Analytic Hierarchy Process (AHP) for the analysis of the viability of fish side streams valorisation

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Introduction

One of the most important hurdles and bottlenecks to overcome when implementing valorisation alternatives is the lack of a methodology to take the right decision while sorting, storing and managing conditions of different fish residual streams.

Different fractions of fish side-streams have different potentials for obtaining high value products. However, the viability of these specific high value products from residual streams depends on a huge amount of viability factors, which are necessary to consider once they are generated. To overcome this challenge, one of the objectives of the WaSeaBi project has been to design a help decision making tool (1).

Multi-Criteria Decision Analysis (MCDA) allows to assess the viability of fish side-streams valorisation since it provides a reliable framework for procedures to rank alternative options and prioritise and it based on their assessment across selected criteria. Such methods have been widely and effectively applied in different environmental areas.

Analytic Hierarchy Process (AHP) is a MCDA method which allows partitioning the problem into smaller decision sets one at a time (2,3). The optimum decision about the sorting, storing and managing conditions of different fish residual streams is based on their potential for being converted to high value products and potential synergies with other fish residual side-streams generated close to them.

AHP methodology has been used in a broad range of applications in the field of urban waste management but have been never applied for making decisions on how to use aquatic side-streams in a full value chain approach.

Material and methods

The main categories that need to be evaluated were defined by a group of experts in the field of food waste management and valorisation according to their experience and a bibliography review. 1) Legal aspects 2) Technical aspects 3) Economic aspects 4) Environmental aspects.

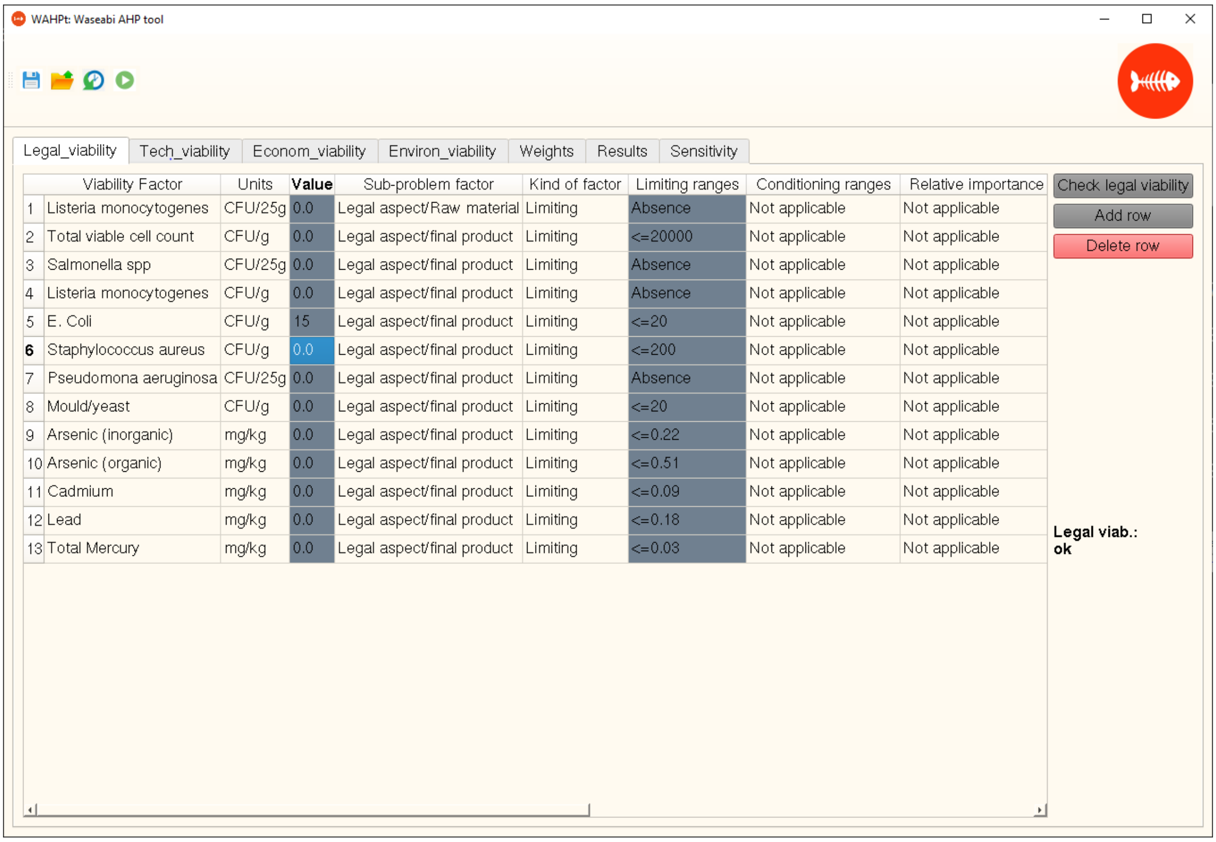
The first step to construct an AHP was to identify the key viability criteria from the technical, legal, economic, and environmental point of view. Legal viability factors were extracted from the European legislation. Technical parameters for each valorisation options were defined by experts, setting the basic requirements and the value-added parameters. Capital Expenses (CAPEX) and Operational expenditures (OPEX) were calculated for each option and standard economical parameters were chosen as indicator. For the environmental analysis, main environmental impacts were chosen and calculated by a simplified LCA analysis, using ECOINVENT 3.0 data base.

