilhã, Portugal; tepcarrola@gmail.com
2 Directors & CE Consulting Group, 6200 Covilhã, Portugal; design.afc@gmail.com
* Correspondence: dac@ubi.pt or denis.a.coelho@gmail.com

Academic Editor: Iain Gordon
Received: 4 January 2017; Accepted: 18 March 2017; Published: 21 March 2017

Abstract: This research was aimed at improving the overall efficiency of the PDO (Protected Designation of Origin) Serra da Estrela cheese production process, a traditional food product with cultural significance. Mapping of the manufacturing and distribution processes was developed from systemic analysis using ethnographic techniques. Critical points were identified, leading to design work. Ergonomic risks in cheese making were detected during the process of chips cutting, fostering the emergence of musculoskeletal disorders of the wrist. A tool that better fitted the job was developed. The systemic analysis provided a relational link across the boundaries of distinct domains approached through the research, including microorganism contamination, ergonomics, energy efficiency, legislation and regulation policies, transportation challenges and economic viability. Based on an analysis that connected various disciplines, maintaining a holistic perspective, a development plan to tackle critical points identified in the system was created. The results ripple across the triple bottom line of sustainability, demonstrating how systemic analysis and design are at the service of improving sustainability. By unveiling and acting on critical points that pushed the system away from zero waste, the environment is conserved; the preservation of cultural heritage has social significance; and the efficiency gains obtained in production attend financial goals.

Keywords: process improvement; ewe's cheese; systemic design

1. Introduction

Improving the social, environmental and financial benefits brought about by traditional food products contributes to sustainable development. Moreover, in order to maintain and expand the market share of traditional food products (an important part of European culture, identity and heritage), improvement in safety, health, or convenience is needed; these may be achieved by innovating in various dimensions [1], including processing technology, origin-ethnicity, novelty-change, variety and convenience. Innovation implies an important and evident benefit for consumers because it increases the variety of available options: variations in taste, in combinations of food ingredients, in product shapes, and sizes [1]. An innovative food may be created by applying new technologies or further processing it, despite the apparent incompatibility between tradition and innovation. The foreign (non-national or non-regional) image of a product tends to play an important role in determining its innovative character in nonlocal sales [1]. Convenience-oriented innovations aim at making the consumer's life easier. Food is also innovative if it is prepared in a different way, when adding unknown or new ingredients or when adding foreign and unusual ingredients; once innovations become widely adopted they lose their innovative character and in some cases may become a tradition [1].

The long history and symbolism carried by the Serra da Estrela (SE) PDO cheese transforms it into a token for an industry and specific geographic region of Portugal. It might be considered the most important legacy of a way of life, part of a system that was gradually developed and adapted to the adversities found in the Serra da Estrela Mountains. With an annual output, on average, of 96.9 metric tons of cheese, and an average value of 1.46 million Euros (€), as shown on Table 1, it becomes clear that as a local economic activity it can be very significant for regional development.

The Serra da Estrela PDO cheese is one of the main results of a way of life that is part of an ecosystem, gradually developed and adapted to the local constraints over generations. Presently, new challenges emerge requiring to steadfastly follow the path of adaptability and flexibility. Thus, the features that make the Serra da Estrela PDO cheese an unparalleled product and so appealing to connoisseurs were investigated. An investigation was carried out to identify the available room for future development of innovations that would not clash with the existing set of rules. This paper is the result of research carried out during the course of the second author's Master's thesis [2]. In the case of traditional products, like the one focused, local actors very often encounter great difficulties to innovate in order to avoid a loss of the traditional character. This sets up the problem of the design of the technical change vis-a-vis the tradition; hence, innovating in a traditional production (as proposed in this paper with a new cheese chip cutting tool) can reinforce quality instead of reducing it, where technical change corresponds, not with a substitution but with an enrichment of the technical culture materialized in the product [3].

Table 1. Serra da Estrela PDO cheese production values and respective price at the producer by year [4] (pp. 62–64).

Year	Cheese Production [1]	Price [2]
2002	90.10	14.96
2003	98.80	15.75
2004	93.60	15.75
2005	74.80	15.75
2006	81.00	14.70
2007	98.60	14.70
2008	101.10	14.70
2009	134.70	14.70

[1] Metric Tons. [2] €/Kilogram.

1.1. The Case for a Systemic Perspective in Food Production Improvement

Life Cycle Assessment (LCA) is a commonly used method to assess the potential environmental impacts that leaves out important variables existing outside the product system that can also influence environmental impacts. LCA is a 'cradle-to-grave' approach for assessing the potential environmental impacts of a product or service over its full life cycle; including resource extraction, production, use, transport and end-of-life stages [5]. It allows for the identification of 'hot-spots' of potential environmental impacts according to design specifications as well as the comparison of different design alternatives and improvement options [6–9]. The interpretation of LCA results is framed by goal and scope definition, system boundaries and selection of the functional unit of the product [10]. Systemic maps identify variables which may not typically be identified and considered in LCA studies but may have significant influence upon environmental impacts through cause-effect chains [11]. Suggestions for optimization are traditionally made on the basis of a single unit, not taking into account, for instance, the product line [12–14], infrastructure systems [15], the interrelations between the products and the infrastructure system. The traditional approach may hinder the possibilities of achieving higher levels of efficiency and of reduction of negative environmental impacts [16].

Contemporary ecology emphasized boundaries and their role in landscapes, as urban climate and urban watersheds studies demonstrate [17,18]. Since the 1970s, Systems Theory and Complexity have been explored in science to provide a new framework for nonlinear, non-rational decision making and planning [19]. Nevertheless, this thinking has often been adopted superficially [20]. The original systemic method, proposed by Alan Berger, entails that large-scale territorial dynamics, if properly understood, could guide design projects and strategies, going beyond the traditional schemes [19]. Systemic design merges the existing territorial dynamics, with multi layer strategies and historical transformations, understanding how natural and artificial systems operate dynamically at the regional and local scale, and how these are interrelated providing the basis for innovative designs [20]. Theories about complexity assist the management of entire food systems and design approaches support the planning of different divergent elements [21]. The need for innovative visualization and mapping techniques to identify and portray the interplay of natural and social processes that shape and structure the artificial environment and the territory has been previously acknowledged: "For designers, new techniques of notation and representation are required. Conventional techniques are inadequate to the portrayal of time and change, and they encourage the continued focus on visible and static form" [22]. The construction of causal maps is a key instrument in a systemic design approach [19].

The process of assembling a model is a way of eliciting mental constructs, ideas about how things work in order to clarify and structure debate about a situation which is seen as problematic [23]. A causal map (also known as inference diagram) represents how chosen variables, and, or, elements of a system interact with each other [16]. In a causal map, interactions between the elements can be either reinforcing (positive) or balancing (negative). This graphical representation may assist in understanding the pattern of behavior presented in a complex system and facilitates communication among different stakeholders [16].

Complexity theories evolved on the basis that living systems continually draw upon external sources of energy and maintain a stable state of low entropy, as physicist Erwin Schrödinger asserted after WWII. Some of the rationales that followed applied those theories to artificial systems [21]. Treating productive organizations as complex adaptive systems allows a new management model to emerge with economical, social and environmental benefits [24]: Cluster Theory [25] evolved into more environmental sensitive theories, such as Industrial Ecology [26] and Industrial Symbiosis [27].

Design thinking, as Buchanan [28] said in 1992, is the way to creatively and strategically reconfigure a design concept on a situation with systemic integration. This needs a strong inter- and trans-disciplinarity during the design phase [29], with the increasing involvement of different disciplines including public policy, business management and environmental sciences [30]. However, design thinking doesn't explicitly include social aspects, so more evolution in the discipline is needed: Systemic Design [31].

