Towards more sustainable food processing: a structured tool for the integration and analysis of sustainability aspects of processing equipment

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Abstract. Sustainable food production along with food security and safety demands attention. Reducing the undiagnosed impacts of the food processing sector contributes to the transition towards a more sustainable food production system. Consequently, food processing technologies and production planning should be developed or modified with caution to align with sustainability issues. Appropriate tools are needed to ensure the complete coverage of different aspects of sustainability in the design phase and to recognize the opportunities for sustainability improvements in the use phase. This study proposes a structured tool to analyze the sustainability of food processing technologies from the stakeholder's points of view, that can be used to make more knowledgeable decisions and find manageable trade-offs. The proposed tool is adapted from the acknowledged Sustainable Development Analytical Grid (SDAG) tool. The theoretical contribution of this study is the synthesis of literature to identify sustainability criteria for integrating into the design phase, thereby enhancing sustainability across the entire life cycle. A case study from the food sector illustrates the applicability of the tool and suggests solutions to address the identified sustainability issues. Future research should strengthen the validity and applicability of the proposed tool through additional cases.

Keywords: Sustainability, food processing equipment, design phase

1 Introduction

The increased need for food globally besides population growth and on the other hand experiences of large loss of edible food resources along the whole value chain demand immediate attention. As a result, food security and safety along with sustainable food production are prioritized in the mainstream of European politics and are also the targets of the Sustainable Development Objectives (SDGs) and Agenda 2030 issued by the United Nations (UN) [1].

The food processing sector often has undiagnosed impacts on sustainability dimensions. Reducing these impacts contributes to the transition towards a more sustainable food production system [2]. For instance, halving food waste during processing could significantly reduce land use and eutrophication potential due to nitrogen release [3]. In addition, it is shown that redesigning food processing equipment (FPE) with a focus on increasing main product yield and reducing loss could have a significant contribution to the reduction of environmental impacts of the salmon supply chain [4]. Reducing water consumption by one-third in a hake filleting plant and lowering the organic content of wastewater in a herring filleting plant are some other practical examples, in which sustainability improved by optimizing or redesigning the processing technologies [5].

Sustainability can be integrated in both the design and the use phases. For the design phase, sustainability is considered as the potential design criterion. On the other hand, in the use phase of existing equipment, it is assumed as a modification. Since in the design phase, there is more freedom of action with a lower modification cost, most of the sustainability is locked into this step [6]. In other words, the design phase can be used as a leverage point for reducing sustainability impacts [4]. Accordingly, giving priority to integrating sustainability into this step is important.

Improving the sustainability performance of processing technologies in the design phase means facing all three dimensions of sustainability; environment, society, and economy, at the same time. Traditionally, the design of technologies has been mainly guided by technical and micro-economic decision criteria to ensure that it is 'fit for purpose' with the maximum financial returns [7]. Even though some of the environmental and social criteria such as system's emissions and health and safety are already integrated into traditional design procedures, their impacts are often overlooked. They are still considered as an 'after-thought, once the technical and economic components have been finalized [7].

From a contingency standpoint for the design of new FPE, we must first identify the areas where existing technologies have the greatest potential to enhance sustainability performance. Appropriate tools are needed to recognize these areas and ensure the complete coverage of different aspects of sustainability.

The purpose of this study is to develop a structured tool that can assist product developers in appraising the domains for sustainability improvements, which is crucial for designing a more sustainability-friendly FPE. In addition, it enables the food processing company to situate itself within a sustainability framework and presents means to enhance its performance while striving for continuous improvement. This can be achieved by analyzing the performance of the existing food processing technologies across all dimensions. To this aim, first, the sustainability aspects associated with FPEs are extracted from the literature. Next, considering these aspects, a set of sustainability objectives are defined such that their fulfillment satisfies sustainability dimensions. The objectives are categorized into different themes each allocated to one of the dimensions to develop the sustainability assessment tool. Finally, a case study is conducted, illustrating the applicability of the tool.

