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Evaluating Environmental Sustainability of Pasta Production through the Method LCA

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***Abstract* – The recent policy of Green Deal aims to a transition towards 'healthy, equitable and sustainable communities'. One of the key sectors analysed within the Green Deal is the agri-food chain, with the strategy 'From Farm to Fork', aiming to design a sustainable food system from production to consumption, passing through industry processing, distribution, and all the related activities. For the agricultural sector, the objectives are in line with those presented in the United Nations 2030 Agenda, from technologies and digitalization, to organic farming. Concerning the transformation and distribution phases, the Commission is promoting the technological and technical innovation, the restructuring of companies and the improvement of the quality of work. The aim of this study is to perform a Life Cycle Assessment related to one of the main products of a company in the agri-food sector in central Italy. The product analysed was durum wheat pasta. A cradle-to-gate analysis was performed, starting from the cultivation of the wheat, arriving at the final pasta product. Different transformation steps were evaluated (e.g., cleaning, grinding, compression, extrusion). The analysis was aimed to identify the most critical phases along the chain, to plan improvements in terms of efficiency of the production process, with consequent enhancement of the environmental performance.**

***Keywords* – Agri-food chain; environmental impacts; Life Cycle Assessment; sustainable production.**

1. INTRODUCTION

Agri-food production systems are complex entities, difficult to manage and intertwined with human health issues and a range of other outcomes, including economic growth, natural and environmental resources resilience, and sociocultural factors [1]. The Farm to Fork Strategy, as part of the European Green Deal, aims to make the European Food production system a global sustainability standard [2]. The strategy focuses on the management of the environment by the EU agricultural sector, as well as on food security and human health outcomes through four areas of improvement, setting concrete policy goals for 2030, in line with what the 2030 Agenda also established [3]. Such an approach requires a management strongly integrated across the agricultural phase, the industrial processing, distribution, and all the related activities, even for traditional food. In particular, agri-food supply chains are called to reduce their environmental burdens, keeping economic feasibility [4].

Pasta can be considered a traditional food; however, it is also one of the most common and popular staple foods thanks to its nutritional value, convenience, and versatility [5], [6]. As a

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consequence, the environmental burden of its production can be significant, therefore, it is important to understand the impact of its life cycle [5]. Analysing the effects through the whole supply chain can be a key point for better management and for addressing stakeholder initiatives in such an important sector. The scientific literature in recent years has largely proven the usefulness of applying such a life cycle approach in increasing the competitiveness of the food industry, through the establishment of a continuous improvement process and the adoption of eco-innovation-based solutions [4].

The aim of this study is to perform a Life Cycle Assessment related to one of the main products of a company in the agri-food sector in central Italy. The product analysed was durum wheat pasta. A cradle-to-gate analysis was performed, starting from the cultivation of the wheat, and arriving at the final pasta product. The different transformation steps were evaluated (e.g., cleaning, grinding, compression, extrusion). The analysis was aimed to identify the most critical phases along the chain, to plan improvements in terms of the efficiency of the production process, with consequent enhancement of the environmental performance.

2. STATE OF THE ART

The importance of Pasta production and its environmental impact is proved by the presence of several life cycle analyses in the literature. The different performed studies focused mainly on the identification of environmental hotspots within the production phase or on the comparison between traditional and industrial pasta. Bevilacqua *et al.* [7], in their seminal work, applied LCA to evaluate the environmental performances of the production and distribution of durum wheat pasta in the Italian market. They assessed the environmental impact of the whole manufacturing process, according to a cradle-to-grave approach. Their results revealed that the biggest burdens in the chain are linked to the agricultural phase and to the production of durum wheat semolina. They also proposed an alternative production system in which wheat comes from organic farming and the packing is made of recycled cardboard, demonstrating an improvement in environmental performance. The good environmental result of low-input practices was pinpointed by Ruini *et al.* [8], who focused specifically on the agricultural phase, including the economic analysis. These outcomes are confirmed by a recent work by Zingale *et al.* [4], which highlighted that the cultivation of ancient varieties and landraces in organic and low-input farming systems has a large potential for reducing the environmental burden of pasta. Moreover, Zingale *et al.* [9] underlined the role of durum wheat cultivation in all the different products made with it. Similar results were also found by Cibelli *et al.* [10], which identified as a hotspot also the house cooking of pasta.

