Open System in bean cultivation for local economical development

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Abstract—The agri-food sector uses large amounts of pesticides and agricultural chemicals and it is also characterized by large volumes of output that are often overlooked and discarded as common organic waste, thus underestimating the qualitative potential hidden in it.

The project discussed in this paper employs Systemic Design research method, which is employed for the recovery and re-use of Cuneo Bean supply chain by-products. The research further considers the input and output of each phase within a local production territory.

The energy requirements of the cultivation and industrial processes that lead to the final product were studied and highlighted the quality of waste, in order to enter it as input for other production processes, to ensure a close-to-zero impact. Some later improvements were related to the consumption of water, including irrigation, the use of pesticides and harmful substances, selection and cooking process, as well as the creation of innovative packagings

The outcome of the project was the sustainable production of the PGI Cuneo Bean. This production method involves high levels of innovation and research. The bean is different from competing products, and has a territorial connotation.

The study was accompanied by consumer analysis, in order to discover the product’s ability to meet the needs of consumers. The complex system that emerges is also communicated through marketing and packaging efforts.

The project involved many local SMEs, which integrate very different skills, languages and approaches. Through Systemic Design, the environmental impacts are transformed into opportunities to innovate.

Keywords: Systemic Design, Eco Design, environmental sustainability, microeconomies, local development.

I. INTRODUCTION

The past decades have witnessed a growing demand for food and greater availability of synthetic products (pesticides and fertilizers). These factors have caused the transformation of seasonal and territorial activities into processes that have been totally uprooted from season and territory, promoting their relocation in strategic areas, using controlled and distorted air-conditioned environments, (Barbero et al., 2012). These processes have generated industrial food products, rather than natural and genuine ones.

In parallel with this, a second related concern for governments is the management of waste. The increase in the development of civilization and technology has increased the quantities and harmfulness of the generated waste (Endo et al., 1997). The agri-food sector is proving to have particularly high impact because of the use of pesticides and fertilizers, the consumption of energy and natural resources, the emissions of greenhouse gases and the large amount of waste produced.

Fortunately, there is also a renewed interest in the use of products that employ waste as raw materials, also called secondary raw materials or by-products (Andreola et al., 2005).

Recently the Politecnico di Torino has engaged in research activities in the agro-food industry, using the Systemic Design (SD) methodology (Bistagnino, 2009), and aims to recover production waste and to optimize energy efficiency in every phase of the production process. The methodology used in this paper enables the scientifically complex project, to engage with very diverse activities associated with food production and consumption. It is sufficient to think about the differences that exist between farming, industrial production and academic research to understand the differences of approaches, languages, needs and objectives that had to find a proactive mediation throughout the project in order to ensure its success. In the complexity of the system and the actors involved it was essential that all stakeholders skills and activities are shared for a real and tangible resource optimization.

Cuneo Bean cultivation was selected for this study as it showed several conceptual criticalities and a production system which required redesigning, initially employing an excessive use of natural and artificial resources, such as synthetic products, energy, as well as waste of secondary raw materials.

II. METHODOLOGY

The aim of the research project, according to the method of SD, included designing materials and energy flows, investigating positive changes in productive processes and activating a new economic model based on open industrial cycles (Bistagnino, 2011).

By employing Systemic Design methods, a holistic approach was possible which included human-centred and systems-oriented aims, as well as production optimization was also used to achieve a total reuse (where possible) of the resources involved in the system delineated, by connecting all the activities together. These activities are considered according to what they need to operate and what they generate, as a product or as waste.
SD aims to redesign human production systems in imitation of natural ones, which are efficient par excellence.

Its methodology is based on the following five guidelines:

- **The output (waste) of one system becomes the input (resource) for another**, which creates an increase in cash flow and new job opportunities;
- **Relationships generate the system itself**: each relationship contributes to the system and it can be within or outside of the system;
- **Self-producing systems support and reproduce themselves**, thus allowing them to define their own paths of action and jointly co-evolve;
- **Act locally**: the local context is fundamental. Acting locally values local resources (human, culture and material) and helps to solve local problems by creating new opportunities;
- **People at the center of the project** to be connected to their own environmental, social and cultural context (Bistagnino, 2011).

In this project that deals with the valorization of the Protected Geographical Indication (PGI) Cuneo Bean, the methodology emerges through the optimization of the resources used at each stage of production, such as water and energy, or other inputs. Moreover all the waste generated has been analyzed and valued in order to be considered as new input for other productive systems.

This work is characterized by a strong multidisciplinary approach. In order to obtain practical and trustworthy results the skills are related to different sectors. This is necessary to understand the scenery complexity and for the creation of a systemic vision, which can relate the activities to each other.