Systemic Design plans the flows of matter and energy from a system to another one towards zero emissions, creating new economic-productive models, communities of strongly related people and conscious connections with the territory [21]. Comprehensive approaches, Systemic Design and Blue Economy [32], define many eco-guidelines, based on different practices and systems of goods production, transformation and consumption. This enables defining new food systems, promoting social and environmental development [21].

Systemic innovation is not amenable to simple recipes or toolkits. Starting from the analysis of the complex interactions relationship between different actors (individuals, society, enterprise, culture, territory, etc.) and the related cultural, economic and community area or territory the aim is to unlock and exploit the innate value of the context as a starting point [33]. There is now a range of tools for mapping and better understanding systems that can give useful insights leading to innovation in those systems [34]. This approach is a strategic way to face design innovation, defined as the process comprising all essentials steps that lead to innovation, generally involving all the internal sources of knowledge generation and learning, the organizational structure and processes of the people and organizations committed in the process [35].

Systemic Design (SD), handling the input and output of processes and the relationships between different industrial stages [36], assists in defining in advance the behaviors that could be triggered, as well as what collection and disposal channels could be used [37], generating added value from what is usually considered waste. Environmental problems generate both difficulties but also major opportunities for innovation related to a supply-chain, from production to distribution, from packaging design to rediscovering and promoting traditional values. This kind of research evaluates the input and output of all stages of production, studies the energy needs, the flows of matter and energy and enables sizing a system to ensure zero impact on the environment [38].

1.2. The Systemic Design Methodology

The logics of linearity present itself in the industrial sector through phenomena such as the cause-effect relationship; technical problems are solved and strategies are drafted on a step by step basis in order to improve the product and innovate. However, a simple change of perspective on how the various situations taking place are observed can lead to more innovation. The key is to observe production processes in a systemic way, considering waste and residue, together with scarcity of raw material, from the onset of analysis. While taking preventive measures rather than corrective action, one can transform shortcomings into strengths and create situations where the outputs of a system become new inputs for the same or a different system [39]. The most common production models that can be found generate a lot of waste and have a general tendency to focus on the product, keeping other aspects dimmed. The methodology of systemic design traces the path of materials and energy during production, monitoring transition from one stage to another, throughout the cycle. As a result, it creates an important economic flow, while eliminating polluting parts. However, the focus is not only on environmental issues, but also on an economic model that encompasses not only the development of the productive system but also of society [39].

Systemic design strives to make better use of material and energy flows, shaping our production and energy systems according to Nature [40]. Systemic theory studies how complex entities interact openly with their environments and evolve continually by acquiring new, and 'emergent' properties [41]. Rather than reducing an entity to the sum of its parts, systems theory focuses on the relationships between all its parts and what connects them into a whole; a reasoning leading to the 'Gaia hypothesis', which claims that the world is a single giant organism [42]. Systemic design proceeds with constant awareness of related systems, boundaries, external effects and potential feedback; it plans entities with inherent 'resilience' by taking advantage of fundamental properties such as diversity (existence of multiple forms and behaviors), efficiency (performance with least consumption), adaptability (flexibility to change in response to new challenges) and cohesion (existence of unifying forces or linkages) [43].

To encourage systems that explicitly incorporate sustainability thinking, systemic design offers a scientific method deriving from generative science and developments from industrial ecology, (focusing on symbiosis and ecosystems) and cluster theory. It can be summed up by its five basic principles [40]:

- Man at the centre of the design project: products have become the fulcrum of a paradigm of values and actions, as economical wellness, the quantity of monetary resources, the desire to achieve social status, negatively shape consumption choices. This approach, instead, questions the present industrial setting and proposes a new paradigm where at the centre of each productive process there are social, cultural, ethical and biological values that every person shares.
- Output as input: as in Nature, what is not used by a system becomes raw material for the development and survival of someone or something else; in production processes waste (output) of a system becomes an opportunity (input) for another one, creating new economic opportunities.
- Relationship: considering, broadly, all the networks of components in a production system, including materials (resources) and energy, which are used, captured and stored through different stages of the product life cycle. Understanding the pattern of material and energy flow and investigating where it can be improved enables identification of entry-points for designing a more sustainable system.

- Towards *autopoiesis*: in Nature, self-maintaining systems sustain themselves by reproducing automatically, defining their own paths of action. The system naturally seeks balance and preserves independence. If a production system were to aim *autopoiesis*, it would be possible to efficiently allocate and distribute material and energy flows.
- Act locally: just as an ecosystem is deeply influenced and shaped by its habitat, the same applies to any type of system. Based on local context, new opportunities can be created by reducing the problems of adaptability inherent to 'general' solutions and increasing people's participation.

Scrap generated by manufacturing processes is typically viewed as a cost. In order to go through the systemic design approach, it is essential to start from the current state and make a peculiar observation of all aspects which are part of the system (input), what occurs inside it and what comes out of it (output). The analysis of these inputs and outputs should be done both quantitatively and qualitatively. The result is a vision that encompasses the whole process and enables perceiving the relationships interwoven within the analyzed system. By exploiting resources in the territory, development has a local dimension and new self-sustained realities are spawned, in terms of energy, production and supply [44]. Any company that wishes to remain competitive, sustainable and meet the needs of society and the market, now or in the future, should seek skills development for handling large amounts of information, the introduction of new technologies and continuously adapt to an ever changing environment [45].

2. Materials and Methods

Throughout the duration of the project reported herein a holistic perspective was adopted in accordance with a systemic analysis based on data collected from an ethnographic approach, observations [44], and interviews, all this under a macroergonomics lens [46]. This lens combines perspectives from technology, psychology, sociology and anthropology in an adjustable manner, providing at one level the contents of argumentative exchange unfolding among persons with different backgrounds and motives, and at a more macroscopic level, it brings into focus varying practices distributed across several collaborating organizations [47]. The design approach employed in the second part of the development work, reported in this paper is presented at the end of this section, following the description of the systemic and ethnographic approaches.

2.1. Ethnographic Approach

Food is an overarching social phenomenon that incorporates the very essence of humanity [48]. A method based on ethnographic data collection, yields information compiled from field observations in order to support design research. A survey was carried out to acknowledge challenges and difficulties currently faced, in order to uncover points of action to make the product more competitive and appealing. This was done considering the product's market penetration, compared with competition, and taking into account considerations and concepts within the systemic design method. Relevant information about the subject of study was collected through analysis of resources readily available, observations at cheese making dairies, at ewe milking pavilions and places of grazing, and interviewing several stakeholders involved in the process, while performing photographic, video and audio documentation.

A compilation of all relevant information was made to support subsequent research developments. When performing this type of work, on-site observation is considered a mandatory requirement, enabling gathering of raw material that will later be processed and analyzed. A project meant to gather this type of information can be split into three stages: conducting a background investigation in preparation for fieldwork; actually carrying out fieldwork; and, finally, processing, organizing and systematizing information [39,49].

Fieldwork followed market research focused on the commercial availability, packaging and sizes available in a sample of general and specialty stores (seven stores visited). Fieldwork entailed five events, summarized in Table 2. Additionally, a focus group session was carried out, described in detail by Vieira [50].

Table 2. Fieldwork events supporting the project.

