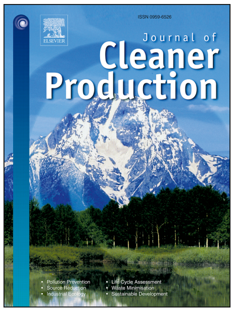

A pragmatic framework to score and inform about the environmental sustainability and nutritional profile of canteen meals, a case study on a university canteen

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PII: S0959-6526(18)30947-8

DOI: 10.1016/j.jclepro.2018.03.265

Reference: JCLP 12523

To appear in: *Journal of Cleaner Production*

Received Date: 4 October 2017

Revised Date: 17 March 2018

Accepted Date: 25 March 2018

A pragmatic framework to score and inform about the environmental sustainability and nutritional profile of canteen meals, a case study on a university canteen

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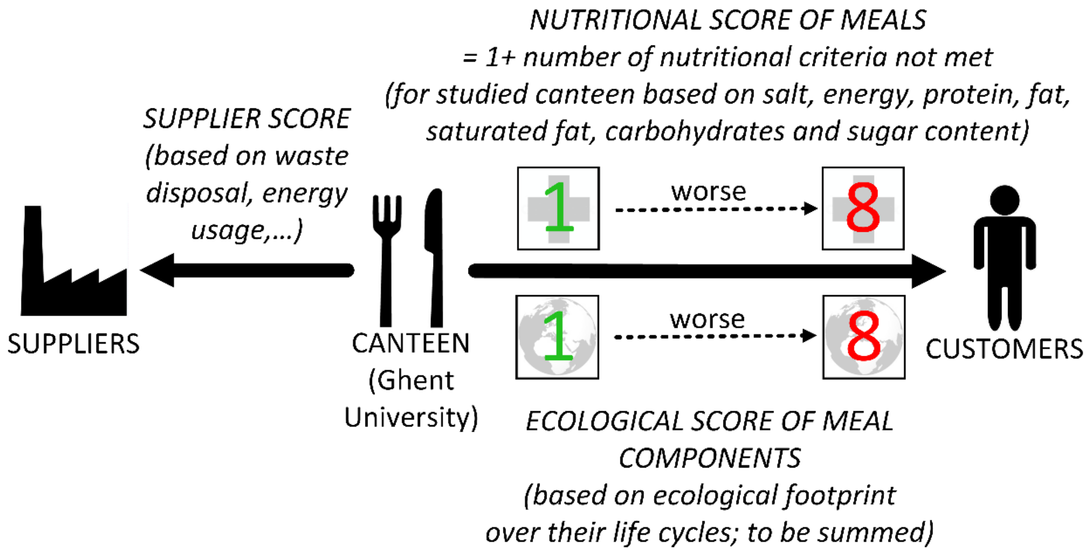
Abstract

This paper presents a pragmatic framework to inform stakeholders about the sustainability of canteen meals. The framework consists of four parts: (1) an ecological scoring system, based on life cycle assessment results, to score the ecological impact of meals or their components, from which the customer can select to compose a meal; (2) a nutritional scoring of meals based on meeting nutritional criteria; (3) a scoring system to assess the efforts undertaken by the canteen suppliers with regard to sustainable production and management and (4) collected information on relevant topics in food sustainability not covered in previous parts. The framework has furthermore been customized for and applied to the canteen of Ghent University. In light of part 1, several methods to characterize the environmental impact of food products were benchmarked, pinpointing the ecological footprint, the amount of land needed for production and to sequester CO_2, as most appropriate one. Moreover, the ecological footprint of harvested fish was newly characterized as amount of land indirectly needed for their growth in nature. This highlighted the much lower (2-15 times) ecological footprint of aquaculture than caught fish products, according to this method. The ecological scoring system was consequently based on the ecological footprint but also the carbon footprint due to its relevance, covering the discrepancy between meat, with relatively higher carbon footprint, and caught fish products, with relatively higher ecological footprint. Besides a promotion of more sustainable meals, following guidelines and conclusions were derived: (1) the ecological impact depends on more than just the main component, e.g. frying oil contributes the most to the ecological footprint of fries, and type of food, e.g. a portion 'pangasius orientale' (fish), has an about 30% lower ecological footprint than a portion 'ratatouille vegetables' (vegetarian); (2) lower salt content, which can mount up to >80% for a meal, to improve nutritional value and (3) provide a variety of portion sizes because nutritional demand varies. Although further improvement is

needed, the framework is prominent because of the better characterisation of environmental impact, its pragmatic coverage of various sustainability aspects through its four parts, feedback to all stakeholders and its easiness of application for a manifold of meals.

