POSTER SESSION G
Case studies / Production, trade and treatment processes

LCA for five transportation scenarios for soybean exported from Brazil to Europe

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ABSTRACT

In the past few years Brazil has become the leading soybean exporter in the world and according to the Brazilian Department of Agriculture, Livestock and Supply, Mato Grosso is the major producer state. Many possibilities of seaports can be used and also different ways of transportation to those seaports. The objective of this study was to make a life cycle assessment of the exported soybean transportation, from a producer center (Sorriso – Mato Grosso state) to a consumer center (Rotterdam – the Netherlands). The functional unit was the transportation of 1,000 kg of soybean. With the existing transportation infrastructure, five scenarios were made. Santarém's seaport scenario appeared to be the best route overall, and Paranaguá's seaport scenario the worst one. We could demonstrate that a change in the route can bring environmental benefits, even though it sometimes just contributes with a small part of the entire soybean life cycle.

Keywords: LCA, transportation, soybean, Brazil

1. Introduction

The rapid growth of soybean production in Brazil began in the 1960s, and in less than 20 years it has become the largest grain production in the country. In 2007/08 season, the soy sown area in Brazil was 20.7 million hectares, with a production of 59 million tonnes (CONAB, 2009). Soy products were the country's leading export from 1970 until 2007. Although the south of Brazil is the most traditional in the production of soybean, especially the states of Paraná and Rio Grande do Sul, since 1990 the production of soybean in the Central-West region of Brazil, which includes the Cerrado biome, has been increasing in Goiás, Mato Grosso do Sul and mainly in Mato Grosso state.

The soybean transportation from the major producing areas to the domestic and foreign markets may be done through different transport types, including road, railroad and waterway (Ojima, 2006).

Based on data of the Brazilian Ministry of Development, Industry and Foreign Trade (MDIC), the biggest producers of soybeans between 2005 and 2008 were the states of Mato Grosso, Goiás, Paraná and Rio Grande do Sul, and the first one responded with more than 40% of it. Among the municipalities, Sorriso (at Mato Grosso state) has been the leader producer on those years, according to the Brazilian Institute of Geography and Statistics.

Also according to data from MDIC, on 2008 the seaports of Vitória, Santos, Paranaguá and Santarém responded for more than 65% of the exportation of soybean to European Union.

The growing awareness on the importance of environmental protection and the potential environmental impacts associated with a product (goods and services) has raised the interest on the development of methodologies that evaluate those impacts. One of them is called Life

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Cycle Assessment (LCA), which evaluates products from cradle to grave (ISO, 2006a; b), but can also be used for cradle to gate, gate to gate and cradle to cradle analysis.

The objective of this study was to make an attributional LCA of the exported soybean transportation, from a producer center (Sorriso – Mato Grosso state) to a consumer center (Rotterdam – the Netherlands), by five transportation scenarios, using the current infrastructure in Brazil.

2. Methodology

The CML (modified) was used as a Life Cycle Impact Assessment (LCIA) method. It was created from changes in the CML 2 baseline 2000 version 2.04. From the latter, we added the Land Occupation category, from CML 2001 (all impact categories) method, version 2.04, and the category of Total Cumulative Energy Demand, from the method of same name. In the Global Warming category we changed the characterization value of methane (CH_4), biogenic methane (CH_4) and dinitrogen oxide (N_2O) for 25, 25 and 298, respectively.

We made a previous evaluation of the ways of transportation (road, railroad and waterway), and except for Land Occupation, all other environmental categories showed road transportation with higher environmental impacts, followed by railroad transportation and finally, river transportation with fewer environmental impacts. Therefore, to build the scenarios, we adopted the following assumption: to use river transportation when possible, then railroad transportation when possible and only when neither of those two was possible, to use road transportation.

The functional unit was the transportation of 1,000 kg of soybean and the scope of the study is from the producer city (Sorriso – Brazil) until the consumer city (Rotterdam – Netherlands). With the existing transportation infrastructure at Brazil, we made five scenarios: (1) Transportation from Sorriso to Santarém (northern Brazil), by river and road; (2) Transportation from Sorriso to Vitória (eastern Brazil), by road and railroad; (3) Transportation from Sorriso to Santos (southeastern Brazil), by road and railroad; (4) Transportation from Sorriso to Santos, but using another route, by road, river and railroad; (5) Transportation from Sorriso to Paranaguá (southern Brazil), by road and railroad. The transportation from each seaport to Rotterdam by sea was also included. We included this part on the study because some seaports are closer to The Netherlands than others (the distance from Santarém's seaport to Rotterdam's seaport is 22% lower than from Paranaguá's seaport).

We used the Simapro 7.1 software to make the LCA of the five scenarios. To know the distances to be traveled by road, rail, river and sea, we used the Google Earth software. Due to the lack of database from Brazil, we used Ecoinvent database to model the transportation. We used the processes that most resembled the Brazilian reality, as showed on table 1:

Table 1: Processes used to model the LCA

Way of transportation	Process on Ecoinvent database
Road	Transport, lorry >32t, EURO3/RER
Railroad	Transport, freight, rail, diesel/US
River	Transport, barge/RER
Sea	Transport, transoceanic freight ship/OCE

In order to evaluate all the environmental impact categories together, it is important to leave out the units. Therefore, the value for each scenario, of each environmental impact category, was divided by the highest value, as shown on Equation 1. This procedure is also called internal normalization.

$$\text{Normalized Value } x_{ij} = \frac{\text{Value } x_{ij}}{\text{Highest value } x_j} \quad (1)$$

In which x_{ij} is the value of the *i-th* scenario at the *j-th* environmental impact category.

3. Results and Discussion

The distance traveled by road, railroad, river and sea, from Sorriso (Brazil) to Rotterdam (Netherlands), by those five scenarios, is showed in table 2.

Table 2: Distance traveled from Sorriso (Brazil) to Rotterdam (Netherlands), by five scenarios

Scenario	Road (km)	Railroad (km)	River (km)	Sea (km)	Total (km)
Santarém - PA	1,415	0	1,115	8,120	10,650
Vitória - ES	1,150	1,630	0	9,175	11,955
Santos 1 - SP	821	1,320	0	10,125	12,266
Santos 2 - SP	1,150	460	670	10,125	12,405
Paranaguá - PR	1,400	840	0	10,430	12,670

It is important to notice that CML method does not evaluate occupation of water courses and water bodies. Therefore, the scenarios that use river transportation (Santarém's scenario and Santos 2's scenario) may have higher land occupation than it is showed in this study.

For acidification, eutrophication, human toxicity and land occupation, the scenario with the best environmental performance was Santarém. On the other hand, for global warming and total cumulative energy demand the best scenario was Santos (by road and railroad – option 1). We can see that Paranaguá was the worst scenario in five impact categories. Only on eutrophication it was different, placing Vitória as the worst one (Figure 1).

Figure 1 shows only the relative values (after internal normalization). In table 3 it can be seen the absolute values. From that we can see that the difference between the best and the worst scenarios for each ton of soybean is: For acidification 0.52 kg of SO_2 eq; for eutrophication 0.05 kg of PO_4 eq; for global warming 47 kg of CO_2 eq; for human toxicity 22 kg of 1,4-DB eq; for land occupation 2.1 m^2a; and for total cumulative energy demand, 841 MJ eq.

From these values from Table 3, at global warming impact category we can see that by changing from Paranaguá's scenario to Santos' scenario (option 1), it is awarded 47 kg of CO_2 eq as credit for each ton of soybean from Sorriso – MT (Brazil).

The better environmental performance of Santarém's scenario for some impact categories was due for its lower total distance traveled and higher percentage on river transportation. It had the higher distance traveled by road, but that was not enough to increase greatly its impacts. Santos 1 was the best scenario for global warming and total cumulative energy demand and the reason for that is because it had the smallest distance traveled by road and, even though it does not use river transportation, the emission of greenhouse gases and the resources consumed were smaller than others scenarios.

Paranaguá was the worst scenario for almost all impact categories and the reason for its worse environmental performance is on the fact that it has the second highest distance traveled by road, the highest distance traveled by sea and the highest total distance traveled. It also had a bad performance on eutrophication, but Vitória's scenario was worse and this is due to the high distance traveled by railroad (powered by diesel engine) on this scenario.

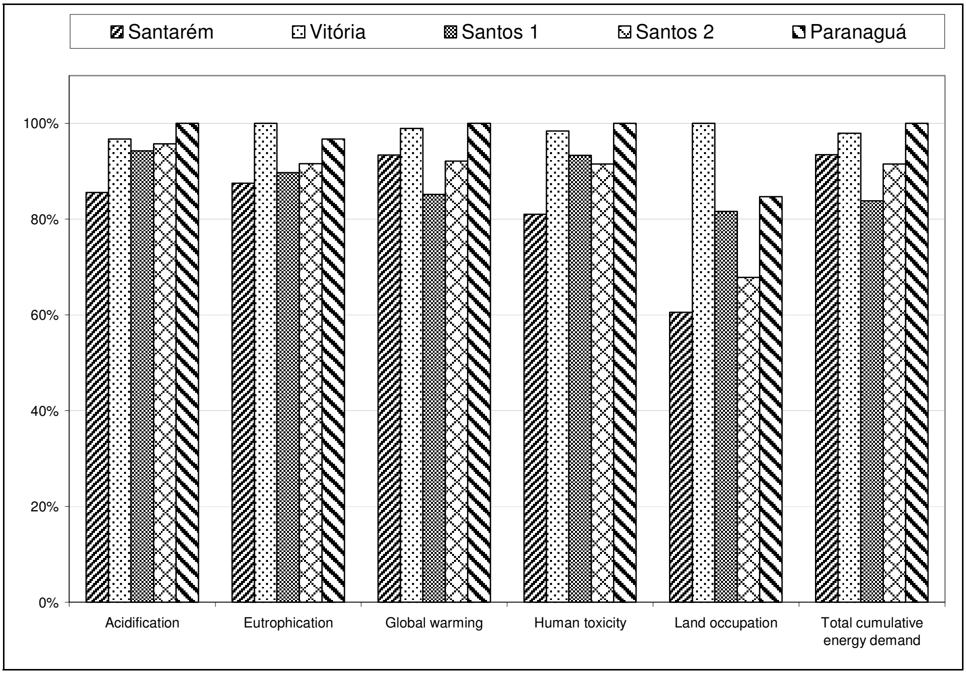

Figure 1: Environmental impacts for five transportation scenarios of one ton of soybean delivered to Europe

Table 3: Absolute values of six environmental categories for five transportation scenarios

CML (modified)		Scenario				
Environmental category	**Unit**	**Paranaguá**	**Santarém**	**Santos 1**	**Santos 2**	**Vitória**
Acidification	kg SO_2 eq.	3.59	3.07	3.38	3.44	3.47
Eutrophication	kg PO_4 eq.	0.45	0.41	0.42	0.43	0.46
Global warming (GWP 100a)	kg CO_2 eq.	318	297	271	293	315
Human toxicity	kg 1,4-DB eq.	116	94	108	106	114
Land occupation	m^2a	4.50	3.22	4.34	3.61	5.32
Total cumulative energy demand	MJ eq.	5,204	4,866	4,363	4,763	5,096

Hence, on a decision to use a seaport to export soybean from Sorriso (Brazil) to Rotterdam (The Netherlands) using environmental issues as criteria, the ones with better environmental performances would be Santarém's and Santos' harbor. About the latter, it would be better to use the first option of path, by roads and railroads.

As can be seen from this work, most impact comes from the predominance of roads in soybean transportation routes. Therefore, Brazilian transportation system could be improved exploiting more its water resources by construction of waterways and through construction of new railroads, powered by hydroelectricity.

Prudencio da Silva et al (2010) made a LCA of soybean production, from cradle to the farm gate. In this study they also mention values from other literature. In order to evaluate if export transportation (from farm gate to consumer center in Europe) play a big role on the entire life cycle of the Brazilian soybean, we confronted our values with the ones from Prudencio da Silva et al (2010), as shown on Table 4.

Table 4: Lowest and highest values from Prudencio da Silva et al (2010) and this study, for production and transportation, respectively, of 1 ton of soybean.

Impact category	Prudêncio da Silva et al (2010) – soybean production (from cradle to farm gate)	This study – exported soybean transportation (from Sorriso to Rotterdam)
	lowest value – highest value	lowest value – highest value
Acidification (kg SO_2 eq)	0.80 – 7.63	3.07 – 3.59
Eutrophication (kg PO_4 eq)	4 – 10	0.41 – 0.46
Global warming (kg CO_2 eq)	241 – 1,308	271 – 318
Land occupation (m^2a)	1,835 – 3,530	3 – 5
Cumulative energy demand (MJ)	1,220 – 11,295	4,363 – 5,204

By Table 4 we can see that the most significant environmental impact categories of export transportation system are Acidification, Global warming and Cumulative energy demand. For Eutrophication and Land occupation, the values from this study are much lower than the soybean production ones. We could not compare our values from Human toxicity category, since it was not on Prudencio da Silva and colleagues' scope.

4. Conclusions

Although this study has some limitations (e.g. the data used), it is possible to conclude from it that a simple change on the imported soybean itinerary may reduce environmental impacts beyond its supply chain.

For acidification, eutrophication, human toxicity and land occupation, the scenario with the best environmental performance was Santarém. On the other hand, for global warming and total cumulative energy demand the best scenario was Santos (by road and railroad – option 1). While that, Paranaguá's and Vitória's scenarios were the worst ones.

The decision-making on the way of transportation usually includes criteria such as price, speed and reliability. Although, include the environmental criterion might provide good results, as it may give a carbon credit for the product.

5. References

CONAB (2009): *ConabWeb*. Retrieved June 5, 2009, from www.conab.gov.br/conabweb/index.php?PAG=131

ISO (2006a): ISO 14040: Environmental management - Life Cycle Assessment - Principles and Framework. Genebra, Suíça.

ISO (2006b): ISO 14044: Environmental management - Life Cycle Assessment - Requirements and Guidelines. Genebra, Suíça.

Prudencio da Silva V.,van der Werf H. M. G., Spies A., Soares S. R. (2010): Variability in environmental impacts of Brazilian soybean according to crop production and transport scenarios. *Journal of Environmental Management*, 91, pp. 1831-1839.

Ojima A. L. R. d. O (2006): Perfil da logística de transporte de soja no Brasil. *Informações Econômicas*, 36 (1), pp.17-25.

The application of Life Cycle Assessment to an agri-food product of Provence-Alpes-Côte d'Azur (PACA)

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ABSTRACT

The paper aims at illustrating the application of the Life Cycle Assessment (LCA) methodology to agri-food sector within the cross border cooperation Italy France (Alps – Alcotra 2007-2013) project FASST "Filière Alpine Senteurs Saveurs Transfrontalière". In particular LCA was applied to agri-food sectors relevant to the economy of French Region of Provence-Alpes-Côte d'Azur (PACA) in order to promote Social and Environmental Sustainability. The application of LCA is an activity of research and development of tools of "certification" and "sustainability" of sectors and territories of PACA. In particular, its application will be the start point for planning improvements and for preparing Sustainability Reports. LCA was therefore included in the research activities in order to achieve the demand for naturalness and sustainability by consumers. Life Cycle Assessment was also applied in order to support improvements in the production chain. The paper illustrates the case study and the results of the LCA application.

Keywords: Social and Environmental Sustainability, LCA, naturalness and sustainability.

1. Introduction

The project *Filière Alpine Senteurs Saveurs Transfrontalière* –FASST- ("Smell and taste cross border Alpin products chain", is a project of cross-border cooperation between France and Italy (Alcotra 2007-2013). The project lead partner is the *Université Européenne des Saveurs et des Senteurs* (UESS) located in the French region of Alpes de Haute-Provence, the project partners are FranceAgriMer, The *Etablissement Francais des produits de l'agriculture et de la Mer* (initiated by Onippam, the *Office national interprofessionnel des plantes à parfum, aromatiques et médicinales*), the Italian research Institute SiTI (Istituto Superiore sui Sistemi Territoriali per l'Innovazione), the Italian scientific and technological park for the Agro Industry *Tecnogranda* and the *Centre Régional d'Innovation et de Transfert de Technologies* (CRITT, French center of innovation and technology transfer) in the Region of Provence Alpes Cote d'Azur (PACA). The partnership includes therefore technical and scientific partners and also partners which operate in close and direct contact with companies, especially small and medium societies. The FASST project is therefore developed in the chain of Scents and Flavors (aromatic and medicinal plants and the manufacture of perfumes, cosmetics, aromatic and agri- food products) which is present along the Mediterranean coast, particularly along the cross border region France -Italy (PACA region - Piemonte).