2 Theoretical background

In this section, we begin by discussing the conventional principles of FPE design, leading to a discussion regarding the importance of integrating all sustainability dimensions in the design phase. Finally, we explore the research gap in this area.

2.1 Design of FPE

Conventionally, the principles of FPE design and manufacturing involve the assessment of sizing and costing of equipment, the body material selection, and finally equipment fabrication. According to the handbook of food processing equipment [8], two groups of construction and operational characteristics should be considered in the design stage. The construction characteristics are the design criteria that the equipment will be constructed based on such as dimension, weight, quality of materials, firmness, durability, and so on. The operational characteristics, on the other hand, are features facilitating the operation of the equipment namely convenience, ergonomics, efficiency, accuracy, effectiveness, environmental impacts, and so forth.

Manufacturers often overlook environmental and social criteria during the design process, considering them only after the technical and economic aspects. This can lead to sub-optimal system performance and neglecting sustainable alternatives [7]. In addition, at the early stage of product development, one must be conscious of the eco-design paradox. Focusing solely on reducing one environmental impact without considering upstream or downstream impacts can lead to unintended negative consequences in other areas of sustainability [9].

2.2 Importance of integrating each sustainability dimension in design phase

Covering all sustainability dimensions mandates acknowledging the importance of each dimension in the design phase. Failure to recognize this importance might result in hesitation to take essential measures and engage in appropriate planning. On top of the economy, environment, and society, a forward-looking view of "sustainability" becomes a synonym for the compatibility of the product with forthcoming trends in the interest industry, introducing future proof dimension.

Economic: economic dimension is usually regarded as a 'generic dimension'. Economic sustainability involves addressing issues that enable a company to maintain competitiveness in the market over a long time [10]. It also assesses the value a company creates in the short and long term and at different levels, from local to global levels [11]. As a result, it's essential to consider the financial feasibility of each step in product development to design a product that is economically sustainable for the future.

Environment: design for environment (DfE) is the development of products by considering environmental criteria to reduce their environmental impacts across all stages of their life cycle [12]. Studies have shown up to 90% of the environmental impacts of a product are determined in the product development process. Thus, environmental requirements should be introduced as early as possible into the design phase alongside quality, cost, and safety requirements [13].

Society: social sustainability pertains to a product's impact on the social system in which it operates and deals with issues such as human well-being.However, this dimension is often neglected and considered a 'concept in chaos' [14]. The findings show that although the companies have adopted several kinds of International Organization for Standardization (ISO) standards, social sustainability is still absent from their operational activities [15]. Nevertheless, the extensive role of human beings in manufacturing, namely strategy, knowledge, design, control, resilience, etc., highlights the fundamental role of this dimension [16]. Consequently, human factors should be considered in addition to the technical issues during the design process [17].

Future proof: thinking about the future is about preparedness, identifying drivers of change, and making wise decisions. Understanding the trends can help product developers proactively manage the major shifts before it becomes too late. The trend represents a profound trajectory of change that will occur over the next few decades, and while change might start gradually, it will eventually have a significant impact [18]. Therefore, having a sustainable FPE demands a design adapted to the upcoming trends in the food industry. The more compatible with the forthcoming trends, the more future-proof product.

2.3 Research gap

A comprehensive tool is needed to address all dimensions simultaneously. The existing tools are often limited to one dimension, quantitative data dependent, not FPE-focused, or lack stakeholder input in generating sustainable solutions.

Azapagic et al. (2006) and Schöggl et al. (2017) propose new methodologies for integrating different sustainability dimensions into the design step of a chemical process and automotive manufacturing, respectively [7, 19]. However, these tools are customized for their specific field of application and not covering all FPE-relevant sustainability aspects.

