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Finding the Best Available Techniques for an Environmental Sustainable Waste Management in the Fish Canned Industry

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This work proposes the use of the life cycle assessment (LCA) to identify the best available techniques (BAT) to the management of the residues generated in the anchovy canning sector. This industry generates huge amount of solid and liquid wastes, and their management is one of the hotspots of the canned anchovy life cycle. The application of BATs can improve the environmental performance of the canned anchovy. However, sometimes it is not clear which BAT is the most appropriated, and an environmental analysis is required. In this sense, several BATs are proposed based on the circular economy concept, which promotes the reutilisation of wastes and they were evaluated under a life cycle approach: (i) valorisation of the anchovy residues into fishmeal, fish oil and anchovy paste, (ii) incineration and (iii) disposal in a municipal solid waste landfill. The LCA was conducted from cradle to gate using the global warming (GW) indicator. The results showed that the disposal of the anchovy residues in a landfill was the least environmental-friendly option, while the valorisation was the best alternative.

1. Introduction: Nexus best available techniques and life cycle assessment

Developing or adapting new techniques to prevent pollution generation or impacts is the huge stake of the century. Due to global regulatory and social constraints, these actions must be accompanied by environmental, social and technical assessment. In this sense, the European context has been policy-driven by several directives to protect the environment (Laforest et al., 2014). In particular, in 1996 the Integrated Pollution Prevention and Control (IPPC) directive (European Commission, 2008) introduced the concept of Best Available Techniques (BAT) to the European environmental regulation. In 2010, the Industrial Emission Directive (IED) (European Commission, 2010) repealed the IPPC directive, which has extended and reinforced the role of BATs. The industrial sectors concerned with the implementation of BATs are listed in its annex I (Evrard et al., 2016). The IED defines BAT as "*the most effective and advanced stage in the development of activities and their methods of operation which indicates the practical suitability of particular techniques for providing the basis for emission limit values and other permit conditions designed to prevent and, where that is not practicable, to reduce emissions and the impact on the environment as a whole"* (European Commission, 2010). The selection of the BAT are based on twelve criteria given in annex III of the IED, but they are not easy to understand due to the phrasing used mixes objectives, criteria, indicators and parameters. To help to identify BAT, the European Commission has drawn up the Best Available Technique reference documents, the so-called BREFs (Ibañez-Forés et al., 2013). The techniques presented in each BREF as BAT are identified at the European level and for the industrial sector concerned as a whole (Laforest et al., 2014). However, BAT can cause transfer of burdens from one environmental medium to another and this problem is referred as cross-media effects, i.e. the generation of wastewater owing to operation of air

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pollution control equipment. To evaluate the performance of BAT it is necessary to simultaneously evaluate (i) environmental benefits, (ii) environmental impacts and (iii) cost of implementation of BAT (Yilmaz et al., 2015). Life cycle assessment (LCA) is a tool to assess the potential environmental impacts and resources used throughout a product´s life-cycle (Margallo et al., 2013). Moreover, it is a valuable tool that quantifies the environmental benefits and impacts of production processes and reveals cross-media issues. As stated Nicholas et al., (2000), LCA is ideally suited to the kind of integrated, holistic assessment required by IPPC to assess the different technologies being considered as BAT. LCA has been successfully applied to identify environmentally most sustainable options among different BAT alternatives for several industrial sectors, such as ceramic tiles industry (Ibañez-Forés et al., 2013) or cement sector (Valderrama et al., 2012). Nevertheless, the use of BAT is rather applied to products and furthermore, the BREF documents are only available to processes in the industrial sectors included in the IPPC. Therefore, this work proposes a technical procedure to determine the BAT of a product rather than of a process. This procedure was applied to the fish canning industry, in particular, to the waste management of the Cantabrian canned anchovy production. In Cantabria (North of Spain), anchovy is the 2nd most preferred fish (Eurofish, 2012), being the quality of Cantabrian canned anchovies is world-renowned, considering consumers this foodstuff as a gourmet product. However, from an environmental point of view, several hotspots are related to the canned anchovy manufacturing. Specifically, the production of canned anchovy generates a huge amount of solid and liquid wastes (approximately 9,000 t/y) that requires a proper management. For this reason, this work combines the use of LCA and the BAT to implement strategies for a sustainable management of the fish residues of Cantabrian canned anchovies.