Date	Fieldwork Events and Field Observations
2 February 2013	Participation in the regional Serra da Estrela Cheese Fair in Fornos de Algodres; visit to a traditional cheese dairy owned by Joaquim Albuquerque de Sousa, in Vila Ruiva (Fornos de Algodres).
12 April 2013	First meeting with ESTRELACOOP's certifying authority chief executive officer in Celorico da Beira; visit to the museum hall of the Cheese Manor in Celorico da Beira.
23 April 2013	Visit to the agriculture society of Vale do Seia, observation and registration of the cheese manufacturing processes, interviews and contact with shepherds in Santiago, Seia; visit to the Fernandes Pessoa dairy in Carragozela (Seia); Visit to "Casa Matias" to meet the company's CEO and discuss market challenges.
7 May 2013	Observation of manual milking in a herd owned by Joaquim Nunes in Monte do Bispo, Belmonte.
20 May 2013	Second meeting with the CEO of ESTRELACOOP in Celorico da Beira.

As an example of outcome of fieldwork, consider the first field activities listed in Table 2. These enabled identifying relationships between pasture improvement and ewe's milk quality improvement, as well as the proposed benefits and challenges involved in mechanical milking of ewes.

Throughout the fieldwork analysis the authors interviewed a representative sample of the different roles performed at several stages of the production system. The authors estimate a total of 60 to 70 individuals directly involved in the production and distribution system were inquired or surveyed, giving their contribution to the research and fieldwork analysis. Starting on a thematic conference about the PDO cheese, which the second author attended, it was possible to discuss with producers and distributors some challenges that were deterring the development of the business. At the same event there was an opportunity to visit an artisanal cheese making facility and collect more precious insights from the stakeholders, in this case a producer and seller.

About the institutional stakeholders, it was possible to establish a mutual and advantageous relationship with the technicians of the cooperative created, and responsible for the certification process of the PDO cheese. With the cooperative technicians' assistance the authors were able to obtain precious data as well as information about producers. From there, several producers were visited, interviewed, and consulted. With the producers authorization the authors were able to contact workers at the various levels of production within the specific company.

All the different work levels were considered, since the shepherd, responsible for the animals' welfare and milk harvesting to the worker responsible for the collection and transportation of the milk, and the female workers making and taking care of the cheese until maturation. In the commercialization field the authors were able to inquire a few local businesses and hear some significant insights about the state of the market for this kind of cheese.

Further outcomes of the ethnographic observations and analysis of requirements in the specification for the product certification are shown in the remainder of this section. Production of Serra da Estrela PDO cheese must satisfy the conditions laid down in Annex II to the Portuguese Law Decree No. 38/2002 of 27 May, in addition to the conditions set out in documents (control plan for third party certification) provided by the certifying authority (ESTRELACOOP). Firstly, only producers authorized by ESTRELACOOP may use the protected designation of origin on their products. For this, producers must comply with certain conditions, exercising their activity exclusively in the production territory defined in Annex I to Portuguese Law Decree No. 38/2002 of 27 May. Only milk from *Bordaleira Serra da Estrela* and, or, *Churra Mondegueira* sheep breeds, from farms in the defined geographical area can be used. These must necessarily produce cheese according to the conditions laid down in Annex II of the above Ordinance and be willing to accept the system of control and certification provided, complying with it. The Portuguese law on PDO Product specifications springs from Council Regulation (EEC) No 2081/92 of 14 July 1992 (protected geographical indications (PGI) and protected designations of origin (PDO) for agricultural products and foodstuffs).

Producers must consider health, hygiene and management conditions of the herds, taking into account the necessary conditions for milking, collection, transport and storage of milk. Producers must control the quality of raw materials and follow the rules and hygienic procedures for cheese manufacturing. Each producer has an obligation to keep a record, which contains information on the origin of the milk and on the production conditions and by applying casein tags provided by ESTRELACOOP. They must also hold updated records of suppliers of raw materials, of the quantity of milk received and of the quantity of cheese produced.

Cheese that does not conform to the production rules stipulated may be sold with the designation of sheep cheese, but may not be given the Serra da Estrela PDO cheese designation. The herds of origin of the milk must be officially disease free. When it comes to milking it is advisable to milk each animal properly and the place where the milking takes place should be clean. After milking, milk should be immediately filtered into a pitcher in order to avoid possible contamination. If, by chance, milk is not used within a time window of 2 h after milking, it must be properly cooled to a maximum of 8 °C if used up to 12 h or less, to 6 °C if the delay is more than 24 h and to less than 4 °C for up to 48 h.

For the manufacture of cheese, milk is coagulated at a temperature of 27 °C to 32 °C. The amount of thistle flower (*Cynara cardunculus*) used to coagulate the milk should not exceed 0.3 g per liter of milk and the salt content should not exceed 30 g per liter of milk. Milk coagulation should take at most 60 min, followed immediately by cutting the curd and slow draining the whey. The weight of the cheese should be in a range of 0.5 kg up to a maximum of 1.7 kg with a diameter which can range from 9 to 20 cm, and a height between 4 and 6 cm. During the forming process of the curd, the casein mark must be applied, while the cheese remains in the "*cincho*" for up to 18 h (Figure 1). After the curd is completely squeezed and has the appropriate diameter, it may continue subjected to pressure in order to almost completely deplete the whey (an average of 5 kg per cheese).

(**a**) (**b**) (**c**) (**d**)

Figure 1. (**a**) Mortar where the thistle flower is crushed; (**b**) Utensils for artisanal cheese production; (**c**) cheese with *cincho*; (**d**) Traditional manufacturing utensils.

The ripening or maturing process should be carried out in an appropriately controlled environment, particularly with respect to temperature. An acceptable interval lies between 6 and 12 °C, while required relative humidity lies between 80% and 95%. The minimum ripening time is 30 days, but it may extend up to 45 days. During the ripening period the cheese must be regularly turned and cleaned, keeping the crust clean and smooth. Once manufactured and certified, cheese must be kept in storage until its distribution. Storage temperature lies between 0 °C and 5 °C. During transportation as well as at points of sale, temperature is accepted to rest between 0 °C and 10 °C.

2.2. Design Methodology

The design approach employed in the development work was presented by Coelho [51] and by Figueiredo and Coelho [52], based on work by Lewis and Bonollo [53] and early work by Hales [54]. The operational model of the design process embedded in this approach is comprised of five subordinate processes (task clarification, concept generation, evaluation and refinement, detailed design of preferred concept and communication of results) (Table 3). In this particular case at hand, detailed design was informed by user feedback and trials, and at the time of writing this paper, is yet to be completed. Task clarification was developed during the ethnographic observations carried out by the first and second authors. Concepts were generated, and evaluated, and refined, leading to the detailed design of the preferred concept. The concept was then prototyped and used by cheese makers in user trials, which provided feedback to serve as input for the next round of iterations of the new hand tool design.

Table 3. Operational model of the design process [51].