Graphical abstract



1. Introduction

The environmental impacts of many food production systems are well studied. Research has illustrated the contribution of food production to the overall environmental impact of human activities (Nemecek et al., 2016; Pelletier, 2015; Sala et al., 2017). For example, Huysman et al. (2016) showcase that up to about 30% of the resource impact of a EU-citizen is related to his or her food consumption. The main societal “function” of food is to fulfil biological needs related to nutrition. To consider this benefit besides damage of production, the nutritional effect of food on human health is also ideally assessed in a holistic environmental sustainability assessment (Nemecek et al., 2016; Pelletier, 2015).

Research on environmental sustainability of food originally mainly focused on selected single defined products or ingredients (Nemecek et al., 2016). Considering the broad dietary level, the selection of an adequate diet, respecting the dietary guidelines for nutritionally adequate diet, would reduce the environmental impact in the developed countries, according to several studies (Nemecek et al., 2016). However, besides adherence to a defined diet, often consumers need to choose among different meals or its meal components, for example choosing between mashed potatoes or fries as a carbohydrate component when taking a serving in a canteen. The latter selection is becoming increasingly important given the fact that population worldwide is increasingly consuming food out of home (Lachat et al., 2012; Nemecek et al., 2016; Sturtewagen et al., 2016). As such customers may request information about both the nutritional value and the environmental sustainability of canteen meals and meal components. Few such studies have been conducted (Heller et al., 2013; Nemecek et al., 2016; Sturtewagen et al., 2016).

For canteens, it is a challenge to work out a feasible policy, providing adequate information to the customers, i.e. potential consumers, but also to their suppliers on the environmental sustainability of the composite meal or individual meal components and to provide a stimulating improvement to evolve to a more healthy and environmentally sustainable food service. The main challenges seem to be the lack of information or data, complexity of the sustainability topic and lack of tools that are standardized (irrespective if it is achievable), user-friendly and have relatively easily graspable outcomes. These issues are discussed by Caputo et al. (2017) and Price et al. (2017). Menu labelling can also act as a key communication tool between operator and consumer, and is important for the establishment of a relationship to foster trust (Price et al., 2016). Besides communication towards costumers, also communication to the suppliers of the canteen seems also relevant to inform them about sustainability aspects of their production and to allow them to interpret scores, argue why other suppliers have been selected and discover possibilities for improvement. A transparent communication with suppliers is also considered to facilitate needed information or data sharing.

The focus of this study is on frameworks for canteens to support such a needed (Nemecek et al., 2016) policy or policy change. Such studies have already been performed (Benvenuti et al., 2016; Jungbluth et al., 2015; Pulkkinen et al., 2015; Ribal et al., 2015; Spaargaren et al., 2013). For an overview of these studies and their main characteristics, please see table S1 in Supporting Information (SI). They all have different foci and related strong aspects and shortcomings. Three major ones, that have been addressed in this work, are here shortly identified. First, the respective studies all provide a flow of information to the canteen itself but none of them provide information to both suppliers and customers through scoring or labelling. Pulkkinen et al. (2015) though discuss that the customer gave positive response to climate labelling in a restaurant setting. Hoefkens et al. (2012) report, for the specific university canteen studied in our work, that nutrition labelling may be used by the customer but that the presentation format of nutrition information plays a crucial role. Besides, it is relevant not only to inform about and guide the consumer to choose the more environmentally sustainable meal but also to inform and guide the canteen and its suppliers to provide such meals, even from the customers' viewpoint, as discussed by Spaargaren et al. (2013) in case of a university canteen. Second, the discussed five studies quantify/score the environmental impact through one or two methods, mainly carbon footprint which expresses climate change effect of greenhouse gas emissions, without a thorough consideration of other environmental impacts or assessment methods (Castellani et al. 2017). In addition, a prudent issue is the overexploitation of species in the wild, identifying the need to characterize the impact of harvesting or catching these. Different methods have been developed to assess this impact (Langlois et al., 2014; Woods et al., 2016). However, these methods do not extend or link with existing impact methods. A major challenge is thus to do so and express environmental damage in the same unit for all products to be able to compare them, e.g. beef with salmon steak. In this work, hereto, the approach of Luong et al. (2015) is adapted. See Material and Methods. Third, a nutritional analysis is lacking except for two studies (Benvenuti et al. 2016; Ribal et al. 2015) which though do not present a score to customers but use it as a way to optimize served dishes regarding nutritional value.

The main goal of our study was to develop an improved and relatively easily applicable framework of indicators, encompassing the necessary methodological improvements, for canteen meals. This was specifically elaborated for the canteen of Ghent University and its served hot meals. Above mentioned three issues, which are also highlighted as research gaps by Nemecek et al. (2016), are addressed in a better manner in the presented study. Furthermore, the assessment of the environmental impact of fish harvest is improved in this work. This work builds further on respective reports (Ceuppens et al., 2016; Schaubroeck et al., 2016; Uyttendaele et al., 2016a, 2016b). In the Material and Methods section, (1) an overview of the general framework is presented, (2) the general selection and improvement of environmental impact methods is provided and (3) the case study is discussed. As the final outputs are the scoring methods for the case study, these are provided in the Results and Discussion section, along with a general discussion.