On the contrary, Recchia *et al.* [6] found contrasting results comparing a 'high-quality pasta' chain, which involves both traditional procedures and ancient wheat varieties, with a 'conventional pasta', following industrial processes. In particular, their results showed a better performance of the high-quality pasta for three categories (soil degradation, agrobiodiversity loss, and non-renewable resources) while the conventional pasta chain was more efficient in terms of land and water resources use. Finally, Gnielka and Menzel [11] focused on the role of consumers in Germany, providing recommendations for minimizing the environmental impacts.

Although most of the literature considered the Italian scenario and wheat-based pasta, recent literature includes regionalized studies in other contexts [12] and the use of plant-based protein [13].

3. METHODS

The LCA methodology was used to perform this study, as a standardized procedure able to assess the environmental impacts of the proposed product system [14].

According to the SETAC (Society of Environmental Toxicology and Chemistry) guidelines, LCA can be defined as an objective procedure for assessing the energy and environmental loads relating to a process or an activity, carried out through the identification of the energy and materials used and the waste released into the environment. The assessment includes all process activities, including the extraction and treatment of raw materials, manufacturing, transportation, distribution, use, reuse, recycling and final disposal [15]. In fact, the so called 'cradle to grave approach' is applied. Partial LCA studies that explore until the gate of the company object of the study (LCA 'from cradle to gate'), can also be performed.

Thus, this method proposes a systemic view of production processes, through an objective assessment and quantification of energy and environmental loads and of the potential impacts associated with a product/process/activity [16], along the entire life cycle.

The study followed the guidelines of the international ISO 14040 and 14044:2006 Standards [17], [18]. According to ISO, we followed the structure of a typical LCA study, which is composed of four main phases: Goal and Scope definition; Life Cycle Inventory; Life Cycle Impact Assessment; Interpretation. Definition of the goal and scope represents the methodological choices, assumptions, and limitations of the study in addition to the functional unit [19]. The Life Cycle Inventory consists of data collection and quantification of the input and output flows involved in the system [20]. The Life Cycle Assessment is the evaluation of the environmental impacts derived from the data collected in the inventory [21], while Interpretation is aimed to determine the conclusions resulting from the study.

SimaPro 9.0 [22] software developed by *Pré Consultants* and *Ecoinvent 3.0* [23] supported the data processing for the creation of the LCA model.

In relation to the impact assessment phase, the overall environmental impacts were evaluated using IMPACT 2002+ method [24], quantifying damns to human health and ecosystems quality, climate change and resources consumption. This method was used because it allowed for a feasible implementation of a combined midpoint/damage approach, linking all types of life cycle inventory results (elementary flows and other interventions) via 14 midpoint categories to the four damage categories [24]. Moreover, the method IPCC 2013 [25] was applied to calculate the carbon footprint of the product.

4. CASE STUDY: LCA APPLIED TO PASTA PRODUCTION

4.1. Goal and Scope Definition

4.1.1. Objective of the Study

The goal of the study was to perform a Life Cycle Assessment related to one of the main products of a company in the agri-food sector in central Italy. The company is named 'Pastificio Mancini', located in the Marche Region and voted to a traditional production process and to obtain high-quality products. The product analysed was durum wheat pasta. In particular, a partial life cycle analysis was executed, related to the pasta production process, considering the stages of cultivation of durum wheat, the transformation from grain to semolina, up to the pasta-making process. The real impact that this production process can generate was studied, in an optical of improving the environmental sustainability.