Then, the limiting and conditioning ranges as well as the relative importance of each viability criterium were set up based on the potential for obtaining high value products. It must be done case by case and adapted to the subject of the study and stated by consensus. Afterwards, the decision matrices and the corresponding algorithms and functions to take right decision were defined to give a score for each category, a final score combining all categories and a final prioritization for the different scenarios.

Finally, the visualization of the results was set up to present to all viability calculations. The computational part of the tool was developed using Python3.7® and the Graphical User Interface (GUI) was designed using its PyQT5 library.

Results and discussion

The Legal viability (Figure 1) allows to verify the compliance of the studied side-stream of the legal viability constraints. The output for this analysis is a simple binary result of the type True/False.



	Viability Factor	Units	Value	Sub-problem factor	Kind of factor	Limiting ranges	Conditioning ranges	Relative importance
1	Listeria monocytogenes	CFU/25g	0.0	Legal aspect/Raw material	Limiting	Absence	Not applicable	Not applicable
2	Total viable cell count	CFU/g	0.0	Legal aspect/final product	Limiting	<=20000	Not applicable	Not applicable
3	Salmonella spp	CFU/25g	0.0	Legal aspect/final product	Limiting	Absence	Not applicable	Not applicable
4	Listeria monocytogenes	CFU/g	0.0	Legal aspect/final product	Limiting	Absence	Not applicable	Not applicable
5	E. Coli	CFU/g	15	Legal aspect/final product	Limiting	<=20	Not applicable	Not applicable
6	Staphylococcus aureus	CFU/g	0.0	Legal aspect/final product	Limiting	<=200	Not applicable	Not applicable
7	Pseudomona aeruginosa	CFU/25g	0.0	Legal aspect/final product	Limiting	Absence	Not applicable	Not applicable
8	Mould/yeast	CFU/g	0.0	Legal aspect/final product	Limiting	<=20	Not applicable	Not applicable
9	Arsenic (inorganic)	mg/kg	0.0	Legal aspect/final product	Limiting	<=0.22	Not applicable	Not applicable
10	Arsenic (organic)	mg/kg	0.0	Legal aspect/final product	Limiting	<=0.51	Not applicable	Not applicable
11	Cadmium	mg/kg	0.0	Legal aspect/final product	Limiting	<=0.09	Not applicable	Not applicable
12	Lead	mg/kg	0.0	Legal aspect/final product	Limiting	<=0.18	Not applicable	Not applicable
13	Total Mercury	mg/kg	0.0	Legal aspect/final product	Limiting	<=0.03	Not applicable	Not applicable

Figure 1 Legal viability panel

The Technical viability (Figure 2) consists of several chemical indicators related to the potential of fish by-products for obtaining high value compounds. The output is a positive number between 0 and 10, representing "0" a low technical viability and "10" a high technical viability. If a parameter is out of the limiting range, the score will be "0", whereas if it is insides the limiting range, the score will be proportional to the conditional range. The score of each parameter viability is balanced by applying its relative importance to obtain a weighted score.

