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Garcia-Garcia, G., Azanedo, L. and Rahimifard, S. (2021) Embedding sustainability analysis in new food product development. Trends in Food Science & Technology, 108. pp. 236-244. ISSN 0924-2244

https://doi.org/10.1016/j.tifs.2020.12.018

Embedding Sustainability Analysis in New Food Product Development

Guillermo Garcia-Garcia[a,b] , Lucia Azanedo[a,c] and Shahin Rahimifard[a*]

[a]Centre for Sustainable Manufacturing and Recycling Technologies (SMART), Loughborough University, LE11 3TU, United Kingdom

[b]Department of Chemical and Biological Engineering, The University of Sheffield, S10 2TN, United Kingdom

[c]R&D Department, Frit Ravich S.L., Cl. Riudellots, s/n, Polígono Industrial Puigtió, 17412, Maçanet de la Selva, Girona (Spain)

*Corresponding author: S.Rahimifard@lboro.ac.uk

Abstract

The food industry is responsible for significant impacts on the environment, such as climate change, water depletion and land use. Although these environmental impacts, along with socio-economic ramifications, are generally difficult to monitor and control, there is a significant interest from the food industry to assess the sustainability of their activities and wider supply chains. However, new food products are being continuously designed and manufactured, for instance complex foods made with a number of ingredients such as sandwiches, prepared salads and ready meals. Most sustainability analyses are currently done after the food product is designed and not during the food product development process. Nevertheless, embedding sustainability considerations in the new food product development (NFPD) process has significantly more potential to improve the overall sustainability of the food business. This paper discusses how the food industry could be more sustainable by identifying methodologies and tools to support such sustainability assessments in food businesses. A case study with a prepared food manufacturer is used to discuss where each sustainability methodology and tool could be used in the NFPD process to optimize the design of more sustainable food products. The main conclusion of this paper is that such methodologies and tools should be applied in the first stages of the NFPD process, and then be continuously used when

more information on the production processes and wider data on its food supply chain is obtained.

Keywords

New product development; food manufacturing; eco-design tools; environmental analysis; Life-Cycle Assessment.

1. Introduction

The food sector is crucial in modern societies because it produces food products (FPs) and makes them available to consumers. The food sector is also key to achieving several of the Sustainable Development Goals (SDGs) established in 2015 by the United Nations, principally Zero Hunger (SDG 2), Good Health and Well-Being (SDG 3), Responsible Production and Consumption (SDG 12) and Climate Action (SDG 13). In order to support achieving these goals, and to maintain competitive advantage, many food companies are implementing series of steps to improve their sustainability performance. Generally, this means considering a combination of environmental, economic and social factors, often known as the triple bottom line (Elkington, 1999; Svensson et al., 2018).

It has been estimated that nearly 80% of the economic costs of products are defined during product design (Cooper & Chew, 1996). Similarly, it is also surmised that around 80% of the environmental impact of a product is determined at the design phase (DG Enterprise & Industry and DG Energy - European Commission, 2014; McAloone and Bey, 2009). Because of this, there is a lot of potential to reduce environmental and economic costs, and consequently improve sustainability performance, by proactively assessing the products before they are produced, rather than using a reactive approach to minimize impacts of a product already designed. It would therefore be especially useful to undertake such sustainability assessments in the first stages of the development of new products. This perspective increases the importance of the new product development (NPD) team in identifying the possible environmental, social and economic impacts of new products.

In view of this, concepts such as Design for Environment (DfE) (Luttropp & Lagerstedt, 2006), Design for Sustainability (DfS) (Spangenberg et al., 2010) and Eco-design (European Commission, 2009) have emerged to support the incorporation of sustainability principles during the design phase of new products. The use of such approaches allows the environmental impact of new products across their life cycle to be considered from the beginning of the NPD process, so the new product can be designed to have a low impact on the environment. To support this, Mandolini et al. (2019) developed a life-cycle standard data model to manage and share life-cycle information along the product development process. These approaches have generated positive results in manufacturing sectors such as automotive (e.g. electric vehicles), electrical devices (e.g. design for disassembly), fast-moving consumer goods (e.g. lighter packaging), and many other sectors that use recycled materials. However, the implementation of such solutions requires significant investment in research and development.

Not only the sustainability performance of products must be assessed in their use and end-of-life phases, but also during their manufacture. Environmental management systems (EMSs) can be used to assess progress on mitigating such environmental impacts of the product manufacturing. EMSs are standardized schemes to manage environmental programs of businesses with the aim of increasing compliance and minimizing impacts on the environment (ISO/TC 207/SC 1, 2015). An assessment of such company's environmental performance involves an integrated managerial process which includes technological capabilities, strict compliance, employee training, supply chain management and stakeholder communication (Dragomir, 2018).

Assessing sustainability implications of new products is complicated. Such assessments necessitate large amounts of quantitative data which are often not available or still subject to change. This is particularly the case for food manufacturers (Azanedo et al., 2020). Figure 1 shows some environmental, economic and social aspects that can be affected by the NPD process in the food sector. Food companies willing to consider sustainability principles during their NPD process would benefit from using methodologies and tools to facilitate such assessments.