Subordinate Process	Nature of Process	Output from Process
1. Task clarification	A set of tasks including negotiating a design brief with the client, setting objectives, planning and scheduling subsequent tasks, preparing time and cost estimates	Design brief, including design specification, project plan with time line and cost estimates
2. Concept generation	A set of creative tasks aimed at generating a wide range of concepts as potential solutions to the design problem specified in the brief	A folio of concept sketches, supported by simple models or mock ups, providing a visual representation of design ideas
3. Evaluation and refinement	A set of analytical tasks in which the concepts in (2) are evaluated and reduced to a small number of refined solutions, usually only one or two candidate solutions	A folio of refined concept sketches, supported by models and technical information as required and illustrating the preferred concepts
4. Detailed design of preferred concept	A set of tasks aimed at developing and validating the preferred concept, including layout drawings, dimensional specifications, selection of materials, finishes, indicative tolerances	A folio of layout and detailed component drawings, supported by a technical report giving preliminary manufacturing information
5. Communication of results	A set of tasks whereby the concept detailed in (4) is communicated to the client via appropriate two- and three-dimensional media and written report.	A folio of presentation drawings, including technical drawings from (4) and supported by a refined three dimensional model and/or prototype

3. Results

The analytical study of the product specifications of the SE PDO cheese prompted the authors to look into how the specifications were being implemented by the different producers. As a result of our field research, we found that the specification guidelines were in fact being applied throughout the production process of all the monitored producers, who would otherwise not be awarded the right to produce certified SE PDO cheese. Most of the companies involved are characterized by being family-owned microenterprises, i.e., small businesses employing nine people or fewer (family style management and traditional organization; production is pushed according to the amount of milk collected, and control is unsupported by information systems, orders are sent from points of sale via telephone, and most product goes to stock, except cottage cheese which is shipped out immediately after production). In most cases these companies only produce the artisanal PDO certified cheese and its derivate cottage cheese seasonally (according to availability of ewe's milk, accommodating the breeding cycle). The production process is hence organized according to the rules on the specification PDO cheese production manual, because compliance to these rules is mandatory and monitored, for the manufacture of this specific cheese. Careful analysis revealed the existence of relevant critical points that act as stifling factors to some system operations, and as such, requiring attention. The development of proper solutions for each one of them will certainly be beneficial for the entire system, resulting in improvements in efficiency and economic benefits. All suggestions of improvement to the production system presented in this section fully accommodated the product specification rules.

The systemic map developed is shown in Figure 2. The systemic map that resulted from the research highlights the inputs, what enters in the system, on the left side and the outputs, the results of the system, on the right side. It shows the flows of matter and energy between the various stages of the process. Beginning in the Pavilion & Milking Room station until the final ones, which consist in the Packaging and the Transport until the point of sale. In the map there are also critical points shown, emphasized with an exclamation mark and numbered from 1 to 8, as well as an overall context note, drawing attention to the main weaknesses found in the system, which are also opportunities for improvement.

The critical points were identified by the authors after a careful analysis of the systemic mapping (Figure 2). Based on data collected in the research phase it was possible to make connections between the different parts of the system. With this tool in hands and with the principles of systemic design as guidance the authors were able to detect missed opportunities and weaknesses that could be tackled in order to improve the system as a whole.

The stakeholders contributed with an array of diverse data inputs, depending on their importance and involvement in the system. They provided personal insights, as well as professional ones, contributing to the mental assembly of the resulting systemic map. As in any other human activity each individual builds his or her own perspective that may or may not be shared with his peers. We may say that the same applies here, with different stakeholders having different strategic visions and expectations, making them move at different speeds between them, sometimes resulting in conflicting points of view.

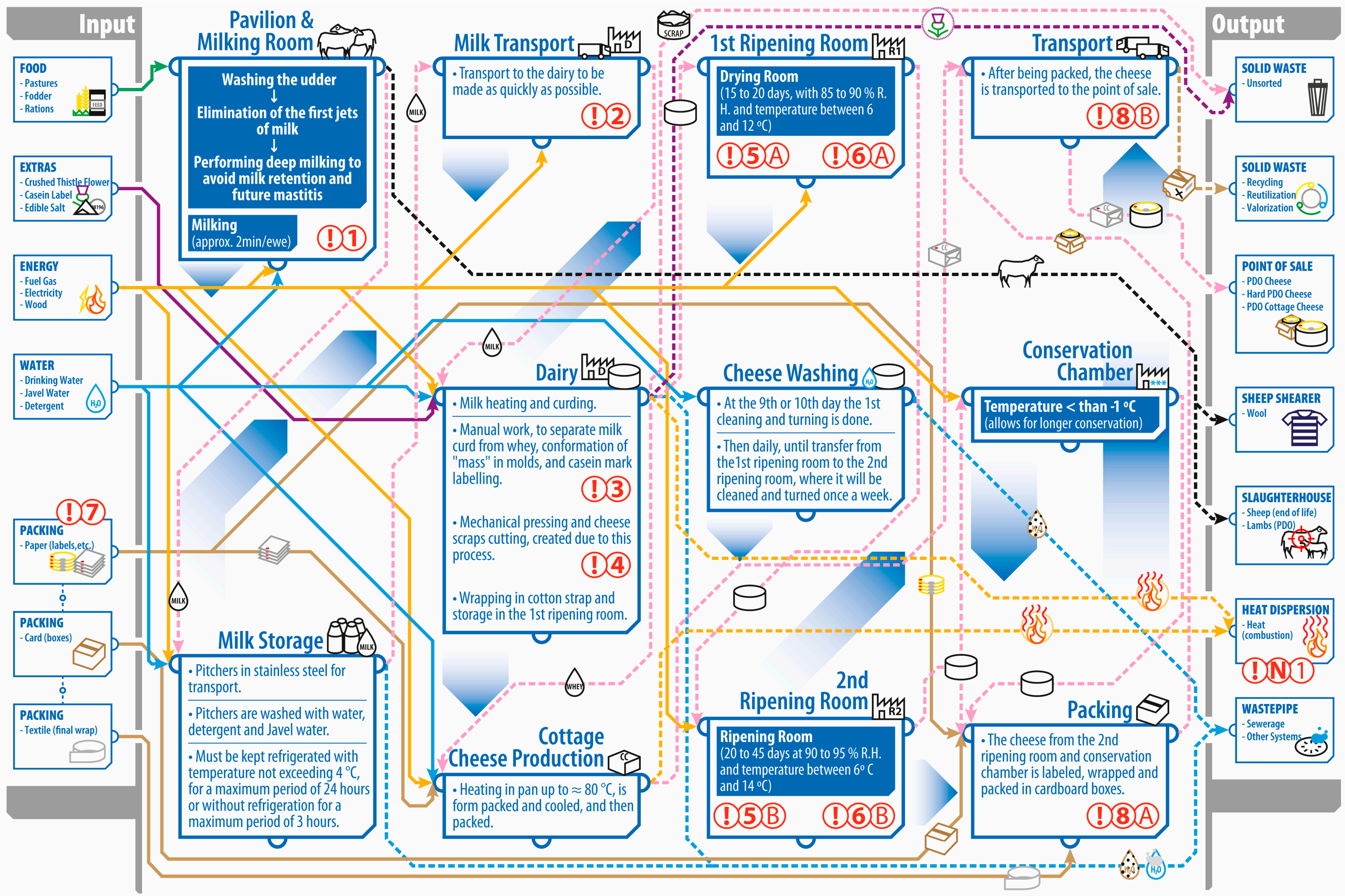


Figure 2. Overview of systemic mapping of the Serra da Estrela PDO cheese production; critical points depicted in red numbers (see text for explanation) © T. Carrola.

3.1. Identified Critical Points

Critical points are opportunities to improve the efficiency of the system, under the umbrella of the rules and specifications implied in the PDO certifications. The critical points found from the research process and represented in the systemic map are listed below.