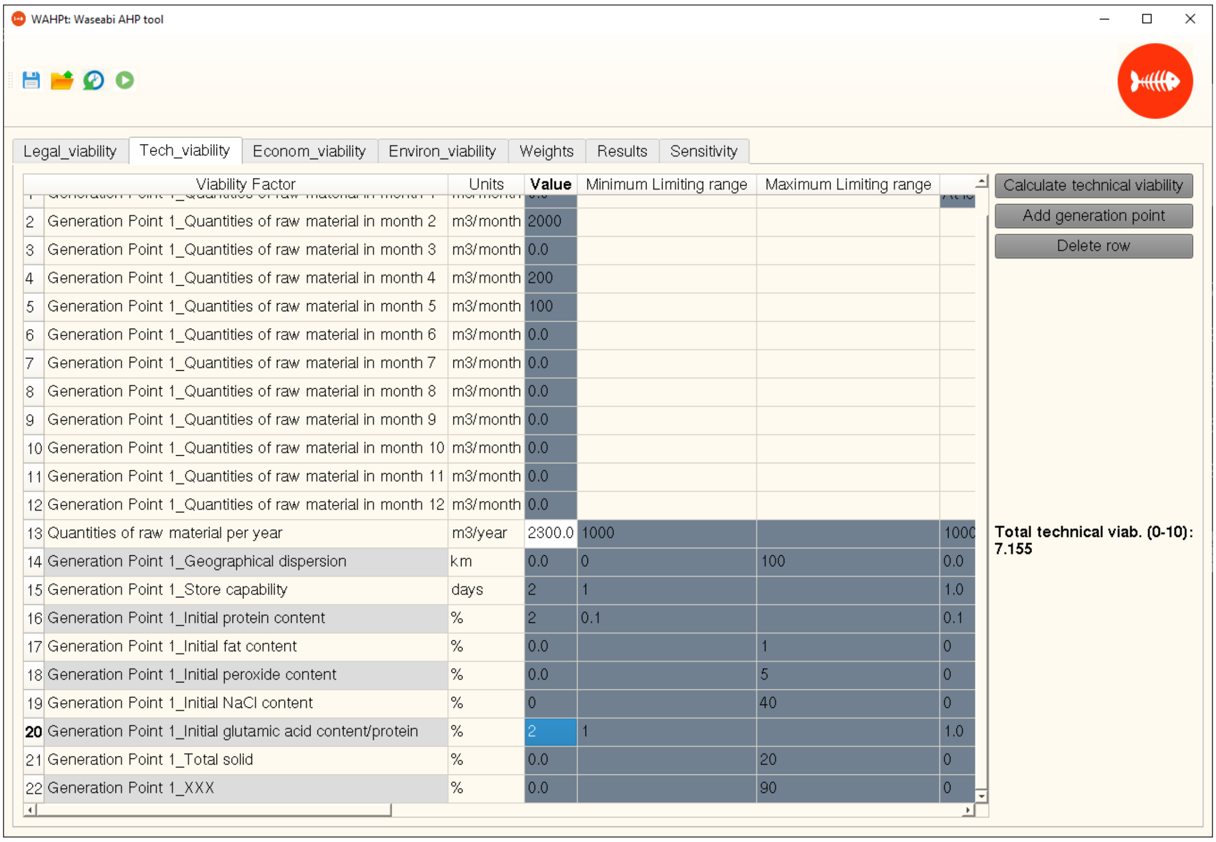


Figure 2 Technical viability panel

The economical parameters selected for the economic analysis are: Net Present Value (NPV), Return on investment (ROI), Payback period (PP) and Gross Operation Profit (EBITDA). The number of years and the CAPEX and OPEX value for the calculation of the scenario can be modified by the user based on their experience. The economic profitability results are presented in the Figure 3.

Figure 3 Economic viability panel

The environmental impacts selected for the environmental assessment are Carbon and Water footprints and the Eutrophication. Based on a Life Cycle Assessment, the tool asks user data about the most important environmental aspects to calculate the selected impacts. The environmental viability results are presented in the Figure 4.