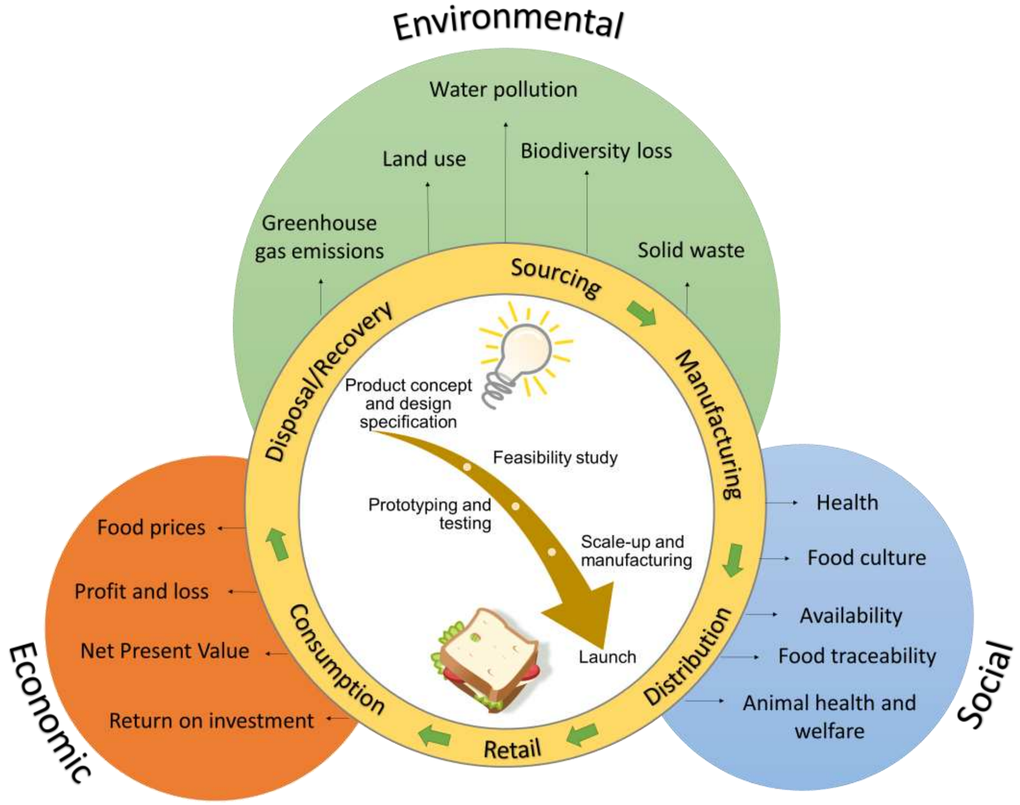

Figure 1. Examples of sustainability aspects that can be considered during NPD in the food industry

This paper provides a review of methodologies and tools that can be used by food businesses to support the implementation of sustainability principles during their NPD process. Firstly, it introduces the principles and attributes for FPs and food companies to be considered sustainable (Section 2) and then it identifies and discusses existing sustainability methodologies and tools used in the food sector (Section 3). Next, the paper presents a case study in which the NPD process for a prepared food manufacturer is described to then discuss opportunities to embed sustainability methodologies and tools in the NPD process and the expected benefits that this would generate (Section 4). Finally, the main conclusions of this work are presented in Section 5.

2. Characteristics of sustainable food products and sustainable food businesses

The food industry is becoming more concerned about sustainability issues associated with its practices because of growing evidence about the impact of industrial activities in nature, stricter regulations and pressure from stakeholders. Consumers are also becoming more aware of the importance of adopting sustainable lifestyles and they often demand more information about how food is manufactured, where the ingredients come from, and generally the environmental footprint of the products they are buying (European Commission. DG Agriculture and Rural Development, 2019).

However, it is not always easy to determine when an FP, or a food company, is sustainable. Although it is generally claimed that a product with low environmental, economic and social costs is sustainable, assessing each of these three pillars of sustainability is complex. Table 1 lists characteristics of a sustainable food industry, proposed by Baldwin (2015) and Morawicki (2012). They are focused on environmental and social factors, and do not include economic costs or benefits for the manufacturers, which is what usually drives business decisions.

Table 1. Characteristics of a sustainable food industry

Characteristics	Reference
1. Provides safe and nutritious food and makes it accessible and affordable 2. Beneficially contributes to the environment at its agricultural stage 3. Uses animal, fish and seafood products in a way that their wellbeing is optimized 4. Strengthens producer equity and the rural economy 5. Provides safe and suitable working conditions for employees 6. Requires minimal additional inputs other than food ingredients 7. Protects food by an effective packaging that does not harm the environment 8. Prevents food waste and uses food waste that cannot be avoided 9. Delivers food to the consumer efficiently 10. Supports the sustainability of the food industry across the entire supply chain	Baldwin (2015)
1. Relies exclusively on renewable energy	Morawicki (2012)

2. Depends on ingredients and materials based from renewable resources 3. Is water neutral 4. Has net-zero air missions 5. Produces completely biodegradable liquid and solid wastes at a rate and level that could be easily degraded by nature	

Examples of progress in incorporating sustainability principles in the food industry include claims to use more sustainable ingredients (e.g. “organic”, “free-range”), farming methods (e.g. “sustainably grown”, “without pesticides and fertilizers”, “conserving biodiversity”), packaging (e.g. “recyclable”, “biodegradable”, “made from recycled materials”), manufacturing processes (e.g. “efficient”, “use of renewable energy”, “low water footprint”, “zero waste to landfill”), logistics (e.g. “local”) and labour (e.g. “fair trade”). To quantitatively evaluate such aspects in an objective manner and promote achievements made, eco-labels, certifications and standards are becoming widely used and advertised in food products. An extensive list of eco-labels and environmental certifications used in the food sector can be seen in the global directory Ecolabel Index - Big Room Inc. (2020).