2. Material and Methods

2.1 Overview of the framework

Our developed indicator framework is presented in Table 1. These measures are then exemplified through the case study on the Ghent university canteen.

Table 1. Developed framework to assess the sustainability of canteen meals.

Measures of the developed framework	Stakeholder to which the measure is mainly directed:	Application to Ghent University

	customer	supplier	canteen	
1. Ecological scoring of meals	Yes		Yes	Section 3.1
2. Nutritional scoring of meals	Yes		Yes	Section 3.2
3. Scoring of sustainability of suppliers		Yes	Yes	Section 3.3
4. Info on sustainability aspects related to meals not covered by above scoring systems	Yes	Yes	Yes	Section 3.4

The considered scoring systems, which result in ecological, nutritional and supplier indicators, should meet following three criteria:

1. The indicator values should differ enough among the products or meals as to allow customers to differentiate between them, which facilitates them to choose differently. However, differences should be not too small because the range in uncertainty might then be too overlapping to underscore small differences in outcomes.
2. The scoring shall be as simple, understandable and reliable as possible in the canteen environment (Pulkkinen et al., 2015; Spaargaren et al., 2013). To inform customer, the information must be reduced in a meaningful way (Nemecek et al., 2016). A simple score is needed to allow the customer not to have to spend relatively much time on interpreting the provided information during meal selection at the counter (Spaargaren et al., 2013). A scale or grade that is colorized and standardized is advised for food labelling regarding environmental impact, to ease the cognitive load in processing information and to make it more accessible for non-experts (Vlaeminck et al., 2014). Hoefkens et al. (2012) also emphasized that in a university canteen, the one also studied in this work, the numerical information is best combined with visual aids like stars or color codes, this based on a customer survey. More detailed information can though be given through flyers on the diner tables as proposed by Spaargaren et al. (2013) or through an app (Price et al., 2017).
3. The scoring systems should also be relatively easily applicable by the canteen itself based on readily available data, e.g. fact sheets provided by supplier.

It is crucial to comprehend that inevitable choices, even though argued as made clear in the next sections, had to be made to meet all criteria and to thus provide scoring systems that are both policy-friendly and reasonably sound.

2.1.1 Ecological scoring

To assess the environmental impact of a product, Life Cycle Assessment (LCA) is an appropriate tool (Hellweg and Canals, 2014; ISO, 2006). LCA characterizes the environmental impact of certain emissions and resource extractions over a (share of a) products life cycle, encompassing e.g. raw material extraction and final product disposal. This is also a key tool in the study of the environmental impact of food products and has been extensively applied to do so (Heller et al., 2013; Nemecek et al., 2016; Pelletier, 2015; Sturtewagen et al., 2016). Easy and adequate application of LCA is though impeded by (1) the not readily available data on the exact ingredient composition (e.g. because of confidentiality), (2) the complexity of the application and construction of the tool and (3) lack of data on supply chains (Price et al., 2017), even in databases, as can be concluded out of the elaborate data collection for the case study shown in SI section C. The exact composition is for example not obliged in Europe. Article 9 of the European regulation document EU 1169/2011 dictates that the list of ingredients should be given but that only the quantities of certain ingredients or categories of ingredients are mandatory, thus not all of them. For canteens that have readily access to the exact ingredient list with quantities (e.g. because they use non-processed ingredients), the use of a simplified LCA tool (Jungbluth et al., 2015; Pernollet et al., 2017) might be an option but then there is still the third issue, the lack of data on supply chains. To deal with all issues, a pragmatic scoring system is presented. To develop this scoring system, first, LCAs of a representative sample of meal components or meals, needs to be retrieved from literature or conducted (at best). Note that identical environmental impact assessment methods (e.g. carbon footprint) need to be used for the results to be comparable. Second, based on the LCA results, scoring intervals are then defined, the studied meal or meal components are scored, and well-associated guidelines to relatively easily score other components using available information are outlined. After development, the canteen may use the developed guidelines, the example scores for the studied meal or meal components, and the available information, to derive scores for other meals or meal components.

In this case LCAs of a representative sample set have been conducted, but these LCA results can also be used for other canteens, keeping into account their limitations and specificity towards the studied case. However, first, a more crucial and general issue in LCA of food products, namely the characterization of the environmental impact through life cycle impact assessment methods, is addressed in section 2.2.