2. Life cycle assessment

2.1 Goal and scope

The goal and scope have to include the intended application of the study, the description of the system under study, the functional unit and the level of detail to be considered (Margallo et al., 2014). Moreover, goal definition is a very important step in an LCA study, because the choices made at this stage influence the entire study (De Marco et al., 2015). In this work, LCA was conducted from cradle to gate (excluding the fish capture) based on data of a representative plant from Santoña (Cantabria). The cradle-to-gate (Cr-Ga) stage included the extraction, production and transport of raw materials (oil, brine, salt, packaging, etc.), and the gate-to-gate (Ga-Ga) stage comprised the anchovy processing and the management of anchovy residues. The functional unit (FU) was one can of final product formed by 30 g of anchovy and 20 g of extra virgin olive oil (EVOO). Figure 1 displays the flow diagram of the system under study. The construction, production and maintenance of necessary infrastructures and equipment were excluded.

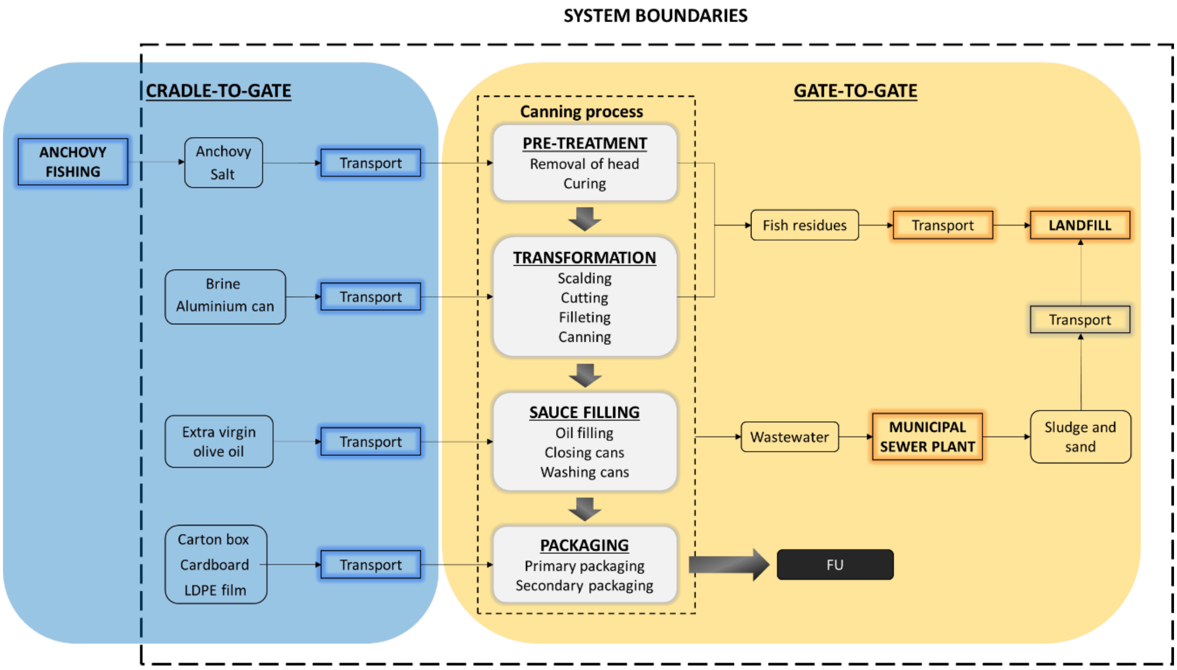

Figure 1: Diagram of the life cycle of canned anchovies, from cradle to gate

In the gate to gate stage, the anchovy is beheaded and placed in layers with a bed of salt between each layer of fish for 6 months. After curing, the skin is removed in the scalding process and each anchovy is cut and filleted by hand. The anchovy fillets are packed in cans filled with EVOO. Finally, the cans are sealed, washed, codified and packed. The primary packaging is composed of the aluminium can and the boxboard. Secondary packaging for the transportation of the final product consists of corrugated cardboard boxes and low-density polyethylene (LDPE) film to wrap the packs. The anchovy residues generated during the process are transported 15 km and disposed in a municipal solid waste landfill, whereas the liquid effluents are sent to a municipal sewer plant. The sludge and sand from the wastewater treatment plant are also disposed in a landfill.

2.2 Data collection

The life cycle inventory (LCI) is one of the most effort-consuming steps and consists on the collection and interpretation of the data necessary for the environmental assessment of the observed system (Iannone et al., 2014). In this study, primary data, such as the consumption of electricity, fuels, water and raw materials (salt, brine, EVOO and packaging); and the generation of solid and liquid wastes, were get from the canning anchovy plant. On the other hand, secondary data such as, the manufacturing or transformation processes to obtain energy, water and raw materials came from databases and literature. Table 1 shows the inputs and outputs data of the life cycle of one can of anchovies in EVOO. These data represented the average values of the canning plant under study for 2014.