However, it is not only environmental or economic considerations which must be taken into account when designing a sustainable FP. Social considerations are also key, as they will drive consumer behaviour. For instance, concern is growing amongst consumers on the relation that eating habits have with health. Therefore, demand for healthier FPs, e.g. with low sugar, fat and salt, is increasing (Emrich et al., 2017; Martin, 2018; Gallup, 2018). Consumers have also started demanding FPs that they associate with foods which are healthier, safer or better for the environment, such as “non-genetically modified organism (GMO)”, “vegan/vegetarian”, “without additives and preservatives” and “gluten free”. The traffic-light rating system, already widely used in labels on sandwiches and ready meals in some countries (e.g. UK), helps the consumer to identify healthy FPs by showing the relative quantity of less healthy ingredients in the food, compared to national guidelines. Similarly, Nutri-Score labelling was introduced in France in 2017 with the same aim (Julia & Hercberg, 2017). A similar rating system, with different scores, could also be used to show environmental impacts of FPs on their packaging.

Sustainability considerations such as those mentioned in this section must be studied across the entire life cycle of FPs, following life-cycle thinking approaches (Anton & McLaren, 2017). FPs' life cycle includes production (e.g. agriculture), manufacturing, distribution, retail, consumption and end of life (i.e. waste management). For most FPs, agriculture is the most significant contributor to the overall environmental impact of the FP in its life cycle (Baldwin 2009). Nevertheless, sustainability assessments must be carried out in all life-cycle stages of the FP. There are many attributes to consider for such analyses, but there is not yet a definitive agreement about which specific attributes to use. For instance, animal welfare attributes are not common yet, although there are attempts to implement them in established sustainability assessment methodologies (Scherer et al., 2018). Nikolaou et al. (2019) and Garcia-Garcia, Woolley and Rahimifard (2019) for instance, attempted to identify the most important sustainability indicators of different activities in the food sector. Table 2 lists relevant attributes commonly used to assess food systems in each of the environmental, economic and social categories of sustainability.

Table 2. Most relevant attributes to assess sustainability of products. Based on Woodhouse et al. (2018) (environmental), Stone, Garcia-Garcia, and Rahimifard (2019) *(economic), Goedkoop, Indrane and de Beer (2018) (social)*

Environmental attributes	Economic attributes	Social attributes
Climate change Ozone depletion Terrestrial acidification Freshwater eutrophication Marine eutrophication Human toxicity Photochemical oxidant formation Particulate matter formation Terrestrial ecotoxicity Freshwater ecotoxicity Marine ecotoxicity Ionizing radiation Agricultural land occupation Urban land occupation Natural land transformation Water depletion Mineral resource depletion Abiotic resource depletion	Raw material cost Capital costs Operational and maintenance costs Sales revenue (both primary and by/co-products) Utilities cost Government subsidies/incentives Net present value	1. Social aspects for workers 1.1 Health and safety 1.2 Remuneration 1.3 Child labor 1.4 Forced labor 1.5 Discrimination 1.6 Freedom of association and collective bargaining 1.7 Work-life balance 2. Social aspects for users 2.1 Health 2.2 Product safety 2.3 Responsible communication 2.4 Privacy 2.5 Inclusiveness 2.6 Effectiveness and comfort 3. Social aspects for local communities 3.1 Health and safety

		3.2 Access to tangible resources 3.3 Community engagement 3.4 Employment <u>4. Social aspects for small-scale entrepreneurs</u> 4.1 Meeting basic needs 4.2 Access to services and inputs 4.3 Women's empowerment 4.4 Child labor 4.5 Health and safety 4.6 Land rights 4.7 Fair trading relationships

There are numerous studies that report on impacts of specific food ingredients or manufacturing processes, also from a life-cycle perspective, but there is still little information available for more complex FPs, for instance, sandwiches and ready meals. Effectively, to undertake a sustainability assessment of complex FPs, firstly such assessments must be completed for each ingredient. This requires enormous amounts of data, human resources and time, compromising the capacity of the food company to complete the assessment and obtain meaningful results. The next section discusses existing methodologies and tools that could be used to facilitate such assessments by food companies.

3. Methodologies and tools to support the development of sustainable food products

Food manufacturing companies use different methodologies and tools to assess their sustainability performance. In this context, a methodology is a method or combination of methods used by a food company to calculate the values of previously established indicators, whilst a tool is a computer program that supports completing these calculations. Frequently, tools use existing methodologies, rather than bespoke methodologies, to automate the calculations, generating an output value, e.g. carbon footprint, from a set of input values introduced to the tool by the user.

These methodologies and tools should be used during the design phase of the development of the new food product (NFP), to make sure the NFP will be economically profitable, socially accepted and the environmental impact associated with it will be within the limits established by the company. However, most methodologies and tools support food companies in analysing only one domain of their activities, for instance environmental impact, and often only one type of environmental impact, e.g. carbon footprint.

Table 3 lists methodologies commonly used to analyse the sustainability performance of FPs. The scope of most of them is the analysis of environmental impacts, e.g. carbon, water or ecological footprint. Nutritional Footprint (NF), Life-Cycle Sustainability Assessment (LCSA) and AgBalance™ also consider social factors of FPs, and the last two methodologies additionally take into account the economic costs and potential benefits. Below, the methodologies are explained and analysed in more detail.