2.1.2 Nutritional scoring

Since the diet as a whole influences human health, it is advised to analyse complete diets and to a lesser extent an individual meal, let alone a meal component. Since a canteen does not define the complete diet we consequently consider nutritional analysis of full meals served at canteens but not of meal components nor ingredients. This implies that results need to be interpreted with care and should not be regarded as completely representative for the consumers' nutritional health. It is imperative to grasp that a score system based on nutritional criteria does not explicitly assess how healthy meals are but just how nutritionally complete or adequate they are (Ernstoff et al., 2017). Nutritional parameters, e.g. protein content, are crucial and guidelines exist about the values they should have, e.g. lower than x g per day. Meals are in our approach scored per parameter: one penalty point is allocated for each parameter which is not in line with a predefined criterion and a nutritional score is then calculated by simply adding up all points, plus one extra, to obtain a score from 1 to x+1, with x the number of criteria. The formula for nutritional score is:

Nutritional score of meal = 1 + number of nutritional criteria not met (*equation 1*)

As brought forward in other works (Drewnowski and Fulgoni, 2008; Fern et al., 2015), the nutritional criteria can be normalized, e.g. divided by the mass or energy content, in order to obtain criteria which are independent of the meal size and of the average consumer's personal daily requirements. The energy demand itself can then also be multiplied with the share the meal should represent, e.g. 0.35 for a hot main meal. The parameters are not weighed, because there is no scientific consensus on a solid basis for weighing (e.g. the nutritional relevance of protein compared to fat is not fixed). This is proven by the fact that a lot of various nutritional single score approaches exist, are applied and their link with overall health is debated (Fern et al., 2015; Heller et al., 2013; Salehi-Abargouei et al., 2016; Sturtewagen et al., 2016; van Dooren et al., 2017). Though other unweighted approaches exist (Drewnowski and Fulgoni, 2008; Fern et al., 2015), our approach provides a single score with integer values and allows to explicitly derive from a value how much criteria are not met, making it easily understandable and applicable (see criteria in section 2.1). The specific selection of the parameters are at minimum these that should be presented to the customer according to legislation and for which specific criteria can also be found. This also implies that certain data-demanding nutritional scoring systems cannot always be conducted because data is not readily available, which is also a reason why, here, a more simplistic system is proposed. It is also best to add colour codes to the numbers, this based on the canteen customer survey of Hoefkens et al. (2012).

2.1.3 Supplier sustainability scoring

In our framework, the environmental impact and nutritional analyses of the studied meal or meal component are based on specific data on composition (e.g. which ingredients and what is the total protein content) but translate these into scores using only rather generic procedures. No environmental impact analysis was made of the exact production system of the particular suppliers but that of generic production systems (e.g. European market averages were considered) though as specific as possible. Hence, additionally, a scoring system based on readily available facts (e.g. the recycling of water, if possible, on site) was needed to judge the specific sustainability of the respective suppliers and their production systems to incorporate this supplier aspect in the selection of an appropriate one for a certain meal or meal component. This supplier scoring is best developed together with the stakeholders, as done for our case study, since it depends on the information they can provide. See section 3.3.

2.1.4 Additional information on sustainability aspects

Finally, our developed scoring systems do not cover all aspects of sustainability that are of interest to the stakeholders and thus some supplementary guidelines and information is provided. There was for example a keen interest in the environmental sustainability of Genetically Modified Organisms (GMO) by the stakeholders in the case study but no general statement regarding whether they are more or less environmentally sustainable than alternatives is possible due to the different types of modifications, which implies case specificity. Moreover, literature points out that science, such as LCA, still falls short to address certain food sustainability topics (Nemecek et al., 2016; Notarnicola et al., 2017a; Pelletier, 2015). Associated general conclusions are by consequence difficult to draw and integration in the scoring systems seemed not yet feasible. This information is presented in section 3.4 and is generic but only covers topics that were specifically raised by the stakeholders of the Ghent University canteen.

2.2 Selecting and improving life cycle impact assessment methods for food products

Characterizing the environmental impact of resource extraction and pollutant emissions over the life cycle of a product, is a main point of attention in this work. In literature often only the impact of greenhouse gas emissions of food products, via the carbon footprint, is assessed (see also table S1) (Nemecek et al., 2016; Pelletier, 2015). However, Nemecek et al. (2016) clearly point out that considering merely fossil energy or greenhouse gas emissions is not sufficient to address the range of environmental impacts of food. Selecting the appropriate impact assessment method, that characterizes the impact on certain categories in a specific manner, is a difficult task and depends on the goal and scope of the study. Following criteria for selection of an impact method are used: (1) reasonably sound coverage of the most important environmental issues of the considered product group, (2) resulting in a single score, (3) the method outcome should be more easily graspable by all stakeholders and (4) extent of correlation with other impact methods, covering possibly other categories. The first three criteria are derived from, as mentioned in the objectives, the fact that the scoring systems shall be as simple, understandable and reliable as possible in the canteen environment (Pulkkinen et al., 2015; Spaargaren et al., 2013). The fourth is specific and derived from the Envifood guidelines (Food SCP RT, 2013) as specified further on. Since agricultural production is a hotspot (Nemecek et al., 2016; Notarnicola et al., 2017b), ideally, all its related aspects should be covered, incl. land use, water consumption. No ideal impact assessment method though yet exists as made clear in the next paragraphs.

