OptiSignFood: developing more sustainable food products through artificial intelligence

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Introduction

The challenge to meet the UN sustainable development goals (https://sdgs.un.org/) and to bring our food system back into the limits of the planetary boundaries requires concerted efforts at all stages of the food value chain. Furthermore, there are 2 billion obese or overweight people worldwide, while ~800 millions suffering hunger or malnutrition (FAO *et al.*, 2021).

The food industry plays a key role in this respect and can contribute to the mitigation of the environmental impacts of the food system in several respects: 1) by using ingredients with low environmental burdens, 2) by reducing the environmental impacts of processing, packaging, storage, and transports, and 3) by offering a product basket to the consumers with low environmental impact, high nutritional value, high quality, which is at the same time safe, tasty, and attractive.

The challenges for the food industry are that the food development process is time- and resource-intensive, information on environmental impacts is either missing or not readily available, the nutritional value, food safety and quality (e.g. microbial growth, pH value, colour, texture) are difficult to predict. Food developers therefore face a multidimensional optimisation problem, with high complexity and many parameters to be considered. There is a need for a tool providing an integrated, fast and reliable solution that takes into account nutritional, sensorial, safety, health and environmental parameters. The EU project OptiSignFood (https://themakers.ai/optisignfood/) is currently developing such a tool.

Methods

The model builds on scientific data and uses artificial neural networks to solve the multidimensional optimization problem. Food quality parameters are being estimated based on product samples derived from different ingredient mixes. The software is implemented as a cloud application using a modular architecture. The overall concept of the model is shown in Fig. 1.

Environmental impacts

Environmental impacts of food ingredients are calculated using life cycle assessment methodology. Life cycle inventory data from five databases (ecoinvent, Agribalyse, WFLDB, Agri-footprint and SALCA) will be used. Life cycle inventories will be selected according to data quality criteria according to the ISO 14040/44 standards. The data will be prepared, harmonized, adapted (e.g. adjusting system boundaries, electricity mixes or transports) and standardized for integration into the meta-database. For missing data, new life cycle inventories will be created or proxies will be used to approximate the environmental impacts according to the procedure described in Milà i Canals *et al.* (2011). The environmental impacts from the different inventories will be aggregated in case there exist more than one inventory. Three sets of impact categories specific for life cycle impact assessment in the agri-food sector are proposed for impact assessment of the LCI data.

- The restricted set considers a selection of the six most important impact categories for food LCA according to Nemecek *et al.* (2011).
- The full set considers all impact categories of relevance to agricultural systems within the SALCA framework. The SALCA impact assessment method is intended for the LCIA in the agri-food sector.
- The PEF compliant set considers the impact categories given by the EU guideline to assess the environmental footprint of a product (European Commission (EC), 2013).

Data gaps (= missing food ingredients) will be identified by comparing the LCI in the databases with the food ingredients in the EuroFIR database. To guarantee a successful integration of the environmental data into the meta-database, LCI data and their respective impacts will be linked to the food ingredients from the EuroFIR database. This is done by applying LanguaL codes and the FoodEx2 food classification system which help to index and describe food products (Møller & Ireland, 2018).