Table 3. Most relevant methodologies used in the industry to analyse the sustainability of food products

Methodology	**Objective**	**Attributes**
Carbon Footprint (CF)	Quantify the greenhouse gas emissions of the food product in its life cycle	Environmental: greenhouse gas emissions
Water Footprint (WF)	Quantify the total amount of fresh water used to manufacture a food product	Environmental: use of fresh water
Ecological Footprint (EF)	Compare planet's biocapacity with resource consumption and waste generation of a food product	Environmental: percentage that ecological footprint exceeds biocapacity, measured in biologically productive land and water needed to produce resources and absorb waste
Product Environmental Footprint (PEF)	Measure all quantifiable environmental impact over the life cycle of the food product	Environmental: indicators such as global warming, freshwater ecotoxicity, acidification, terrestrial eutrophication, marine eutrophication, freshwater eutrophication, land use, mineral and resource depletion, non-renewable energy resource depletion, water scarcity footprint, human toxicity, particulate matter, ionizing radiation, photochemical ozone formation, ozone depletion
Nutritional Footprint (NF)	Assess the main health and environmental indicators of a food product	Environmental: material footprint, carbon footprint, water use, land use. Social: energy intake, sodium intake, content of dietary fiber, saturated fat
Life-Cycle Assessment (LCA)	Determine the environmental impacts of the food product throughout its life cycle	Environmental: indicators such as global warming, freshwater ecotoxicity, acidification, terrestrial eutrophication, marine eutrophication, freshwater eutrophication, land use, mineral and resource depletion, non-renewable energy resource depletion, water scarcity footprint, human toxicity, particulate matter, ionizing radiation, photochemical ozone formation, ozone depletion. LCSA also considers, in addition to the above, economic and social considerations
AgBalance™	Analyse ecological, economic and social sustainability of agricultural activities	69 indicators in the following categories: Environmental: biodiversity, soil, land use, water use, energy consumption, resource consumption, emissions, ecotoxicity potential. Economic: fixed costs, variable costs, macroeconomy. Social: farmer and

		entrepreneurs, consumer, local & national community, future generations, international community.

The Carbon Footprint (CF) is a popular methodology to assess the greenhouse gas (GHG) emissions associated with a product in its entire life cycle. CF is measured in CO_2 equivalents (CO_2eq), which allows a consistent and reliable comparison of results from different studies. Due to its widespread use, CF has been standardized in ISO 14067:2018 standard, first published in May 2013 (ISO 14067:2013). CF can be used to calculate other related common indicators such as global warming potential (GWP) and climate change, for which the IPCC method is recommended (Intergovernmental Panel on Climate Change, 2014). CF has great value for communicating environmental results in the market, due to the simplicity of the concept that aids increasing consumer awareness (Weidema et al. 2008; Espinoza-Orias and Azapagic, 2018). BSI published a complete guide to support SMEs in calculating CF and identifying opportunities where this environmental impact can be reduced (BSI Group, 2014). There are a number of examples of CF studies in the food sector. For instance, Veeramani et al. (2017) assessed the impact of dietary patterns on climate change via CF.

The Water Footprint (WF) measures the use of fresh water, which includes the volume of water consumed and polluted. The calculation of WF is standardized by ISO 14046:2014. Recent efforts have been directed towards increasing the efficiency of water use, both to reduce costs and the WF itself. In this regard, benchmarking the WF of similar products may be an incentive to produce more water-efficient products (Water Footprint Network, n.d.). Furthermore, joint collaborations between relevant companies and organisations, such as the Water Footprint Network, helps in disseminating practical solutions to reduce the WF. Hoekstra et al. (2011) published a useful assessment manual to calculate the water footprint of products. An example of the application of this methodology in the food sector is the work by Tom et al., (2016), who assessed the water footprint of food consumption patterns and dietary recommendations in the US.

The Ecological Footprint (EF) measures how a given population or activity consumes resources and generates waste, measured as biologically-productive land and water needed to produce the resources and absorb the waste, and then compares them with the planet's biocapacity, as a way to analyse humanity's impact on nature. This term, and the basic methodology to calculate EF, was developed by Wackernagel and Rees (1996). Although EF is more commonly used to assess the footprint of a region of the world, typically a country, it can also be used to analyse the footprint of activities and products. The most accepted methodology to calculate EF was developed by Lin et al. (2018), based on the principles explained by Borucke et al. (2013). The Global Footprint Network publishes National Footprint Accounts every year to show EF data for different regions of the world (Global Footprint Network, 2018). Świąder et al., (2018) studied the EF of food in Wroclaw, Poland.

The Product Environmental Footprint (PEF) is a method developed by the European Commission (2013) that provides a multi-indicator to measure all quantifiable environmental impacts over the product life cycle. The method, based on LCA, is explained in detail by Manfredi et al. (2012). A pilot phase to assess the PEF method concluded in 2018, resulting in the PEF method being completely finalized. The next phase is a transition phase that will conclude when new PEF policies are implemented in the European Union, which is planned for early 2022. Although PEFs are supposed to make it possible to compare similar products in terms of their environmental performance, there is criticism as to whether PEF guarantees fair comparability (Bach et al., 2018). PEF has been successfully used to assess the environmental impacts of producing different dairy products (Bengoa, Dubois and Humbert 2018) and strawberries (Soode-Schimonsky et al., 2017).