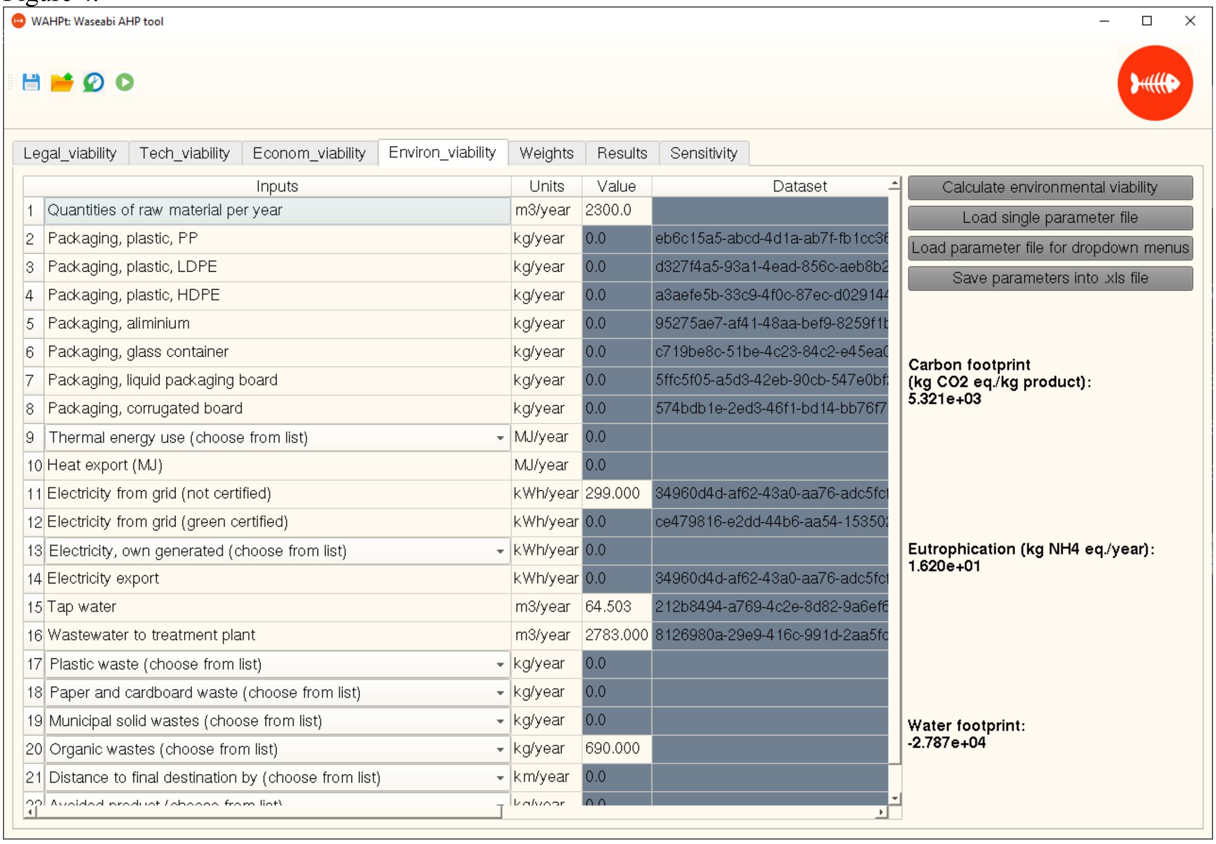
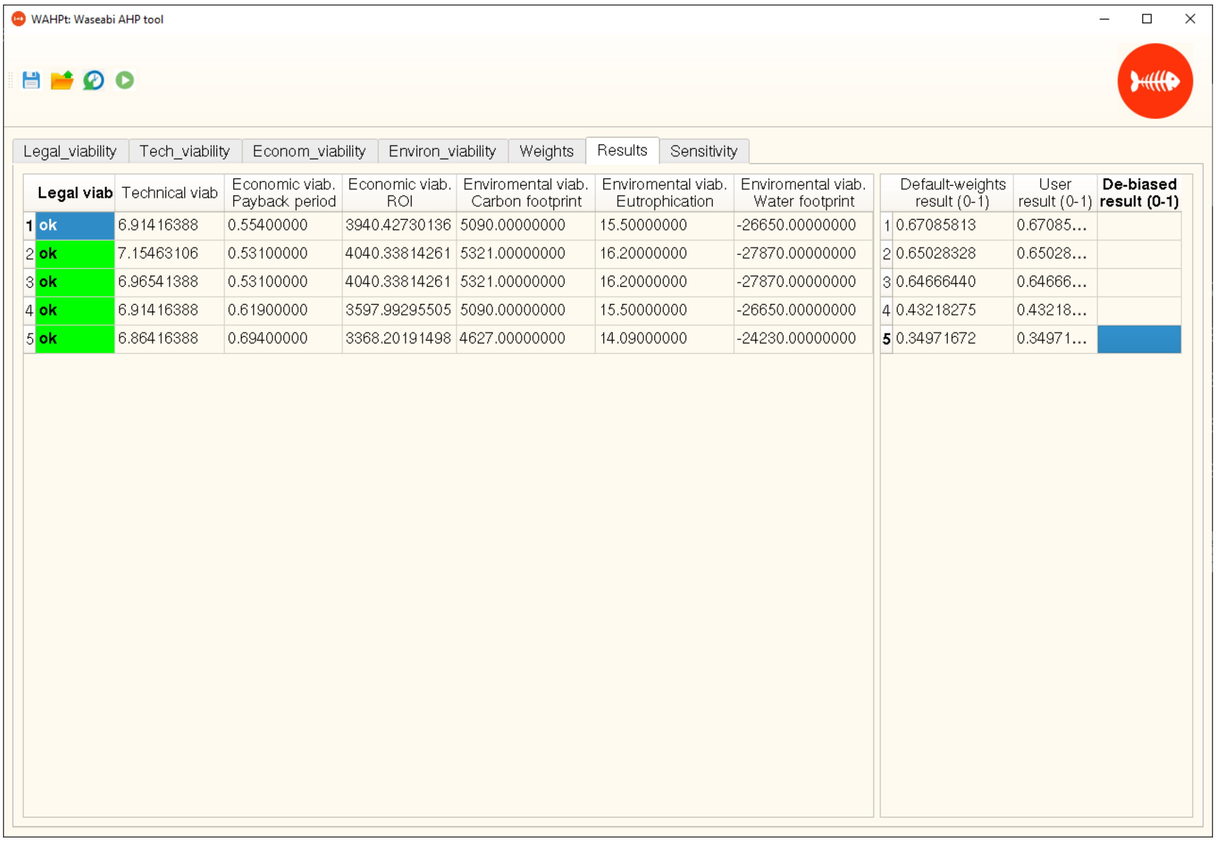