1. The lock mechanism for milking systems in use in the region is designed for hornless sheep breeds. This can lead to injuries in ewes with horns. Ewe's milk for Serra da Estrela PDO cheese production can only originate from "Bordaleira Serra da Estrela" breed with helical, elongated, strong, rough horns with a triangular section, and "Churra Mondegueira" breed with thin horns of an open spiral shape, elongated in the horizontal plane, and with a slightly elliptical profile. Thus, this anatomical detail turns a procedure that would otherwise be simple in something considerably difficult. Redesign of the lock systems to accommodate the anatomy of the ewe's horns is hence a potential process improvement.
2. A producer of cheese may depend on dozens of small ewe's milk producers scattered in a mountainous area, where gathering and transporting milk becomes an obstacle to overcome, translating as increased production cost. Moreover, ewe's milk does not undergo any kind of conservation procedure, milk has to be transformed raw, as a requirement of the specification, contributing to a health risk to the consumer. Contributing to mitigate the potential risks to human health in the cheese making process, may involve improvements in self refrigerating containers for raw milk transportation for added consumer health and safety.
3. Postures that place dairy workers at risk of injuries at work and cause productivity loss. The design of the "francela", which acts as a table to support the process of whey draining, forming the resulting mass in molds called "cinchos" and other minor tasks, has a slope in relation to the horizontal plane, which makes it useful for an uninterrupted fluid flow of the whey but at the same time contributes to erosion of the task's ergonomic qualities. This task hence places cheese makers at risk of injuries associated with task repetition at the level of the upper limbs and vertebral spine. Process improvement by equipment redesign is hence desirable to safeguard workers health.
4. After removal of the cheese molds from the mechanical press, the resulting cheese cylinders present a barb, which manifests itself in the top edge, as a result of the contact area between the "cincho" and its lid. For the surface of the cheese cylinder to coincide with the description contained in the Serra da Estrela PDO cheese specification rules, regarding the characteristics of the outer shell, it is necessary to trim excess material. Currently this activity is done manually using a cutting tool, an ordinary kitchen knife, requiring skill for it to be done in a short time, while single handedly bearing the load of 0.5–2 kg cheeses. This places workers at the risk of developing musculoskeletal injuries of the hand and forearm during the cheese chip or barb trimming process. Tool redesign hence represents an opportunity for improvement overcoming this criticality.
5. The equipment that is used to store and support cheese during its entire ripening process should be composed of stainless steel or plastic that is suitable for food use, and may be alternatively made of unspecified wood. This being an option, each producer's decisions are based on what is deemed best. Hence, there are different kinds of equipment in use, some of these can facilitate incubation of preferred microorganisms but also unwanted ones. A technical study setting preferred standards for cheese support and storage equipment is desirable for improvement in this regard.

6. During the entire ripening time, various microorganisms, fungi and bacteria contribute to and are also essential to the success of the cheese ripening process. Although tests and quality control analysis for screening of pathogenic microorganisms are regularly performed, the type of microorganisms responsible for the ideal characteristics that are wanted in the Serra da Estrela PDO cheese is not known with accuracy. This allows for variation in the product, taking into account variables such as the dairy where the cheese is produced, the season it is produced, as well as slight variations in humidity and temperature. Inconsistency of the organoleptic characteristics of the cheese and propensity for contamination by harmful microorganisms ripples across multiple dimensions, including product recognition and consumer safety. Further microbiological research is deemed necessary to create additional standards regarding cultures of microorganisms for the cheese curing process and microbiological control of the ripening.
7. There is no uniformity in some of the features of the label (Figure 3) that identifies the product as a Serra da Estrela PDO cheese. This prevents consumers from developing stronger recognition. Competition from similar looking but uncertified products, which in the eyes of the consumer is considered a product of the same category and quality as the SE PDO cheese, and the fact that those alternatives are more affordable, is the result of an inability to provide a communications strategy to underline and emphasize the Serra da Estrela PDO cheese as unique. Due to reduced visibility and distorted consumer perception of the Serra da Estrela PDO cheese, the consumer accepts similar products for the genuine product. A communication and logotype redesign work extending to all stakeholders is deemed as an important step towards overcoming this problem.
8. One of the problems encountered by producers focuses exactly on the number of orders that are returned from retailers due to issues in which the structural integrity of the product is called into question, as well as the appearance of mildew, which appear naturally in the cheese, an issue seen as a consumer deterrent at points of sale. Packaging that enables safety and ventilation of the cheese, preventing the appearance of molds (additionally, while it is transported some cracks may appear in its surface due to its fragility, resulting in retailer returns) is hence a desirable design development.

(**a**) (**b**) (**c**)

Figure 3. Several Serra da Estrela DOP cheese labels from a cheese dairy company (company identity digitally removed): (**a**) Regular label; (**b**) Premium label; (**c**) Selection label.

Additional information that is not directly concerned with a single critical point but involves several aspects of the production process (rippling across multiple dimensions and stages of production) is given in this paragraph as contextual information to the aforementioned critical points. When it comes to heating of milk during the coagulation process and later during production of cottage cheese, heat is generated which is dispersed into the atmosphere of the dairy. This heat is considered a waste product, and as such, an output of the system. This waste is currently not used; however, the possibility for development of solutions and processes in order to make good use of it should be pursued. The production of this heat has its source in the combustion of gases (butane) that occur during heating of the milk. The fact that the combustion takes place in spaces with limited ventilation in which the workers perform the various functions required raises the question of the existence of a health risk, with respect to them, since it creates uncontrolled oscillation of carbon dioxide levels and oxygen concentration present in the working space atmosphere. There is also a situation where the production room is located adjacent to the cold room where the ripening process of the cheese is developed. These chambers are required to have controlled temperature and humidity. Direct contact with the work room in which the temperature varies in a random manner during the time in which the production takes place interferes with the ripening chambers. Due to practical reasons of ease of work, the latter are kept with the doors open so that a fluid traffic of workers may accrue, as they transport various cheeses simultaneously and are unable to make immediate alternative use of their upper limbs.

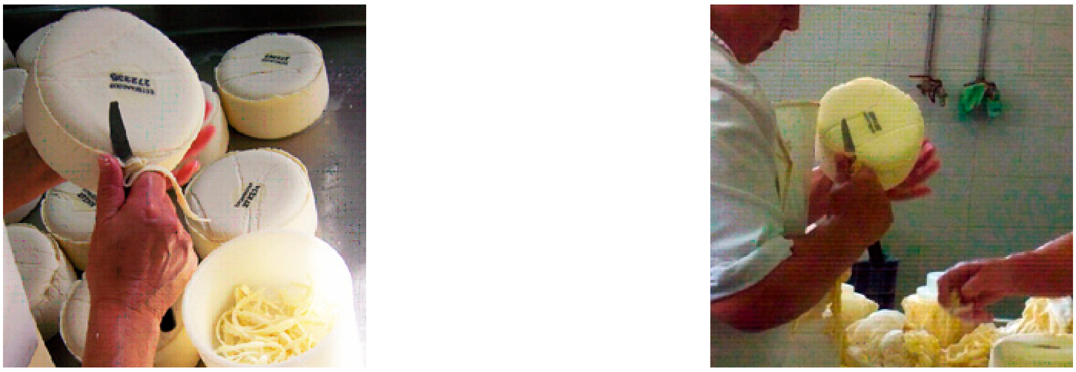
The mapping of process and critical points developed can serve as a starting point for the development of future design work. The critical points unveiled represent challenges for improvement that reverberate in several domains, including the organoleptic qualities of the cheese, the cheese making process and respective tools, the well-being and safety of workers, as well as food safety, and visibility of the Protected Denomination of Origin certification. Systemic analysis has started to come to the forefront of production process analysis, given the pressures for sustainability. In the region of Beira Interior, where the study was developed, and particularly Serra da Estrela, traditional cheese making is undergoing many challenges. There is a need for innovation while respecting the requirements brought by the certification granted as part of the Protected Denomination of Origin label. The results of this study represent opportunities for efficiency gains, keeping in strict respect to the certification requirements and at the same time looking to satisfy the interests of all stakeholders of the Serra da Estrela PDO cheese sector.