1.1 The scents and flavors sector in Italy and France

The sector "Scents and Flavors" shows many common elements, on both sides of the Alps: industrial companies are mainly composed of small and medium enterprises. If on one hand this element contributes to the dynamism of the sector, on the other hand the same element requires the development of specific tools for animation of the sector, which meet

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the needs of businesses and encourage the development of projects of innovation and development. While SMEs are an engine of growth and innovation researches, they have more difficulties to develop research and innovation projects. Small and medium enterprises, both Italian and French, show a structural weakness, due to its small size and localization (e.g. production of herbs and cheese in mountain areas), and practical difficulties in meeting the challenges of an economic scenario, which is competitive, very complex and requires significant resources and investments. In particular the analysis of the agri-food sector in regional cross-border between France and Italy highlighted the following elements. The common specificity of the chain on both sides lies in the strong interaction between the industrial vision of the area: local products are often associated with particular types of landscape.

1. 2 The project activities

The FASST project has been developed around these main axes of activity:

- technology transfer, through the enhancement of mutual knowledge and the development of partnerships of firms and laboratories;
- study of measures to developing new services, tools and methods for aggregating the chain;
- identification of shared tools, innovative technology and R&D tools;
- actions to encourage the spread of social and environmental responsibility over the entire chain of production, from farming to finished product.

The Scents and Flavors chain has an important image: naturalness, authenticity and territory. Currently, this identity is strongly driving in the markets of food and cosmetics, and more generally of "wellness". The evolution of consumer behaviour, environmental trends and compliance of consumer health have directed all development areas to search for a stronger natural. In particular, the cultivation of plants for the manufacture of perfumes and aromatic plants and the production of perfumes and cosmetics are an example of sustainable development: traditional farming, based on knowledge and quality, rather than on productivity, using little or no fertilizers and pesticides, cosmetics production by short chains of the territory, etc. Therefore it is important for the chain the identification of resources and weaknesses in the field of sustainable development and then the information of customers and consumers on them. For these reasons the case study of lavender (production of its essential oil) was chosen. The area concerned is the region of Alpes de Haute-Provence.

Through the Life Cycle Assessment study carried out on the chain of lavender it’s possible to detect the resources and energy consumption and environmental impacts from the entire life cycle, from extraction of raw materials and cultivation of natural raw materials, through the process of production, distribution, use and end of life of the product in a perspective that goes beyond the gates of the company, anticipating the LCA as a complementary tool for environmental management systems. One of the main applications of LCA in terms of visibility and marketing company will be the use of environmental in formations for preparing Sustainability Reports. In particular, LCA is a part of the activities which aim at identifying economic, social and environmental values for the operators of the chain, in order to promote the development of Sustainability Reports of the production chain and the territories.

2. The case study of lavender of PACA

The application of Life Cycle Assessment to the chain of lavender was realized in accordance with the requirements of reference standards:

- EN ISO 14040. Environmental Management-Life cycle assessment-Principles and Frame work (ISO, 2006);
- EN ISO 14044. Environmental Management-Life cycle assessment-Require-ments and guidelines (ISO, 2006).

Table 1. The research activities: LCA application to the case study.

Activity description	Objectives, expected results and documents
Preparation and definition of questionnaire for data collecting.	- Specific questionnaire for the chain of lavender; - Explanation and data collection in PACA.
Literature Analysis: economic and technical aspects of the chain of lavender; LCA application in agri-food sector.	- Technical and socio-economic aspect; - Classification of the chain; - LCA studies on the agri-food sector.
Goal and Scope definition (geographic and temporal boundaries, farms involved, functional unit, data, allocation criteria).	- Identification of geographical and temporal boundaries; - Definition of a sample of firms to be involved in the LCA study; - Identification of the functional unit; - Input data and critical analysis; - Allocation criteria.
Life Cycle Inventory (Analysis of inventory through the completion of questionnaires).	- Creating data base of the sector; - LCA Model of chain of lavender; - Input-output tables; - LCA Model of all possible alternatives and improvements in the chain.
LCA application.	- Application of LCA (UNI EN ISO 14040-14044) to the chain lavender essential oil; - Results of the inventory.
Life Cycle Impact Assessment.	- Definition of methods and impact categories (specific and useful for the reporting and the preparation of sustainability reports); - Environmental and energy impacts of lavender chain.
Life Cycle Improvement (interpretation of results and suggestions for improvement).	- Identifying critical areas-phases of the chain; - proposals for improvement, LCA analysis and comparisons; - Discussion of results and their analysis.
Integration with socio-economic indicators (LCC and/or Social LCA).	- Integrating environmental data with socioeconomic data.
Writing sustainability reports of chain and territories.	- Sustainability Reports.

Table 2. Essential oil of Lavender: LCA application (ISO 14040-14044).

System	Boundaries	Function Unit	Goal and scope of study	Data
Essential oil of lavender	PACA – FR Medium data 2007-2009	1 kg	- Assessment of the impacts of the production chain. - Analysis of the contributions of each stage of the life cycle. - Short chain from the perspective of Environmental sustainability. - Provide Eco-Profile for LCA of products which use essential oil.	- Primary: collected directly from a sample of producers. - Secondary: Ecoinvent and Literature.

The planned activities are summarized in Table 1. The project is still under development and will be completed by the end of 2010: Some of the following steps have already been implemented and others are still ongoing. In particular the completion of all phases of application of LCA to the chain of lavender and cosmetics that use as raw material.

2.1 Description of case study: objective and scope and inventory analysis

The case study is the chain of lavender and in particular the production of essential oil obtained from lavender distillation. The production of lavender oil is an example of "short" chain. Cultivations require extremely low use of pesticides and fertilizers. The distillation process is traditional. In the model of the life cycle were also included machinery and service elements. The system under study includes all the processes realized for the production of essential oil of lavender of PACA Region in France.

The study considers all the life cycle phase: from the installation of the culture of plants to the cutting and distillation activities. The management of culture was also included. The function unit is the mass of essential oil (1 kg). Table 2 illustrates the goal and the scope of the study.The study was conducted using the application SimaPro 7.1, which is used for the analysis of environmental impacts caused by products and services and which includes several international databases (Ecoinvent, ETH ESU, etc. Buwal 250.) containing the energy and environmental profile of many products and processes, including materials, energy, transports, processes for disposal and waste treatment. For the composition of processes, directly identified primary data have been used and, if it was not possible to gather such data, secondary data mainly from the database in the code Ecoinvent v2 SimaPro 7.1. are used. In the latter case data from literature and bibliography are used. In particular the French Official catalogue oh phyto-sanitary products and their use, developed by the French Ministry of Agriculture, was used (e-phy. Le catalogue des produits phytopharmaceutiques et de leurs usages des matières fertilisantes et des supports de culture homologués en France). The publications of the *Office National Interprofessionel des Plantes à Parfum* (Onnipam). The publications and informations of the *Centre Règionalisé Interprofessionel d'Expérimentation en Plants à Parfum, Aromqtiques e Médicinales* (Crieppam) were also used.

2.2 Impact Assessment

For the impact assessment, the following impact methods were used (Table 3):

- IPCC method for calculating the carbon footprint;
- Method of calculating EPD 2007, with the addition of some impact categories contained in the CML 2001 method; the specific impact categories ecotoxicity in fresh water (Fresh water aquaticecotoxicity), Human toxicity and land use (Land competition) were added (modified EPD methods).

3. Results and discussion

The phases of impact assessment and interpretation and improvement have been developed according to the goals and scopes of the study and to reference standards (UNI EN ISO 14040:2006-5.4 and 5.5). Table 4, and figures 1.1 and 1.2 show the characterization for the cycle of essential oil of lavender. These highlighted the greatest contribution of crops management and the use of agricultural machinery. The distillation has a smaller contribution because it is punctual and very short . It lasts a few days during the summer.

4. Conclusions

Life Cycle Assessment applied within the European project "Filière Alpine Senteurs Saveurs Transfrontalière (FASST)" was developed in research and development of specific tools for "certification" and "sustainability" of sectors and territories.

Table 3: Essential oil of lavender: impact methods.

Impact Category	Characterization
Carbon footprint	kg CO_2 eq
Ozone Depletion	kg CFC^{-11} eq
Photosmog	kg C_2H_4
Acidification	kg SO_2 eq
Eutrophication	kg PO_4--- eq
Consumption of non renewable resources	MJ eq
Human toxicity	kg 1,4-DB eq
Freshwater ecotoxicity	kg 1,4-DB eq
Land use	m^2year

Table 4. Life Cycle of essential oil of lavender: Characterization (IPCC Methods, Modified EPD methods). Functional units: 1 kg of essential oil.

Impact Category	Unit	Essential oil of lavender (distillation with natural gas)
Carbon footprint	kg CO_2 eq	1,927
Ozone Depletion	kg CFC^{-11} eq	0,000000507
Photosmog	kg C_2H_4	0,0036
Acidification	kg SO_2 eq	0,0363
Eutrophication	kg PO_4--- eq	0,231
Consumption of non-renewable resources	MJ eq	165,151
Human toxicity	kg 1,4-DB eq	1,904
Freshwater ecotoxicity	kg 1,4-DB eq	0,53
Land use	m^2year	1000,152

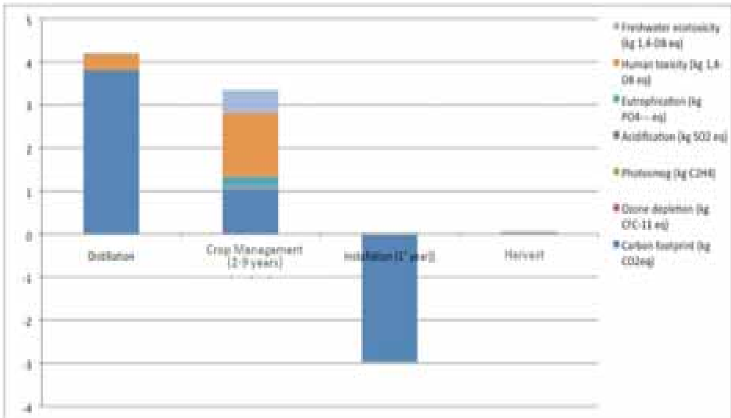

Figure 1.1. Life Cycle of essential oil of lavender: Characterization (IPCC Methods, Modified EPD methods). Functional units: 1 kg of essential oil.

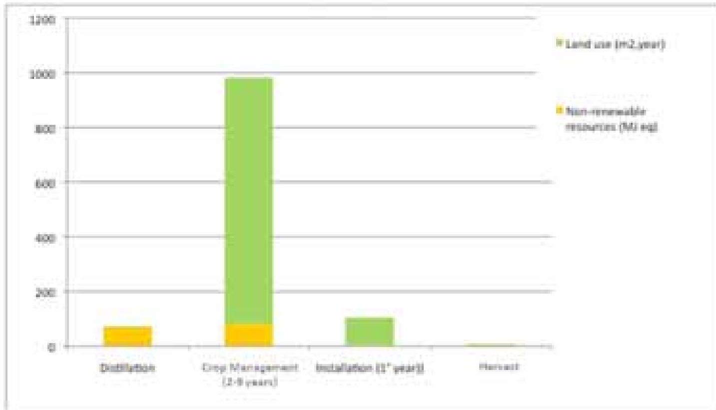

Figure 1.2. Life Cycle of essential oil of lavender: Characterization (IPCC Methods, Modified EPD methods). Functional units: 1 kg of essential oil.

In particular, objective scientific data supplied by the application of LCA, supplemented with methods developed by French Partnership (*Bilan Carbone*®), will be the basis for writing Sustainability Reports of sectors, products and territories.

In the research specific technical centers were involved, in order to identify resources and energy consumption and environmental impacts, and then to design improvement and promotion actions along the chain. LCA methodology in this case was therefore a tool that allowed to evaluate a scenario for environmental improvement and to provide guidelines for future research. An important element of the application of LCA in the FASST project was also an opportunity to assess, in a scientific manner, as a short chain is not so much in terms of distance but rather in terms of sustainability.

5. References

Baldo G. L., Agenzia Nazionale per la Protezione dell'Ambiente - ANPA (2000): LCA. Life Cycle Assessment- Uno strumento di anali energetica ambientale, Ipaservizi Editore, Milano.

Barilla G. e R. Fratelli e Life Cycle Engineering (2008): EPD. Dichiarazione Ambientale di Prodotto. Applicata alla pasta secca di semola di grano duro prodotta in Italia e confezionata in astuccio di cartoncino. Barilla, 2008.

Centre Règionalisé Interprofessionel d'Expérimentation en Plants à Parfum, Aromqtiques e Médicinales –Crieppam. (www.crieppam.fr).

Ecoinvent (2009): Sito internet del "Swiss Centre for Life Cycle Assessment", fornitore del database ecoinvent (www.ecoinvent.ch).

e-phy. Le catalogue des produits phytopharmaceutiques et de leurs usages des matières fertilisantes et des supports de culture homologués en France (www.e-phy.agriculture.gouv.fr).

Fiore M., Breedveld L., Arrivals C., Lgiaino, Notaro A. (2008): Certficazione Ambientale di prodotti agroalimentari. LCA dell'olio d'oliva. *ARS*, 122 – luglio/settembre 2009, pp. 12-20.

International EPD Corporation (IEC), General Programme Instructions for Environmental Product Declaration EPD, Version 1.0, dated 2008-02-29.

International EPD Cooperation (IEC) (2008): PCR Basic Module. CPC Division 01. Products of agriculture, horticulture and market garden.

ISO (2006): UNI EN ISO 14040. Environmental Management- Life cycle assessment- Principles and framework. International Organisation for Standardisation. Ginevra.

ISO (2006): UNI EN ISO 14044. Environmental Management- Life cycle assessment- Requirements and guidelines. International Organisation for Standardisation. Ginevra.

Office National Interprofessionel des Plantes à Parfum –Onnipam. (www.onnipam.fr).

Onnipam (2009): Rapport d'Activité. 2008, Onnipam.

PRè Consultans, Olanda. Software SimaPro 7.1.

PRè Consultans, SimaPro Database Manual, Methods Library.

SETAC (1993): Guidelines for Life-Cycle Assessment: a Code of Practice, Edition 1, SETAC, Bruxelles.

SETAC, UNEP (2009): Guidelines For Social Life Cycle Assessment Of Products, SETAC, UNEP, Paris.

Stichnothe H., Hospido A., Azapagic A.(2008): Carbon footprint estimation of food production systems: The importance of considering methane and nitrous oxide, *Aspects of Applied Biology* 87, 2008 - Greening the Food Chain, 3 and 4.

Assessing the environmental performance and eco-toxicity effects of biodegradable mulch films

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ABSTRACT
Novamont is active in the sector of bioplastics and known worldwide for the production of Mater-Bi®, a family of biodegradable and compostable materials containing renewable constituents. The greatest benefits of biodegradable products, both at environmental and economical level, are attained when the biodegradation of the materials positively influences the waste management so to improve the efficiency of the overall system. At the end of their crop cycle traditional plastic mulch films need to be removed and disposed of (up to 400 kg of waste per 6000 m^2 of mulched soil). Thanks to their biodegradation and absence of accumulation and toxicity effects, biodegradable mulch films do not need to be removed from the soil and disposed of. The LCIA results showed that an overall reduction in the potential impacts from 55% to 80% was gained, by replacing traditional plastic mulch film with biodegradable mulch film.

Keywords: mulch films, biodegradability, biopolymer, LCA, eco-toxicity

1. Introduction

Mulch films provide significant agronomic advantages:

- increased yield and higher quality of crops;
- weed control and reduced use of pesticides;
- early crop production (important for crops such as muskmelons, melons, watermelons), due to the higher soil temperature;
- reduced consumption of irrigation water (up to 30 % less water than for bare soil).