This kind of analysis is generally performed for identifying the environmental impacts caused by the single processes along the product life cycle, in order to highlight any critical phases and to establish whether or not improvements can be made in terms of efficiency of the production process, with a consequent improvement of the environmental performance of the product [14].

Moreover, one of the most significant advantages of an LCA study is the possibility of comparing different products or processes consistently and systematically. This approach is thus applicable at different technological levels, from pilot to industrial [26]. Therefore, a comparison in terms of impacts was made, within the first phase of the production cycle – i.e. cultivation, between traditional farming techniques and hypothetical organic farming techniques. At the moment the company does not apply organic farming, but it could be a further development implemented within the farm production strategy, if leading to environmental benefits.

4.1.2. Functional Unit

Depending on the objective and the scope of the application, the functional unit was chosen, acting as a reference to which attributing all the data and information collected during the LCA study. All the incoming and outgoing flows of the system are therefore linked to it. The functional unit, or comparison basis, describes the primary functions fulfilled by a product system and indicates how much of this function is to be considered in the intended LCA study, to be used as a basis for selecting one or more alternative product systems that might provide these function(s) [21]. Therefore, it is also a necessary element to allow the comparability of the LCA results.

In the specific case, which concerns the pasta production process, the functional unit chosen for the analysis was 1 kg of durum wheat pasta. This quantity of product was identified in order to have final results to be easily used by the company, comparable with other studies and also understandable to consumers.

4.1.3. System Boundaries and Quality of Data

A relevant choice for the purposes of the results of the study is that of leaving out of the LCA the data relating to capital goods and infrastructures [19], as their consideration would lead to an excessive increase in the complexity of the system. On the other hand, all the raw materials necessary to produce the wheat were included in the study, with the connected loads relating to their production (e.g., production and transport of seeds and fertilizers), together with the subsequent treatments and procedures up to obtaining the final pasta product. The phases of packaging, distribution, and consumption of the product were excluded from the system. The system boundaries are shown in Fig. 1.

Therefore, a partial 'Cradle-to-gate' LCA was performed, including four main phases: Field cultivation; Cold storage; Milling; and Pasta making. The four phases will be described in the following paragraph. As mentioned, the transport of the raw materials from the different provision points to the company was included in the analysis.

In relation to the quality of data, Life cycle inventory data are incorporated with background data and foreground data. Foreground (or primary) data include specific data to build a process or product model [27]. The majority of the data were primary ones, which were directly provided by the company. Indeed, the company has its own land where cultivating wheat, and also its own storage point and pasta factory. This allowed having specific primary data, which did not require the definition of the level of precision, since they were not estimated, but data used by the company itself in the context of ordinary management.

The data entered for the field cultivation phase were the result of an average of 6 years, from the crop year 2016/17 until 2021/2022. The average allowed for a reduction in the variability of production in the different agricultural years. The energy data of the storage and milling phases were specifically collected by the mill manager and referred to the 2021. This year was chosen as a reference because it was the last year before the company started some warehouse and production expansion works in 2022, which would not be representative of a standard production year. Other secondary data (e.g., related to transport or electricity consumption) were taken from the *Ecoinvent* database. As suggested by ISO, all the contributions to the environmental impact that have little importance can be considered negligible. In this case, therefore, a 5 % cut-off rule was adopted.

4.2. Inventory Analysis

4.2.1. Data Assumptions and Description of the Inventory Data for Each Stage

As mentioned, a partial "Cradle-to-gate' LCA was performed, including four main phases: Field cultivation; Cold storage; Milling; Pasta making. Table 1 reports the inventory table.