Figure 4 Environmental viability panel

The single score is generated based on the relative weight given for each viability. If there are more than one scenario, one-score projection of the different viability calculations for different scenarios is included based on the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) technique. Its basic principle assumes that the chosen alternative should simultaneously have the shortest distance from the positive-ideal solution and the farthest distance from the negative-ideal solution.



	Legal viab	Technical viab	Economic viab. Payback period	Economic viab. ROI	Enviromental viab. Carbon footprint	Enviromental viab. Eutrophication	Enviromental viab. Water footprint		Default-weights result (0-1)	User result (0-1)	De-biased result (0-1)
1	ok	6.91416388	0.55400000	3940.42730136	5090.00000000	15.50000000	-26650.00000000	1	0.67085813	0.67085...	
2	ok	7.15463106	0.53100000	4040.33814261	5321.00000000	16.20000000	-27870.00000000	2	0.65028328	0.65028...	
3	ok	6.96541388	0.53100000	4040.33814261	5321.00000000	16.20000000	-27870.00000000	3	0.64666440	0.64666...	
4	ok	6.91416388	0.61900000	3597.99295505	5090.00000000	15.50000000	-26650.00000000	4	0.43218275	0.43218...	
5	ok	6.86416388	0.69400000	3368.20191498	4627.00000000	14.09000000	-24230.00000000	5	0.34971672	0.34971...	

Figure 5 Calculated alternatives analysed by TOPSIS methodology

Conclusions

AHP method is an appropriate methodology for helping making decisions about waste management strategies.

This tool assesses different scenarios with a minimum effort and minimize the time required to evaluate and perform a sensitivity study of the different scenarios under study.

It will help to define fish by-product valorisation strategies reducing the effort, the environmental impacts and the costs comparing to the traditional procedure.

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