Mulch film accounted for 41% of the 3.6 million tonnes of agricultural plastic consumed worldwide in 2007 (Reynolds, 2009). In Italy, the consumption of mulch film was in 2005 about 42,000 tonnes (Picuno *et al*., 2010). In accordance with legislation (Decree 152/08 and further amendments), plastic mulch films must be removed from the field and properly disposed of. This implies collecting and recycling or, where this is not possible, landfilling or incinerating with energy recovery.

The recovered film is heavily contaminated with soil, stones and biological waste which makes mechanical recycling difficult. In general, the contamination of mulch films ranges from 50% to 75% of their initial weight (Sorema, 2008). Occasionally, plastic films are not properly collected and disposed of after their use. Generally the main “illegal” ways for the disposal of plastics are: burning in the field and uncontrolled landfilling. Both practices cause environmental concern (Garthe and Miller, 2006). A valuable solution is given by biodegradable mulch films which show the positive effects of traditional plastic mulch films

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during the cultivation phase without the post-consume removal and disposal (environmental and economic) costs. Mater-Bi® mulch films have been specifically designed for 1 to 9 month crops and their processability is close to that of traditional plastics (Bastioli and Facco, 2001).

2. Research objectives

First aim was, to evaluate the environmental performance of two different mulch film systems (traditional and biodegradable mulch film). The second aim was to demonstrate that Mater-Bi® mulch films are biodegradable and safe for the soil ecosystem.

3. Methodology

Life Cycle Assessment (LCA) methodology was applied for assessing the environmental performance of the systems. The eco-toxicity tests were carried out by external laboratories.

4. The LCA study

The Functional Unit (F.U.) is defined as: "*1 ha of mulched agricultural land*" that corresponds to 6000 m^2 of mulch film (based on average mulching practice). Two scenarios were considered. The "traditional" scenario considers the total amount of film applied and then removed from the soil and disposed of according to the average Italian waste treatment. The "alternative" scenario considers the total amount of biodegradable mulch film applied and left in the soil. Mulch film characteristics are shown in Table 1.

Table 1: Main characteristics of the analyzed mulch film

Mulch films characteristics	Biodegradable mulch film	Polyethylene (PE) film
Thickness [µm]	13	52
Weight [grams*m^{-2}]	16	48
Colour	black	Black

The thickness of PE film was obtained from the consumption of plastic for mulch film in Italy and the covered surface (Picuno *et al.*, 2010). The thickness of biodegradable mulch film is the average of current commercial products (Degli Innocenti *et al.,* 2009). The study was a "Cradle to grave" LCA. A simplified process flow diagram showing the analyzed scenarios can be seen in Figure 1.

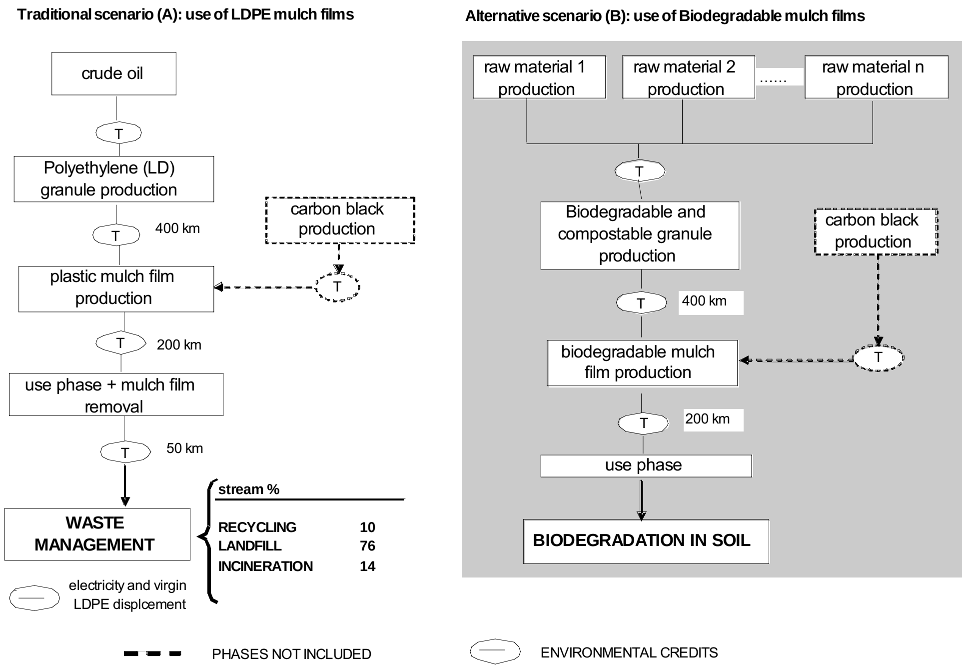

Figure 1: Simplified flow diagram of studied scenario: Traditional (A) and Alternative (B) scenarios

Mulch films are produced through blown film extrusion. The electricity consumption is about 0.4 kWh per kg. Diesel consumption for mulch film lying in the field is about 15 l/ha. Same consumption was considered for the mechanical removal. No complete data about the end of life treatments of plastic mulch films in Italy is available; however, the amount of recycled plastic mulch film is quite low. Only 10% of the original PE film is considered to be recycled (Corepla, 2007). The remaining stream is considered to be disposed of according to the average Italian scenario: 84% landfill and 16% incineration with energy recovery (Osservatorio Nazionale dei Rifiuti, 2004). A sensitivity analysis regarding different End of Life scenarios for non biodegradable mulch film was conducted. Mineralization of biodegradable mulch film was considered to be complete. The following impact categories were used: Acidification (AC), Eutrophication (EU), Photochemical oxidation (POF), Global Warming (GW), Non renewable energy resources (NRER) and Abiotic Depletion (AD).

The impact categories were selected considering that:

1. They are characterized by low uncertainty;
2. They are the most relevant impact categories for plastic materials based on normalization factors (Breedveld *et al.*, 1999).

Moreover about the methods used:

1. International consensus has been reached;
2. The characterisation methods of the different impact categories are scientifically robust, well documented and available.

All waste generated throughout life cycle stages has been included in the system boundary.

5. Biodegradation and eco-toxicity

The suitability of Mater-Bi® to be used as a mulch film was assessed in terms of biodegradability and absence of eco-toxicity and hazardous substances both in composting conditions and in soil. The main standards and certification programs were used as references; namely EN 13432 "*Packaging – Requirements for packaging recoverable through composting and biodegradation – Test scheme and evaluation criteria for the final acceptance of packaging*" for compostability and the programmes "OK2" and "OK10" of the certification institute Vinçotte (Belgium) for biodegradability at low temperature (i.e. "Home composting" and biodegradation in soil). Based on tests results, certificates have been released by the certification institutes Vinçotte (Belgium), DINCERTCO (Germany) and BPI (USA).

6. Results and discussion

In Table 2 "Cradle to grave" LCIA results are shown. Figures in bold indicate the highest impact for each impact category. The granule production phase contributes most to the NRER and GW for both materials. The end of life treatments are significant for PE plastic mulch films. For some impact categories such as EU and AC the PE plastic granule production has a lower/similar potential impact compared to Mater-Bi®. However, since a higher amount of plastic is required for producing the PE mulch film and considering the compulsory removal and the disposal phases, the environmental performance obtained is worse whichever end of life scenario is considered. The overall reduction of the potential impacts when biodegradable mulch film is used as an alternative to non biodegradable plastic ranged from 25 % to 80 %, depending on the impact categories analysed and the end of life scenario for non biodegradable mulch film. The reduction for GW and NRER were about -60 % and -80 % respectively.

Table 2: Life cycle impact assessment "cradle to grave" of 6000 m^2 mulch film (1 hectare of mulched soil)

Impact category ***(method used)***	**Unit**	**Ion biodegradable mulch film**				**Biodegradable mulch film**
		100% incineration	**100% landfill**	**100% recycling**	**IT average scenario**	
AC *(International EPD system)*	kg SO_2 eq	1.83	3.22	**4.66**	3.16	1.40
EU *(International EPD system)*	kg PO_4 eq	0.45	**1.91**	0.76	1.58	0.34
POF *(International EPD system)*	kg C_2H_4 eq	1.52	**1.66**	0.86	1.56	0.31
GW *(IPCC 2007 – 100 years)*	kg CO_2 eq	**1340**	849	1076	943	402
NRER *(IMPACT 2002+)*	MJ eq.	20476	**25831**	19597	24436	5496
AD *(CML 2001)*	kg Sb eq	8.65	**11.08**	8.72	10.49	2.7

The biodegradation and eco-toxicity tests performed on Mater-Bi® mulch films fully satisfied the reference standards. Results are shown in Table 3.

Table 3: Biodegradation and Eco-toxicity tests performed for Mater-Bi® mulch film

Title of study	Description	Origin	Result
Disintegration requirements of EỊ13432			
Study FDI-42 - Pilot-scale composting + sieving test for measurement of disintegration	Disintegration in a pilot-scale aerobic composting test	OWS Belgium	More than 90% by weight disintegration in 3 months. In compliance with **EỊ13432**
Biodegradability and eco-toxicity requirements of EỊ13432			
Study FDI-31- Compostability testing program	Compostability test at 75 µm - Aerobic biodegradation test - Disintegration test - Ecotoxicity test (Summer Barely Plant Growth test, Cress Test)	OWS Belgium	More than 90% biodegradation relative to Cellulose in 6 months. More than 90% by weight disintegration in 3 months. No negative effects on compost quality. In compliance with **EỊ13432**
Study FDI-8/4-5- Compostability Testing programme	Material characteristics (Analysis on heavy metals) - Disintegration and chemical analysis - Ecotoxicity tests (Summer barley plant growth test Cress test)	OWS Belgium	More than 90% biodegradation relative to Cellulose in 6 months. More than 90% by weight disintegration in 3 months. No negative effects on compost quality. In compliance with **EỊ13432**
Quality of final compost: requirements of EỊ13432			
Reports N° 90125-1 and 2090411-002 Elemental analysis according to EN13432	Determination of the Concentration (ppm) of eleven elements (heavy metals and other elements of concern) in the material	COMIE	Heavy metal content (ppm in dry matter): As: < 3.5; Cd:< 0.5, Cu: < 1, Pb: < 5.0, Hg: < 0.5, Ni: < 12, Se: < 0.75, Zn: < 5.0, Cr: < 2.9, Mo: < 1, F: < 50
Vinçotte *Ok Biodegradable Soil* Certification Program			
Study FDI-43 - Dynamic soil biodegradation test	Aerobic biodegradation test in soil at ambient temperature	OWS Belgium	Requirement of testing program “OK 10”: 90% biodegradation relative to cellulose in 24 months at temperature between 20°C and 25°C. Result: 91% biodegradation relative to cellulose in 300days. In compliance with Vinçotte testing program “OK 10”
Additional info concerting composition			
No plasticizer of the phthalate family, no chlorinated compounds, no substances classified as CMR or known to be endocrine disruptors, no substance from the SVHC list published by ECHA are intentionally added to Mater-Bi® grades.			

7. Conclusions

Biodegradable plastics simplify mulch film practice by reducing waste to zero at the end of the crop cycle: on average about 400 kg per mulched hectare[1]. Laboratory and field tests performed by independent Institutes (e.g. OWS Belgium) demonstrated that biodegradable Mater-Bi® mulch films biodegrade in soil and do not produce any toxic effect on it. The

[1] Of which 290 kg of mulch film and the remaining amount of soil, stones, organic residuals.

"Cradle to grave" LCA indicates that the production phase of both materials dominates the environmental impacts. Non biodegradable mulch films must add on that the burden of the end of life treatments. Mater-Bi® biodegradable mulch film provides a valuable option for reducing the potential impacts: lower consumption of plastic required (thanks to the lower thickness), no removal and disposal phase. The overall (i.e. "Cradle to grave") reduction of potential impacts obtained by shifting to biodegradable mulch film is quite significant: from 55 % up to 80 % depending on the impact categories considered. The worse scenario is represented by landfilling of non biodegradable mulch film since neither energy nor material is recovered. This research, performed in 2009 within the Agri-food sector task force activities related to the Italian network on LCA (ENEA - Bologna), represents a preliminary LCA study based on high quality primary data that were collected and calculated for Mater-Bi® biodegradable mulch films (2009).

Acknowledgements. *Many thanks to all people of Ecology of Products and Environmental Communication (ECOPEC) group of Ịovamont for having provided valuable suggestions and Tony Breton for proof reading the manuscript.*

8. References

Bastioli C., Facco S. (2001): Mater-Bi® starch based materials: present situation and future perspectives. Biodegradable Plastics 2001 Conference. Frankfurt, Germany, November 26-27, 2001.

Breedveld L. *et al.* (1999): A Framework for Actualising Normalisation Data in LCA: Experiences in the Netherlands. *International Journal of LCA*. 4(4), pp. 213-220.

Corepla (2007): Quantità riciclate e budget 2007 http://www.corepla.it/articolo.jsp?IdDoc=27&ignoreGest=true

Degli Innocenti F. *et al.* (2009): Pacciamatura considerazioni ambientali. Italian Congress: I materiali biodegradabili in agricoltura Soluzioni sostenibili attuali e future. University of Bologna November 12, 2009 (http://agronotizie.imagelinenetwork.com/agrotecnologie/materiali-biodegradabili-dalla-ricerca-al-campo-08497.cfm).

Garthe J. W., Miller B. G. (2006): Burning High-Grade, Clean Fuel Made from Low-Grade Used Agricultural Plastics. 21st International Conference on Solid Waste Technology and Management. Philadelphia, USA, March 26-29, 2006 (http://www2.widener.edu/~sxw0004/21proceedings.html).

Osservatorio Nazionale dei Rifiuti (2004): Rapporto rifiuti 2004. (http://www.apat.gov.it/site/it-IT/APAT/Pubblicazioni/Rapporto_Rifiuti/).

Picuno, P., Sica C., Scarascia Mugnozza G. (2010): La gestione dei rifiuti plastici agricoli. Problematiche ambientali e soluzioni tecnologiche (prima parte). *Colture Protette*. March 2010, pp. 73–76.

Reynolds A. (2009): Agricultural film markets, trends and business development. The International Conference for the Agriculture and Horticulture Film Industry, Agricultural Film 2009. Barcelona, Spain, February 24-26 2009.

Sorema (2008): Recycling schemes for thin mulching agricultural film. Analysis of the process and application examples. International Congress Plastic & Agricolture. MACPLAS 2008. Bari, Italy, February 21-22, 2008 (http://www.macplas08.org/).

Life Cycle Assessment of an urban wastewater tertiary treatment plant

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ABSTRACT

Water is a precious and increasingly scarce resource especially in regions like Apulia in Italy, characterized by water shortage for agriculture and, in some cases, even for drinking purposes. Farmers partly resolve this shortage problem by drilling water wells with subsequent groundwater overexploitation and seawater intrusion. Since the Ministerial Decree n. 185/2003 has been adopted, it is allowed to reuse urban wastewaters subjected to an advanced tertiary treatment for agricultural, civil and industrial use. However, the existing regional grid of urban wastewater treatment plants lacks such an advanced tertiary treatment step; particularly suitable disinfection units are lacking, in order to reach the quality parameters of reused water. Regional authorities are now planning to adapt the disinfection units in the existing tertiary treatment plants of urban wastewater and to finance research projects supporting the selection of the best environmental friendly technology among various possibilities. This paper aims at describing the LCA of an advanced tertiary treatment plant for wastewater reclamation in Apulia mapping the impacts of urban wastewater reuse compared to groundwater use.

Keywords: LCA, wastewater, reclamation, tertiary treatment, disinfection

1. Introduction

Italy is considered a water-stressed country by the European Environment Agency (European Environment Agency, 2005), like Spain, Cyprus and Malta, as withdrawals are greater than 20% of total available supplies of water. Spain is planning to prevent shortages with plans for a large network of desalination works and the implementation of more efficient irrigation systems. In Italy a strategy strengthening the water reuse potential of existing urban wastewater treatment plants has been adopted: the Ministerial Decree n. 185/2003. With this Decree it is nation-wide allowed to reuse urban wastewaters for agricultural, civil and industrial uses, if subjected to an advanced tertiary treatment.