The domains of agricultural production and microbiology turned out to be aspects of high importance for the issue under focus. If it were not for the systemic analysis, which served as a link between the boundaries of the various domains, new bridges between these various problems might not have opened, as these are usually tackled in specialized disciplines and predetermined by the restrictions of each specific area of knowledge.

This case study demonstrates the deployment of systemic design analysis within an activity centered and ethnographic approach. As a consequence of the development of this research, based on an analysis that sought possible connections between various disciplines and trying to constantly maintain a holistic perspective, design seeds have been laid out for the development of a plan to tackle the critical points identified by the systemic analysis reported in this paper. One of these critical points (number 4, listed in this section) is tackled in the following sections.

3.2. Design Requirements of a New Chip Cutting Hand Tool

As a consequence of the fieldwork carried out in the form of observations and interviews to a myriad of actors in the SE PDO cheese universe, as well as visits to several cheese making facilities, systemic analysis was performed and the critical points emphasized. This led to the consideration of the need for a device or utensil that is better suited to the task at hand was to be designed, to better support the cheese chip cutting process shown in photographs in Figure 4, for this was adopted an operational model of the design process described before. The need to trim the cheese barb that is formed as a consequence of the cheese pressing, to remove excess whey, has not only aesthetic grounds, but also functional ones. During the cheese ripening process, molds form on the outer surface of the cheese. As part of this process, washing of the cheeses is done regularly. This process is more efficient once the trimming is made. Task clarification yielded the following goals for the new hand tool: Cutting cheese chips in the upper face of the cheese in a hygienic manner; enabling easy repair, maintenance and cleaning of the hand tool; preventing the development of musculoskeletal disorders in the upper limbs of the cheese makers.



(**a**) (**b**)

Figure 4. Cheese chip cutting process using a regular knife and supporting the full weight of the cheese: (**a**) Detail of cutting method; (**b**) Detail of cutting method with overall posture.

3.3. Alternative Concepts and User Trials of Prototype

Several design concepts were generated (Figure 5) and these were rated against evaluation criteria derived from the initial goals set for the project. Upon the first iteration of evaluation, the alternative concepts were crossed with one another, producing a new design that combined the best features of each of the original concepts generated by the first author. This concept was then designed in detail and prototyped in order to undergo user trials (Figure 6). The trials showed the need for an improvement in the prototype, in order to make the cheese cutting blades more versatile by angling them in relation to the disc shaped part of the design. Alternative handle designs are also to be developed in order to enable a more neutral posture of the wrist, when using the tool for cheese chip cutting. At the time of writing the project is awaiting funding to proceed to the next iteration of redesign of the hand tool and user trials.

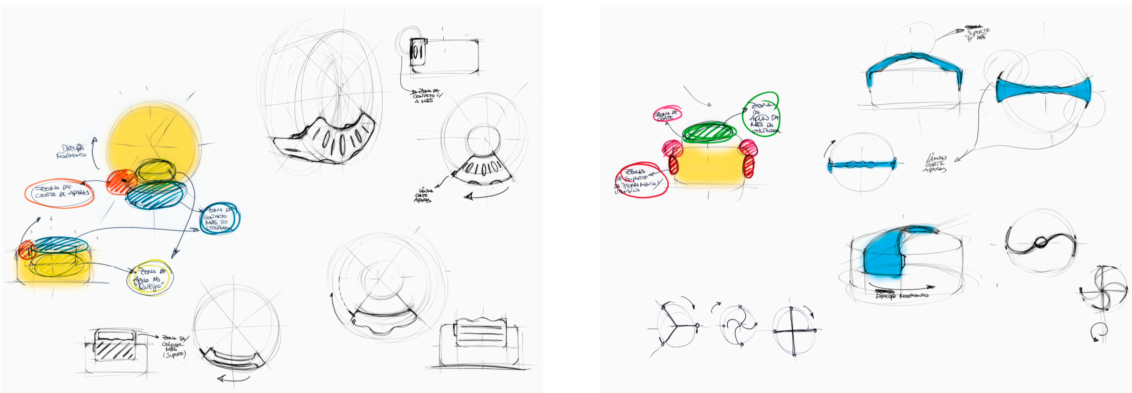
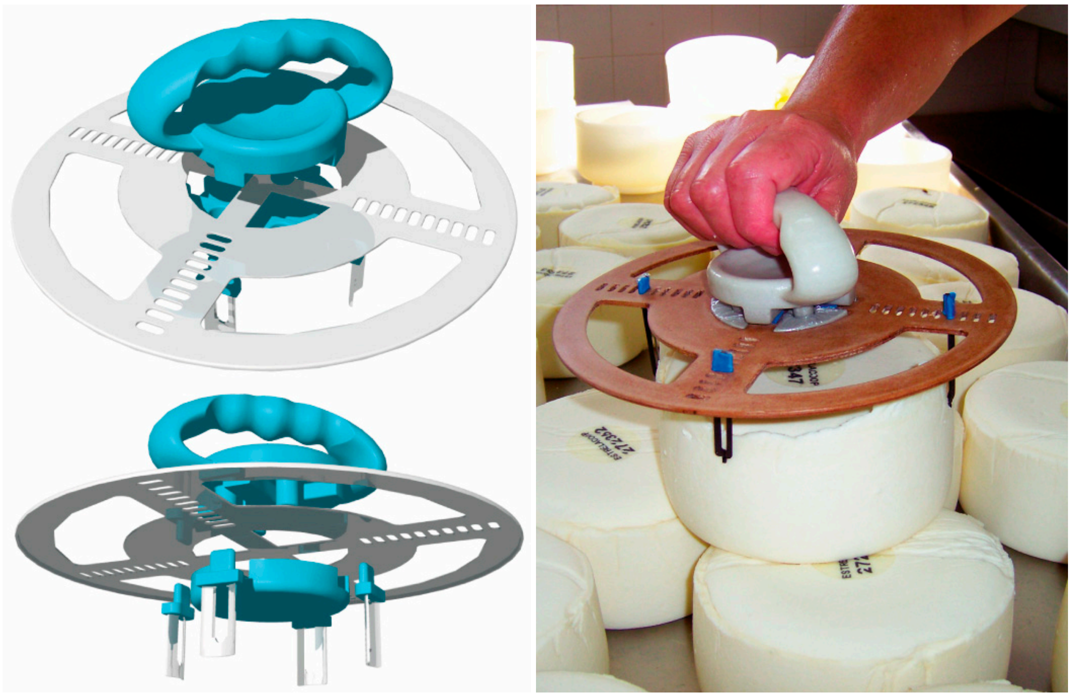


Figure 5. Alternative conceptual sketches © Tiago Carrola.



(**a**) (**b**)

Figure 6. Detailed design and user trials of the new hand tool: (**a**) Computer 3D model render; (**b**) Prototype being used by worker © Tiago Carrola.

4. Discussion and Conclusions

The different processes associated with the manufacturing and distribution of Serra da Estrela PDO cheese were causally mapped based on a systemic approach. The process relied on systemic analysis, and on application of techniques from ethnography, which resulted on a substantial amount of data collected and provided the immersion of the researchers in real-life situations. Critical points were identified in the resulting systemic map in order to encourage initiatives to overcome detected inefficiencies and at the same time to develop well suited environmental and sustainable solutions. One of those critical points was further developed in a design process for a new hand tool for excess cheese chip removal, thus demonstrating how a systemic analysis following the systemic design approach fosters new designs to improve the efficiency of the process through innovation. This hand tool design goes towards the processing-technology innovation dimension presented by Guerrero et al. [1]. Additionally, the critical points presented were also set against the backdrop of the improvements needed to maintain and expand the market share of the PDO cheese focused in the paper.