The PGI Cuneo Bean is a local product whose cultivation is strictly regulated by the presence of a consortium. It is a product of high historical value, with strong connotations within the culinary and material cultures of the geographical area analyzed. Territoriality is considered a significant benchmark in sustainable design.

The project included a feasibility study, followed by the industrial testing of each stage of production. This involved many local SMEs (in some cases family-owned businesses). The project provided the opportunity to employ innovative production systems, develop new products and test them.

### III. PROJECT STAKEHOLDERS

The stakeholders involved in the project are:

- **Politecnico di Torino – Architecture and Design Department (POLITO-DAD)**: the Systemic Design research group applies the theory of complexity to various industrial sectors including the agri-food. The primary objective of the research group is to develop a renewed culture of production quality.

  Its role is the coordination of the entire project, with the responsibility in the application of the specific methodology. In this activity, the graphic communication is able to show the complexity of relations and exchanges between partners and regions. Furthermore, POLITO-DAD is in charge of both the new product packaging and brand communication presenting the complexity and the environmental benefit of this complex approach and project.

- **Agroinnova**: This research center operates in the agri-environment sector. It focuses on the transferring of knowledge and technologies. Its role in the project is the technology transfer for the feasibility study, mapping local production and checking the quality of cultivation.

- **CRESO**: it is an applied research centre in Piedmont Region, which works in the agronomic sector, by preserving horticultural germplasm, varietal innovation and defense. Its role in the project is to schedule seedings for the varietal innovation, at the Horticultural Experimental Center in Boves (Cuneo, Italy). It works on seed treatment for the reduction of pathogenic telluric, localized irrigation, diversified amounts of water and fractional contribution of nutrients. Furthermore, it selects regional beans in conservative ways (climbing ecotypes for the production of grain).

- **Coldiretti**: With half a million members, Coldiretti is the largest organization of farmers at national and European level. Its role in the project is to manage the aspect of growing and the collection through threshing. It has also provided a report on proteins present in beans.

- **Arese Franco** is a family business specialized in cleaning and drying grain products, such as legumes, cereals, dried fruit and green coffee beans, especially from organic production. Its role in the project is the junction between the farmers and the industrial processes. It selects the raw beans from farmers to make them suitable for human consumption. They clean and sort the beans from the field, to ensure that the project proceeds with the next industrial manufacturing stages.

- **Geovita** evolved from an historical flour mill into an industry for processing and the production of food ingredients. Its role in the project consists in preliminary tests of the product, cooking in the autoclave of undamaged beans, and cooking, lamination and drying of the broken beans (second choice).

- **North West Technology** has a patented system of cold drying, which leaves the majority of enzymes, vitamins and mineral salts unchanged. In addition, the condensation liquid that results is still very rich and fragrant. Its role in the project is the cold drying of the undamaged beans, cooked by Geovita, and it makes a comparison between their drying system and the traditional one.

- **Molino Borgo San Dalmazzo** deals with traditional food packaging as well as vacuum ones. Its role in the project is the packaging of Cuneo Beans, processed by Geovita and North-West Technology, through different types of packaging systems, including a feasibility check and prototypes of packaging designed by the DAD.
IV. PROJECT

The project is based on research carried in SD by the POLITO-DAD, which analyzes every stage of the production of the PGI Cuneo Bean, through analysis of its critical aspects, in order to transform them into new opportunities for a local territorial development. The design of a complex system in which outputs are valued as input of other production sectors, ensures environmental benefits such as the reducing of wastes. It involved also economic benefits, such as the development of several new economies in the area. A graphical view of the system complexity with all the interconnected activities helps to underline material and energy flows, inputs and outputs (Figure 1).

It is pointed out that the processes which present major criticalities in the management of the cultivation of the PGI Cuneo Bean involve water and defense of the plant cultivation, collection, selection, cooking and packaging processes.

A. Cultivation: Coldiretti, Agrinnova and CReSO

Coldiretti is responsible for the proper growing of plants. Agrinnova and CReSO studied seed control, seed dressing, micro-irrigation and fertigation, use of auxiliary insects and antagonistic fungi in the defense of the plant. It is a common practice among farmers to plant seeds obtained from the crop of the previous year.

With a good seed selection and the control of seed variety, plants better withstand pest diseases and it is prevented the spread of plant species which are not controlled.

As regards to the sowing of seed, the Cuneo Bean seeds were treated with two different types of seed dressings, leaving a part of the field with unaltered seeds to evaluate the differences. Seed dressing is a treatment which defeats the germs present in seed, in order to avoid the continuous spread of herbicides (Giannelli et al., 2012). The results are evaluated at the end of the growth of the bean, through a qualitative analysis of plant roots used as a sample.