The Nutritional Footprint (NF) is a more recent development in the set of footprint methods only applicable to FPs. It was developed by Lukas et al. (2016). The methodology is based on the combination of four environmental indicators (material footprint, carbon footprint, water footprint and land use) and four health indicators (energy intake, sodium intake, content of dietary fiber and saturated fat), that in combination give an NF. Results for each indicator are scored 1-3 and are then displayed using diagrams with a three-color rating system, inspired by the traffic light rating system and therefore easy to understand by the consumer. Blas et al., (2019) analysed the nutritional value of current food consumption patterns in Spain by using a similar methodology to NF.

Life-cycle assessment (LCA) is a widely used methodology to assess environmental impacts associated with all life-cycle stages of a product or material. The term “product”, in an LCA context, may refer to a physical good or a service, and frequently the function of the product is considered rather than the product itself (Guinée et al., 2004). Luz et al. (2018) proposed a methodology to integrate LCA in the Product Development Process (PDP), namely LCA-PDP. This allows the identification of better options for the development of sustainable products. One of the purposes of LCA is informing decision-makers in the industry during the design or redesign of a product or process. LCA provides the information required in the second step of the decision-making process, i.e. the evaluation of alternatives. However, in addition to collecting and calculating quantitative environmental data, decision makers must apply their personal, value-related and critical judgement (Nebel, 2007). Although there are numerous examples of successful LCA studies of FPs (Roy et al., 2009), the use of LCA to analyse food systems remains challenging, due to issues like the inherent variability and geographical specificity of food systems. Consequently, LCA should be complemented by other approaches (Notarnicola et al., 2017). Furthermore, undertaking an LCA study is complex due to the large amount of data needed to build life-cycle inventories

(LCI) and the complex calculations of the life-cycle impact assessment stage (LCIA). Because of this, LCA software is now widely used, e.g. SimaPro (PRé Sustainability), Gabi (thinkstep), Umberto (Ifu Hamburg) and OpenLCA (GreenDelta). Most LCA software packages include databases of different food systems, allowing calculation of their environmental impacts. An alternative to undertaking a full LCA is using a streamlined LCA approach to get a simplified picture of the environmental impact of a product. There are different tools to undertake an LCA with a simplified LCI and and/or LCIA stages, such as BilanProduit, CCaLC, eVerdEE (Arzoumanidis et al., 2017) and Footprinter. Food companies like Pret a Manger have used a streamlined LCA to determine the main sustainability issues of key ingredients in their supply chain (Forum for the Future, 2007). Strategic life-cycle management (SLCM) is a methodology that lies between LCA and streamlined LCA, used to identify strategic pathways towards sustainability by providing an environmental overview and then a detailed analysis of key environmental issues (Ny et al., 2006). Furthermore, LCA has been recently expanded to life-cycle sustainability assessment (LCSA), which includes not only environmental impacts but also economic and social considerations (UNEP/SETAC Life Cycle Initiative, 2011). There are many published LCA studies of food products, as reviewed by Dijkman et al., (2017).

AgBalance™ is an assessment methodology developed by BASF to analyse ecological, economic, and social sustainability in the agricultural stage of the food supply chain (Uhlman & Saling, 2017). A total of 69 environmental, economic and social indicators are calculated through an assessment of almost 200 evaluation factors, enabling comparison of different farming systems, processes, and products in the course of a product's whole life cycle (BASF SE, 2011). BASF developed AgBalance™ based on their Eco-Efficiency Analysis (EEA) methodology, and expanded it to incorporate additional indicators specific to agriculture, such as soil, biodiversity and ecotoxicity (environmental indicators), separate fixed and variable costs and macroeconomy costs (economic indicators), and employees, consumer, local and national community, international community and future generations (social indicators) (BASF, 2016).

Table 4 lists relevant tools to analyse the environmental performance of FPs. Food companies tend to use bespoke tools to assess the economic costs and benefits associated with each FP, then integrate them into their Profit and Loss analysis. Because of this, and the fact that businesses are often not willing to share their economic data and methods used to calculate them, it is difficult to identify economic tools that are used by several food companies. Unfortunately, tools are not yet commonly used to assess social considerations of NFPs. The tools listed in Table 4 are explained and analysed in more detail below.

Table 4. Most relevant tools used in the industry to analyse environmental considerations of food products

Tool	Purpose	Attributes
Cool Farm Tool	Calculate on-farm greenhouse gas emissions and soil carbon sequestration, crop irrigation requirements and blue and green water footprints, and the support of farm management to biodiversity	Environmental: greenhouse gas emissions, soil carbon sequestration, crop irrigation requirements, blue and green water footprints, biodiversity
SENSE tool	Assess the environmental and social life cycle impacts of food and drinks manufactured in Small and Medium Size Enterprises	Environmental: land use, fertilizers use, pesticides use, energy use, freshwater use, wastewater generation, waste generation
EcodeEX	Assess greenhouse gas emissions and impacts from water, energy and biodiversity across the entire life cycle of food products	Environmental: greenhouse gas emissions, water consumption, energy use, minerals use, impacts on ecosphere, land use
Packaging Impact Quick Evaluation Tool (PIQET)	Support the design of more sustainable packaging	Environmental: climate change, cumulative energy demand, minerals and fuels use, photochemical oxidation, eutrophication, land use, water use, solid waste generation
Packaging Eco-design Tool for Environmental Responsibility Tool (PETER)	Analyse the environmental performance of different packaging solutions	Environmental: carbon footprint, water footprint, land occupation

The Cool Farm Tool (CFT) is an online calculator for the farming sector developed by Unilever, the University of Aberdeen and the Sustainable Food Lab (Cool Farm Alliance, n.d.). It enables calculation of on-farm greenhouse gas emissions and soil carbon sequestration, crop irrigation requirements and blue and green water footprints, and the support of farm management for biodiversity. Companies like Tesco, Danone, PepsiCo and Kellogg's are members of the Cool Farm Alliance, which supports the implementation of and training for the tool. Cool Farm Alliance (2017) also claims that the CFT helps identifying practices to improve yield and quality, and reduce impacts, costs and risks.