Four impact assessment methods were selected and compared in this study considering above three criteria. Table S8 in SI presents an overview. Due to the relevance of greenhouse gases, the carbon footprint method, which expresses impact in kg CO_2-equivalents, is considered. This method covers all greenhouse gases, among which CO_2, CH_4 and N_2O. It has been calculated as the global warming potential induced by greenhouse gases, with a 100-year timespan, and following additional characteristics: (1) accounting for CO_2-emissons due to land transformation, (2) to CO_2 emission of biogenic carbon no impact is assigned and (3) to biogenic methane emissions a factor of 22.3 kg CO_2 equiv. kg^{-1} CH_4 is assigned, this according to the used version of ReCiPe 1.12. However, the carbon footprint is clearly lacking in coverage of other impact types, as discussed, such as those related to agriculture production: land use, water consumption and eutrophication. Moreover, the ecological footprint (Huijbregts et al., 2008; Wackernagel, 1998; Wackernagel et al., 2005) was regarded, covering both CO_2 emissions and land occupation. The ecological footprint is more easily graspable, in our opinion, especially since its unit (m^2*year) refers to the amount of land occupied over time, which seems more easily linkable with food production. It does though not encompass other categories of impact (e.g. toxicity), nor other greenhouse gases besides CO_2. To consider all types of resources in one approach, the Cumulative Exergy Extraction from the Natural

Environment (CEENE) v2013 method was also selected (Alvarenga et al., 2013b; Dewulf et al., 2007). A strength of it is also its assessment of land occupation (as the deprived natural primary production) (Alvarenga et al., 2013b; Swart et al., 2015), which makes it an interesting method for biomass products. Through latter approach, the impact of land occupation on ecosystem health is also characterized (Taelman et al., 2016). However, the exergy concept is difficult to comprehend, in our opinion, and no emission impacts are accounted for in the CEENE method. Furthermore, all the above mentioned methods do not express the final impact on so called endpoints (human health, natural resources and ecosystems) but only at midpoint level. In order to do so and to account for the impact through all types of emissions but also resources, the holistic method ReCiPe was also selected (Goedkoop et al., 2009) (Hierarchist v1.12). To also address water consumption in the ReCiPe scoring method, the approach of Pfister et al. (2009) was considered to quantify water consumption in terms of the ReCiPe endpoint scores, which can then be added to them. For some categories the midpoint scores were presented since the endpoint modelling was lacking. Normalisation to deliver a single score in the ReCiPe method was not done as its soundness is relatively questionable (Dahlbo et al., 2013; Schaubroeck, 2014).

To characterize the environmental impact of fish harvest, Luong et al. (2015) have outlined how to extend the ecological footprint through food chain modelling. Using such modelling one can derive the amount of net primary production (NPP; the net amount of mass synthesized by primary producers that provides the basis for higher trophic levels) that is indirectly needed to grow the respective species in the wild, this ratio is called the specific primary production required (SPPR; kg NPP kg^{-1} species harvested) (Luong et al., 2015; Pauly and Christensen, 1995). Subsequently these SPPR amounts can be converted to biological productive land usage amounts (ecological footprint), by dividing by areal productivity (kg NPP m^{-2} yr^{-1}). Moreover, this rationale has also been applied to the CEENE method, via multiplication of SPPR values with the exergy content of the NPP (Jex kg^{-1} NPP). Per harvested species, impact factors can thus be developed through following equations:

Ecological Footprint-Impact factor for harvested species (m^{2}*yr kg harvested species^{-1}) = SPPR (kg NPP kg^{-1} harvested species) / average marine productivity (1 kg NPP m^{-2} yr^{-1}) * 0.36 (ratio of marine to world average productivity) (*equation 2*)

CEENE-Impact factor for harvested species (MJoules exergy kg harvested species^{-1}) = SPPR (kg NPP kg^{-1} harvested species) * exergy content of NPP (4.62 MJoules exergy kg^{-1} NPP) (*equation 3*)

Marine productivity was calculated by Taelman et al. (2014) for 2012, more precisely 0.11 kg C m^{-2} yr^{-1}, i.e. 1 kg m^{-2} yr^{-1} based on 9 kg per kg C NPP as reported by Pauly and Christensen (1995). The ratio of marine to world average productivity was derived from the work of Wackernagel et al. (2005). Luong et al. (2015) introduced an improved methodology to quantify these SPPR factors and this was applied for the considered harvested fish species in the case study, based on the 1997 Icelandic marine ecosystem foodweb (Mendy and Buchary, 2001). Further explanation can be found in supporting information section E.