Bar (2015) conducted a life cycle assessment (LCA) study on a sorter and grader equipment to identify environmental design requirements lined to the equipment's lifecycle. However, the study only addresses the environmental aspect of sustainability [4]. In addition, LCA as the most commonly used tool for the quantitative assessment of sustainability can only be applied to fully developed products whose components, processes, and materials, are already detected. As a result, it is inappropriate for a new product design where there is a high degree of uncertainty and limited data and experience [20].

The Global Reporting Initiative Sustainability Reporting Standard (GRI 13) offers guidelines for sustainability reporting, including the assessment of aquaculture industry's sustainability. It offers valuable post-hoc data, insights, and identifies areas needing improvement for more sustainable product design. However, it's a broad reporting standard that may not fully encompass all sustainability aspects of FPE and primarily focuses on environmental and social impacts, neglecting economic aspects.

Another tool, the Sustainable Development Analytical Grid (SDAG), is a versatile and scientifically robust assessment tool. Developed as part of the SDG Acceleration toolkit, it forms a framework for assessing the sustainability of projects, strategies, and programs in the context of Agenda 2030. Its comprehensive coverage of sustainability dimensions and its emphasis on stakeholder participation sets it apart [21]. However, it uses a generic criterion that may not be precise enough for FPE, possibly overlooking critical aspects such as food safety, hygiene, and energy efficiency.

Despite the growing literature on developing sustainability assessment tools, there remains a gap in assessing all sustainability aspects and improvement areas across all dimensions specifically for food processing technologies.

3 A tool for sustainability analysis of FPE

The purpose of this section is to develop a tool for sustainability analysis specifically for FPE, bridging the research gap. To this aim, first, we examine all the aspects through which FPE impacts the sustainability dimensions across its life cycle. Then, this examination is utilized as a foundation for developing the tool and finally, the method for conducting sustainability analysis is explained.

3.1 Sustainability aspects associated with FPE

Examining sustainability aspects related to FPE helps to identify potential ways that a FPE impacts sustainability dimensions throughout its whole life cycle. Evaluation of these impacts can validly be used to guarantee the design of a more sustainable product and their resolution contributes to SDGs targets [32]. The aspects are extracted from the literature for different dimensions of sustainability. It has been performed by analyzing manuscripts in scientific databases, namely ScienceDirect, Scopus, and Google Scholar. The following keywords and combinations thereof were used: "food processing", "environmental sustainability", "social sustainability", "economic sustainability", "food processing equipment design", and "sustainability impact", "smart food processing technology". The titles and abstracts were assessed individually for their relevance. The sources were collected in Mendeley (Elsevier), and duplicates were removed. The initial criteria for inclusion were peer-reviewed journals, books, or reports written in English.

To properly analyze these aspects, it is important to establish the scope of the analysis and choose an appropriate time frame for investigation [33]. In addition, the eco-design paradox highlights the need for a holistic approach to a sustainability-induced design, where the entire life cycle of a product is taken into account [9]. For FPE, the sustainability aspects are classified into the three life cycle phases of manufacturing (design and fabrication), use (operation and maintenance), and end-of-life (Table 1). The categorization of sustainability aspects into life cycle phases of FPE is based on when these aspects are most relevant and influential in determining the equipment's sustainability performance.

Table 1: Sustainability aspects per life cycle phase. Sustainability Dim. = Sustainability dimension, Env.= Environmental, Eco. = Economical, Soc. = Social, F.P. = Future proof.

