Adapting MEANS-InOut LCA software to food engineering, in relation to the PO^2 food ontology and PO^2-BaGaTel food engineering database

Julie Auberger, Geneviève Gésan-Guiziou, Caroline Malnoë, Guilhem Rostain, Magalie Weber, Hervé Guillemin, Stéphane Dervaux, Caroline Pénicaud

Adapting MEANS-InOut LCA software to food engineering, in relation to the PO² food ontology and PO²-BaGaTel food engineering database

Julie Auberger[1]*, Geneviève Gésan-Guiziou[2], Caroline Malnoë[1], Guilhem Rostain[3], Magalie Weber[4], Hervé Guillemin[5], Stéphane Dervaux[6], Caroline Pénicaud[7]

[1] *INRAE, Institut Agro, SAS, 35000 Rennes, France*
[2]*INRAE, Institut Agro, STLO, 35000 Rennes, France*
[3]*CIRAD, DSI, 34398 Montpellier, France, 78850, Thiverval-Grignon, France*
[4]*INRAE, UR BIA, 44000 Nantes, France*
[5]*INRAE, PLASTIC Platform,*
[6]*Université Paris-Saclay, INRAE, AgroParisTech, UMR MIA Paris, 75005, Paris, France*
[7]*Université Paris-Saclay, INRAE, AgroParisTech, UMR SayFood, F-78850, Thiverval-Grignon, France*

Keywords: *LCI tool, interoperability, food engineering*

**Corresponding author. Tel.: +33-223 485 665, E-mail address: julie.auberger@inrae.fr*

1- Rationale and objective

Food systems are the main contributors to environmental impacts (e.g. climate change, water scarcity, land use). Meanwhile, half humanity suffers either from lack of food or from low-quality diets. Drastic changes in diets and in food production are necessary both to decrease environmental impacts of food and to improve global human health (Willet et al., 2019). To accompany or pilot these changes, data on food are necessary. In France, databases such as Ciqual and Agribalyse provide information on nutritional composition and environmental impacts, respectively, of standard food products. However, they neither cover the huge variability of products in the food sector nor help to assess new products or the new ways of production that are needed. The DataSusFood project aims to develop a modular IT system to organize, store and share data related to food engineering, and to assess the composition, nutritional and sensory properties, and environmental impacts of food products. Initially, researchers will be the main users of the IT system, but the data and knowledge produced will be available in open access.

The IT system of DataSusFood relies on two tools: the PO² ontology developed by INRAE (French national research institute for agriculture, alimentation and environment) and MEANS-InOut, developed by INRAE and Cirad (French agricultural research and international cooperation organization working for the sustainable development of tropical and Mediterranean regions). The PO² ontology (Ibanescu et al., 2016) organizes all relevant information about food and bio-product engineering; its core model is embodied in the PO²-BaGaTel database that capitalizes data on production processes and product characteristics. MEANS-InOut (Auberger et al., 2018) is a user-friendly web app that helps users to apply life cycle assessment (LCA) by building life cycle inventories (LCI) from data that describe the system studied. MEANS-InOut is currently operational to generate LCI of agricultural production systems at farm gate. In the IT system of DataSusFood, the role of MEANS-InOut is to support the calculation of environmental data about food and bio-products. The objective of this presentation is to describe how MEANS-InOut has been adapted to food and bio-product engineering, in relation to PO² ontology and PO²-BaGaTel database.