SENSE is an online tool developed by the European project SENSE with the purpose of simplifying the assessment of the environmental and social life-cycle impacts of food and drink manufactured in Small and Medium Size Enterprises (SMEs). The methodology, developed by Ramos et al. (2016), includes a standardized method for data collection, selection of the key environmental performance indicators and a simplified method for LCA. The SENSE tool generates an environmental identification document (EID) that can be used by customers and stakeholders (SENSE project, n.d.). The tool has already been tested with some FPs, such as beef, dairy, orange juice and salmon, although it obtained different results for some environmental impact categories than with previous LCA studies carried out with SimaPro software.

The EcodEX tool was developed by Selerant Corporation (2015) for Nestlé to assess greenhouse gas emissions and impacts from water, energy and biodiversity across the entire life cycle of FPs. It uses databases such as ecoinvent and the World Food LCA Database to build an inventory for use in simplified LCA studies of FPs, considering the following life-cycle stages: ingredients, packaging, processing, distribution, consumer use and end of life (*Sustainable production support tools. Overview of EcodEX*, n.d.). The World Food LCA Database, developed by Quantis with support from Nestlé, has developed hundreds of new life-cycle inventory profiles from a wide variety of production systems and crop types (Brennan P Schenker U, 2016). Although originally designed for internal decision making, its results are also useful for external communication (Sonnemann & Margni, 2015).

The Packaging Impact Quick Evaluation Tool (PIQET) is a streamlined LCA tool for the design of sustainable packaging (Verghese, Horne and Carre 2010). PIQET uses life-cycle inventory data for packaging materials for material manufacture, converting, filling, cleaning of returnables, transport and end-of-life management processes, and combines them with packaging-specific indicators, such as product/packaging ratio and number of packaging materials per format. PIQET has been used by large food and drinks manufacturers, such as Asahi, Green's, and manufacturers of packaging for food, like Bemis. Nestlé also used PIQET before starting using EcodEx (Dri et al., 2018).

Packaging Eco-design Tool for Environmental Responsibility (PETER) is a web-based tool developed by Quantis in 2017 to support Danone in their assessment of their environmental performance for different packaging solutions considering all stages of their life cycle. The user can create a packaging model with selection of materials, shipping logistics, description of the production process and other packaging parameters such as weight and recyclability. Next, the life-cycle performance of the packaging is analysed based on CF, WF and land occupation (Quantis, 2017). Up to three packaging solutions can be compared in the same time based on the aforementioned parameters and indicators (Danone Waters, n.d.). In addition to PIQET and PETER, other streamlined LCA tools for packaging have been recently developed, for instance COMPASS (GreenBlue, n.d.) and PackageSmart (EarthShift Global, n.d.).

4. Case study

This section presents a case study undertaken with a food manufacturing company to analyse their new food product development (NFPD) process and discusses how the use of the methodologies and tools described in Section 3 could help them to design more sustainable FPs. The criteria to select the food manufacturing company were that they produce a FP to be consumed as an entire meal (i.e. rather than selling single ingredients), they have staff dedicated to NFPD, they launch NFPs regularly, and they have interest in reducing their environmental impact and improving their sustainability performance. Based on these criteria, a prepared food manufacturer located in England was selected. This food manufacturer is anonymized in this paper due to commercial sensitivity.

The authors visited the food manufacturer's site and toured the different areas in the factory to gain a better understanding of their food manufacturing activities. They met with some of their staff, including the NPD manager, and discussed issues around identifying market needs and developing NFPs to meet these needs, and how the NFPD process operates in the business. Following in-person meetings, further communication continued via email. These interactions enabled a NFPD process to be drawn, as shown in Figure 2. The NFPD process includes the major steps involved from the analysis of consumer trends up to product launch. In broad terms, the major steps are the generation of the initial idea, development of the new recipe, costing analysis, presentation to the customer, factory trials and launch.