Life cycle phase	Sustainability aspect	Sustainability Dim.			
		Env.	Eco.	Soc.	F.P.
Manufacturing	Manufacturing complexity [8]			x	
	Manufacturing cost [19]		x		
	Body Materials impact [4]	x			
	Durability [4]	x	x		
	Equipment weight and volume [19]	x			
	Design for clean-ability [8]	x			
	Design for dismantling [22]	x	x		
Use	Water consumption [23]	x	x		
	Washing agents use [4]	x			
	Food waste during processing [24]	x			
	Greenhouse emissions of refrigerators [24]	x			
	Atmospheric emissions (exhausted gases, steam, etc) [24, 25]	x			
	Energy consumption [24]	x	x		
	Noise emission [23, 26]	x		x	
	Liquid effluents [23]	x		x	
	Odor emission [23]	x		x	
	Machinery waste products such as sludge and used chemicals and their pollution [23, 17]	x		x	
	Food safety [27]			x	
	Capital and operating cost [19]		x		
	Convenience to work with [8]			x	
	Energy demands for a specific task [28]			x	
	Task repetition [17]			x	
	Ergonomics conditions with considering gender, age, and the level of demanded concentration of task [8]			x	
	Task duration [17]			x	
	Monotonous task [28]			x	
	Safety issues [8]			x	
	Thermal conditions [29]			x	
	Lightening condition [17]		x	x	
	Occupied space of equipment and the space in between equipments in line processing [17]			x	
	Industry 4.0 compatibility [27]				x
	Data management and digitalization [30]				x
	Smart production planning and control [31]				x
End of life	Reuse [19]	x	x		
	Recycling [22]	x	x		
	Material labeling [19]	x	x		
	Disposal [22]	x	x		

3.2 Development of a tool for sustainability objectives for FPE

The study uses literature findings in Table 1 to develop objectives, whose fulfillment satisfies relevant sustainability dimensions and associated SDGs. For instance, minimizing food-grade water consumption contributes to SDG 6 - sustainable water management. The tool is inspired by sustainability aspects across all life cycle phases (Table 1), translated into objectives that should be considered in the manufacturing phase of equipment. These objectives also include aspects from interviews at the case company and existing sustainability frameworks mainly [21], [4], and [19]. The objectives are then themed depending on the way that they impact the dimension. For instance, the objective categorized in the ecosystem protection theme could positively impact the environment by protecting the ecosystem. The framework summarizing the objectives for design consideration in the manufacturing phase is shown in Table 2.

Table 2: Sustainability themes and objectives across dimensions for design consideration in equipment manufacturing process. Dim. = Dimension, IoT = Internet of Things, AI = Artificial Intelligence.

Dim.	Theme	Sustainability Objectives
Environment	Ecosystem protection	• Minimize yield loss during processing • Facilitate optimal use of rest raw material
	Resource efficiency	• Minimize energy consumption • Minimize food-grade water consumption • Efficient and easy clean-ability • Easy-to-dismantle • Weight and occupied space reduction • Choose low-impact body materials • Choose easy-to-clean materials • Use recyclable materials • Use durable materials • Plan for the prudent use of resources • Optimize resources nearing their end
	Output control	• Identity liquid, solid and gaseous outputs • Reduce their negative environmental impacts • Reduce need for washing agents/disinfectant • Minimize noise emission • Minimize odor emission • Minimize liquid effluents • Minimize solid wastes, e.g., sludge • Manage hazardous waste properly
	Climate change	• Quantify greenhouse gas (GHG) emissions • Reduce GHG emissions • Compensate for greenhouse gas emissions • Reduce atmospheric emissions like steam

Table 2 Continued

		• Plan climate adaptation measures
Social	Food integrity	• Ensure food safety during processing • Ensure food security • Align processing impact on food quality with consumer preferences
	Health	• Provide an ergonomic condition for employees • Consider gender status in ergonomic design • Reduce task duration • Reduce task repetition • Reduce susceptibility to machine pollutions • Reduce task energy requirement • Foster a healthy environment • Reduce factors causing mental health issues • Reduce irritants
	Safety	• Create a feeling of security • Ensure effective safety • Provide basic safety education
	User-friendly	• Easy to be trained and work with • Ensure a non-complicated FPE design
	Work environment	• Reduce noise pollution • Reduce heat generation due to processing • Provide proper thermal conditions • Provide a proper lightening condition
Economic	Responsible production	• Producing quality goods and services • Ensure a time-efficient/immediate processing • Ensure a continuous line processing • Easy and predictive maintenance • Ensure match of needs and produced goods • Promote eco-design in product life cycle • Promote sustainable production • Implement extended producer responsibility
	Economic viability	• Ensure economic viability • Minimize capital and operational cost • Ensure a high-profit margin • Adhere to limiting the return on capital • Limit the financial risks
	Job creation	• Enhance job creation
	Energy cost	• Reduce energy consumption • Plan a wise use of energy
Future proof	Innovation	• Increase innovation potential in equipment • Promote R&D involvement in design • Have a more automated operation • Develop robotic washing solutions • Develop new FPE drying technologies