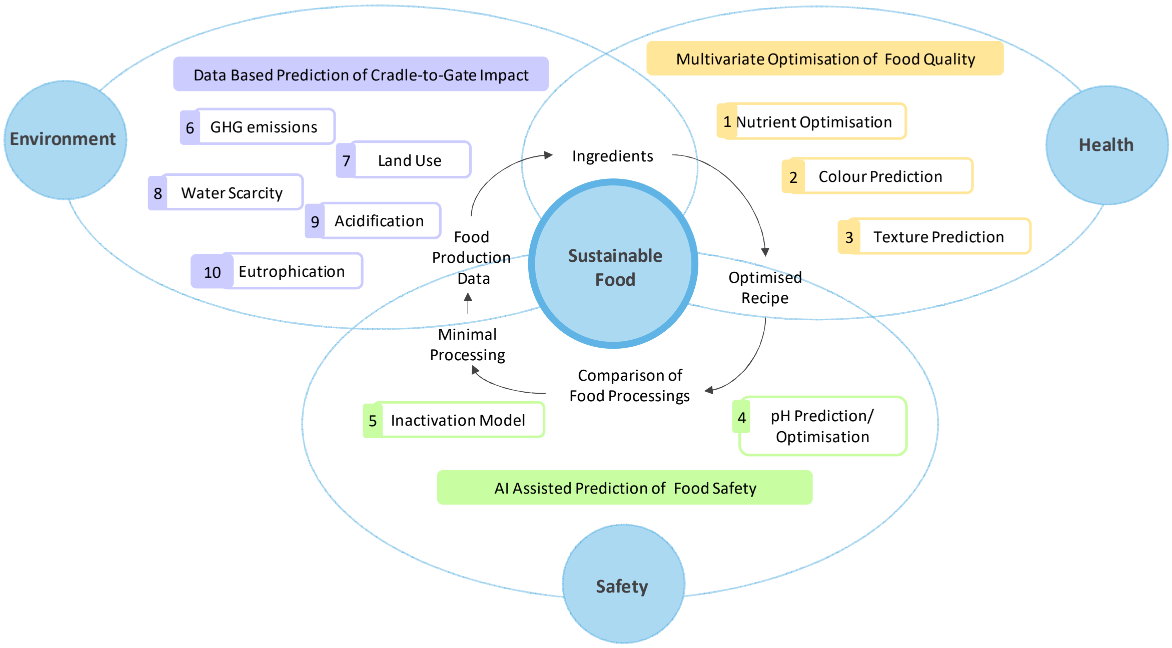

Fig. 1: Concept of the OptiSignFood tool for the food and beverage industry.

Nutritional indices

Nutritional indicators are used to assess the nutritional quality of foods products. They are based on the concept of nutrient profiling, a ranking system to classify foods based on their nutritional composition relative to nutrient needs of qualifying nutrients (nutrients to encourage) and disqualifying nutrients (nutrients to avoid or limit) (Fulgoni *et al.*, 2009). For this project, the EuroFIR database (https://www.eurofir.org/) is used to determine the nutrient contents of different food ingredients. As each nutritional indicator takes into account different nutrients, the values of each indicator might rank foods differently. In addition, some nutritional indicators require a large set of nutrients that might not be available in the EuroFIR database. In this case, when the missing nutrient is not essential for the target population, a modified/adapted nutritional index will be used but if the nutrient is relevant for the target population, proxies from other databases will be included. One aim of the OptiSignFood project is to link and standardize robust, strong and valid nutritional composition datasets from different EuroFIR countries that will allow for better calculations of the nutritional indicators.

The main objective to include nutritional indicators in the OptiSignFood project is to be able to optimize the production of new or modified food products based on the principle that foods with better nutrient profiling scores, encourage healthier diets than those with lower nutrient profile values. However, this has been debated as some reformulation procedures just decrease disqualifying nutrients and increase qualifying nutrients, but might not be synonym of an overall healthier diet. Still, when assessing individual foods or specific food mixtures, nutritional indices help the food industry produce foods with better profiles and the consumer to choose more nutritious options that will at the end increase the overall nutritional content of the diet. In addition, some indices are being associated to health outcomes, such as the Health Nutritional Index (HENI), which will be used in the optimization model, and considers dietary risk factors based on the global Burden of Disease Study (Stylianou *et al.*, 2021).
To facilitate the comparison between different food products, different nutritional indices will be included in OptiSignFood (e.g NRF9.3, Nutri-Score, etc.). The aim is to include not only nutrient information (e.g. grams of nutrients, kilocalories or percentages of daily recommended intakes), but also nutrient indicators that will: 1) help the food industry produce more nutritious foods; 2) enable consumers to evaluate the contribution of a food product to a healthy and balanced diet considering its nutritional composition and; 3) to compare food products of the same category and choose a healthier option.

Database harmonization and standardization
A particular challenge is to link the nutritional, life cycle inventory and the laboratory parameter databases, since all databases use different classification systems and data structures. Figure 2 shows examples of different type of information for food ingredients available in the databases, which need to be connected in between databases.

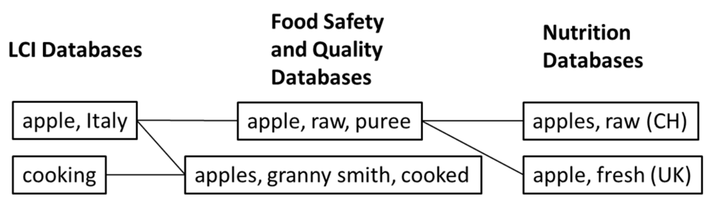

Fig 2: Type of information for food ingredients available in the databases

Different wording (apple vs. apples; raw vs. fresh) and sometimes missing information on the status or processing of the food ingredient in the databases render a connection by names tedious. Additionally, certain information (e.g. cooking/cooked) is sometimes part of the food ingredient, but sometimes embedded as standardized code. To overcome this challenge, the LanguaL standardization system will be applied to the food ingredients in order to standardize the names of the food ingredients consistently. The LanguaL food description thesaurus (https://www.langual.org/) provides an automated method to describe, capture and retrieve food-related data and will be used for this purpose. The EuroFIR nutritional database will serve as a backbone for the meta database and has already LanguaL codes implemented and connected to food ingredients. Other databases (environmental and parameters database) will be connected to the EuroFIR database. Already implemented LanguaL codes in EuroFIR should serve to facilitate the connection of the databases. However, due to inconsistent application of the LanguaL system, the assignments of LanguaL codes to the food ingredients in the EuroFIR have to be checked and validated.