Apulia, a southern-east region in Italy, extends for 19,400 km^2, with 834 km of coasts and a population of about 4 million inhabitants. It has an annual rainfall lower (660 mm/y) than the national average (980 mm/y) (Lopez, *et al.*, 2008). Only part (15–20%) of these scarce water resources are actually available mainly because of the lower rainfall than the national average and out of date water distribution systems. For these reasons, Apulia owns one of the smallest amounts (136 m^3/capita/year) of potentially available water resources in the south of Italy, while most of Apulia's land is used for agricultural purposes (15,250 km^2). The economy of the region basically relies on water demanding activities: agriculture, tourism, a steelmaking factory, oil refineries. Water is supplied by the regional water agency (AQP: Acquedotto Pugliese) and by water irrigation consortia. Nevertheless there exists a negative

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gap in water needs for irrigation of about 700 Mm^3, which is partly covered by water well drillings by farmers. Due to groundwater overexploitation and the proximity to the sea, some water wells are experiencing sea water intrusion with subsequent unavailability of freshwater for irrigation purposes.

Regional authorities promulgated a "Water Resources Protection and Management Master Plan" that drastically restricts water well drillings and on top of that aims for a strategic reuse of treated municipal wastewater in agriculture as well as in the industry (SOGESID, 2007). In Apulia there are 197 urban wastewater treatment plants, 186 are managed by AQP and 40 of them have been identified as suitable for water reuse, as they can comply with quality requirements of reclaimed water. Among these 40, 13 plants are currently eligible for reuse and 27 need additional improvements or are new construction.

The most important improvement needed is the construction of advanced tertiary treatment systems with appropriate disinfection units complying with quality requirements of reclaimed water as stated in the Ministerial Decree and in the Regional Plan.

One of the projects assessing the best options for such advanced tertiary treatment systems is "SIRPAR" (Integrated Strategies for Urban Wastewater Reclamation in the Apulia Region). The project is financed by regional authorities and the partners involved are a number of water treatment companies, the University of Bari Aldo Moro, the Polytechnic of Bari and ENEA (Italian Agency for the New Technology, the Energy and the Environment). The general goal of the research project is to acquire the knowledge necessary to choose and manage the advanced tertiary treatment needed by the specific wastewater treatment plant to reach the quality requirements of the regional plan and to implement new and unexplored solutions. The staff of the University of Bari "Aldo Moro" has been mandated to study the sustainability of the options for water reuse.

The plant for which the disinfection options for tertiary treatment are assessed is situated in Fasano Forcatella, in the Brindisi Province, right at the border of the Adriatic Sea. Groundwater abstraction of aquifers is chosen as reference technology for water supply in a no-reuse scenario.

2. Application of LCA

2.1 Goal, scenarios assessed, function and functional unit, Life Cycle Impact Assessment methodology

The goal of this case study is to assess the environmental advantages and drawbacks of urban wastewater reclamation in agriculture, particularly concerning the choice of the best environmental option for irrigation. The following scenarios have been considered (figure 1):

1. Irrigation with groundwater withdrawals from water wells in the area of Fasano Forcatella: a deep well and a superficial well.
2. Irrigation by reused waste water treated in an urban wastewater treatment plant including an advanced tertiary treatment system.

The basic assumption has been to consider the construction and dismantling of the plant negligible with respect the use phase according to literature in similar cases (Pillay *et al.*, 2002). Emissions to the sea were not considered at this stage in this study yet. Actually emissions to sea after the secondary treatment should be included as part of scenario 1 and compared to emissions to soil and then to sea after tertiary treatment and irrigation as part of scenario 2.

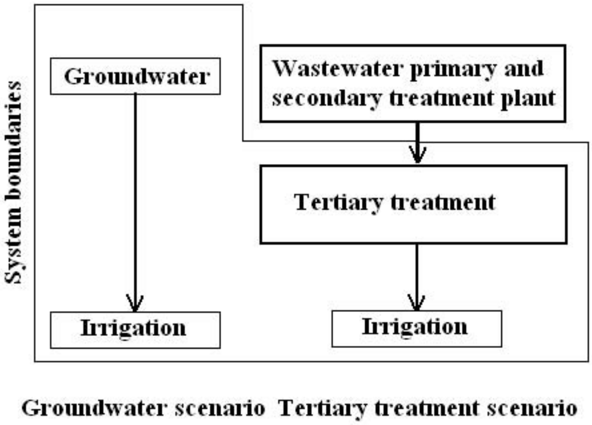

Figure 1: System under study and scenarios assessed.

The function of the system under study is defined as "supplying the agriculture production system with water for crop irrigation". The functional unit of the system is the provision of 1,000 m^3 of water for irrigation which complies with limits stated by the Ministerial Decree n. 185/2003 and by the regional water resources protection and management master plan. We have applied the CML baseline characterisation factors (Guinèe *et al.*, 2002) for all relevant impact categories.

2.2 Inventory analysis

The tertiary treatment plant under study can produce a maximum of 8,000 m^3/day of reclaimed water and is connected to a distribution grid of about 30 km that can deliver 1 m^3/min of water with a pressure of 3 atm, to serve 500 hectares (30% of surface cultivated as vegetables and 70% as olives) and sustain a maximum demand of 1 Mm^3/year.

The primary treatment consists of a grilling step to remove solids and sand while the secondary treatment of an activated sludge with denitrification line, both are carried out in a plant with total dimension of 50,000 person equivalent, located very close to the tertiary treatment plant. Tertiary treatment in the plant under study consists of coagulation and flocculation of suspended solid particles. It is followed by sedimentation and a post treatment with sodium hypochlorite and UV, both of which can be separately activated depending on the bacterial content of the influent. The total treatment and accumulation basin has a capacity of 6,000 m^3 (Figure 2). For the comparison of the different scenarios, all processes taking place in the wastewater treatment plant (primary and secondary) are excluded, as these are considered to be qualitatively and quantitatively equal for all scenarios (difference analysis; cf. Guinée et al., 2002). The transport of reclaimed water and groundwater to the user is not included as this depends on the extension of the irrigated areas. The production of the chemicals is included (Akifloc, modelled from hydrochloric acid and aluminium hydroxide reaction, according to data provided from "Braia" manufacturer, and NaClO), as is transport of the chemical to the plant site and production of UV lamps. As the manufacture of the UV lamps lacks in databases, an useful approximation, once its various components had been sourced in the raw materials stage, would be that of the assembly of an LCD screen, because an LCD screen is also a complex electrical product, involving circuits and components that are assembled, and because the manufacturing impacts are expressed on a basis of kg of screen produced as in the case of the UV lamps (Department for Environment, Food and Rural Affairs, 2009). Disposal of lamps has been modelled with the same plants used in the case of fluorescent lamps assuming 100% of recycling with no direct reuse of the recycled materials in the manufacture of new lamps. Emissions of trace pollutants to agricultural soil through the use of reclaimed water and groundwater have been excluded as both the qualities of reclaimed water and groundwater comply with the requirements for irrigation. Sludge is landfilled without any treatment, with biogas production but no electricity generation. The analysis of chemical and energy consumption data collected on the plant are reported in figure 2, considering the evaporation loss of water and the rainfall loadings as negligible.

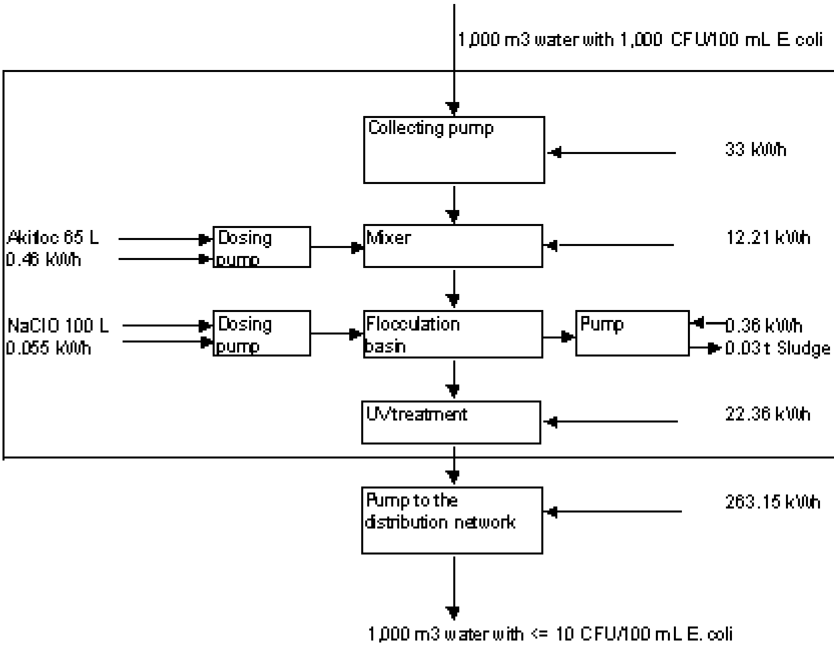

Figure 2: Flux diagram of the plant under study and system boundaries.

Table 1: Inventory of material and energy requirements for each scenario per functional unit.

Inputs from technosphere	Scenario		
	Groundwater (deep well)*	Groundwater (superficial well)*	Reclaimed
Electricity (kWh)	1,333	148	68.45
Flocculant (kg)	0	0	89.05
NaClO 18% (kg)	0	0	120
UV Lamps	0	0	0.12
Water from WWTP	0	0	1,000
Groundwater	1,000	1,000	0

*Depth of water level: superficial 33 m, deep 70.5 m; pump type: superficial – Robuschi, H=36.5 m, flow=27 m^3/h, 4 kW; deep – Rovatti, H=75 m, flow=0.9 m^3/h, 1.2 kW.

Background inventory data for production of chemicals, constituting components of UV lamps, electricity from the Italian grid and road transport have been obtained from the Ecoinvent database version 2.0 (Frischknecht *et al.*, 2007), from BUWAL and GaBi databases, from literature and from the operators of the plant. GaBi 4.3 software from PE International has been used. Table 1 shows the inventory of the technosphere processes for each scenario.

3. Results and discussion

In table 2 the selected impact categories analyzed reveals that the deep well option performs worst, due to emissions related to the generation of the electrical energy with the Italian grid mix, except for Radioactive Radiation, in which emissions are related to the production of chemicals. Increased purchase of renewable energy will improve the potential indicator results but probably will not perform better than the superficial well and reclaimed scenarios.

Table 2: Impact potentials for each scenario, per functional unit.

Impact potential	Units	Scenario		
		deep well	**superficial well**	**Reclaimed**
Abiotic depletion	kg Sb-eq	5.06	0.56	0.71
Acidification Potential	kg SO_2-eq	7.29	0.81	0.71
Eutrophication Potential	kg Phosphate-eq	0.27	0.03	0.11
Freshwater aquatic ecotoxicity potential	kg DCB-eq	12.4	1.38	0.75
Global Warming Potential, 100 years	kg CO2-eq	828	92	132
Human Toxicity Potential	kg DCB-eq	140	15.6	9.4
Marine aquatic ecotoxicity potential	kg DCB-eq	219,210	24,338	14,904
Photochemical ozone creation potential	kg ethene-eq	0.83	0.09	0.07
Ozone layer depletion pot.	kg R11-eq	4.7e-4	5.2e-5	2.8e-5

In the “reclaimed” scenario, abiotic depletion is affected 37% by electricity generation, 35% by flocculant production, 27 by transportation. 54% of the acidification impact potential is related to electricity generation, 25% to transportations, 19% to flocculant production. Eutrophication potential impact category is mainly affected by air emissions related to landfilling (48%), transportation (28%), electricity generation (13%), and flocculant production (8%). For the impact category global warming the major contributions are traced back to the production of electricity; the emissions to air resulting from this process are the main contributors, electricity production accounts for about 33%, flocculant production for 30%, transport for 21% and landfill of sludge about 15%. Freshwater aquatic ecotoxicity impact category is mainly affected by water emissions related to electricity generation (88%) and flocculant production (7%). Human toxicity potential impact category is mainly affected by electricity generation (79%), flocculant production (10%) and transportations (10%). Marine aquatic ecotoxicity potential impact category is affected mainly by electricity generation (78%) and flocculant production (18%). Photochemical ozone creation potential impact category is mainly affected by electricity generation (59%), flocculant production (14%), transportation (20%) and landfilling (7%). Ozone layer depletion potential impact category is mainly affected by electricity generation (87%) and flocculant production (13%). Lamp production doesn't significantly contribute to any of the impact categories examined. Little differences exists between reclaimed and superficial well scenario but the latter suffers higher levels of salinity in the water extracted (deep well: 468 mg/L Cl^-, superficial well 3,472 mg/L Cl^-) and is subjected to groundwater depletion and subsequent seawater intrusion.

4. Conclusions

Water extraction from deep well suffers severe environmental impacts due to electricity generation primarily from non renewable resources as is the case of the Italian energy grid mix. The superficial well and reclaimed scenarios have quite the same environmental impacts (chemicals and lamps production and transportation, doesn't affect significantly the environmental profile of the reclaimed scenario) but extraction of groundwater from superficial well will suffer groundwater depletion impact and salinization of irrigated area. Moreover the superficial well is closer to sea and will suffer of seawater intrusions that worsen the water quality upon abstraction.

With these assumptions urban wastewater reclamation seems at the moment the best environmental friendly choice in every case, bearing the limitation of this study in mind. A method for assessing the environmental impact of groundwater consumption should be used to evidence this claim.

5. References

Department for Environment, Food and Rural Affairs (2009): Life Cycle Assessment of Ultra-Efficient Lamps Navigant Consulting Europe, Ltd. A research report completed for the Department for Environment, Food and Rural Affairs, 5th May 2009, Department for Environment, Food and Rural Affairs Nobel House 17 Smith Square London SW1P 3JR, www.defra.gov.uk

European Environment Agency (2005): The European environment: state and outlook. Part A: integrated assessment, pp. 112-131: http://reports.eea.europa.eu/state_of_environment_report_2005_1/en.

Frischknecht R., Althaus H., Doka G., Dones R., Heck T., Hellweg S., *et al.* (2007): Overview and methodology. Final report ecoinvent v2.0 No. 1, Swiss Centre for Life Cycle Inventories, Duebendorf, Switzerland.

Guinée J.B. (Ed.), M. Gorrée, R. Heijungs, G. Huppes, R. Kleijn, A. de Koning, L. van Oers, A. Wegener Sleeswijk, S.Suh, H.A. Udo de Haes, J.A. de Bruijn, R. van Duin and M.A.J. Huijbregts (2002): Handbook on Life Cycle Assessment: Operational Guide to the ISO Standards. Series: Eco-Efficiency in Industry and Science, Vol. 7. Springer. Dordrecht.

ISO 14044 (2006): Environmental management life cycle assessment requirements and guidelines, Geneva, Switzerland.

Lopez A., Vurro M., (2008): Planning agricultural wastewater reuse in southern Italy: The case of Apulia Region, *Desalination*, 218, pp. 164-169.

Pillay S.D., Friedrich E., Buckley C.A., Life Cycle Assessment of an industrial water recycling plant, *Water Science and Technology*, 46 (9), pp. 55-62.

SOGESID S.P.A. (2007): Piano di Tutela delle Acque della Regione Puglia, Relazione Generale, Delibera di Giunta Regionale n. 883/07, 19 June 2007, Official Bullettin of Apulia Region n. 102, 18 July 2007, www.regione.puglia.it.

Environmental benefits of anaerobic digestion of biological wastes in the COOP cattle-meat supply chain

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[2]Life Cycle Engineering

ABSTRACT

For many years, COOP Italia has defined long-term policies with suppliers to reach the best economic and technical conditions in the production of house brand products. Among the most important of such policies in terms of development in regards cattle meat. Aside from the standard actions regarding the main operations of the chain (e.g. animal feeding and farms management) COOP, in cooperation with some of the relevant players of the supply chain, is promoting the anaerobic digestion of biological waste (manure and slaughterhouse waste) in order to reduce overall environmental impact. This paper shall present a real case study consisting in an LCA project performed to quantify the environmental impacts of the whole chain, both before and after the start up, of the digestion plants installed in a farm of about 15,000 bred cattle per year. One of the main results shows a reduction of about 15% of carbon dioxide equivalent emissions.