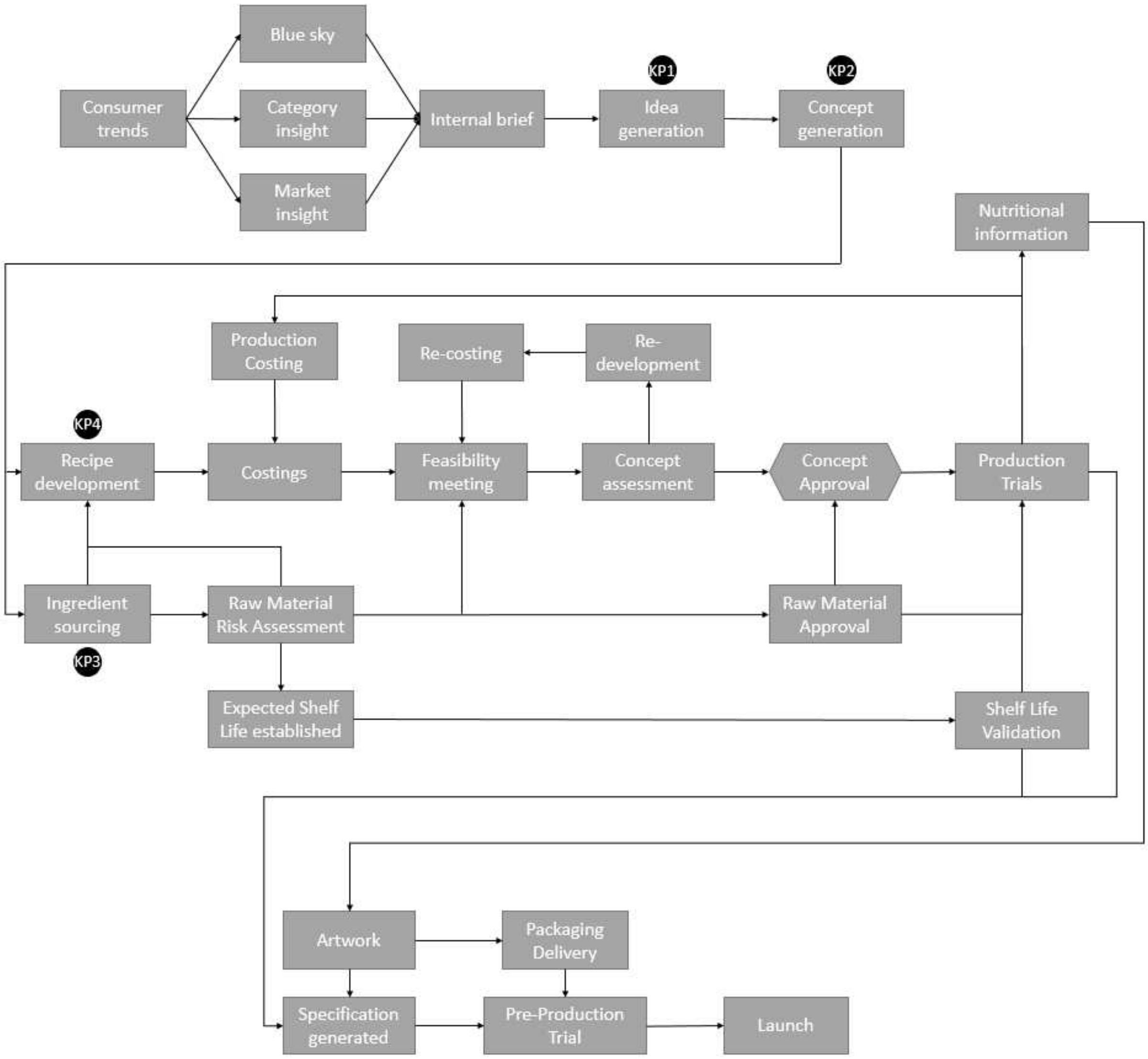

Figure 2. NFPD flowchart of the prepared food manufacturer. KP: key points

Figure 2 is a simplified version of food manufacturer's NFPD process, with all confidential and sensitive information removed. There are additional steps in each of the major stages of the process that have not been added to the flowchart, e.g. a number of subprocesses and milestones in the technical processes. There are additional steps after the launch of the NFP as part of their post-launch review. Furthermore, the NFPD process slightly varies depending on different suppliers, clients and FPs. The NFPD process shown in Figure 2 should be considered as a simplified, non-specific NFPD process for the generic development of NFPs.

Following an analysis of the sustainability methodologies and tools discussed in Section 3 and the food manufacturer's NFPD process, the key points (KPs) in the flowchart, where such methodologies and tools could be applied, were identified and numbered 1-4, as shown in Figure 2: idea generation, concept generation, ingredient sourcing and recipe development (KP1-4). These KPs were identified based on discussions with the company staff and on the authors' knowledge about NPD and the different methodologies and tools. The identified KPs are between the idea generation and feasibility meeting where the application of the sustainability methodologies and tools would have the most potential to produce better results for the food manufacturer. Steps before KP1 are too early in the NFPD, since not enough information would be available to use the methodologies and tools. Steps after recipe development have smaller potential to change the sustainability performance of the FP, since, as explained in Section 2, around 80% of the environmental and economic impact of a product is determined at the design phase, in the early stages of NFPD. Below is an analysis of how each methodology and tool could be integrated into the food manufacturer's NFPD process to support the development of more sustainable FPs.

KP1: Idea generation is the first KP where sustainability methodologies and tools could be applied. One of the main aspects to assess at this stage of the NFPD would be the nutrition target of the FP, which is currently considered at later stages of the food manufacturer's NFPD process. NF would be fundamental at this stage, where different product ideas with specific nutrition requirements could be assessed. NF is the only methodology analysed in Section 2 that can be used to assess the nutrition level of FPs. Specifically, the energy intake, sodium intake, content of dietary fibre and saturated fat should be analysed. This information would be useful to determine the overall health quality of the FP, which is needed to assess the social impact or benefit of the FP for the consumer. Furthermore, since consumers are becoming more interested in the health quality of food, this information should be displayed on the packaging. Displaying this information as a weight and percentage is already a requirement in the UK, and a traffic-light rating system to make this information more easily understandable to the consumer may become mandatory in the UK in the short-term future. In addition to the health quality of the FP, NF can be used at this stage to perform an initial, streamlined environmental impact assessment of the NFP.