Moreover, the impact assessment methods were applied to the circa 40 meal components of the case study and the correlation among the outcomes were checked. Hence, though certain methods do not cover all aspects or categories, they might correlate well with other methods that do account for these and thus indirectly represent these. As mentioned in the Envifood guidelines: "Exclusion of impacts is allowed only when robust, substantiated and transparent argumentation is provided. A stepwise approach (screening phase and detailed analysis in order to check accuracy and improve precision) is recommended in that regard.". To a large extent their stepwise approach has been applied in this study. It consists of: (1) identifying relevant impact categories for food, (2) considering scientific robustness and applicability and (3) considering correlation between impact categories (Food SCP RT, 2013). See the thorough correlation analysis presented in SI section F. The ecological footprint (EF), CEENE-method, carbon footprint, ReCiPe method for impact on human health and biodiversity appeared to correlate relatively best with most of the considered methods, which is of relevance for criterion 4 outlined in the beginning of this section. However, only the EF and CEENE methods were improved to better assess impact of fish harvest, covering criterion 1. Out of these two, the EF was selected as the more appropriate for food products, to base the ecological scoring system on, due to its consideration of CO_2 emissions and relatively easily graspable outcome, in our opinion, addressing criteria 2 and 3. However, the results of the carbon footprint method were also taken into account, given it is often applied to food products because of the relevance of their greenhouse gas emissions (Nemecek et al., 2016; Pelletier, 2015). Multi-criteria approaches that aggregate outcomes of the different impact assessment methods (Diaz-Balteiro et al. 2016) were not applied, as their weighing can be questioned and they lead to scores that are intangible, making it difficult to grasp the impact of choosing another alternative.

2.3 Description of Ghent University catering and onset of the case study

The Ghent University canteen serves foremost meals to their students and staff. The considered period is the academic year 2014-2015. Concerning hot meals (about 650 000 served in 2014), the customer has to choose between different meals or meal components, which can be combined into different meals. These meal components consist generally out of three types: protein (meat, fish or meat replacers; variable portion size but if unknown 120 g is assumed), starch (200 g, except 125 g for croquettes) and vegetable (200 g) components. For single meals that are not composed of different served meal components, e.g. spaghetti, a weight of 500 g is considered. Additionally, as a side dish, a soup (280 g) can also be selected. The canteen mainly stores and heats the meal or meal components or conducts final cooking steps; the chilled or frozen meal components as such are provided by the suppliers. Ghent University controls the selection of the suppliers for a certain product and performs a screening of these based on taste, costs and further criteria. Already some sustainability aspects are incorporated in the current canteen policy, e.g. products known to be produced through illegal child labour are prohibited, but a more elaborate study is needed (Uyttendaele et al., 2016a). Goals for the canteen through this study are: (1) to provide a nutritional healthy and environmentally sustainable offer of meals, (2) to better discuss and screen the sustainability of provided meals by suppliers and (3) to inform and sensitize customers about the nutrition and sustainability of the meals. Our study supports the achievement of some of these goals to some extent. For the environmental impact and nutritional value assessment of the meals a thorough study of all the meal components provided by the canteen was not feasible due to lack of readily available data on exact ingredient composition and on the inventory, even generic, of their supply chains. Hence, the meal components served during one week of the academic year 2014-2015, 42 components in total, were studied in detail. These are listed in Table S2, in the supporting information, and shown in Figure 1. Overall, the study has been performed in close collaboration with the canteen and with input or feedback from stakeholders, suppliers and student and staff representatives.