Table 2 Continued

	• Enhance equipment versatility • Optimize cooperation between processes • Consider future trends in the food industry • Equip FPE with Industry 4.0, e.g., IoT, AI
Risk management	• Manage risks related to new technologies • Identify risks at different operation levels • Apply the principle of prevention • Easy to control in the case of FPE failure • Promote an equitable distribution of risks • Plan for adaptation to global changes
Data digitalization	• Monitor food processing during operation • Smart production planning and control, Digitalizing processing data

3.3 Method for analysis of FPE sustainability

The developed tool is versatile and beneficial to diverse stakeholders like product developers, FPE manufacturers, and food processors. It identifies areas for improvement and addresses all sustainability dimensions early in development, enhancing FPE sustainability. It also helps practitioners such as food processors analyze their operations' sustainability performance.

The analysis involves weighting, a performance assessment based on planned or already implemented actions, and the generation of ideas for improvements where required. This method of analysis makes it possible to prioritize the objectives that need to be addressed in a continuous improvement process.

Optimal enhancement of sustainability performance necessitates giving the sustainability objectives the importance they demand. This is also a crucial step when the trade-offs between the objectives in the design process are inevitable [22]. The developed tool weighs the objectives based on the stakeholders' perspectives, allowing the stakeholders to fully play their roles in assessing sustainability.

Together with weighting analysis, assessing how well a company meets sustainability objectives through its processing technologies, and production planning demonstrates the company's capacity to adhere to SDGs and provides a better understanding of the reasons behind that.

The weighting and performance assessments are conducted based on the established tool of SDAG, whose assessment methodology is simple, efficient, and scientifically robust [21]. For the weighting, each objective needs to be assigned a numerical value ranging from 1 to 3 according to its level of significance, which is determined as follows.

(1) *desirable objective:* achieving this objective is not deemed important or is not a priority.

(2) *important objective:* achieving this objective is important but is not one of the immediate priorities related to the needs targeted by the company.

(3) *indispensable objective:* achieving this objective is important and is an immediate priority. It is deemed indispensable to the success and aim of the company.

Regarding the performance assessment, a numerical scale from 0 to 100% should be used as follows, scoring the sustainability performance of each objective.

- Below 20%: This objective is not considered.
- Between 20% and 39%: This objective is insufficiently considered.
- Between 40% and 59%: This objective is slightly considered; with no concrete actions and measures, and minimal positive impacts are expected.
- Between 60% and 69%: This objective is moderately taken into account, with planned actions, but with no innovative elements.
- Between 70% and 79%: This objective is taken into account, with concrete actions and some innovative elements but still improvable.
- Between 80% and 89%: This objective is well taken into account, with innovations and concrete measures, significant positive impacts are expected.
- Between 90% and 100%: This objective is strongly taken into account; the company is exemplary in that respect.

The overall sustainability performance of themes and dimensions determined by taking a weighted average over all the designated performance percentages for respective objectives. We propose a weighted average is more accurate than a simple average and measures an average that reflects the relative importance of each objective.

4 Case study

In this section, we first introduce the case company and then present the case findings with regard to the sustainability of the company's deployed FPE and production planning using the tool in Table 2.