KP2: During concept generation, the initial, simplified design of the FP is completed. At this point the packaging of the FP must be either selected, or if new packaging is going to be used, designed. Key aspects to consider at this stage are the packaging specification, for which the type and quality of the packaging should be considered along with the shelf life of the FP, and the packaging design, reflecting the image and brand of the FP. Once these initial packaging aspects are defined, PIQET and PETER would be useful for assessing the sustainability performance of each packaging solution considering the entire packaging's life cycle. At present, packaging aspects are considered towards the end of the NFPD process.

KP3: Once an agreement about the initial design of the NFP is reached, the specific ingredients needed must be identified. Ingredient sourcing is the task where ingredient sustainability (KP3) can be introduced. There are three different options to address at this stage: the company can review their existing list of suppliers, select new suppliers (e.g. if new ingredients are needed), or work directly with farmers removing the need of intermediate suppliers. For the review of suppliers, CF, EF and WF would be useful methodologies to assess the environmental impact associated with different ingredients, so sustainable ingredients can be identified and selected for the recipe. For the selection of new ingredient suppliers or working directly with farmers, CFT can be used to analyse the environmental impact created in obtaining different ingredients, whilst AgBalance™ would support the assessment of ecological, economic, and social sustainability at the agricultural level. The combination of the information from methodologies and tools, along with ingredient specification and material risk assessment, would help selecting the source of ingredients. At this stage, the NF could be applied again to reassess the nutrition provided by different ingredients.

KP4: After the ingredients and packaging have been selected, possible NFPD scenarios are generally reduced to 2-5 options. For the final NFP specification, a detailed recipe must be developed, so the final characteristics of the NFP are precisely defined. Once the NFP is designed and all data with regard to its manufacturing are collected, methodologies and tools to assess the environmental impact of the NFP in its entire life cycle can be used. PEF, SENSE, EcodEX and LCA methodologies such as LCA-PDP and SLCM would be useful to quantify such environmental impacts. SENSE could also be used to assess the social implications of the NFP, whilst LCSA is the only methodology that would allow estimation of environmental, social and economic impacts and benefits over the entire life cycle of the NFP.

Once the NFP is finally launched, some of these methodologies and tools, particularly related to life-cycle analyses, should be reapplied with new empirical information when this becomes available. Similarly, these types of analyses should be undertaken regularly, since all factors that contribute to the overall sustainability performance of the NFP continuously change. For instance, improvements in the efficiency of several processes in the production line of the factory could reduce waste generation and consequently minimize environmental and economic costs.

Nevertheless, the authors acknowledge that using the suggested tools could be a costly and complex process for the food manufacturer, and in general for any food manufacturer. Solutions for this may include considerable simplification of the tools, such as streamlined tools, commercial off-the-shelf (COTS) products and plug and play (PnP) products that are intuitive to use. Alternatively, food manufacturers may prefer to outsource the sustainability assessments at different stages of the NFPD process to an expert provider who could be more efficient than the food manufacturer's staff at doing such assessments because of their experience and expertise. These expert providers would have all the tools needed because they would use them frequently for many clients, thus spreading the overhead of the cost. Although the implementation of the solutions proposed in this section may be costly in the beginning, it is expected that it will also support the optimisation of the efficiency of the different manufacturing processes as well as consumer demand for such sustainable NFPs, making the NFPs economically profitable.

5. Conclusions

There are a wide range of methodologies and tools available to food businesses to support the implementation of sustainability considerations in their NFPD. These methodologies and tools, which vary in their level of complexity and knowledge required by the user, aid in calculating the environmental impact of NFPs and potential socio-economic benefits and costs. In order to more effectively assess the sustainability implications of NFPs, sustainability methodologies and tools should be applied at the beginning of the NFPD process, and then be continuously used as more information becomes available and data varies over time due to changes in the production processes or the wider food supply chain.

These sustainability assessments are generally complex and as a consequence time and labour intensive. Economic analyses are essential to balance the work needed and potential benefit obtained from sustainable NFPD, so economic performance is prioritised, as required by most businesses. Nevertheless, it is often the case that sustainable FPs are more valued by customers and their production is economically profitable. Although some sustainable ingredients may be more expensive than alternative ingredients, and producing NFPs may produce high-failure rates, sustainable production also helps reducing economic costs, e.g. by reducing water footprint, emissions and waste generation. Therefore, embedding sustainability analysis in NFPD not only improves environmental performance, but may also optimise social and economic performance.

Decisions and activities that affect the sustainability performance of the food company are made at many different levels of the business, thus the entire company should continuously monitor their sustainability performance and aim to improve the aspects that currently generate least desirable results. Environmental management systems are useful to support this approach. Similarly, training should be offered to all staff within the business and everyone should be made aware of their role in improving the sustainability performance of the entire food company. These practices will allow food businesses to produce more environmentally-friendly food products without compromising their quality, safety and profitability.

Acknowledgments

This work was supported by the Engineering and Physical Sciences Research Council (EPSRC) UK under Grant number EP/K030957/1. The authors thank the anonymized food manufacturer for the data provided.

Disclosure statement

No potential conflict of interest was reported by the authors. The funders had no role in study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

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