2.4 LCA methodology for the case study

Using life cycle assessment (LCA), the environmental impact was assessed per served meal component portion (see section 2.3), thus, the latter serves as the so called functional unit, since these are fixed amounts and the client can choose freely among them. Other functional units that focus more on functionality, e.g. that focus on protein quality (Sonesson et al., 2017), exist but meal sizes are not altered in function of these by our studied canteen and nutritional parameters are in our framework covered through the nutritional scoring approach. As mentioned in the previous section, thorough LCAs were only conducted for 42 meal components. The studied life cycles encompass agricultural production or harvest and, if relevant, transport and processing, thus excluding consumption and end-of-life. Food losses might comprise a considerable share for a supply chain in a regular retail and consumer chain (Chen et al., 2017; Corrado et al., 2017). However, these losses are considered of minor relevance in this study since there is no final retail step (Heller and Keoleian, 2015), the loss in bones for meat is accounted for through allocation, and the consumption phase is not part of the studied life cycle, which is after all also dependent on the client. The food loss before consumption should ideally be exactly accounted for but is here not done because of lack of specific data and latter considered lack of relevance. Moreover, valorization of food waste is improving, this also with regard to environmental sustainability (Muíño et al., 2017; Salemdeeb et al., 2017; Salomone et al., 2017; Willersinn et al., 2017). To obtain life cycle inventory data of the 42 studied meal components, the exact ingredient composition was obtained, this mostly confidential through suppliers, and then data on the production life cycle of these ingredients was retrieved out of databases and literature. Though assumptions are made, overall the same rules or choices are applied per food product category. A full explanation of these aspects is given in SI section C. Simapro version 8.0.5 software was used to consult and use databases to obtain production data and to assess the environmental impact through life cycle impact assessment methods. The selection and improvement of latter methods is researched in detail in this study. See section 2.2. From the LCAs of the 42 meal components, conclusions are drawn and, based on these, a general simplistic scoring system has been developed and applied to the other served hot meal components (> 200 per year), as mentioned in section 2.1.

3. Results & Discussion

3.1 Case study: environmental impact analysis and ecological scoring

In this section the derivation, as explained in section 2.1.1, and discussion of ecological score for the Ghent University case study is provided. In the first subsection, the LCA results of the sample week are discussed. In the second subsection, based on the LCA findings and other criteria, a specific ecological score is presented.

3.1.1 Results of the LCAs

Figure 1 depicts the outcomes regarding ecological footprint (EF), selected because considered the most appropriate (see section 2.2), and carbon footprint (CF), picked because of the relevance of greenhouse gas emissions for food products (Nemecek et al., 2016; Pelletier, 2015). Comparing the outcomes for these two methods also showcases the discrepancies between impact method outcomes. The outcomes of all the considered methods, are shown in the supplementary excel file and discussed in the first annex of the original report (Schaubroeck et al., 2016). Here, the most relevant findings are discussed.

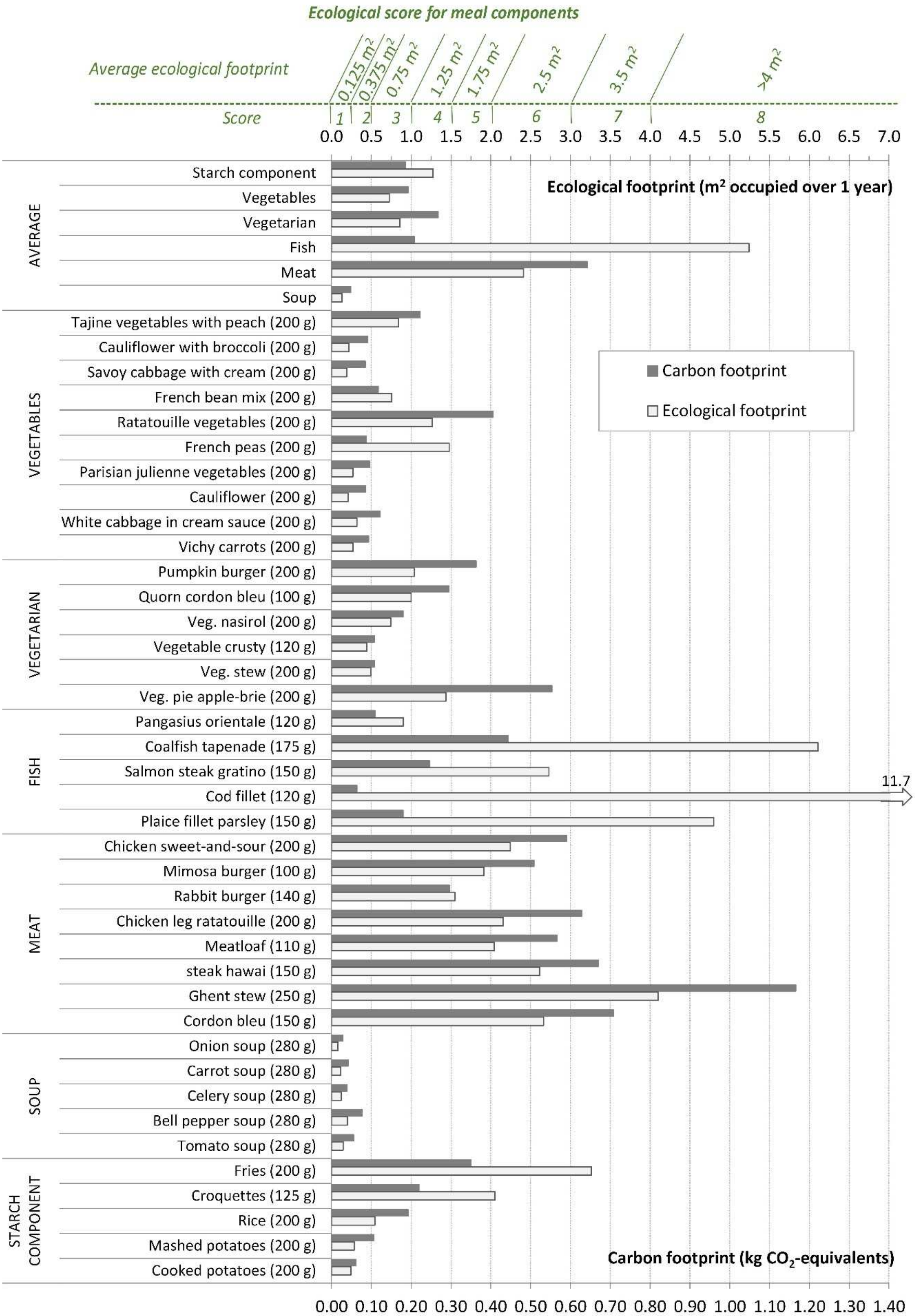
Concerning the improvement of the EF of caught fish, as explained in section 2.2, it is quite clear that species that are at a higher trophic level need much more net primary production per kg, i.e. having a considerably higher footprint. For example the ecological footprint per mass for cod is about 30 times that of forage fish such as capelin, similar to what was concluded in the work of Luong et al. (2015). The specific factors can be found in supporting information section E.