Another change made was the introduction of drip irrigation, instead of water scrolling one, in which two types of different fertilizers were tested in two different crops. This technique had already been tested with success in other types of crops and it is known as fertigation. It takes place through the use of biodegradable hoses which allow reducing the water consumption, locating the distribution near the roots and avoiding suitable conditions for the development of diseases. The ground remains soft, spongy and oxygenated and may
promote vigorous growth of the crop, while the use of fertilizers was reduced by 50%.

To evaluate the results, the field was divided into three parts, fertigation1, fertigation2 and scrolling. Beans produced have been counted, to quantify the test, taking them from several plants in the three sample areas of the field.

Some specific insects and fungi were used for the defense of the plant against mites, together with leaf treatments with products based on copper. Both actions allowed the reduction of the chemicals used.

At reached maturation, the plants were cut off at the base to allow the drying of the pods. Plant and pods were then lying on the ground and threshed to obtain the grain.

B. Collection: POLITO-DAD

The analysis carried out by DAD for the recovery of qualitative waste from the plant usually abandoned in field is still in progress. It is difficult indeed to encourage farmers to invest in removing the plant from the field, as there is not a network ready to collect this by-product. The reasons are actually fully economic.

Future developments deals with the topic of the plant recovery, highlighting that none of the proposals made have practical applications in Piedmont region company activities.

Now a sample of the plant is going to be analyzed by a company that produces 100% recycled paper with a small percentage of micronized organic food waste, but these tests will be conducted outside of the Piedmont territory.

C. Selection: Arese Franco

The company selected raw beans, bought from farmers, to make them suitable for human consumption. In particular, they clean and sort beans through several processes including calibration, to allow the further steps of the industrial processing. Waste are accumulated with those that arise from the selection process and are sold to local companies that use them, after appropriate treatments, as animal feed supplements, while the rest is used as soil fertilizer.

During these phases, some beans are erroneously considered as a waste, because of their shape or because they are no longer intact or split in half, but for this reason they do not pass qualitative tests of machinery. This second choice can be used to make human edible products, in which the form is not relevant, in addition to animal feed.

D. Cooking process: Geovita

Cleaned and selected beans (first and second choice) were transported to the company that makes a rehydration with water baths, before cooking them. The first choice was cooked in an autoclave and subsequently cold dried with a North West Technology patented dryer. The result obtained is an undamaged and pre-cooked bean, with a lower cooking time, that moves from 3 hours to 10 minutes and eliminates the soaking time, while maintaining intact taste and nutrients. Moreover, this cold dried product is able to be stored and kept for a long time.

Second choice beans, separated during the selection phase, are also pre-cooked and then laminated to obtain a new bean product - bean flakes, which can be eaten raw in salads or used to create tasty meals and snacks, allowing new scenarios and a reconsideration of beans as a popular food.

In this case a careful design of packaging and distribution channels was essential, for a product that was not yet on the market (Barbero et al., 2011).

E. Packaging: POLITO-DAD – Prototipazione: Molino Borgo San Dalmazzo

After market analysis, a communication and packaging study investigated that potential for the pre-cooked product (both intact beans and flakes) relating to mass market products and niche products, from functional, communicative and environmental points of view. The target market segment was identified as one that is careful to environmental issues, defining the user needs towards new eco-friendly packaging (Barbero et al., 2009).

This phase saw an intense activity, also developed within the Bachelor degree in Design and Visual Communications, in which the students of Communication Design II (Module of Design for Communication II) coordinated by Professor Paolo Tamborrini (Tamborrini et al., 2009, 2012) designed an innovative range of packaging that are currently in the prototyping phase at Molino Borgo San Dalmazzo. Some of the designs are illustrated below, in Figure 2.

Figure 2. Packaging designed, now in the prototyping phase.

V. PROJECT STAKEHOLDERS

A. Cultivation: Coldiretti, Agrinnova and CReSO

Experimental testing methodology showed that seed dressing and fertigation were successful. There was a
considerable reduction in the amount of water used and the use of fertilizers was reduced by 50%. As a result the plant builds up its natural defenses. The use of the red spider effectively contrasted the proliferation of mites, which was observed on adjacent crops where such treatment had not taken place.

B. Collection: POLITO-DAD

Waste recovery was only studied from the theoretical point of view, due to the lack of local companies who were ready to reuse waste. Experimental tests will be brought forward in order to encourage companies to experience this quality output, which could potentially add value to this project.

C. D. Selection and cooking processes

Two different types of products ( precooked and dried) were obtained: intact beans and bean flakes. The second is a qualitative output and can be used in various ways, such as a new contemporary snack. Both intact and bean flakes are characterized by a very low cooking time or, in the case of flakes, no cooking may be required. This reflects contemporary consumer needs, without losing organoleptic and nutritional properties, by using cold drying processes that protect the product’s characteristics.