Keywords: meat production, manure management, anaerobic digestion

1. Introduction

During recent years, COOP Italia, in cooperation with Life Cycle Engineering (Baldo *et al.* 2008), has implemented several Life Cycle Assessment studies (LCA) to investigate the environmental aspects of the production chain and to plan necessary investments aimed at improving the environmental performances over medium and long term intervals.

This paper focuses on the analysis of the cattle meat production chain with particular regard on manure management. The later, in relevance to cattle farms, constitutes one of the main factors that inflicts greatest environmental impacts in terms of greenhouse effect.

The LCA approach has been applied to compare the use of manure as fertilizer in agriculture with the anaerobic digestion process, which is considered the best process to produce energy from renewable resources to cut down on fossil fuel consumption.

2. Methods

The Life Cycle Assessment was performed following the international standards ISO 14040 series (EN ISO, 2006).

According to ISO 14040 (2006), an LCA is comprised of four main stages: goal and scope definition, life cycle inventory, life cycle impact assessment, and interpretation of the results. Goal and Scope Definition is aimed at identifying the objectives, functional unit, system boundaries, cut-off criteria, data sources and data quality requirements.

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Life Cycle Inventory (LCI) consists of a detailed collection of all the environmental inputs (material and energy) and outputs (air, water and solid emissions) at each stage of the life cycle.

Life Cycle Impact Assessment (LCIA) aims at quantifying the relative importance of all the environmental burdens identified in the LCI by analysing their influence on selected environmental effects. It has been focused on the mandatory elements (classification and characterisation).

The indicators evaluated are: GER (Gross Energy Requirement), GWP_{100} (Global Warming Potential), AP (Acidification Potential), EP (Eutrophication Potential), ODP (Ozone Depleting Potential). However, due to the scope of this paper, only GER and GWP_{100} are reported given their highly representative nature in this field of study.

The characterisation factors of GWP_{100} come from IPCC 2007 (Forster *et al.*, 2007); while the characterisation factors of GER come from International EPD Cooperation IEC (2008).

The final step of the LCA methodology involves the interpretation of LCI and LCIA stages, in order to find hotspots and compare alternative scenarios.

The SimaPro 7.1.8 software application and the Ecoinvent 2.01 (2007) database were used in this study to implement the LCA model and carry out the assessment.

3. Goal and scope

The aim of the study is to evaluate the environmental impacts related to breeding activities and cattle meat production with particular regard to manure management. Furthermore, the scope of the study also includes the identification of future areas of investment to improve the production chain's environmental performances on both a medium and long term timeframe.

One of the largest cattle farm suppliers of COOP Italia was involved in the study to help facilitate scope achievement.

The farm has a capacity of about 15,000 cattle per year and it is based on an open-loop system because it receives calves from French Farms after the weaning period and develops the growth phase before slaughter.

Since the start of 2008, the farm has implemented a digestion plant for treating about 80,000 tons of manure per year. The plant became operational in 2009.

In order to compare the environmental aspects of farms that employ the anaerobic digestion process and those that do not,, two scenarios are investigated:

- Traditional scenario, where manure is used in agriculture as fertilizer; and biological waste from slaughterhouses are sent to an incineration plant (Figure 1)
- Anaerobic digestion scenario, where both manure and biological waste coming from slaughterhouses are used in an anaerobic digestion process to produce energy (Figure 1)

4. System description

The functional unit of the LCA developed is *the production of 1 kg of bone - free meat over one year*; the system boundaries considered are those represented in Figure 1.

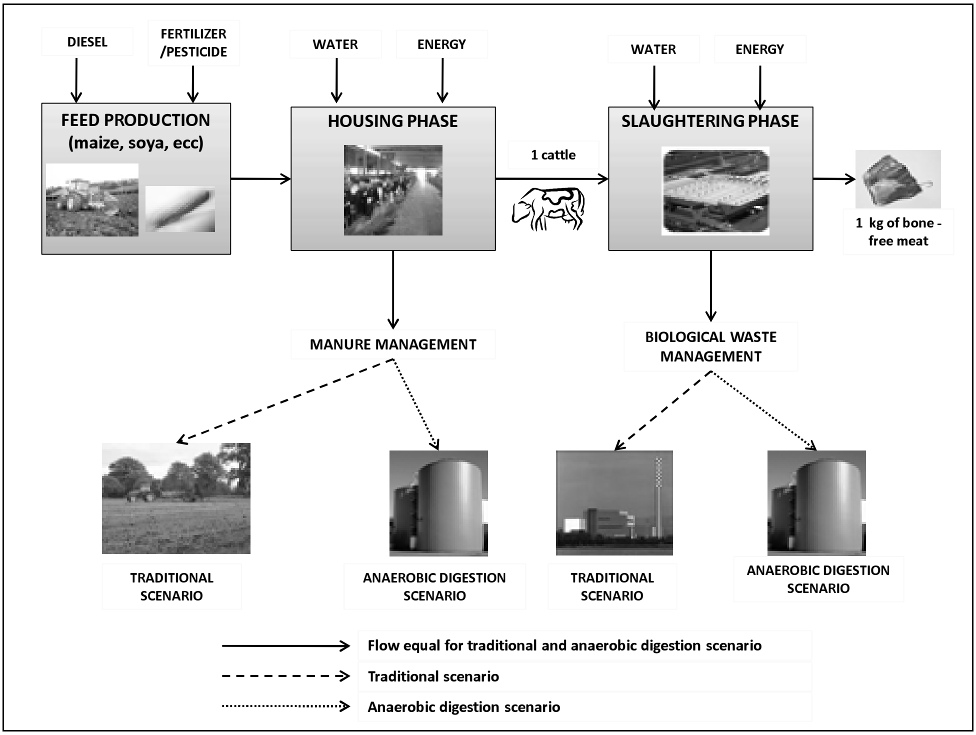

Figure 1: System boundaries related to 1 kg of bone - free meat

Feed production. This phase takes into considerations each environmental aspect related to feed crop, such as water consumption, diesel consumption, fertilizer used, air, water and soil emissions; feed are given to cattle in different type and quantity depending on the breeding period.

Housing phase.

This phase lasts about seven months because it accounts for only two breeding phases: post – weaning and fattening period; the weaning period is not considered in the ambit of this study. In this phase all features related to farm management (electricity and water consumption, waste production and feed management) are considered.

Slaughtering phase.

Cattle are slaughtered when they reach a weight of about 600 - 700 kg. The considered slaughtering yield to obtain bone-free meat is 45% (300 kg of meat from 1 cattle).

Biological waste originating from the slaughterhouse (cattle rumen and blood) is handled in two different manners:

- in the traditional scenario it is sent to an incineration plant
- in the anaerobic digestion scenario itis treated in an anaerobic digester together with biological sludge.

Manure management.

Manure is analyzed under two different destinations:

- use of manure in agriculture as fertilizer (traditional scenario)

- manure disposal in the anaerobic digester to produce energy (anaerobic digestion scenario)

The first scenario involves the storage of manure to obtain a stabilized product ready for the use in agriculture followed by its spreading on the ground. The main element considered in this scenario is given by the air, water and soil emissions evaluated, in consideration of an average manure composition and emission factors indicated by ISPRA (ISPRA, 2008).

The second scenario involves the anaerobic degradation of manure in a specific digester installed with the aim of producing biogas. The plant in question can produce 88 m^3 of biogas and 300 kg of stabilized fertilizer derived from manure (data per ton of treated manure). After the anaerobic digestion, the stabilized fertilizer is left on a composting platform for 180 days. The emissions due to this phase are considered in the model.

For each scenario analysed cattle enteric fermentation is included in the system boundaries and is considered equal to 44.72 kg of CH_4 per head per year (ISPRA, 2008).

Taking a closer look at detail, the data accounted for (Type and sources) in the LCA model is reported in Table 1.

Table 1: Description of type and sources of data used in the LCA model

Phase	Type of data	Data sources
Feed production	Secondary data	Ecoinvent database[1]
Housing	Primary data	Interviewed farm by dedicated questionnaire
Slaughtering	Primary data: anaerobic digestion process of biological waste Secondary data: cattle slaughtering and biological waste incineration	Primary data: anaerobic digestion plant Secondary data: BREF documents (European Commission, 2005)
Manure Management	Primary data: anaerobic digestion process Secondary data: manure management when used as fertilizer (air and water emissions)	Primary data: interviewed farm and society that has projected and realized the anaerobic digester Secondary data: Ecoinvent database and ISPRA inventory report (ISPRA, 2008)

5. Results

For each scenario analysed, the main contribution to the Global Warming Potential is due to (Figure 2):

- Feed production
- Enteric fermentation
- Manure management

Comparison of the two scenario results in terms of GWP_{100} shows a total reduction of CO_2 equivalent emission of about 15% in the anaerobic digestion scenario.

This reduction is due to several factors:

- lack of N_2O emissions, generated by the spreading of manure in agriculture as fertilizer
- use of biological anaerobic digestion instead incineration for disposal of slaughterhouse waste
- fossil resource saving and use of biogas instead of traditional energy sources

[1] http://www.ecoinvent.ch/

Results in terms of GWP_{100} and GER are reported respectively in Figure 2 and 3.

On the grounds of these results, COOP Italia intends to raise the awareness of its suppliers on the environmental benefits correlated to the anaerobic digestion of manure and biological waste in order to apply this process to the whole supply chain.

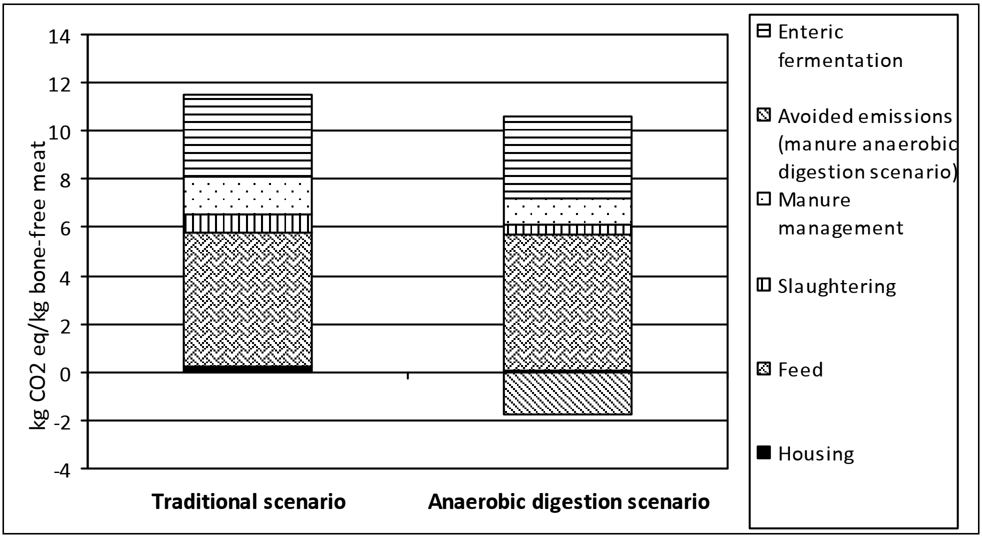

Figure 2: Greenhouse gases emission per kg of bone-free meat

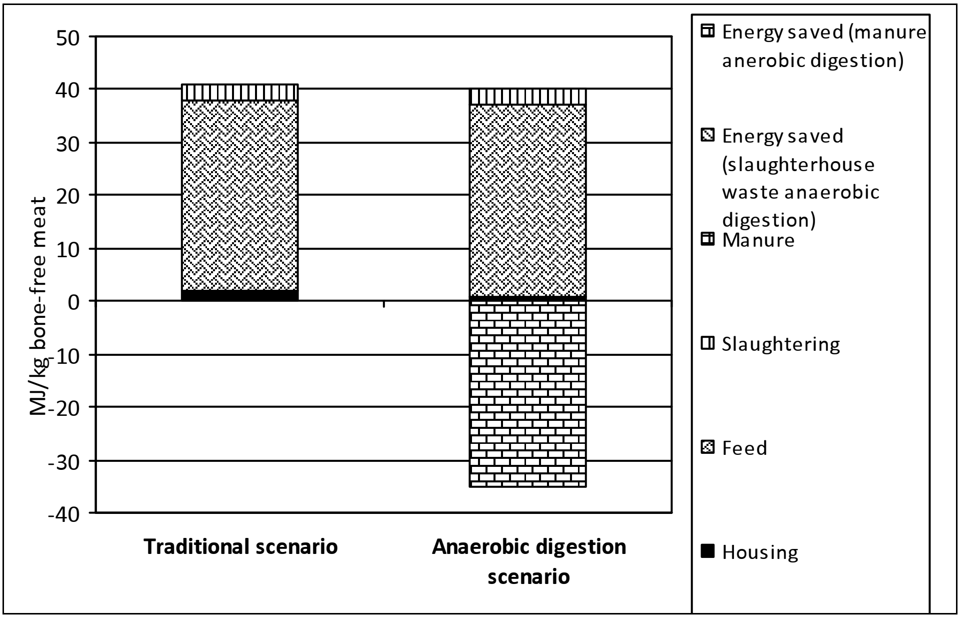

Figure 3: Energy consumption per kg of bone-free meat

6. Conclusions

The application of the LCA methodology has made it possible to determine the weak point of the product chain, further allowing the identification of areas of future investment aimed at improving the environmental and economical performance of the chain itself.

In regards to this study, manure management constitutes one of the main weak points of the chain; therefore, may be improved overall. For example, use of the anaerobic digestion process may lead to great benefits, as confirmed by the following summarized results:

- The use of energy, generated from burned biogas (generated by the manure anaerobic digestion process) implies a reduction in energy consumption. Consequently emissions of greenhouse gases in the anaerobic digestion scenario decrease of about 15% in comparison to the traditional scenario;
- Anaerobic digestion of slaughterhouse cattle waste (rumen and blood) shows that obtainable energy-savings are rather low. The only environmental benefits that can be associated to the slaughtering phase are: waste reduction because rumen, blood and sludge are sent in an anaerobic digester and the reduction of CO_2 equivalent emissions (about 2-3%) by using incineration disposal;

7. References

Baldo G., Marino M, Rossi S. (2008): Analisi del ciclo di vita LCA, gli strumenti per la progettazione sostenibile di materiali, prodotti e processi, Edizioni Ambiente;

European Standard, Environmental management - Life cycle assessment – Principles and framework (EN ISO 14040:2006);

European Standard, Environmental management - Life cycle assessment - Requirements and guidelines (EN ISO 14044:2006);

Forster P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz and R. Van Dorland, 2007: Changes in Atmospheric Constituents and in Radiative Forcing. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA;

Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA), Agricoltura, Inventario nazionale delle emissioni e disaggregazione provinciale, report n°85/2008;

International EPD Cooperation IEC (2008): Supporting Annexes for Environmental Product Declarations, EPD — Version 1.0 dated 29/02/2008, annex B (www.environdec.com);

European Commission (May 2005), Reference Document on Best Available Techniques in the Slaughterhouses and Animal By-products Industries (http://eippcb.jrc.ec.europa.eu/reference/sa.html);

The LCA approach as a tool to improve the environmental sustainability of the aquaculture sector

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ABSTRACT
Fish farming implies high costs in terms of energy and materials, as well as various environmental impacts depending by farming typology: anyway, when tanks are used, great attention should be paid to the feed and dissolved oxygen supplies. Fishing and packaging phases must also be taken into account: for instance, different design solutions can significantly reduce the environmental costs associated. Basing on these assumptions, the present work has concerned the fish farming "Il Padule" located in Grosseto (Italy) within a natural reserve: the high value of the environment requires specific attention and care to preserve it, therefore the LCA methodology has been applied. The results have highlighted that over the 50% of the total CO_2 equivalent emissions are caused by the feeding process: with the aim to improve the study, future developments should include the modelization of the feed production chain within the boundaries of the analysed system.