This study demonstrates how systemic analysis and systemic design may be articulated at the service of improved sustainability within its three fundamental vectors. The goal of zero waste, transforming all outputs in inputs for other processes attends the environmental aspect, the preservation of tradition and its promotion contributes to grounding a sense of community and heritage that attends to the social aspect. The efficiency gains in the production and distribution process attend to the financial aspect. Hence, the triple bottom line of sustainability is addressed.

The mapping of process and critical points developed can and must serve as a starting point for the development of future related work. The critical points unveiled represent challenges for improvement that reverberate in several domains, including the organoleptic qualities of the cheese, the cheese making process and respective tools, the well-being and safety of workers, as well as food safety, and visibility of the Protected Designation of Origin certification. In the region of Beira Interior, where the study was developed, and particularly Serra da Estrela, traditional cheese making is undergoing many challenges, therefore there is a need for innovation while respecting the requirements brought by the certification granted as part of the Protected Designation of Origin label. The results and findings of this study suggest opportunities for gains in the overall efficiency of the system, keeping in strict respect to the certification requirements and at the same time looking to satisfy the interests of all the Serra da Estrela PDO cheese sector stakeholders. The domains of agricultural production and microbiology turned out to be aspects of high importance for the issue under focus.

As a consequence of the development of this research, based on an analysis that sought possible connections between various disciplines and trying to constantly maintain a comprehensive approach, a first step was given towards the development of a plan to tackle the critical points identified by the systemic analysis reported in this paper. The sustained and informed development of the proposals carried out, as well as the possibility of highlighting other opportunities for action, was in good part only possible due to the intersection points that arose during the process of observation, research and project-development. In this paper only one of the identified critical points was developed. The results achieved allow us to conclude that a broader and profound approach could only be beneficial to the whole system. The study demonstrated that there is space in the sector for this kind of innovation and thinking. Also, the utilization of other methods and tools to assist in the resolution of said critical points, such as life cycle assessment and other methodologies, can contribute to improve results.

Acknowledgments: Selected aspects of this paper have been presented in conference proceedings [55,56]. The work reported in this paper has been supported in part by project Centro-01-0145-FEDER-000017—EMaDeS—Energy, Materials and Sustainable Development, co-financed by the Portugal 2020 Program (PT 2020), within the Center Regional Operational Program (CENTRO 2020) and the European Union through the European Regional Development Fund (ERDF).

Author Contributions: D.C. and A.C. advised on the experiments; T.C. performed the research; T.C. and A.C. analyzed the data; D.C. and A.C. contributed with analysis tools; D.C. wrote the paper.

Conflicts of Interest: The authors declare no conflict of interest. The funding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

References

1. Guerrero, L.; Guàrdia, M.D.; Xicola, J.; Verbeke, W.; Vanhonacker, F.; Zakowska-Biemans, S.; Sajdakowskac, M.; Sulmont-Rossé, C.; Issanchoud, S.; Contele, M.; et al. Consumer-driven definition of traditional food products and innovation in traditional foods. A qualitative cross-cultural study. *Appetite* **2009**, *52*, 345–354. [CrossRef] [PubMed]
2. Carrola, T.E.P. Análise Sistémica da Manufatura e Discursiva da Imagem do Queijo Serra da Estrela DOP: Aplicação de Metodologias Projetuais à Solução de Pontos Críticos. Master's Thesis, Universidade da Beira Interior, Covilhã, Portugal, 2013.
3. Casabianca, F.; de Sainte Marie, C. Concevoir des innovations pour les produits typiques. Quelques enseignements des charcuteries sèches corses. In Proceedings of the 52nd EAAE Seminar, Parma, Italy, 19–21 June 1997.
4. Lamas, M. Evolução dos Produtos Tradicionais Qualificados. Direção-Geral de Agricultura e Desenvolvimento Rural. 2014, pp. 62–64. Available online: http://ptqc.drapc.min-agricultura.pt/documentos/evolucao_prod_trad_2002_2009.pdf (accessed on 18 November 2016).
5. International Organization for Standardization. *Environmental Management—Life Cycle Assessment—Principles and Framework (ISO 14040:2006)*; ISO: Geneva, Switzerland, 2006.
6. Ekvall, T.; Weidema, B.P. System boundaries and input data in consequential life cycle inventory analysis. *Int. J. Life Cycle Assess.* **2004**, *9*, 161–171. [CrossRef]
7. Finnveden, G.; Hauschild, M.Z.; Ekvall, T.; Guinée, J.; Heijungs, R.; Hellweg, S.; Koehler, A.; Pennington, D.; Suh, S. Recent developments in Life Cycle Assessment. *J. Environ. Manag.* **2009**, *91*, 1–21. [CrossRef] [PubMed]
8. Tillman, A.-M. Significance of decision-making for LCA methodology. *Environ. Impact Assess. Rev.* **2000**, *20*, 113–123. [CrossRef]