2- Approach and methodology

The DataSusFood project organizes collaboration between methodological questions and development of MEANS-InOut. First, two scientists in food and bio-product engineering defined user needs. Next, a larger group of food-engineering scientists and LCA practitioners at INRAE reviewed,

enriched and validated these needs. The main users targeted are food and bio-products engineering scientists, who are specialists of the systems and processes they want to assess; secondary targeted users are people who want to assess food processes without being familiar of food engineering. The needs were thus defined for users who want to gather detailed information about processes, and to be guided for LCA modelling. The users' needs were translated into requirements of MEANS-InOut. Two requirements fall under "general functionalities" of software. MEANS-InOut should (1) be user-friendly for food scientists, rather than for LCA practitioners; (2) connect LCA data to other tools, especially PO² ontology and PO²-BaGaTel database, in order to capitalize knowledge on food and bio-product engineering. The objective is to store in PO²-BaGatel database the data describing the process, the associated Life Cycle Inventory and the LCA results: the values of environmental impact indicators related to a functional unit. Three requirements are related to the implementation of LCA of food and bio-products processes. MEANS-InOut should: (3) cover a wide range of production processes and of food and bio-products; (4) allow all information relevant for LCA of food and bio-products and/or their production processes to be collected to create life cycle inventories of good quality; and (5) address several questions about environmental impacts of food and bio-product engineering, such as identifying hotspots, comparing processes for the same product, comparing products.
The first phase of developing MEANS-InOut for food and bio-product engineering is completed. MEANS-InOut has been presented to food scientists regularly during the development phase to verify that the tool is adapted to their needs. Food scientists have tested it, which has revealed modeling errors and omissions. These errors have been corrected before the delivery of MEANS-InOut to users.

3- **Results and discussion**

We describe the main features of MEANS-InOut developed to meet the requirements for food and bio-product engineering (Figure 1). In MEANS-InOut, users will be able to study food and bio-product transformation at the process scale, by describing the foreground system. To represent a process under study, users draw a process-flow diagram. This is a usual way of process description for food and bio-product engineering scientists, (requirement 1). The process-flow diagram defines all steps of the process, including cleaning and transport. A generic framework was developed to describe the steps (requirement 3). Each box in the diagram generates input forms to guide data collection for process flows: ingredient and product flows, energy, water, cooling practices, packaging, equipment, consumables, detergents, waste or water treatment, pollutant emissions and transport (type and distance). The forms are built at a fine level of detail, for the process study. These detailed forms ensure that users do not forget important input, product, waste, or pollutant flows. Mass-balance checks are performed between inputs (ingredients and product under process, coming from previous step) and outputs (product under process going to further step, coproduct going out of the process, losses, waste, and emissions) for each step of a given process to reduce the risk of data-entry errors (requirements 1 and 4). A reference vocabulary (e.g. names of ingredients, products, processes, steps) comes from the PO² ontology (requirement 2). This reference vocabulary is used to assist data entry using drop-down menus and to specify the products and processes under study. An export function generates LCI files from the information collected by users. The creation by MEANS-InOut of these process or product Life cycle inventories is based on an embedded mapping between the resources mobilized by the process (ingredients, energy, machines, waste treatment...) and LCI from ecoinvent and Agribalyse databases (requirement 1). This ensures the coverage of background system. Depending on their objective, users can create a process LCI or product and coproducts LCI, and for the latter, several allocation methods are possible: mass on a dry or wet basis, volume, protein, fat, energy or economic. Process LCI and products LCI are structured as a combination of unit operations and ingredients, which allows identifying the hotspots of the process (requirement 5). The LCI files generated with MEANS-InOut are ready to be imported in LCA software, which is required

to calculate environmental impact indicators.
The developments are not yet fully adapted to represent a food supply chain, as data collection forms have been designed for the fine description of the processes. The consistency of the forms with other steps of a value chain such as retail has not been evaluated. A further adaptation of MEANS-InOut to the whole food supply chain is thus needed. It should be based on concepts to be added in PO2-ontology, which describe the elements of the supply chain.

Web services are under development to exchange data on processes (process description, LCIs, LCIAs), first from MEANS-InOut to the PO²-BaGaTel database. We also plan to create a link between MEANS-InOut and OpenLCA, to launch directly from the interface of MEANS-InOut the module for calculating the indicators of environmental impacts of the studied system (requirement 2). Being able to export LCA data from MEANS-InOut to the PO²-BaGaTel database and connect it to other dimensions of food products will be an achievement for the DataSusFood project.