Table 1: Life cycle inventory of one can of Cantabrian anchovies in extra virgin olive oil

	Input/output data	Units	Value
Inputs	Fresh anchovy	kg	9.60×10^{-2}
	Salt	kg	5.30×10^{-2}
	Brine	m^3	5.42×10^{-5}
	Extra virgin olive oil	kg	2.90×10^{-2}
	Energy	kWh	3.19×10^{-2}
	Water	m^3	4.97×10^{-4}
	Aluminium can	kg	1.50×10^{-2}
	Cardboard	kg	5.00×10^{-3}
	Corrugated board	kg	2.00×10^{-3}
	Plastic (LDPE)	kg	1.20×10^{-4}
	Natural gas	m^3	1.47×10^{-3}
Outputs	Canned anchovy	Ud.	1.00
	Solid fish residues	kg	6.50×10^{-2}
	Wastewater	m^3	4.97×10^{-4}
	Extra virgin olive oil	kg	8.97×10^{-3}

3. Life cycle impact assessment results

The life cycle impact assessment (LCIA) was conducted with the LCA software GaBi 6.0 (PE International, 2014) and using the indicator Global Warming (GW) owing to the characteristics of this sector. The latter was based on the potential factors proposed by the Institution of Chemical Engineers (ICheme, 2002).

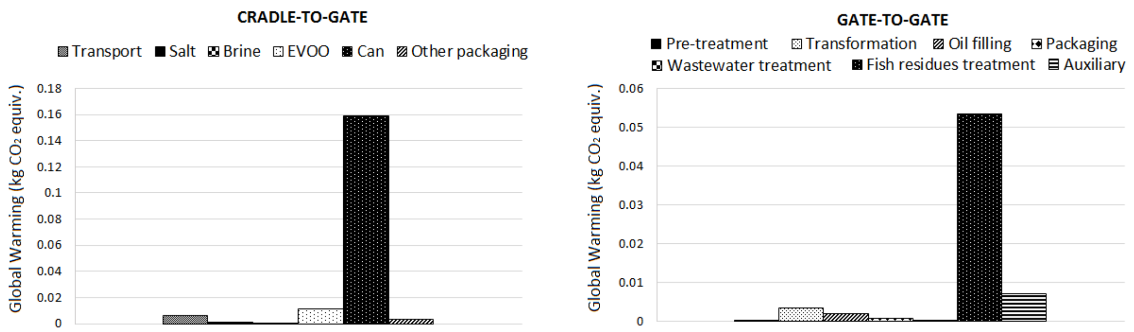

Figure 2: Life cycle impact assessment of cradle-to-gate and gate-to-gate stages.

The life cycle from cradle to gate, of one can of Cantabrian anchovies in EVOO, produced 2.47 ×·10^{-1} kg CO_2 equivalent. Figure 2 shows that in Cr-Ga stage the production of the aluminium can presented the greatest GW contribution (1.59 ×·10^{-1} kg CO_2 equivalent) representing 64 % of the total impact category. The production of aluminium is a high-energy demand process due to the extraction of bauxite. On the other hand, the production of EVOO represented 5 % of the total GW (1.10 ×·10^{-2} kg CO_2 equivalent) owing to the energy required in the farming. In the Ga-Ga stage, the management of the fish residues generated during the canning process presented the highest value of GW, 5.35·× 10^{-2} kg CO_2 equivalent, representing 22 % of the total GW. This was due to the emission of greenhouse gases (CO_2, CH_4, NO_x) in the landfill.
The LCA results showed that, the manufacture of aluminium cans and the management of the anchovy residues were the main hot spots of the anchovy canning process. In this sense, other authors have evaluated the use of several materials for the packaging. Almeida et al., (2015) employed tinplate cans for canned sardines reducing by half GW impact. Moreover, Hospido et al., (2006) reported that the use of plastic bags instead of tinplate cans decreased more than half the GW. However, the management of anchovy residues has not yet been assessed from a LCA approach. Therefore, some improvements candidates to be BAT are suggested in the next section.

4. Proposal of BAT for the management of anchovy residues based on circular economy concept

The techniques considered in this section are based on the concept of circular economy proposed by the European Commission. This concept aims to keep the added value in products for as long as possible and to eliminate waste. Figure 3 shows the circular economy approach applied to the canned anchovy process through the environmental sustainable waste management.