Keywords: Life Cycle Assessment, greenhouse gases emissions, aquaculture, sea bass farming

1. Introduction

During the last decades the agro-food sector in general and the aquaculture in particular have paid more and more attention to food safety and quality (Grigorakis, 2007; Poli et al., 2001; Recchia, 2007), not just following the rules of the sector, but also adopting voluntary guidelines and certification (Schau, 2007). On 2006 the BAT (Best Available Techniques) have been issued, supplying indications able to reduce energy and water consumption, as well as to limit the production of wastewater and wastes. According to this approach, an increased interest in the application of the LCA methodology to agro-industrial chains is developing: the LCA allows to quantify and evaluates the environmental sustainability associated with a specific production process and looked forward to the future forms of the environmental certification (Pelletier, 2007). Fish farming implies high costs in terms of energy and materials, as well as different environment impacts depending by farming typology: anyway, when tanks are used, great attention should be paid to the feed and dissolved oxygen supplies (Aubin, 2009; Ayer et al., 2009), considering that the quantities may vary significantly during the year because of different climatic conditions (e.g. temperature). In addition, the energy consumption due to tanks management plays an important role (Aubin, 2009; Ayer et al., 2009), either directly for pumps, materials transport, etc., either indirectly related, for example, to the wastewater treatments. Fishing and packaging phases must also be taken into account, with particular attention to the used materials: often different design solutions can significantly reduce the environmental costs associated.

Basing on these assumptions, the present work has concerned the fish farming "Il Padule" located in Grosseto (Italy) within a natural reserve: the high value of the environment needs

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constant attention and care to preserve it, therefore an evaluation of the pressures due to the industry is needed. Particularly, LCA results have highlighted that over the 50% of the total CO_2 equivalent emissions are caused by the feeding process (Aubin, 2009; Ayer et al., 2009), therefore future developments should include the modelization of the feed production chain within the boundaries of the analysed system.

2. Data inventory

2.1 Description of the fish farming

The fish farming "Il Padule" (see Figure 1) is semi-intensive, with low concentration of sea bass per m^3, water supply exclusively from surface water, large size of the final product (1 kg) and a production cycle of about 5 years. The farm insists on the edge of the marshes of Castiglione della Pescaia (Grosseto, Italy), also called Diaccia Botrona, in a natural reserve with international relevance. The plant covers an area of about 70 hectares and adopts a technology that provides water control and purification through large pounds. All the 15 tanks for rearing have an area variable from a minimum of 1000 m^2 for the fry to over 5000 m^2 for the adults, allowing fishes to swim with great freedom. In addition, the use of liquid oxygen supports the respiratory needs of fishes and the natural self-purification process of water, even if it affects production costs, especially energy costs, for the presence of 268 pumps by 1.5 HP each. The operative time of rearing is long because the water temperature is conditioned by the environment and consequently in winter, when temperature decreases below 10°C, fishes do not eat reducing growth rates.

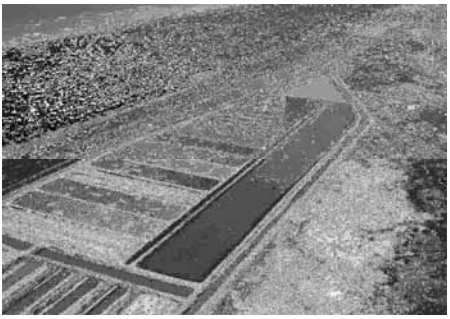

Figure 1: Area of the fish farming “Il Padule” (Grosseto, Italy).

2.2 Data collection and analysis

The work done for the case study has permitted to quantify the energy requirements in terms of electricity consumption and of feed, oxygen and medicines used during the production process of sea bass in 2009.

Figure 2 shows the minimum energy consumption during January, February and December: in this period, also feed and oxygen consumptions are minimal, since the low water temperatures induce the fishes to reduce their metabolism, requiring less feed and less oxygen. For the remaining nine months, slightly higher values are detected in March and April, and much more higher from May until November. The peak value is during the summer months, when the use of oxygen and feed demand are higher. Moreover, in this period lower precipitations imply the use of three pumps (by 45, 30 and 10 kW) located upstream of the plant, with the aim to limit the eutrophication process. The consumption of liquid oxygen follows the trend of the electricity demand, with more pronounced variability among the coldest months and the warmest ones (see Figure 3).

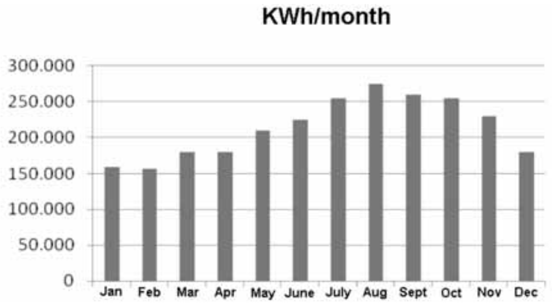

Figure 2: Average monthly energy consumptions in "Il Padule" in 2009.

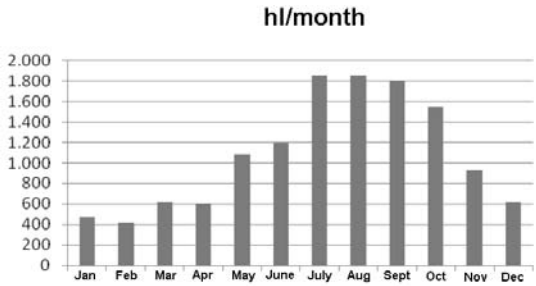

Figure 3: Average monthly oxygen consumptions in "Il Padule" in 2009.

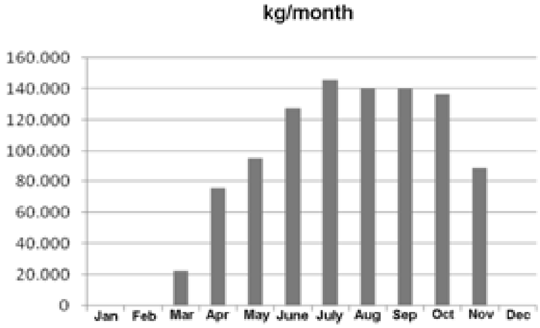

Figure 4: Average monthly feeding in "Il Padule" in 2009.

Finally, Figure 4 shows the requirement of feed: also in this case, the average monthly amounts follow a trend influenced by the ambient temperature. Particularly, the optimal value of temperature to ensure good levels of feeding is between 23°C and 30°C, even if up to 10°C animals are able to eat: therefore, the months of December, January and February usually do not require feed distribution. The medicated feed is distributed for a period of about ten continuous days per year in each tank: the impact of medicated feed on total feed amounts is equal to 1% and it may be considered negligible for the level of detail of the present work. Data reported in Table 1 shows the electricity consumption, the oxygen demand and the feed requirement per kg of the whole fish and of the filleted fish. In addition, the quantities of medicines, referred to the active ingredient, remain negligible.

Table 1: Consumptions of electricity, oxygen and feed for “Il Padule”.

Inputs	Units	Values for whole fish	Values for fillets
Electricity	kWh/kg	5.70	12.13
Oxygen	l/kg	2.89	6.15
Feed	kg/kg	2.12	4.51
Medicines			
- trimetoprim	kg/kg	$2.79 \cdot 10^{-4}$	$5.93 \cdot 10^{-4}$
- copper	kg/kg	$2.32 \cdot 10^{-7}$	$4.94 \cdot 10^{-7}$

The inventory phase has not considered the following inputs: overhead (e.g. energetic consumptions associated to buildings, offices, homes, etc.); packaging; transport of material inputs used during the production process; transport of fish produced to the point of sale; medicines supplied to fishes; algae removed from the tanks during cleaning operations; dead fishes disposal. Packaging and transport may play an important role for evaluating the environmental impacts associated with the production chain: therefore, the future development of a complete and detailed LCA must include the inputs associated to these phases during the inventory. Regarding algae and dead fish to be disposed during the year, no experimental data were available.

3. LCA results

Figure 5 reports the flowchart of materials and energy for the production chain of sea bass from "Il Padule" farm. As previously discussed, only electricity, oxygen and feed have been considered; but these data are a good basis for future implementations of a complete LCA. For quantification of CO_2 equivalent, the following conversion factors have been used:

1) for production of liquid oxygen, 351.50 gCO_2eq/kgO_2, considering the process "Xtra-generic\O2(liquid)" in GEMIS 4.5;
2) for production of electricity, 453.35 gCO_2eq/kWh, considering the process “el-generation-mix-IT-2010” in GEMIS 4.5;
3) for production of feed, 2646.20 $gCO_2eq/kgfeed$ as reported in (Aubin et al., 2009).

Particularly, the characteristics of the feed used in “Il Padule” have been compared with these of the feed indicated in (Aubin et al., 2009), as shown below in Table 2. The calculation of the environmental pressures caused by the production of the feed used in “Il Padule” would require a more detailed approach, so it was decided to use appropriate data from literature. Values reported in (Aubin et al., 2009) have been considered adequate because, in the reference, the feed is used for sea bass farming, even if with different methods of rearing, and presents a similar composition, i.e. fish meal (40-45%), fish oil (8-10%), cereals (20-22%), cereals meal (8-10%), soybeans meal (12-15%), other additives (4-5%). It has been impossible to collect information about the geographical origin of the various components of the feed.

The study carried out has permitted to assess the environmental impact due to greenhouse gas emissions throughout the life cycle of production of sea bass, only considering the three main inputs of the process, i.e. consumptions of electricity, liquid oxygen and feed (see Fig. 5). Table 3 shows the annual quantity of the inputs and the associated emissions of CO_2 equivalent. The contribution of feed covers more than 50% of the total CO_2eq.

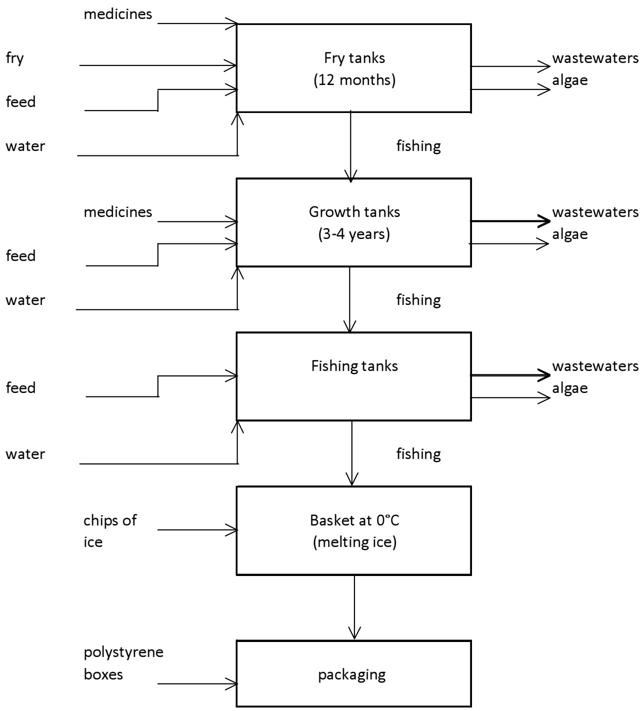

Figure 5: Flowchart of materials and energy in "Il Padule".

Table 2: Composition of feed considered in (Aubin et al., 2009) and of feed used in "Il Padule".

Composition	**Unit**	**Values in (Aubin et al., 2009)**	**Values for "Il Padule"**
Proteins	%	55.00	50.00
Fats	%	12.00	21.00
Phosphorous	%	1.60	1.40

Table 3: Annual consumptions and the associated CO_2eq emissions for "Il Padule".

_Inputs	**Values**		**CO_2eq emissions**	
Liquid oxygen	1'484'441	kg/year	521'781	kgCO_2eq/year
Electricity	2'566'000	kWh/year	1'163'296	kgCO_2eq/year
Feed	954'195	kg/year	2'524'990	kgCO_2eq/year
Total	-		4'210'067	kgCO_2eq/year

Table 4: Total CO_2eq emissions per ton of the whole fish for "Il Padule" and (Aubin et al., 2009).

References	**CO_2eq emissions**
"Il Padule"	9'356 kg/t_fish
(Aubin et al., 2009)	3'601 kg/t_fish

A comparison of the values of CO_2eq for sea bass farming between values reported in (Aubin et al., 2009; Ayer et al., 2009) and in the present case study, has shown that

- the major contribution to the emissions is due to the feeding phase;
- the difference in latitude between the two farms and, consequently, the difference in temperatures that affect the ability of fish feeding, determine a significant difference in the total CO_2eq emissions;

- the widespread use of O_2, determined by the not suitable environmental conditions, imply amounts three times greater of the emissions.

Moreover, it is possible to affirm that no significant differences are evident between salmon and sea bass farming if the climatic conditions and farming typology are similar: in (Aubin, 2009) the sea bass cages system implies 3'601 kg/t_fish of CO_2eq emissions, while in (Pelletier, 2007) the cultured Atlantic salmon caused an amount of CO_2eq emissions up to 2700 kg/t_fish.

4. Conclusions

The objective of the work has been a first analysis of the process inputs and the CO_2eq emissions assessment through the LCA approach for a specific sea bass farming characterised by a low concentration of fishes per m³ of water, water supply exclusively from surface water and large pieces of the product (1 kg) with a production cycle of about 5 years.

The data inventory of consumptions, their analysis and a first partial processing through a LCA approach, helped to identify the feeding as the input which provides the greatest impact from both economic and environmental point of views.

As a future development of this work is possible to promote a complete LCA of the production process including all the inputs not taken into consideration such as packaging and transport. Finally, it must be highlighted that modelling the feed production would increase the quality of the input data and, consequently, the accuracy of results.

5. References

Aubin J., Papatryphon E., van der Werf H.M.G., Chatzifotis S. (2009): Assessment of the environmental impact of carnivorous finfish production systems using life cycle assessment. *Journal of Cleaner Production*, 17, pp. 354-361.

Ayer N.W., Tyedmers P.H. (2009): Assessing alternative aquaculture technologies: life cycle assessment of salmonid culture systems in Canada. *Journal of Cleaner Production,* 17, pp. 362-373.

Grigorakis K. (2007): Compositional and organoleptic quality of farmed and wild gilthead sea bream (Sparus aurata) and sea bass (Dicentrarchus labrax) and factors affecting it: a review. *Aquaculture*, 272, pp. 55-75.

Pelletier N.L., Ayer N.W., Tyedmers P.H., Kruse S.A., Flysjo A., Robillard G., Ziegler F., Scholz A.J., Sonesson U. (2007-a): Impact categories for Life Cycle Assessment research of production systems. *The International Journal of Life Cycle Assessment,* 12, pp. 414-421.

Pelletier N., Tyedmers P. (2007-b): Feeding farmed salmon: Is organic better?. *Aquaculture*, 272, pp. 399–416.

Poli B.M., Parisi G., Zampacavallo G., Mecatti M., Lupi P., Gualtieri M., Franci O. (2001): Quality outline of European sea bass (Dicentrarchus labrax) reared in Italy: shelf life, edible yield, nutritional and dietetic traits. *Aquaculture*, 201, pp. 303-315.

Recchia L., Cini E., Corsi S. (2007): Life Cycle Analysis methodology applied to sunflower oil utilisation in Tuscany farms. *15th European Biomass Conference and Exhibition on biomass for energy, industry and climate protection*, Berlin, Germany, May 7-11 2007.

Schau E.M., Fet A.M. (2007): LCA studies of food products as background for environmental product declarations. *The International Journal of Life Cycle Assessment*, 13, pp. 255-264.

Environmental impacts of replacement of fish protein by plant-based sources in trout diets, at feed and farm scales

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ABSTRACT

In order to assess the influence of replacing fish oil and meal by plant-based sources of lipids and proteins in aquaculture fish diets, an environmental assessment using Life Cycle Assessment (LCA) methodology was conducted. We compared two trout diets, containing the same quantity of protein and energy, but differing in fish meal content: 24% in the control diet, 5% in the low fish meal diet. The low fish meal diet had lower Net Primary Production Use than the control diet, and similar energy use and greenhouse gas emissions. The replacement of fish meal by crop-based sources induced an increase in land occupation, eutrophication and terrestrial ecotoxicity. This should be considered in feed formulation to minimise these impacts.

Keywords: fish farming, LCA, fish protein, plant protein, feeds,

1. Introduction

Compared to fisheries, fish farming remained negligible until the 1970s (except in China). Aquaculture started to develop rapidly from the 1980s and represents now more than half of the aquatic resource production for human consumption (120 million tonnes), with 67 million tonnes produced in 2006 (FAO, 2008). In Western Europe, fish farming is mainly based on carnivorous species such as salmonids (salmon and trout), sea bream, sea bass, turbot, and Atlantic cod (emerging). The production of these species is highly dependent on marine capture fisheries for the provision of fish meal and fish oil, the main components of the fish diet (Naylor et al., 2000; Tacon, 2005). Over the world, aquaculture is the main consumer of these resources with 68.2% of the fish meal and 88.5% of the fish oil, in 2006 (Tacon & Metian, 2008).