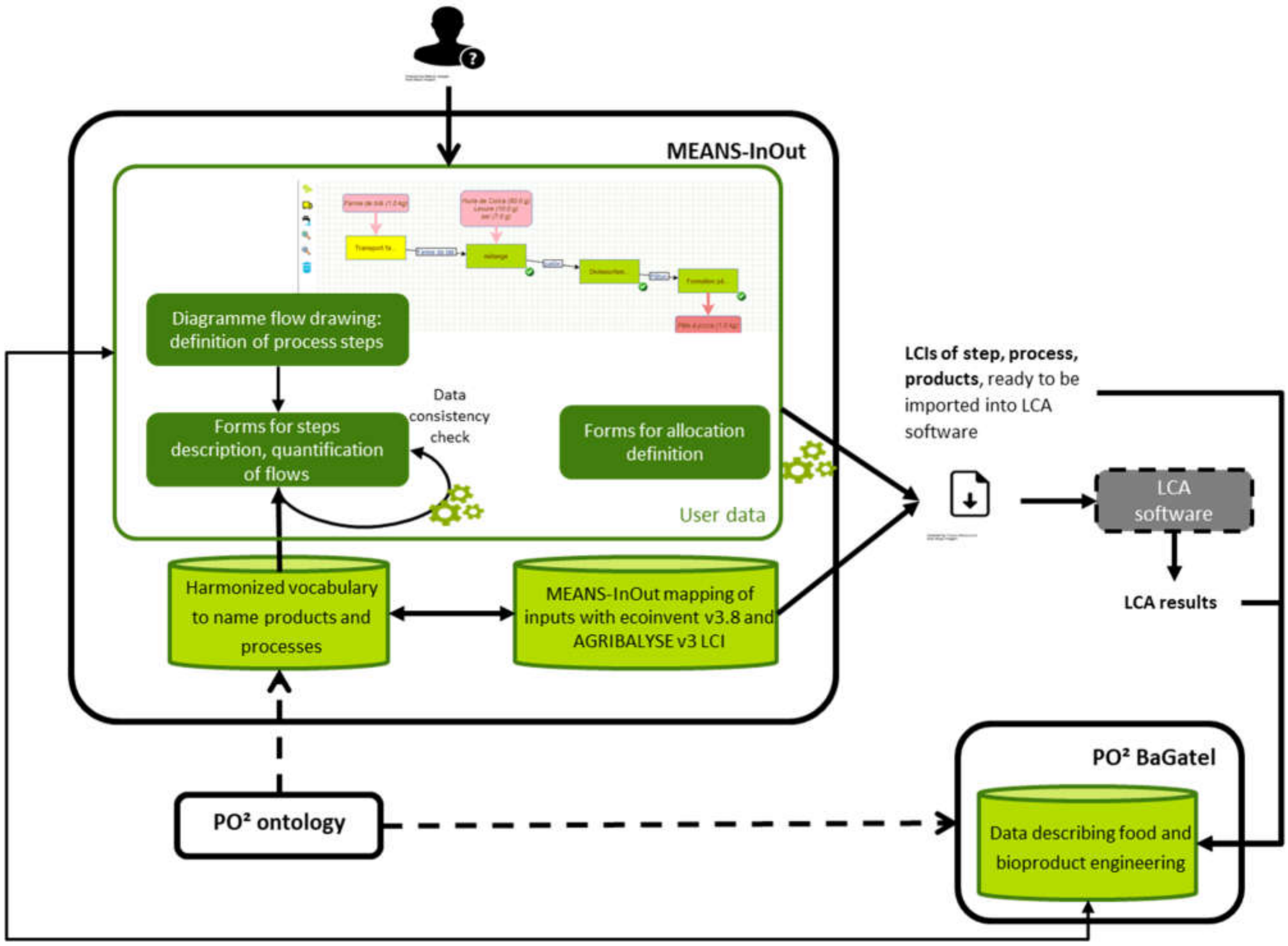

Figure 1 : Main functions of MEANS-InOut for food and bio-product processing, link to PO²-BagaTel database will not be available at first delivery but after further developments.