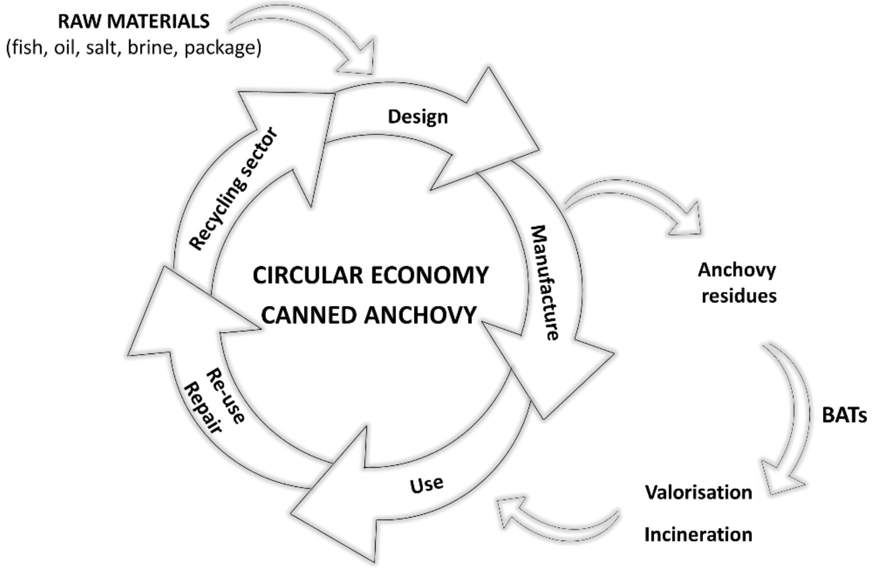

Figure 3: Circular economy concept applied to the management of the anchovy residues

According to this concept, a series of improvement measures are proposed regarding the whole life cycle of fish residues:

Waste collection: First BAT suggested is the collection of anchovy residues into two groups: heads and spines, and anchovy remains. This selective collection with the canning plant facilitates the management of the anchovy residues.
Waste transportation: Second BAT is the transportation of dried anchovy residues to minimise the total mass transported.
Waste management: Two BATS are proposed as management alternatives: valorisation and incineration, and they were compared with the disposal in a landfill. On one hand, heads and spines can be used to produce fishmeal and fish oil, whereas the anchovy remains can be employed to produce anchovy paste. On the other hand, anchovy residues can be incinerated to obtain energy. LCA was used to determine the GW to

apply these BATs in the anchovy canning process. Figure X shows the comparison GW values of the anchovy canning process when the anchovy residues are disposed in a landfill, valorised or incinerated. The GW was reduced 21 % when valorisation was used, and 18 % when incineration was applied.

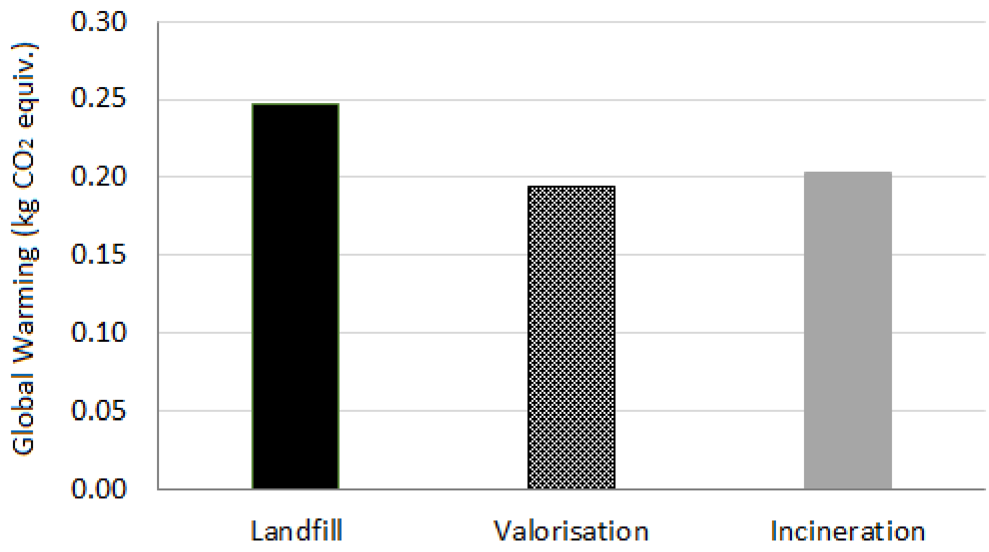

Figure 4: Life cycle assessment of canned anchovies comparing landfill, valorisation and incineration as anchovy residues management