1. Field cultivation. The first phase considered was wheat cultivation. This phase is certainly one of the most important and complex in the entire production process. The various cultivation operations follow 'specific field' guidelines, which can undergo modifications to adapt to the climatic and seasonal variability that is intrinsic in agricultural processes. The quantity but above all the quality of the output, i.e., the grain of durum wheat, which will be the input for the subsequent processing, depends on this first phase. The reference cultivation area is one hectare. The yield of the crop consists of 4.8 tonne/ha of grain and 3.26 tonne/ha of dried straw (primary data provided by the company). The straw is not collected, but is left in the ground and chopped, to incorporate as much organic substance as possible into the soil. The amount of CO_2 stored by wheat is equal to 4.72 tonne/ha. The company obtains the raw materials necessary for the cultivation (e.g., fertilizers, seeds, pesticides) from a local reseller, 16 km far from the company centre. Moreover, the average distance travelled from the warehouse to the cultivated fields to transport these inputs was taken into account, amounting to 5.6 km. The main operations included were subsoiling, ploughing, harrowing, sowing, fertilizing, currying, rolling, and harvesting. Concerning fertilization, the company only carries out nitrogen and phosphate fertilization. The nitrogenous fertilizers distributed are urea (280 kg/ha) and ammonium nitrate (200 kg/ha). Potassium is not used because it is already present in adequate quantities in the area. The fertilization process is carried out at different moments of the cultivation (before and during the rising of wheat). In relation to the emissions coming from the cultivation phase, nitrous oxide emissions were calculated using Global Nitrous Oxide Calculator [28], an online tool that returns the output data after entering information on the environment, agronomic management and geographical location; ammonia emissions were considered equal to 15 % of the total nitrogen used [29]; CO_2 emissions were considered equal to 20 % of the total urea used [30].
2. Cold storage. Once the wheat is collected, then the grain is immediately transported from the field to the storage centre. Here it is pre-cleaned, and subsequently stored in a warehouse which allows the mass to be kept in motion and at the same time to be cooled, by keeping it at a maximum temperature of 18 °C, in order to avoid the development of mold or insects. In this second phase, the main input required consists of the electricity necessary for the pre-cleaning process (5.9 kWh/tonne of grain) and for the cooling process (4.9 kWh/tonne of grain). The transport of the grain from the fields to the storage centre, at an average distance of 65 km from the company, was included in the system. In addition

to the stored grain, an output called 'dust and impurities' derives from this process, which is approximately 3 % of the quantity processed. The dust and impurities are residues of straw, soil and other unwanted elements, which have been considered as a final waste to be correctly disposed of, given that they cannot be used in any other production process.

3. Milling. In the milling phase the inputs that are involved in the transformation are the pre-cleaned grain, energy and a negligible part of water which facilitates the process, preventing the grain from overheating excessively. The grain is not milled immediately after pre-cleaning, but only when new semolina is requested from the pasta factory for pasta making. In this way the company always has fresh semolina available, which is never stored in warehouses because once it leaves the mill it is immediately transported to the pasta factory, so as to maintain the best possible organoleptic characteristics. Therefore, the grain is transported from the warehouse to the mill every time it is necessary to produce new semolina. The transport from the mill to the pasta factory was considered (65 km). The milling process determines energy consumption equal to 80 kWh/tonne of grain. The semolina yield is 73 %, this means that from the milling of 1 tonne of pre-cleaned grain, 0.73 tonnes of semolina are obtained as the main product, and 0.27 tonnes of wheatmeal as a co-product.
4. Pasta making. Once the semolina arrives at the pasta factory, it is unloaded into special silos and here the pasta-making process begins. First, a vacuum quality control is carried out, and subsequently the semolina is sieved through a machine called 'centrifugal destroyer': this is a centrifuge that allows destroying any insect eggs that could be present in the semolina, in order to completely eliminate the risk of contamination in the subsequent sub-phases. Once sieved, the semolina is mixed with water at a temperature of 38–40 °C, with a ratio of 70 % semolina and 30 % water. At this point a pre-mixing takes place first, followed by a main mixing in a vacuum with humidity of 30–32 % and a temperature below 50 °C. The mixture is then subject to a process of extrusion by means of bronze dies, to acquire the desired shape. Once the pasta, whether short or long, comes out of the die, it undergoes an initial external drying process and then a main drying process: the low temperature drying takes place in special drying rooms until the humidity of the pasta is lower than 12 %. The pasta is dried at temperatures below 55 °C, with minimum peaks of 36 °C. These values involve drying times ranging from 24 to 44 hours depending on the format, guaranteeing wholesomeness and taste in the finished product. At this point, the pasta is ready to be packaged. Not the whole semolina is converted into pasta; in particular, in 2021 the yield in pasta was 93.3 %. This means that out of 1578 tonnes of semolina, 1472.3 tonnes of pasta were produced, with a residual pasta percentage of 6.7 %. The residual pasta is not disposed of as waste, but represents a co-product that the company uses for animal feed and the feed sector. The main inputs necessary for the process above explained consist of electricity (546 459 kWh), gas (53 032 m^3) and water (2333 m^3). The amount of input in the inventory is referred to the total pasta produced in 2021.