The interview, attended by researchers and the company's operational manager, began with the participant signing a consent form and being informed about the sustainability analysis method. A survey listing all objectives for assessment and weighting was given, along with a detailed guide for interviewers. Participants were encouraged to provide additional details during the assessments. The interview was somewhat spontaneous, with questions asked based on the company's performance in each theme, probing for areas of excellence or potential improvement.

4.1 Introduction to case company

The interview is conducted on the salmon filleting sector of a Norwegian seafood company, whose strategy is sustainable growth in the entire value chain and satisfying quality-conscious consumers. This company could be a typical representative of a wider class of food processing companies with the same strategy. The company operates in the aquaculture industry, specifically in the farming of Atlantic salmon and rainbow trout. As of 2022, the company had around 275 employees across its land-based and sea-based locations. In 2020, it generated a turnover of NOK 2.2 billion and produced around 3.6 million smolts that year. To illustrate the applicability of the tool on an existing FPE, a commonly used FPE in the processing industry, the trimming machine is chosen. Trimming is performed after the fish has been cut into fillets.

4.2 Results and insights from case study

The importance and performance percentage of each sustainability dimension given by the case company is illustrated in Figure 1. The average weighting numbers have been normalized and presented as percentages to simplify the comparison with performance results.

Figure 1 shows that the case company has a hierarchy for weighing different dimensions, with the future-proof dimension being the most important, followed by the economic, social dimensions, and the environmental dimension as the least important one. Prioritising of future proof dimension on economic dimension highlights the economic benefits of being a future-proof company. Investing in high technology and smart production increases profitability by enhancing efficiency in production time, energy consumption, and operating costs, thereby reducing long-term expenses. Additionally, establishing a reputation as a sustainable company with future-proof technologies improves the company's brand image which can lead to increased sales and customer loyalty.

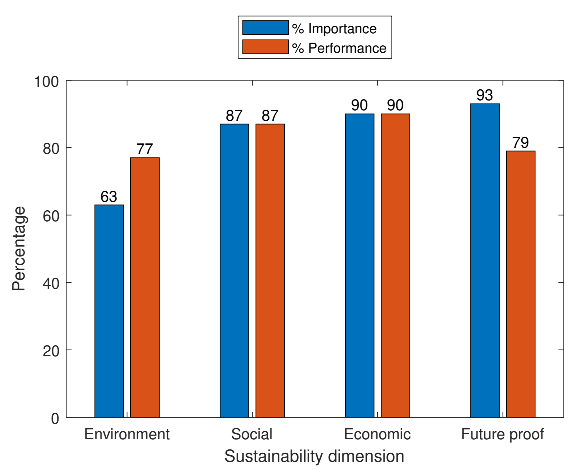

Fig. 1: Importance and performance percentage of case company for all sustainability dimensions.

Although the company places significant importance on the future-proof dimension, they have not achieved a comparable level of performance in meeting this dimension (Figure 1). The average performance of this dimension is 79% meaning that it is taken into account but there is still room for improvement. The reasons for this could include insufficient financial resources, the company's resistance to change, inadequate infrastructure, ineffective planning and strategy, difficulties in integration of new technologies, and lack of data analysis, resulting in missed opportunities for improvement in their performance.

Table 3: Average weighting and performance for sustainability dimensions and themes. Ave. = Average.

Dimension (Theme)	Ave. weighting	Ave. performance
Environment	1.9	77%
Ecosystem protection	2.5	82%
Resource efficiency	2.3	78%
Output control	1.8	79%
Climate change	1.2	70%
Social	2.6	87%
Food integrity	3	92%
Health	2.1	79%
Safety	3	93%
User-friendly	2.5	86%
Work environment	3	92%
Economic	2.7	90%
Responsible production	2.8	88%
Economic viability	2.6	92%
Job creation	2	90%
Energy cost	3	90%
Future proof	2.8	79%
Innovation	2.8	77%
Risk management and resilience	3	78%
Data digitalization	2.5	88%

The economy is the next important dimension which is assigned the same level of performance as its weight. The high 90% of performance demonstrates that the company has strongly taken into account this dimension and has imposed enough measures such as strong financial management, marketing and sales strategies to satisfy this dimension and its relative themes.