Considering that the dependence on fish capture source imposes an important pressure on marine resources and may limit the current expansion of fish farming, scientific programs were developed to explore ways of substitution of marine protein and oil with plant protein and lipids. In the framework of the Aquamax EU project, crop-based diets were proposed for different species (sea bream, Atlantic salmon, rainbow trout, common carp, and Indian major carps). The Aquamax project aims to strike a balance between the need to lower use levels of marine resources and the need to preserve the health benefits of farmed fish, maintaining high levels of omega 3 fatty acids.

Its strategic goal is to replace as much as possible of the fish meal and fish oil currently used in fish feeds with sustainable, alternative and contaminant-free feed resources, ensuring

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the health benefits of fish consumption. In order to fulfil this goal an environmental assessment using Life Cycle Assessment (LCA) methodology was undertaken on feeds and fish production at the farm level. The results presented here only concern the rainbow trout case study.

Recently many LCA studies were conducted on fish farming, especially on carnivorous species (Aubin et al., 2009; Pelletier et al., 2009; Papatryphon et al., 2004b). Some guidelines and a specific framework were proposed to adapt the general concepts of LCA to aquatic products (Pelletier et al., 2007; Ayer et al., 2007). For these production systems, the contribution of feeds to the overall impacts was quantified. The introduction of organic diets in salmon farming did not significantly reduce environmental impacts (Pelletier & Ayer, 2007). The replacement of fish meal and fish oil in trout diets has been investigated using nutritional modelling and LCA (Papatryphon et al., 2004a). The authors showed that a total replacement of fish meal and fish oil by plant sources did not improve environmental performances, but reduced the pressure on the fishing resource. The best compromise consisted of a partial substitution of fishery sources, by keeping 5% of fish meal in the diet. Based on these results the Aquamax project proposed to compare a control and a low fish meal diet, on their physiological, nutritional and environmental performances, in a large scale experiment, in a commercial farm.

2. Material and methods

The study focused on two stages, the feed production and the fish farm. The feed production stage takes into account raw material extraction, energy production and feed ingredient production through agriculture and fishery, and their processing. For around 50 feed ingredients Life Cycle Inventories (LCI) were established, based on a precise data collection and calculation of inputs and pollutants associated with their production and transformation. These inventories concern crop-based ingredients of different origins (US, Brazil, Europe…) such as wheat and gluten, maize, soybean meal and concentrate, rapeseed oil, palm oil, and fishery products such as fish meal and fish oil from Norway or South America. The transportation of the material was taken into account. Using this data and the description of the pelleting process, an LCA was conducted of the two diets, at the feed mill gate. The diets have similar chemical compositions but differ in their ingredients (Table 1). In particular, fish meal content is 5% in the Low Fish Meal diet (LFM), and 24.4% in the Control diet. It should be noted that fish oil content is low (5%) in both diets, in order to propose low fish-content diets for trout.

For the fish farm stage, the LCI was based on animal production data (growth, survival rate, feed conversion ratio) from a trial production of large trout (3kg) receiving these two diets at the Viviers de France company. This company also supplied data on feed production and other production factors (farm energy use, liquid oxygen, fingerling, equipment and infrastructure production). At each step transportation of material was taken into account. The slaughtering, processing, and sale phases were not included. Fish farm emissions of nutrients to the river, associated with fish growth, were estimated by nutrient-balance modelling (Cho & Kaushik, 1990; Kaushik, 1998).

This data was used to calculate the environmental impacts of the production of one ton of fish at the farm gate. The rearing performances of the two groups of fish were similar (Table 2). Two scenarios based on the use of the two diets for the farm during one year were built.

Table 1: Ingredients and chemical composition of the Control and Low Fish Meal trout feeds.

Feeds	Control	Low Fish Meal	
Ingredients	%	%	**Geographic Origin**
Fish meal 73	24.4	5	Norway
Soybean meal	17	3.3	Extraction: France; Soybean: Brazil
Wheat	17	8.1	France
Maize gluten 60		16	France
Rapeseed oil	7.1	14.6	France
Rapeseed meal	6	10	France
Wheat gluten		7.8	France
Fish oil	5.6	5	Peru
Soya concentrate	5.6	20	Brazil
Palm oil	5	4.9	Malaysia
Extruded soybean	5	2	Extrusion: France; Soybean: Brazil
Dehulled protein pea	1		France
Brewer's yeast	1		Brazil
Monocalium phosphate	0.15	2	France
Amino acids by-products	4.4		France
Premix	0.84	0.84	France
Lysine		0.41	France
DL methionine		0.05	Japan
Moisture	7	7	
Protein	40	39	
Fat	23	27	

Table 2: Rearing performances of the fish lots fed with Control and Low Fish Meal diets

Fish lots	Control	Low Fish Meal
Initial Weight (g)	65	60
Final Weight (g)	2990	2830
Mortality (%)	17.1	20.7
Feed Conversion Ratio	1.11	1.16

Attributional LCA was conducted using the method CML 2001 version 2.04 completed by Total Cumulative Energy Demand version 1.05, GWP100 characterisation factors were up-dated according to IPCC (2007). Adaptations for aquaculture proposed by Papatryphon et al. (2004a) were implemented. For co-products economic allocation was applied.

The impact categories considered in this study are: Eutrophication (kg PO_4-eq), Acidification (kg SO_2-eq), Global Warming (kg CO_2-eq), Terrestrial ecotoxicity (kg 1.4 DB-eq), Net Primary Production Use (kg C), Water Use (m^3), Land occupation (m^2a), Total Cumulative Energy Demand (MJ-eq).

3. Results and discussion

LCA results are synthesised in Table 3.

3.1. Feed stage

At the first step, the Life Cycle Impact Analysis is calculated for 1 tonne of feed at the feed mill gate. The environmental performances of the two diets are compared. As expected, the Net Primary Production Use reflecting the pressure on biotic resources, especially on fishery resources, was dramatically lower for the low fish meal feed (-73.5%). Acidification, energy demand and global warming can be considered as equivalent for the feeds (differences less than 8%), despite their ingredient profiles. This result suggests that the energy requirement of the fishery (and fish meal processing) and its associated impacts due to fossil energy sources (global warming and acidification) are completely compensated by the production of plant protein and especially of concentrated plant protein (soy pass, wheat gluten and maize gluten). The increased content in plant resources in the low fish meal diet lead to increases in: land occupation by 39%, eutrophication by 41%, and terrestrial ecotoxicity by 36% (due to high-impact crop-based products such as rapeseed oil).

3.2. Farm stage

Compared to the Control scenario, the Low Fish Meal Scenario induced a reduction of Net Primary Production Use by 71%; energy demand, acidification and global warming were similar. Land occupation was higher (46%) for the Control scenario, as feed production is the major contributor to this impact. For eutrophication and terrestrial ecotoxicity, the difference between the two scenarios was much less than in the feed stage (14% and 16% respectively). This can be explained by the influence of other production factors, such as nitrogen and phosphorus emissions at the farm outlet, which are more important than the nutrient emissions during the feed production (including the ingredient production).

These results are consistent with the study of Papatryphon et al. (2004a) that showed that none of the studied diets led to an improvement on all impact categories. Despite the differences between the two studies due to the feed formulation (especially on the fish oil content), the lack of impact of the fish meal substitution on energy requirement and associated impacts categories (global warming, acidification) is common to both studies. The differences in eutrophication values between the two studies may be due to the digestibility of components taken into account and to different Food Conversion Ratios.

4. Conclusion

The Aquamax study showed that it is possible to decrease the quantity of fish meal down to 5% in the diet of trout (even at a low level of fish oil), without any physiological and rearing effects. This practise strongly reduces the pressure on fishery sources and biotic resources (net primary production use), and has no consistent influence on the energy requirement and greenhouse gas emissions. Nevertheless it may induce an increase in land occupation as well as for eutrophication and terrestrial ecotoxicity. This has to be taken into account in the future aqua-feed formulations. This study will be conducted on other diets for sea bream, common carp, Atlantic salmon and Indian carps.

Our study has shown the importance of considering the processes under study (i.e. feed production), in the whole production system, in order to balance the influence of the different impacts, that might seem very high in some steps (i.e. eutrophication at feed mill gate), and less important at the whole system scale.

Table 3: Extract of Life Cycle Inventory for the main resources and emissions and Life Cycle Impact Assessment calculated for 1 tonne of feed at the feedmill gate and for 1 tonne of trout at the farm gate, according to the two feeds and the two farm scenarios.

			Feed Stage		Farm stage	
			Control Feed	Low Fish Meal Feed	Control Scenario	Low Fish Meal Scenario
Life Cycle Inventory			UF	UF	UF	UF
Resource use		**Unit**	1 tonne feed	1 tonne feed	1 tonne trout	1 tonne trout
Pesticides		kg AI	0.33	0.39	0.37	0.45
Electricity		MJ	1413	1687	10182	10653
Gas		m3	95	158	139	214
Fuel/diesel		kg	225	109	351	228
Emission	**Compartment**					
CO_2	Air	kg	1207	980	1880	1683
N_2O	Air	kg	0.73	1.29	0.85	1.60
NH_3	Air	kg	1.56	2.52	1.79	3.08
NO_X	Air	kg	6.48	3.95	10.38	7.80
SO_2	Air	kg	2.6	2.5	4.1	4.1
CH_4	Air	kg	4.5	3.9	5.70	5.27
NO_3	Water	kg	29.6	48		
NH_3	Water	kg	0.06	0.15		
PO_4	Water	kg	1.01	1.62		
Nitrogen	Water	kg			51.60	57.80
Phosphorus	Water	kg			4.92	5.91
Cd	Soil	g	1.85	1.18	1.10	1.43
Cr	Soil	g	9.51	12.98	8.77	15.43
Cu	Soil	g	8.22	14.96	9.24	18.37
Pd	Soil	g	3.57	4.50	4.2	5.44
Ni	Soil	g	2.56	2.92	2.07	3.53
Zn	Soil	g	48.18	82.52	48.61	96.98
Life Cycle Impact Assessment			UF	UF	UF	UF
Impact category			1 tonne feed	1 tonne feed	1 tonne trout	1 tonne trout
Acidification		kg SO2-eq	8.86	8.99	12.98	13.76
Eutrophication		kg PO4-eq	5.69	8.00	43	49
Global warming (GWP100)		kg CO2-eq	1543	1453	2272	2269
Terrestrial ecotoxicity		kg 1.4-DB-eq	5.64	7.65	17.09	19.80
NPPU (net primary production use)		kg C	99776	26378	113980	32872
Water use		m3	39.3	35.07	72.40	69.00
Land occupation		m2a	1618	2256	1931	2820
Total cumulative energy demand		MJ-eq	19600	18070	56957	56269

Abbreviations: UF: Functional Unit; kg AI: kg Active Ingredients

5. References

Aubin J., Papatryphon E., van der Werf H.M.G., Chatzifotis S. (2009): Assessment of the environmental impact of carnivorous finfish production systems using life cycle assessment. *Journal of Cleaner Production* 17, pp 354-361.

Ayer N.W., Tyedmers P.H., Pelletier N.L., Sonesson U., Scholz A.(2007): Co-product allocation in life cycle assessments of seafood production systems: Review of problems and strategies. *International Journal of Life Cycle Assessment*, 12(7), pp 480-487.

Cho C. Y., Kaushik S. J. (1990): Nutritional energetics in fish: energy and protein utilization in rainbow trout (Salmo gairdneri). *World Reviews in Nutrition and Dietetics* , 61, pp. 132-172.

FAO (Food and Agriculture Organisation) (2008): State of world aquaculture 2006. Rome: *FAO Fisheries technical paper* no. 500. 128 p.

Guinée J.B., Gorrée M., Heijungs R., Huppes G., Kleijn R., de Koning A., van Oers L., Wegener Sleeswijk A., Suh S., Udo de Haes H.A., de Bruijn H., van Duin R., Huijbregts M.A.J. (2002): Handbook on life cycle assessment. An operational guide to the ISO standards. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Huijbregts M.A.J.(1999): Life-cycle impact assessment of acidifying and eutrophying air pollutants. Calculation of characterisation factors with RAINS-LCA. Amsterdam, The Netherlands: Interfaculty Department of Environmental Science, Faculty of Environmental Science, University of Amsterdam.

IPCC (2007): Climate Change 2007 : The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC. S. Solomon, D. Qin, M. Manninget al. Cambridge, United Kingdom and New York, NY, USA: 996.

Kaushik S.J. (1998): Nutritional bioenergetics and estimation of waste production in non salmonids. *Aquatic Living Resources,* 11(4) pp 211-217.

Papatryphon E., Petit J., Kaushik S.J., van der Werf H.M.G. (2004a): Environmental impact assessment of salmonid feeds using Life Cycle Assessment. *Ambio*; 33(6), pp 316-323.

Papatryphon E., Petit J., van der Werf H. M. G. (2004b): The development of Life Cycle Assessment for the evaluation of rainbow trout farming in France. In: Halberg N., editor. Life Cycle Assessment in the Agri-food sector. Proceedings from the 4th International Conference. Danish Institute of Agricultural Sciences, Horsens, Denmark, pp73-80.

Pelletier N.L., Ayer N.W., Tyedmers P.H., Kruse S.A., Flysjo A., Robillard G., Ziegler F., Scholz A.J., Sonesson U. (2007): Impact categories for life cycle assessment research of seafood production systems: Review and prospectus. *International Journal of Life Cycle Assessment*, 12(6), pp 414-421.

Pelletier N., Tyedmers P. (2007): Feeding farmed salmon: Is organic better? *Aquaculture* 272, pp 399-416.

Pelletier N., Tyedmers P., Sonesson U., Scholz A., Ziegler F., Flysjo A., Kruse S., Cancino B., Silverman H. (2009): Not All Salmon Are Created Equal: Life Cycle Assessment (LCA) of Global Salmon Farming Systems. *Environmental Science & Technology.*

Tacon A. (2005): State of information on salmon aquaculture feed and the environment. Salmon Dialog Report, World Wildlife Fund.

Tacon A.G.J., Metian M. (2008): Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: Trends and future prospects. *Aquaculture* 285, pp.146-158.

Official inspections of pesticides residues in the food and beverage in Puglia

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ABSTRACT

In ARPA laboratory of Bari, in Puglia, 971 food samples originating from all Puglia territory were analyzed for the official inspection to look for pesticide residues. We show the results of this analysis with graphics and comparative tables. The most frequently found active residues are shown together with the most contaminated matrices. On average, in every single sample, we looked for over 170 active residues. Particular attention was placed to look for the presence at the same time of more than one active residue on the same matrix.

Keywords: food, pesticides, active substance, residues, Puglia

1. Background

In Italy, the Ministry of Health with its central and branch offices is responsible for ensuring the safety of food products. Official inspections of food and beverages are carried out to ensure compliance with the provisions of the law, to prevent risk to the public while protecting the customer and to guarantee the fairness of the transitions**.** The inspection is carried out on all the products regardless of its country of origin that is intended to be used on the Italian territory as well as on all the products exported to another country inside or outside the European Community.

In compliance with the Ministerial Decree of 23rd December 1992, as part of the Regional Program, a research on pesticide residues products was carried out in 2008. As of September 2008, Regulation EC 396/2005 of the European Community on maximum residue levels (MRL) of pesticides in products of plant and animal origin defines a new fully harmonized set of rules for pesticide residues. The harmonization of MRL was necessary in order to unify in a unique regulation the numerous Community and individual member states regulations and to facilitate the trade among the member countries of the European Community.

2. Results

971 samples were taken and analyzed (total of the 41.8% of all the food samples analyzed from a chemical stand point). On average, in every single sample, we looked for over 170 active residues (**Tab. 1**).

Out of 971 samples analyzed to look for pesticide residue, 70.1% (including the organic products) did not contain any residue or we could not find anyway the residues in an amount exceeding the detection limits; from one up to eight residues were detected in the 28.1% of the samples; the percentage of samples that failed to meet the minimum standards was equal to 1.8%.