4.2.2. Allocation

In reference to the allocation procedure, there are two by-products obtained from the first phase of the life cycle analysed: grain and straw, coming from the wheat cultivation phase. An allocation of 70 % and 30 %, based on economic criteria, was applied in this case. Then, in the third phase of the life cycle the two by-products coming from milling are semolina and wheatmeal. Wheatmeal represents the external parts of the grain and it is destined for animal feed or further processing in feed mills, thanks to the high presence of fibres and the richness of nutritional principles. For this reason, it is considered a co-product, as it is not disposed of as waste, but reused in other production processes. In this case, an economic allocation was chosen, assigning 90 % of the impacts to semolina and 10 % to wheatmeal. Finally, in the last phase related to pasta making, two by-products are obtained, i.e., pasta and residual pasta, coming from the extrusion process, which is used within the feed sector. Also in this case, an economic allocation was chosen, assigning 90 % of the impacts to pasta and 10 % to pasta residue.

Fig. 1. System boundaries of the system.

TABLE 1. INVENTORY TABLE

Grain Cultivation Phase (Average of 6 years)					
Input	**Amount**	**Unit**	**Distance**	**Type**	**T·km**
Tillage, subsoiling	0.9	ha			
Tillage, ploughing	0.1	ha			
Tillage, harrowing	1	ha			
Tillage, harrowing	0.5	ha			
Wheat seed	245.78	kg	21.6	By road truck	4.87
Sowing	1	ha			
Tillage, harrowing	1	ha			
Tillage, currying	0.5	ha			
Tillage, rolling	0.5	ha			
Urea, as N	280	kg	21.6	By road truck	6.05
Ammonium nitrate, as N	200	kg	21.6	By road truck	4.32
Phosphate fertilizer, as P2O5	270	Kg	21.6	By road truck	5.83
Fertilising processing (4 times)	1	ha			
Fungicide	0.373	kg			
Herbicide	0.484	kg			
Application of plant protection product, by field sprayer	1	ha			
Application of plant protection product, by field sprayer	1	ha			
Harvesting	1	ha			
Output	**Amount**	**Unit**	**Distance**	**Type**	**T·km**
Grain	4.8	tonne	65	By road truck	387
Straw	3.26	tonne			
Pre-Cleaning and Storage Phase (data referred to 2021)					
Input	**Amount**	**Unit**			
Electricity for refrigeration	4.9	kWh			
Electricity for movement	5.9	kWh			
Output	**Amount**	**Unit**			
Pre-cleaned and stored grain	0.97	tonne			
Dust	0.03	tonne			
Semolina at milling Phase (data referred to 2021)					
Input	**Amount**	**Unit**			
Electricity for milling	80	kWh			
Output	**Amount**	**Unit**	**Distance**	**Type**	**T·km**
Semolina at milling	0.73	tonne	65	By road truck	195
Wheatmeal	0.27	tonne			