9. Zamagni, A.; Guinee, J.; Heijungs, R.; Masoni, P.; Raggi, A. Lights and shadows in consequential LCA. *Int. J. Life Cycle Assess.* **2012**, *17*, 904–918. [CrossRef]
10. Clift, R.; Doig, A.; Finnveden, G. The application of Life Cycle Assessment to Integrated Solid Waste Management—Part 1—Methodology. *Process Saf. Environ. Prot.* **2000**, *78*, 279–287. [CrossRef]
11. Laurenti, R.; Lazarevic, D.; Poulikidou, S.; Montrucchio, V.; Frostell, B.; Bistagnino, L.; Wennersten, R. Using causal maps to identify potential sources of environmental impact outside the scope of LCA studies: Preliminary findings from case studies on washing machines and road vehicles. In Proceedings of the 18th Annual International Sustainable Development Research Conference, Hull, UK, 24–26 June 2012.
12. Field, F.; Kirchain, R.; Clark, J. Life-cycle assessment and temporal distributions of emissions: Developing a fleet-based analysis. *J. Ind. Ecol.* **2000**, *4*, 71–92. [CrossRef]
13. Levine, S.H.; Gloria, T.P.; Romanoff, E. A dynamic model for determining the temporal distribution of environmental burden. *J. Ind. Ecol.* **2007**, *11*, 39–49. [CrossRef]
14. Stasinopoulos, P.; Compston, P.; Newell, B.; Jones, H. A system dynamics approach in LCA to account for temporal effects—A consequential energy LCI of car body-in-whites. *Int. J. Life Cycle Assess.* **2012**, *17*, 199–207. [CrossRef]
15. Chester, M.V.; Horvath, A. Environmental assessment of passenger transportation should include infrastructure and supply chains. *Environ. Res. Lett.* **2009**, *4*, 024008. [CrossRef]
16. Laurenti, R.; Lazarevic, D.; Poulikidou, S.; Montrucchio, V.; Bistagnino, L.; Frostell, B. Group Model-Building to identify potential sources of environmental impacts outside the scope of LCA studies. *J. Clean. Prod.* **2014**, *72*, 96–109. [CrossRef]
17. Spirn, A.W. Ecological Urbanism: A Framework for the Design of Resilient Cities (2014). In *The Ecological Design and Planning Reader*; Island Press/Center for Resource Economicsm: Washington, DC, USA, 2014; pp. 557–571.
18. Cadenasso, M.L.; Pickett, S.T.; Weathers, K.C.; Bell, S.S.; Benning, T.L.; Carreiro, M.M.; Dawson, T.E. An interdisciplinary and synthetic approach to ecological boundaries. *BioScience* **2003**, *53*, 717–722. [CrossRef]
19. Furlan, C.; De Meulder, B. Leftover as a resource. A systemic design approach to re-cycle a diffuse territory. In Proceedings of the AA. VV., Atti della XVII Conferenza Nazionale SIU, L'urbanistica Italiana nel Mondo, Milan, Italy, 15–16 May 2014.
20. Berger, A. *Systemic Design Can Change the World*; Sun Publishers: Amsterdam, The Netherlands, 2009.
21. Barbero, S.; Tamborrini, P.M. Systemic Design goes between disciplines for the sustainability in food processes and cultures. In Proceedings of the 7th International Aesop Sustainable Food Planning Conference, Torino, Italy, 7–9 October 2015; pp. 517–525.
22. Spirn, A.W. The poetics of city and nature: Towards a new aesthetic for urban design. *Landsc. J.* **1988**, *7*, 108–126. [CrossRef]
23. Vennix, J.A.M. *Group Model Building: Facilitating Team Learning Using System Dynamics*; John Wiley & Sons: New York, NY, USA, 1996.
24. Pisek, P.E.; Wilson, T. Complexity, Leadership, and Management in Healthcare Organizations. *Br. Med. J.* **2001**, *323*, 746–749.
25. Porter, M.E. *Competitive Advantage of Nations*; Free Press: New York, NY, USA, 1990.
26. Frosh, R.A.; Gallopoulos, N.E. Strategies for Manufacturing. *Sci. Am.* **1989**, *3*, 94–102. [CrossRef]
27. Chertow, M.R. Industrial Symbiosis: Literature and Taxonomy. *Annu. Rev. Energy Environ.* **2000**, *25*, 313–337. [CrossRef]
28. Buchanan, R. Wicked problems in design thinking. *Des. Issues* **1992**, *8*, 5–21. [CrossRef]
29. Fuller, R.B. *Critical Path*; St. Martin's Press: New York, NY, USA, 1981.
30. Chertow, M.R.; Ashton, W.; Kuppali, R. *The Industrial Symbiosis Research Symposium at Yale: Advancing the Study of Industry and Environment*; Yale School of Forestry & Environmental Studies: New Haven, CT, USA, 2004.
31. Jones, P.H. Learning the lessons of systems thinking: Exploring the gap between Thinking and Leadership. *Integral Leadersh. Rev.* **2009**, *9*, 1–30.
32. Pauli, G. *The Blue Economy: 10 Years, 100 Innovations, 100 Million Jobs*; Paradigm Pubblications: Taos, NM, USA, 2010.
33. Gaiardo, A.; Tamborrini, P. Systemic Innovation design methodology: The comparison of two cases studies. In Proceedings of the 11th European Academy of Design Research, Paris, France, 22–24 April 2015.

34. The Organisation for Economic Co-operation and Development. *Data-Driven Innovation for Growth and Well-Being*; OECD: Paris, France, 2014.
35. Filippetti, A. Innovation modes and design as a source of innovation: A firm-level analysis. *Eur. J. Innov. Manag.* **2011**, *14*, 5–26. [CrossRef]
36. Bistagnino, L. *Systemic Design, Designing Environmental and Productive Sustainability*; Slow Food Editore: Bra, Italy, 2011.
37. Barbero, S.; Pereno, A.; Tamborrini, P.M. Qualitative/quantitative cross analysis to design eco-pack. In Proceedings of the International Symposium on Sustainable Design, Recife, Brazil, 29–30 September 2011.
38. Barbero, S.; Tamborrini, P. Systemic Design in AgroFood Sector: EN.FA.SI Project. In Proceedings of the International Conference on Designing Food and Designing For Food, London, UK, 28–29 June 2012; pp. 285–296.
39. Bartis, P. *Folklife and Fieldwork: A Layman's Introduction to Field Techniques*, 3rd ed.; Library of Congress: Washington, DC, USA, 2002; Volume 3, p. 38.
40. Bistagnino, L.; De Morais, D. Design Sistêmico: Uma abordagem interdisciplinar para a inovação. *Cadernos de Estudos Avançados em Design Sustentabilidade* **2009**, *2*, 79.
41. Principia Cybernetica Web. Available online: http://pespmc1.vub.ac.be (accessed on 7 March 2012).
42. Lovelock, J. *The Ages of Gaia: A Biography of our Living Earth*; Norton: New York, NY, USA, 1988.
43. Fiksel, J. Design resilient, sustainable systems. *Environ. Sci. Technol.* **2003**, *37*, 5330–5339. [CrossRef] [PubMed]
44. Couvinhas, A.F.; Ferrara, P.R.; Coelho, D.A.; Jorge, S.; Walter, J.K. Ergonomic considerations for a systemic approach: The millennium maize mills project in northern Mozambique. *Work* **2012**, *41*, 568–575. [PubMed]
45. Bistagnino, L. *Design Sistemico. Progettare la Sostenibilità Produttiva e Ambientale*; Slow Food Editore: Bra, Italy, 2009.
46. Coelho, D.A.; Ferrara, P.R.; Couvinhas, A.F.; Lima, T.M.; Walter, J.K. Macroergonomic aspects in the design of development programs in IDCs. *Work* **2012**, *41*, 2651–2655. [PubMed]
47. Lighthall, F.F. *Disastrous High-Tech Decision Making: From Disasters to Safety*; Dog Ear Publishing, Kilburn Sackett Press: Indianapolis, Indiana, 2015.
48. Maffei, S. Foodplexity and Design. Planning the Food Experience. In *Arts & Foods. Rituals Since 1851*; Celant, G., Ed.; Electa: Milano, Italy, 2015.
49. Fetterman, D.M. *Ethnography: Step-by-Step*, 3rd ed.; Sage: Thousand Oaks, CA, USA, 2010; p. 173.
50. Vieira, M.F. O Impacto da Dinâmica de Grupos na Criatividade. Master's Thesis, Universidade da Beira Interior, Covilhã, Portugal, 2013.
51. Coelho, D.A. A Method for User Centering Systematic Product Development Aimed at Industrial Design Students. *Des. Technol. Educ. Int. J.* **2010**, *15*, 44–54.
52. Figueiredo, J.F.; Coelho, D.A. Semiotic Analysis in Perspective: A Frame of Reference to Inform Industrial Design Practice. *Des. Princ. Pract. Int. J.* **2010**, *4*, 333–346.
53. Lewis, W.P.; Bonollo, E.E. An analysis of professional skills in design: Implications for education and research. *Des. Stud.* **2002**, *23*, 385–406. [CrossRef]
54. Hales, C. *Analysis of the Engineering Design Process in an Industrial Context*; Gants Hill Publications: Eastleigh, UK, 1991.
55. Carrola, T.E.; Couvinhas, A.F.; Coelho, D.A. Manufacturing Analysis of the Serra da Estrela PDO cheese under the Perspective of Systemic Design. In Proceedings of the ODAM2014—Human Factors in Organizational Design and Management–XI & Nordic Ergonomics Society Annual Conference—46, Copenhagen, Denmark, 17–20 August 2014.
56. Carrola, T.E.; Vieira, F.L.; Couvinhas, A.F.; Coelho, D.A. Redesign of the logo and design of a new ergonomic hand tool enabled by systemic analysis of the Serra da Estrela PDO cheese universe. In Proceedings of the ODAM2014—Human Factors in Organizational Design and Management–XI & Nordic Ergonomics Society Annual Conference—46, Copenhagen, Denmark, 17–20 August 2014.