E. Selection and cooking processes

The product packaging study meets the needs for communication and product differentiation on shelves, providing new products, characterized by communicative and attractive packagings. The packaging has the role of advertising the research work done and adds value through the communication of the complex system at the base of this production.

VI. FUTURE DEVELOPMENTS

There are some potentialities within the project, which could be developed further. The bean plant is currently being abandoned in agriculture because of its high costs of removal and farmers prefer to leave them to rot or be burnt in the field. This practice is not only harmful ( developing volatile gas products, which increase CO2 in the air) but it is also inconvenient, as it does not involve the recovery of waste in monetary terms.

Waste collecting would open several scenarios:

- **Biodigestion**: evaluation of the fermentation and the possible performance, if it is processed within a biodigester, in terms of gas and electricity production (Barbero, 2008). Some studies have already been carried out around the processing of other organic remains such as fruit and vegetable waste (Liu et al., 2009), weed samples and bagasse (Sen et al., 2013). Anaerobic digestion is a well-established technology for the reduction of organic matter and stabilization of wastewat er. Biogas, a mixture of methane and carbon dioxide, is produced as a useful by-product of the process. Liu et al., 2009).

- **Biopolymers and paper production**: Analysis of the bean plant residual biomass with the aim of converting the waste into simple sugars and other fine chemicals such as levulinic and lactic acids, in the creation of new materials and biopolymers. The possibility of waste uses as additives for composite materials based on polymers could be identified as already studied for tomato plants (Hauff et al., 2010). Further possible applications include the use in cellulosic mixtures for paper and cardboard, as raw material or as an additive in 100% recycled papers (Anon, 1998).

- **Construction**: A further possible use is in the construction sector, where we see a great need for raw materials (Menezes et al., 2002). Several studies found that polymers, cement and ceramics are the best suited materials for achieving inertization and neutralization of waste by encapsulating it in the matrix (Pérez et al., 1996). Due to environmental regulations, the demand for bricks with high insulation capacity is increasing, since decreasing the thermal conductivity is a decisive factor in limiting energy consumption (Eliche-Quesada et al., 2011). One way to increase the insulation capacity of the bricks is to generate porosity in their microstructure by incorporating lightening, pore-forming, and organic additives into the clay matrix (Eliche-Quesada et al., 2011). The uses of organic residues in brick production to obtain porous ceramic bodies with better insulating properties have been studied by several authors (Demir, 2006, 2008; Duckman et al., 2001; Sütcü et al., 2009) evidencing the possibility of mixing the clay with different types of food waste or the production of bricks, including coffee grounds, urban sewage sludge, brewing industry sludge and bagasse, and waste from the paper industry. The latter, in particular, was mixed up to 30 mass %, decreasing the fired density of the bricks to 1.28 g/cm3 and the thermal conductivity by more than 50% compared to bricks without residue, while maintaining adequate mechanical strength. (Eliche-Quesada et al., 2011). The experimentation on bean plant wastes has not been conducted yet, but can be assumed to be successful, by reducing the plant to a dried powder, since it is to be considered very similar to spent coffee grounds, or to waste from the paper industry due to the high amount of cellulose included in it. It is also possible to make an evaluation of the plant reuse in absorbent panels through the theoretical study of the supposed thermal and acoustic absorption, already conducted on the tomato plant (Saddeq, et al. 2012) as well as the appropriate treatment to contrast its tendency to perish.

- **Mushroom cultivation**: Another evaluation of the possible use of this waste is as a cultivation substrate for the growing of Pleurotus Ostreatus mushrooms, as already studied for spent coffee grounds (Barbero et al., 2010, 2013).

VII. CONCLUSIONS

This project will have effects on:

- **The environment**, through the recovery of vegetable wastes and agri-food industrial production waste, the
development of clean and sustainable processes and industrial activities.

- The territory, supporting an improvement in the regional competitiveness by increasing the skills of local technicians and operators involved in the production sector, thus valuing territory productions, waste arising therefrom, protecting native species through seed dressing and, consequently, the local culture.

- The society, for the transferring of skills and know-how between companies and between Universities and companies, which provides a general enrichment, making it possible to build long term partnerships and to develop and evolve the practical applications, as well as job creation, new local employment, new professional figures who put into practice the innovations introduced, the rediscovery and promotion of healthy and traditional products and recipes.

- The economy, an increase is expected in the productive activities of that area and a growth in revenue, a continual company investment in research and development, as well as the attraction of new resources and investments on the territory by internal and external, national and international stakeholders

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