Pasta factory Phase (data referred to 2021)		
Input	**Amount**	**Unit**
Water	2 333 000	kg
Electricity	546 459.46	kWh
Natural gas	566 912.08	kWh
Photovoltaic	1231.38	kWh
Output	**Amount**	**Unit**
Pasta	1472.3	tonne
Pasta residue	105.73	tonne

5. Results and Discussion

Analysing the life cycle inventory of pasta Mancini, we found that the process having the major influence in the system was that of wheat cultivation (85.8 % of incidence), followed by a 10.1 % of the incidence caused by the pasta-making phase, and about 2.86 % caused by the milling phase. The cold storage influenced the life cycle of pasta by only 1.24 %.

Fig. 2 shows the impacts evaluation, by means of the IMPACT 2002+ method, illustrating the normalized values. It is evident that 'Land occupation' determines a sensibly greater impact than the other categories, followed by 'Respiratory inorganics' and by 'Global warming'. With respect to the latter category, an in-depth analysis was carried out to determine which substances were involved in the determination of this environmental impact. As a result, the substance that contributes most to the item 'global warming', with 77 % of the total, was found to be carbon dioxide emitted into the atmosphere by the consumption of fossil fuels (Carbon dioxide, fossil).

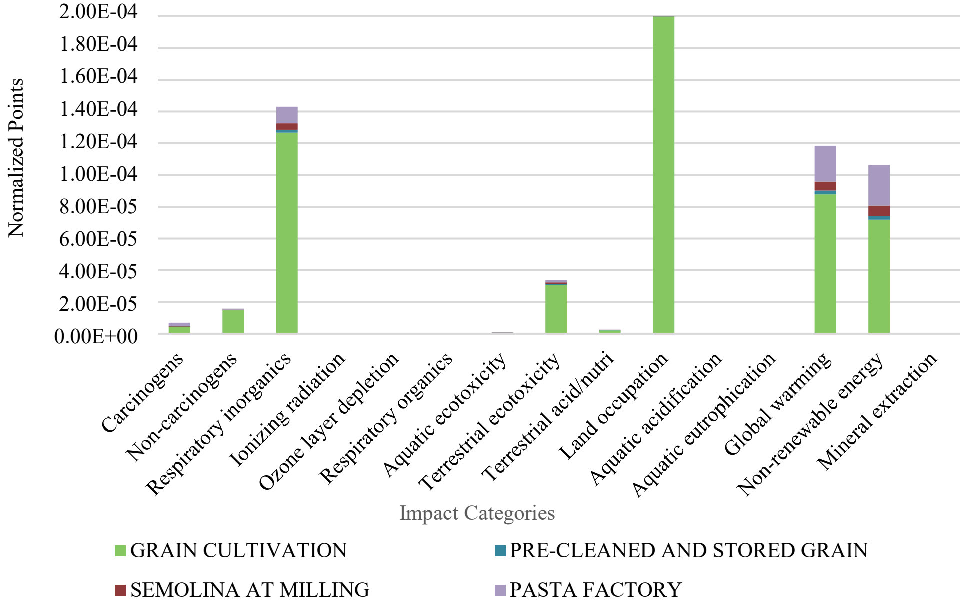

Fig. 2. Impact evaluation of pasta Mancini – normalized values (IMPACT 2002+).

The analysis made by means of the method IPCC 2013 (Table 2) showed that the production of 1 kg of Pasta Mancini caused the emission of 1.376 kg of CO_2 eq. The phase that released the most emissions into the environment was that of wheat cultivation, with 76.3 % of the total, the second phase with the greatest impact in terms of CO_2 emissions was pasta making (17.6 %), followed by the milling phase (4.4 %) and finally by cold storage (1.7 %).