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Table 1: Samples deriving from traditional and organic agriculture in which we looked for pesticides residues

analyzed samples	without residues	with residues	not-regular
971	681	273	17
	70,1%	28,1%	1,8%

Altogether, the result of our 2008 inspection is analogous to the one obtained at a national level: 1.4% is the percentage of irregular samples due to the detection of residues in an amount exceeding the law limit reported in the summary of 2008 Annual Report by the Ministry of Labor, Health and Welfare –Department of Veterinary Public Health, Nutrition and Food Safety (National Integrated Plan). In the following Tables and Graphics we reported in detail the data of the analytic inspection

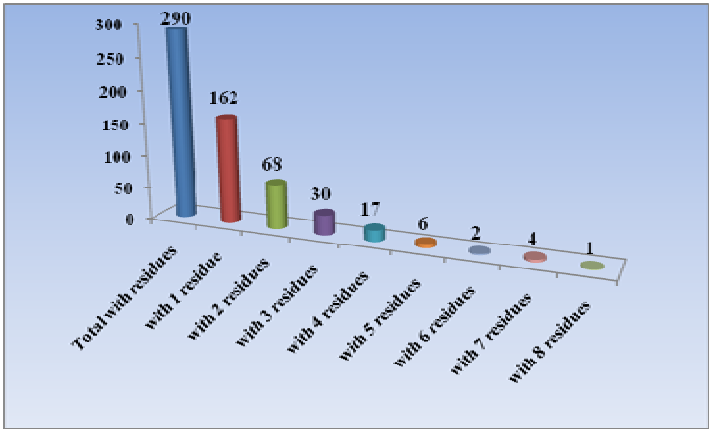

Figure 1: Total number of samples with residues in relation to the number of residues found

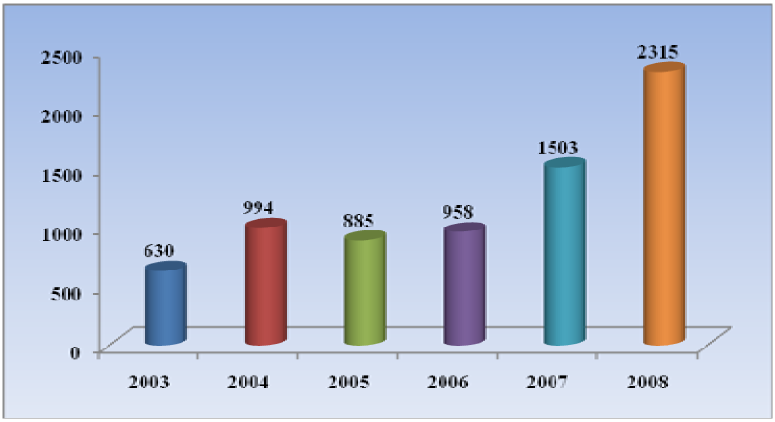

Figure 2: Number of samples that failed to meet the minimum standards in the period 2004-2008. It is clear that this number has increased over the years: one explanation could be that the number of samples analyzed for residues has increased but most of all it is increased the number of active principles we looked for.

Table 2: Different kind of not-regular samples and active substance found.

SAMPLES	ACTIVE SUBSTANCE
Grapes	Pyrimethanil, Metalaxyl, Cyprodinil, Fludioxonil, Myclobutanil, Tebuconazole, Boscalid
Orange	Methidathion
Mandarins	Chlorpyriphos, Fenitrothion
Mandarins	Chlorpyriphos, Fenitrothion, Carbaryl, Methidathion, Fenazaquin
Apple	Captan, Bromopropylate, Boscalid
Pears	Procymidone, Azinphos-methyl, Boscalid
Celary	Chlorpyriphos-methyl
Strawberries	Carbaryl
Strawberries	Boscalid, Fludioxonil, Cyprodinil, Bupirimate
Strawberries	Procimidone, Metalaxyl, Fludioxonil, Boscalid, Cyprodinil, Bupirimate,
Cherries	Cypermethrin, Diazinon
Cherries	Diazinon, Cypermethrin, Fenhexamid
Cherries	Diazinon
Cherries	Diazinon, Fenhexamid
Oil	Fenitrothion
Organic pasta	Pirimifos-metile
Organic pasta	Pirimifos-metile

According to **Tab.2**, in four samples of cherries from Turkey, analyzed according to the import control plans for goods on behalf of USMAF, residues of the active substance Diazinon were detected up to ten fold above the law limit: the result was communicated to the Competent Health Authority who returned the lots at the border.

The non-compliance on three strawberry samples was due to the presence of Carbaril and Boscalid residues exceeding the law limit.

Fenitrotion was also found in quantities exceeding the limit of law in an olive oil sample.

In a grape sample we found seven active residues including Boscalid, whose use was not regulated in Italy yet at the time of sample taking.

Not authorized residues of active principles were also found in celery (Clorpirifos-metile), pears and apples (Boscalid), oranges (Metidation), mandarins (Fenitrotion, Carbaril).

Two organic products also failed to meet the minimum standards.

Organic agriculture represents an environmentally friendly production system, which utilizes authorized substances in accordance with specific rules.

Currently, the reference normative law is the Reg. EC 834/2007 whose mode of application is defined by the Reg EC 889/2008. The use of synthetic chemical substances is not allowed and their presence represents a fraud towards the customer.

Residues of the active principle Pirimifos-metile, a synthetic insecticide of the phosphate esters family, which cannot be used in organic productions, were found in two samples of organic pasta taken from the school refectory.

The distribution of food according to the number of pesticide residues found is the following:. the samples with a small number of residues (one, two, three) are related to different type of food. Four residues have been found at the same time in samples of broad beans, strawberries, mandarins, eggplants, oil, pears, tomatoes and grape (nine samples indeed!). The higher is the number of detected residues, the more limited is the type of food involved: 80% of the samples with five to eight residues detected at the same time are represented by grape; six residues were detected simultaneously on a strawberry sample, 7 residues on a sample of pears (**Fig. 3**).

Table 3 shows the kind, the number active of principles detected and the kind of samples in which they have been found.

Active substance	Class	Number of matches	Types of samples
Clorpirifos	insetticide	85	oranges, bananas, cherries, green beans, corn, kiwis, lemons, tangerines, eggplant, apples, olive oil, pears, peaches, grapefruit, grapes
Fludioxonil	fungicide	42	oranges, cucumbers, strawberries, lettuce, oil, pears, peaches, tomatoes, grapes
Cyprodinil	fungicide	33	strawberries, salad, pears, tomatoes, grapes
Clorprofam	herbicide	21	bananas, tangerines, potatoes,
Procimidone	fungicide	21	beans, strawberries, lettuce, oil, pears, peaches, tomatoes, grapes, wine
Metalaxil	fungicide	18	cucumbers, strawberries, grapes, wine
Boscalid	fungicide	17	strawberries, apples, pears, tomatoes, grapes
Clorpirifos-Metile	insetticide	17	oranges, wheat, pears, peaches, celery, grapes
Tebuconazolo	fungicide	16	cherries, tangerines, peaches, tomatoes, plums, grapes
Pirimifos-metile	acaricide	17	wheat, rice, pasta
Pirimetanil	fungicide	13	strawberries, grapes, wine
Fosmet	acaricide	12	oranges, mandarins, oil, pears, peaches, plums
Miclobutanil	fungicide	12	bananas, cucumbers, grapes, zucchini
Fenexamide	fungicide	11	cherries, strawberries, grapes, wine
Triadimenol	fungicide	11	grapes
Malation	insetticide	10	oranges, corn, lemons, tangerines, grapes
Fenitrotion	insetticide	9	wheat, mandarin oil
Diazinone	insetticide	8	cherries
Azossistrobina	fungicide	7	bananas, lettuce, mandarin oranges, tomatoes, grapes
Carbaril	insetticide	7	beans, strawberries, mandarin oranges, eggplant, olive oil, wine
Cipermetrina	insetticide	7	cherries, beans, lettuce, grapes
Metidation	insetticide	7	oranges, mandarins, oil
Tolclofos-Metile	fungicide	6	carrots, salad, peaches
Difenoconazolo	fungicide	5	dill, beans, peaches, celery
Fenazaquin	acaricida	5	mandarins, peppers, pears, grapes
Fention	insetticide	5	***oil***
Azinfos-Metile	insetticide	4	oil, pears
Bromopropilato	acaricida	4	mandarins, apples, grapefruit
Imazalil	fungicide	4	oranges, bananas, mandarins
Oxifluorfen	herbicide	4	oil
Propizamide	herbicide	4	dill, salad
Bupirimate	fungicide	3	strawberries
Endosulfan	insetticide	3	oil
Iprodione	fungicide	3	beans, salad, pears
Penconazolo	fungicide	3	beans, grapes, zucchini
Bifentrin	acaricide	2	mandarins, grapes
Captano	fungicide	2	apples, pears
Clorotalonil	fungicide	2	apples, peas
Fenbuconazolo	fungicide	2	oil
Pendimentalin	herbicide	2	dill
Procloraz	fungicide	2	mushrooms, grapefruit
Spiroxamina	fungicide	2	grape
Triflossistrobina	fungicide	2	pears, grapes
Acrinatrina	acaricide	1	grape
Dicofol	acaricide	1	tangerines
Dimetoato	acaricide	1	cherries
Fosalone	acaricide	1	fennel
Kresoxim-metile	fungicide	1	wine
Lamda-Cialotrina	insetticide	1	peaches
Pirimicarb	insetticide	1	grape
Tetraconazolo	fungicide	1	tomatoes

Table 4. Agreement types of samples-active substance

Types of samples	Active substance to be found
Grapes	Clorpirifos, Fludioxonil, Cyprodinil, Procimidone, Metalaxil, Boscalid, Clorpirifos-Metile,Tebuconazolo, Pirimetanil, Miclobutanil, Fenexamide, Triadimenol, Malation, Azossistrobina, Cipermetrina, Fenazaquin, Penconazolo, Bifentrin, Spiroxamina, Triflossistrobina, Acrinatrina, Pirimicarb
Mandarins	Clorpirifos, Clorprofam, Tebuconazolo, Fosmet, Malation, Fenitrotion, Azossistrobina, Carbaril, Metidation, Fenazaquin, Bromopropilato, Imazalil, Bifentrin, Dicofol
Oil	Clorpirifos, Fludioxonil, Procimidone, Fosmet, Fenitrotion, Carbaril, Metidation, Fention, Azinfos-Metile, Oxifluorfen, Endosulfan, Fenbuconazolo
Pears	Clorpirifos, Fludioxonil, Cyprodinil, Procimidone, Boscalid, Clorpirifos-Metile, Fosmet, Fenazaquin, Azinfos-Metile, Iprodione,Captano,Triflossistrobina,
Strawberries	Fludioxonil, Cyprodinil, Procimidone, Metalaxil, Boscalid, Pirimetanil, Fenexamide, Carbaril, Bupirimate
Peaches	Clorpirifos, Fludioxonil, Procimidone, Clorpirifos-Metile,Tebuconazolo, Fosmet, Tolclofos-Metile, Difenoconazolo, Lamda-Cialotrina
Salad	Fludioxonil, Cyprodinil, Procimidone, Azossistrobina, Cipermetrina, Tolclofos-Metile, Propizamide, Iprodione
Orange	Clorpirifos, Fludioxonil, Clorpirifos-Metile, Fosmet Malation, Metidation, Imazalil
Tomatoes	Fludioxonil, Cyprodinil, Procimidone, Boscalid, Tebuconazolo, Azossistrobina,Tetraconazolo
Cherries	Clorpirifos, Tebuconazolo, Fenexamide, Diazinone, Cipermetrina, Dimetoato
Wine	Procimidone, Kresoxim-metile, Carbaril, Fenexamide, Pirimetanil, Metalaxil,
Bananas	Clorpirifos, Clorprofam, Miclobutanil, Azossistrobina, Imazalil
Wheat	Clorpirifos, Clorpirifos-Metile, Pirimifos-metile, Malation, Fenitrotion
Apple	Clorpirifos, Boscalid, Bromopropilato, Captano, Clorotalonil
Beans	Carbaril, Cipermetrina, Difenoconazolo, Penconazolo
Dill	Difenoconazolo, Propizamide, Pendimentalin
Cucumbers	Fludioxonil, Metalaxil, Miclobutanil
Green bean	Clorpirifos, Procimidone, Iprodione
Grapefruit	Clorpirifos, Bromopropilato, Procloraz
Lemmon	Clorpirifos, Malation
Aubergine	Clorpirifos, Carbaril
Celary	Clorpirifos-Metile, Difenoconazolo
Plums	Tebuconazolo, Fosmet
Zucchini	Miclobutanil, Penconazolo
Carrot	Tolclofos-Metile
Fennel	Fosalone
Mushroom	Procloraz
Kiwi	Clorpirifos
Potatoes	Clorprofam
Chilly	Fenazaquin
Peas	Clorotalonil
Rice	Pirimifos-metile
Pasta	Pirimifos-metile

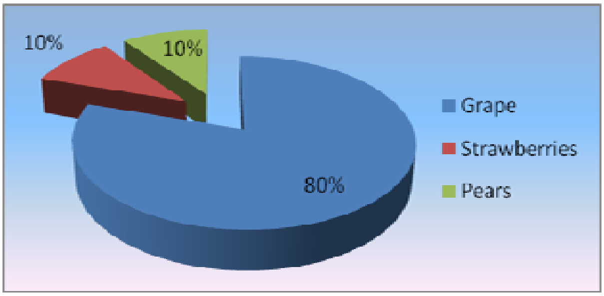

Figure 3. Samples with five to eight residues detected at the same time.

The most frequently detected active principles are: Clorpirifos (detected in 85 samples), Fludioxonil (42 samples) Cyprodinil (33 samples), Clorprofam and Procimidone (21)….

The data in T**able 3** show the problem of how widespread is the presence of samples with residues even if within the regulations.

Frequently detected combinations of matrix-active principles are seen (**Tab. 4**).

You can see a large use and therefore detection of active principles in particular in the grape.

A substantial number of active principles are also found in other kind of products (mandarins, oil, pears, strawberries, peaches).

On the contrary, no residues (or presence of residues in an amount not exceeding the detection limits) or detection of only one active residue were found in: some kind of fruit (apricots, medlars, kiwi), of vegetables (onion, cabbages, turnips, Swiss chard, broccoli, basil, spinach, chicory, peppers) and of legumes (lentils, beans, green peas).

Neither irregularities nor residues were detected in food sample for childhood. We should remember that these matrices are allowed to have a maximal residue not superior to 0,01 mg/kg (M.D. April 6, 1994 n 500; R.P.D. April 7, 1999 n. 128; M.D. Dec. 23 2002 n. 31).

3. Conclusions

It is important to emphasize some points and to make some observation in view of the 2008 results and the information obtained from previous years.

- Currently, Bari laboratory performs chemical inspection on over 80% of food samples obtained from the regional territory, therefore the 2008 results are a good, even if not complete, representative picture of the official control in Puglia.
- The presence of multiple residues also in the MRL is quite frequent in many commonly used food products (fruits, vegetables and oil) that represent the typical diet in our region and are widely recommended as a part of the general Mediterranean diet. A consideration on this subject: the data about the grape indicates that, on a single parcel, multiple active principles are used instead of one, which could exceed the LMR. On the contrary, the low levels of active principles often found in the oil suggest that the treatments are likely performed on different olive parcels; these will thereafter come together in the same oil press and will form a single parcel of oil. What we found in the oil is also related to the “drift” phenomenon that is the contamination from treatments performed on cultivations close to the olive-grove.
- Regarding the current LMR, it is important to underline that the aim is not only to control the correct use of pesticides and to guarantee the trade of food products, but also to guarantee a high level of protection of the customer.
- It is true that, when a single active principle exceeds occasionally the LMR, this does not imply a danger for the health but only the overcoming of a legal threshold acceptable from a toxicologically stand point
- Comparing to the previous years, the number of irregularities due to the presence of residues on fruit and vegetables has increased: this is due to the increased number of checked samples and the increased number of active principles that we look for: “…. **the more you search, the more you find** …”.

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