The social dimension is weighted as the next significant dimension, with a high priority on food integrity including food safety and security, employee safety, and an appropriate work environment in the operation sector (Table 3). Its high performance of 87% shows the corresponding themes are well taken into account with concrete measures and positive impacts are expected. A comparable performance and importance level for this dimension highlights the strong focus of the company on meeting customers' or employees' needs and providing excellent customer service. This could lead to increased customer loyalty, repeat business, and positive word-of-mouth marketing.

The last and the least important dimension from the company's perspective is the environmental dimension. However, the company's performance in this area is higher than its given importance level (Figure 1). The potential explanation is that the environmental aspects are usually met at the minimum level required by legislation [7]. As regulatory authorities prioritize environmental protection, companies tend to comply with regulations to avoid the risk of costly fines or lawsuits and improve their long-term financial stability. It is evidenced by the high average performances of 82% and 79% allocated to ecosystem protection and output control themes, respectively, compared to other themes of this dimension (Table 3). On the other hand, considering the general overlooking perspective of the company to this dimension, the company may feel that they are already doing more than necessary in this area due to legislation, giving it higher performance than the actual level that it has.

The low performance and importance level assigned to the environment compared to other dimensions necessitated an urgent change in perspective. Climate change represents a new and somewhat daunting topic for many companies as evidenced by the low weight and performance given to this theme (Table 3). However, investigating its potential risks to business and required actions to mitigate those risks is of great importance [34].

The case company suggested ideas for sustainability improvements in different dimensions. Some of them are namely avoiding waste of fillets while flipping, saving electricity by turning off lights and machines during idle times, cleaning and distilling seawater to use as food-grade water, promoting a healthy work environment, using automation and high-technology equipment, being compatible with future trend of on-board processing, controlling energy usage, facilitating data digitalization, and improving risk assessment. The company also emphasizes the importance of collaboration with FPE manufacturers, researchers, and product developers to promote innovation and responsible production.

5 Conclusions and directions for future research

The food processing sector often has undiagnosed impacts on sustainability dimensions and reducing these impacts contributes to the transition toward a more sustainable food production system.

This paper has three main contributions. Firstly, it synthesizes the literature to identify the sustainability aspects associated with FPE and then outlines a set of sustainability objectives specifically for the food production system, categorized into different themes and dimensions. Moreover, it considers the future proof as one of the sustainability dimensions, which are mostly defined by three pillars of economy, society, and environment. Secondly, it proposes a framework, adapted from the acknowledged SDAG tool, enabling to prioritize the sustainability objectives and identify areas where sustainability performance has the highest potential to be improved across the whole life cycle. Providing opportunities for sustainability improvements, the framework encourages the company to the deployment of more sustainable technologies and production planning which also enhances its reputation in sustainability. Thirdly, the case study illustrates how the framework in Table 2 can be used to analyze the sustainability of a company's technologies and its production planning. Additionally, it generates a set of ideas for improvement to be applied to the most critical sustainability objectives.

Future research should strengthen the validity and applicability of the proposed tool through additional cases across food industrial sectors. It would also be interesting to interview FPE manufacturers, who are another primary stakeholder. By interviewing FPE manufacturers, we can also identify additional needs of their customers, the food processors, and discover common pain points and areas for improvement. More importantly, comparing the results of interviews with both stakeholders can help identify similarities and differences in priorities and concerns, enabling product developers to make knowledgeable design decisions. Overall, considering different stakeholders' perspectives assists in gaining a deeper understanding of the industry's priorities and concerns, informing design decisions and production planning, leading to a more sustainable food production system.

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