5. Conclusions

This paper proposes several BATs for the management of anchovy residues in the canning industry based on an LCA approach. Once determined the current techniques applied in the life cycle of one can of anchovies, the environmental profile was obtained. The LCA study showed that the management of the anchovy residues represented 22 % of the total GW when these residues were disposed in a landfill. According to these results, some improvements measures were suggested based on the circular economy concept, which promotes the reutilisation of wastes. Two alternatives were evaluated using the LCA methodology: the valorisation and the incineration. In case of valorisation, heads and spines can be used to produce fishmeal and fish oil, whereas anchovy remains can be employed to produce anchovy paste. On the other hand, the incineration of residues produces energy. The results showed that the valorisation reduced 21 % the total GW of the anchovy canning process, while the incineration reduced 18 % the impact. Valorisation seems to be most effective technique to reduce global warming impact. Moreover, this alternative generates three marketable products with added value. However, a further study considering other impact categories such as atmospheric acidification and eutrophication is necessary to obtain a complete study of the BATs proposed. Moreover, the anchovy fishing step should be included to determine its influence environmental performance of the canned anchovies and, it is necessary, to propose BATs of other stages.

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References

Almeida C., Vaz S., Ziegler F., 2015, Environmental life cycle assessment of canned sardine product from Portugal, Journal Industrial Ecology, 19, 607-617.

De Marco I., Iannone R., Miranda S., Riemma S., 2015, Life Cycle Assessment of Apple Powders Produced by a Drum Drying Process, Chemical Engineering Transactions, 43, 193-198.

European Commission, 2008, Directive 2008/1/EC of the European Parliament and of the Council of 15 January 2008 concerning integrated pollution prevention and control, Official Journal of the European Union, L24, 8-29.
European Commission, 2010, Directive 2010/75/UE of the European Parliament and of the Council of 24 November 2010 concerning industrial emissions (integrated pollution prevention and control), Official Journal of the European Union, L334, 17-119.
Eurofish, 2012, Overview of the world´s anchovy sector and trade possibilities for Georgian anchovy products. <www.fao.org/fileadmin/user_upload/Europe/documents/Publications/Anchovies_report_2.03.2012.pdf> accessed 10.03.2016.
Evrard D., Laforest V., Villot J., Gaucher R., 2016, Best Available Technique assessment methods: A literature review from sector to installation level, Journal of Cleaner Production, 121, 72-83.
Hospido A., Vazquez M.E., Cuevas A., Feijoo G., Moreira M.T., 2006, Environmental assessment of canned tuna manufacture with a life-cycle perspective. Resource, Conservation & Recycling, 47, 56-72.
Iannone R., Miranda S., Riemma S., De Marco I., 2014, Life cycle assessment of red and white wines production in southern Italy, Chemical Engineering Transactions, 39, 595-600.
Ibañez-Forés V., Bovea M.D., Azapagic A., 2013, Assessing the sustainability of Best Available Techniques (BAT): methodology and application in the ceramic tiles industry, Journal of Cleaner Production, 51, 162-176.
IChemE, 2002, The sustainability metrics. Institution of Chemical Engineers, Rugby. United Kingdom.
ISO 14040, 2006, Environmental management – Life cycle assessment – Principles and framework, International Organization for Standardization, Geneva, Switzerland.
Laforest V., 2014, Assessment of emerging and innovative techniques considering best available technique performances, Resource, Conservation & Recycling, 34, 261-271.
Margallo M., Aldaco R., Irabien A., 2013, Life cycle assessment of bottom ash management from a municipal solid waste incinerator (MSWI), Chemical Engineering Transactions, 35, 871-876.
Margallo M., Aldaco R., Irabien A., 2014, A Case Study for Environmental Impact Assessment in the Process Industry: Municipal Solid Waste Incineration (MSWI), Chemical Engineering Transactions, 39, 613-618.
Nicholas M.J., Clift R., Azapagic A., Walker F.C., Porter D.E., 2000, Determination of "Best available techniques" for integrated pollution prevention and control: A life cycle approach, Process Safety and Environmental Protection, 78, 193-203.
PE International, 2014, GaBi 6.0 software and databases for life cycle assessment. Clean Technologies and Environmental Policy, 13, 595-605.
Valderrama C., Granados R., Cortina J.L., Gasol C.M., Guillem M., Josa A., 2012, Implementation of best available techniques in cement manufacturing: a life cycle assessment study, Journal of Cleaner Production, 25, 60-67.
Yilmaz O., Anctil A., Karanfil T., 2015, LCA as a decision support tool for evaluation of best available techniques (BATs) for cleaner production of iron casting, Journal of Cleaner Production, 105, 337-347.