TABLE 2. RESULTS OF IPCC 2013 METHOD

Process phase	**kg CO_2 eq.**	**%**
Wheat cultivation	1.042	76.3
Cold Storage	0.023	1.7
Milling	0.060	4.4
Pasta making	0.240	17.6
Total	**1.376**	100

Moreover, in relation to only field cultivation, a comparison in terms of impacts was made between the conventional method of cultivation and a hypothetical process using organic farming techniques. This comparison was made in order to hypothesize further development to be implemented within the farm production strategy, if leading to environmental benefits. The comparison results are shown in Fig. 3. The organic cultivation resulted in being better for the majority of the impact categories; however, the conventional did not have always a greater impact than organic one. In particular, for the 'Ecosystem quality' macro-category organic agriculture had a greater impact than conventional, this was probably due to the 'Land occupation' impact category which was the one with the greatest environmental impact within the macro category. The lower yield of the organic and at the same time the use of the same amount of land could affect this result. The comparison of the two cultivation methods was analyzed also with the IPCC 2013 method, and we found that the cultivation of durum wheat with the organic method impacted only 38.1 %, in terms of kg of CO_2 eq., compared to the cultivation with conventional agriculture.

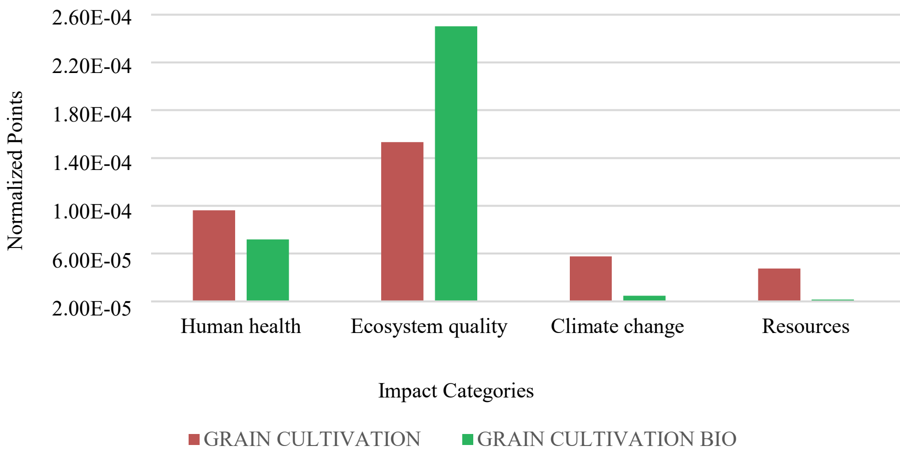

Fig. 3. Comparison between conventional and organic farming techniques (IMPACT 2002+).

As mentioned, the most impacting phase resulted to be the wheat cultivation. The majority of the impacts were probably due to the several farming operations that are necessary to produce the final product grain. These imply a consumption of fossil fuels (during the processes of ploughing, harrowing, sowing, fertilizing, currying, rolling, etc.) and also a consumption of chemical fertilizers and pesticides, since we are dealing with not organic cultivation.

These results are in line with the current literature, which sees the cultivation as the phase contributing to the greatest impacts within the overall pasta production process. As for Cimini *et al.* [31], this can be attributed to the consumption of aged manure and diesel fuel for soil management activities, together with direct and indirect N_2O emissions. However, it should be specified that in this analysis the input of manure aged in the soil was not taken into consideration. The study of Zingale *et al.* [9] aimed to perform a systematic literature review of life cycle assessments in the durum wheat (DW) sector. Given the findings from the papers reviewed, the authors could document that the cultivation phase is the primary environmental hotspot of DW-derived food products and suggested several mitigation and improvements solutions, including organic farming practices, diversified cropping systems, reduction of N fertilisers and pesticides application and irrigation optimisation strategies. Another case study from Zingale *et al.* [4], which analysed through LCA the case of organic whole-grain durum wheat pasta in Sicily, found that cultivation is the phase contributing the largest impacts for all the midpoint categories considered by the LCIA method. Results of Bevilacqua *et al.* [7], who studied the environmental performances of the production and the distribution of durum wheat pasta in the Italian market, revealed that the agricultural production (i.e., cultivation of wheat) and the production of durum wheat semolina were the sub-processes that accounted for most of the environmental load. Therefore, to improve the environmental performance, an alternative production system was designed in which organic agriculture was used to produce wheat; recyclable cardboard was used as the only packaging material, and a more efficient dust collecting system was installed at the mill (for semolina production). In our case study, the packaging and distribution phases were not considered in the analysis, but this step could be a further development of the research. Finally, according to Cappelli and Cini [32], the correct management of the wheat cultivation stage was found to be essential since it represents the most impacting phase for the environment. Successively, particular attention needs to be paid to the milling process, the kneading phase, breadmaking, and, finally, the manufacturing of pasta.