The generic framework for collection forms allows describing processes with flexibility. Users can describe systems with more or less details, more or less unit operations aggregated in steps and test different process scenarios. However, in this generic framework, default or reference values for specific processes such as energy consumption for sterilization, or the quantity of water needed to clean a membrane are not available. The absence of default values is intended to make MEANS-InOut more flexible to use for food and bio-product engineering specialists, to study all types of processes, including innovative processes or processes for which few references are available. But this absence of default values may also make MEANS-InOut more difficult to use for those who are not specialists of their studied process, or users who study food engineering within a system, when food engineering is not the core issue. The possibility of querying PO²-BaGaTel from MEANS-InOut, which is intended in further developments, will be helpful to overcome this limitation: knowledge and data available on food and processes in PO²-BaGaTel will be accessible to MEANS-InOut users in order to perform LCA with adequate system descriptions and data.

PO² ontology defines both a data structuration to describe the food and bio-products production processes and the vocabulary associated. It is a reference in INRAE for food and food processes description. Process representation and data collection forms in MEANS-InOut are based on PO² data structuration and vocabulary. Using PO² data structuration ensures that MEANS-InOut data format for food and bio-product processing is validated by the scientific community, and is shared with INRAE food and bio-products engineering scientists. It also ensures the connection with PO²-BaGaTel database and the capitalization of the data generated with MEANS-InOut. However, MEANS-InOut collects data that are specific for LCA calculation (e.g.: functional unit, factor used to calculate allocations) or documentation (e.g.: PEF quality notation, temporal boundaries of the process). It can also be data important in environmental assessment but initially not identified as essential when describing a transformation process, such as data about cleaning of equipment (detergent types, quantity of water involved).

Therefore, new concepts have been added in the PO2 ontology to allow the description of these data specific to LCA. Thus the intended inter-operability between PO2 ontology and MEANS-InOut has not only given a structure to the latter but also it has enriched PO2 ontology.

4- Conclusion and perspectives

MEANS-InOut aims to become an international reference tool for environmental assessment in the agri-food sector. It was able to calculate agricultural production LCIs at farm gate. The described new developments of MEANS-InOut allow to calculate food or bio-products LCIs at food-plant output gate. In the next years, further developments will be pursued to model food chains and perform economic assessment at the food-chain scale, allowing environmental and economic assessment of complete value chains from farm to fork. By studying agricultural systems in MEANS-InOut or addressing methodological questions, users have identified new needs, which have led to improvements in the tool for agricultural systems. We therefore look forward for the use of MEANS-InOut for the study of food engineering systems to arise needs or to improve existing functionalities.

Access to and use of MEANS-InOut (available in English and French) is open to anyone, free of charges for six months. Further use is subject to the terms of a service contract.

Acknowledgement
The authors thank the French National Agency for Research (ANR), for funding the DataSusFood Project (grant number ANR-19-DATA-0016), and Michael Corson for reading this article and providing most helpful language corrections.

References

Willett, W. et al. 2019. Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. Lancet 393: 447-492. http://dx.doi.org/10.1016/S0140-6736(18)31788-4

Ibanescu, L. et al. 2016. PO² - a process and observation ontology in food science. Application to dairy gels. In: Research Conference on Metadata and Semantics Research, p. 155-165. Springer.

Auberger, J. et al. 2018. MEANS-InOut: user-friendly software to generate LCIs of farming systems. In: Proceedings of the 11th International Conference on Life Cycle Assessment in the Agri-Food Sector (LCA Food 2018), p. 317-320. Bangkok, Thailand: Kasetsart University, King Mongkut's University of Technology Thonburi, National Science and Technology Development Agency.