Results and discussion
The EuroFIR databases for different countries differ not only in the number of nutrients considered, but the values can also differ considerably between databases for the same nutrient. A data

harmonization is therefore needed. Environmental impacts also differ and depend on the country of origin, the production system, and the yield level. Representative environmental impacts are calculated for the European food and beverage market.
As a first step, LCI data of food ingredients have been organized, structured and classified into the EFSA FoodEx2 classification system by assigning LanguaL codes. The first overview shows that there are more than 15'000 food LCI out of roughly 42'000 LCI datasets available from selected LCI databases (35%) which can be grouped into 21 different food categories. Those 15'000 inventories cover a total of 952 different and individual food ingredients.
The prediction of the model will be validated in real environments by food and beverage manufacturers.

Information provided to the users
Figure 3 shows the first layer of the design of the software. The user can choose ingredients and their amounts and can see the prediction of a set of the basic parameters and the legally important nutrient values. We are also working on implementing a nutrition and an environmental score, like the Nutriscore. From this general overview, the user can switch to the optimization window where the recipe composition can be optimized based on these and other parameters. We are also planing a window where the parameters of different compositions can be compared with each other. Currently, we are designing another window for the environmental impact of the food composition, which needs a separate tab, since it is multi-dimensional and has several parameters to be calculated and also needs a higher degree of input from the user.

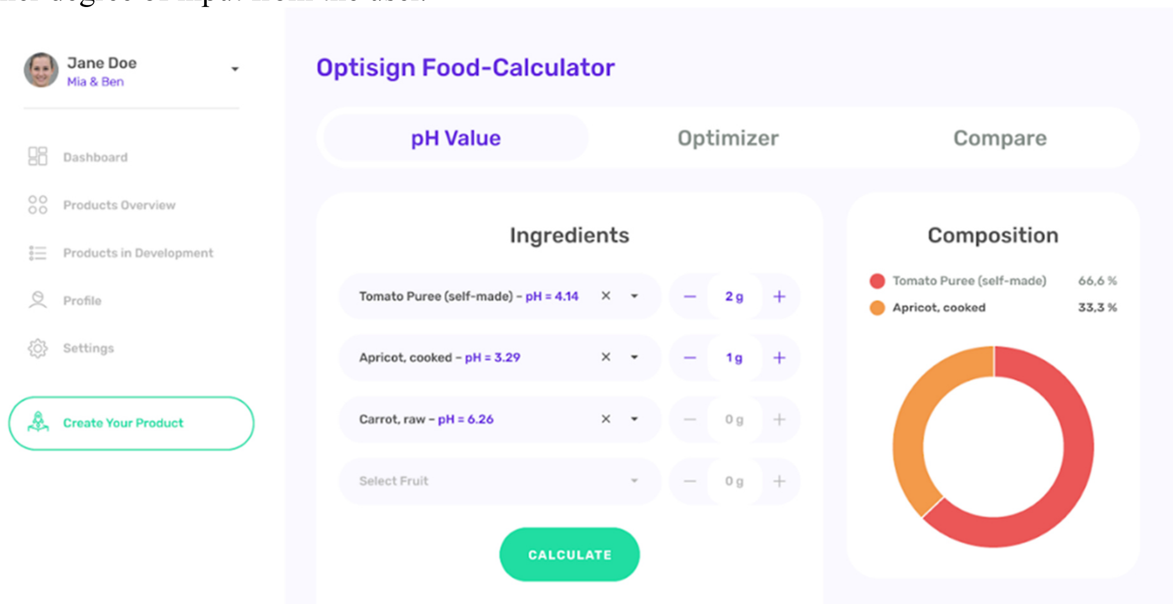

Fig. 3: Possible user interface of the OptiSignFood software.

Conclusions
OptiSignFood should lead to faster product development with less developments being rejected and food waste being avoided. This enables the manufacturers to react faster to societal and market trends, e.g. replacing animal-sourced ingredients by plant-based alternatives. The systematic consideration of environmental impacts and food quality, while ensuring food safety will lead to more nutritious food with lower environmental impacts and improved resource efficiency. Potential trade-offs between different parameters can be clearly shown.
OptiSignFood will enable the food and beverage industry to deliver nutritious food with high quality and safety as well as low environmental impacts and thus to contribute to the sustainable development of the food system.

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