6. CONCLUSION

The aim of this work was to analyse the life cycle of the production process of pasta produced by a traditional and high-quality company in Central Italy, evaluating all the phases starting from the raw materials provisioning, the cultivation of the wheat, and going on with the transformation process for obtaining the final product of pasta. To carry out this evaluation we used the LCA methodology, which allowed us to better evaluate all the impacts of the production process and to make a comparison, within the cultivation phase, between conventional and organic farm techniques.

The cultivation resulted to be the most impactful phase within the system, for all the impact categories, in line with the current literature. The categories most involved were Land Occupation, Respiratory Inorganics and Global Warming, this last category was especially connected with emissions of fossil fuels during the different farming operations.

From the analysis with the IPPC method, it can be seen that 1 kg of Pasta Mancini caused the emission of 1.376 kg of CO_2 eq. The phase that released the most emissions into the environment was wheat cultivation, with 76.3 % of the total. In the comparison with a hypothetical scenario including organic farming, the environmental impacts decreased sensibly, except for the Land Occupation category. A thing to be noted, however, is that the company already implements a set of best practices within the cultivation phase that cannot be detected by the LCA instrument (e.g., use of cover crops and leguminous cultivations, crop rotation, reduction of deep tillage of the soil, etc.), which already contributed during the years to an increase of organic substance within the soil, and as a consequence to an improvement of the environmental performances.

As regards the electricity consumption of the pasta factory, the data used indicate the energy consumed by the entire pasta-making phase. For a future LCA study with a greater degree of detail, it would be ideal to measure the consumption of each individual machine involved, in order to make changes and innovations within the line, perhaps replacing a high-consumption machine with a more efficient new generation one in this area.

The analysis stopped at the stage of pasta production; therefore, the packaging process together with the distribution phase could be an object of further analysis.

To date, the company has a snapshot of the environmental impact due to its production process. Process changes can be envisaged in the future, which would lead to a reduction of this impact. An example could be the installation of new photovoltaic panels on the roof of the pasta factory or of photovoltaic canopies acting as covers for the parking spaces, for the production and self-consumption of electricity. The company also plans to build a biomass generator, with the perspective of further reducing electricity consumption.

Given these improvements, and the improvement of cultivation and production techniques in the coming years, it would be interesting to carry out a new LCA study of the same process, to observe if and how much the environmental impact has decreased.

As already mentioned, the LCA tool for studying the product life cycle is useful for monitoring the company's ability to move in the direction of sustainability, and its dissemination as a study and self-analysis tool can help companies going towards a circular economy model. This approach allows also following what is currently outlined by the European Green Deal policy, in relation to the creation of agri-food supply chains that are as sustainable and circular as possible. An analysis of the life cycle, in fact, allows us to visualize which are the critical points in terms of impacts within the company production cycle, allowing for any future improvements from the point of view of environmental sustainability. Furthermore, any reuse of products and energy recovery that the company already implements, or other advantages from an environmental point of view, can be considered within the system. Finally, this work could be of interest to researchers, LCA practitioners, farmers and producers, policy and decision-makers, and other stakeholders, and could support the promotion of environmental sustainability in the pasta production sector.

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