In general, large discrepancies among products can be observed, underscoring that meal choices can have a considerable influence. The average scores of the meal groups do not differ that much except for that of soup (much lower CF of 0.048 kg CO_2 eq. and EF of 0.13 m^2*year per portion), meat (much higher CF of 0.64 kg CO_2 eq. and EF of 2.41 m^2*year per portion) and fish (high EF of 5.25 m^2*year per portion). Meat needs significant areas of land and its production emits considerable amounts of greenhouse gases (incl. CH_4 and N_2O), not only chiefly appointable to the animal metabolism but also to manure and its handling, explaining the high EF and CF results, in particular for beef. Though fish products have on average a much higher EF (> 117%), their CF is 68% lower than that of meat, which showcases the influence of the selection of an impact method. In section G of the supporting information, environmental impact of meat and fish products are thoroughly compared per kg. Moreover, there is also a large spread within each meal group. Results can differ considerably between products of the same group, e.g. as is the case for fish species as elaborated further on. Large differences in impact are also estimated among meal components of different groups. For example 'pangasius oriental' (produced via aquaculture) has a 29% and 72% lower EF than 'ratatouille vegetables' and 'fries', respectively. This shows that one needs to look beyond 'conventional' classification and paradigms (e.g. fish is always worse than vegetarian) and rather to the specific product, a first relevant conclusion.

Furthermore, not only the product is decisive for estimating the environmental impact but also the type of supply chain is, highlighting the need for life cycle thinking (Pelletier, 2015). This is especially of relevance for fish products, which are generally provided using two approaches: aquaculture or caught via fisheries. The adapted EF, and also CEENE, of caught fish (coalfish, cod and plaice; with higher trophic level fish having a larger impact) are much higher, 2-15 times, than for bred fish (salmon and pangasius). >90% of the EF of caught coalfish, cod and plaice are due the ecological footprint of its production in nature, as assessed using equation 2. A considerable difference exists also between the herbivorous pangasius, fed mainly with crop-based ingredients but also with a (indirect) small amount of fish-based input, and salmon. The EF of pure pangasius fillet is only 36% of that of a salmon fillet. The salmon is fed with pellets that are 50% plant-based but also 50% fish-based (see also Table S3 in SI) (Pelletier et al., 2009). Nevertheless, natural production of caught fish used in salmon feed constitutes 80% of the EF of salmon. However, latter fish-based ingredients are mainly from small forage fish, at the bottom of the food chain, and thus the ecological footprint is most probably much lower than for wild caught salmon. In fact, these differences were to be expected as human-driven or industrial animal production can be operated, as far as the authors know, more efficiently and animals are slaughtered at the optimum age corresponding to the highest qualitative meat production. This contrasts with the fact that harvested fish might be not at the optimal age, implying more inefficient production, and also their food chains might consist of more steps. The finding that the ecological footprint is considerably lower for aquaculture (compared with fishing) and herbivorous fish (compared with non-herbivorous), a second interesting finding, seems to turn the tide in favour of these. However, the limitations of the applied impact methods have to be carefully considered, e.g. not considering automatic natural regeneration or the fact that terrestrial land needed for aquaculture, mainly for feed production (Huysveld et al., 2013; Nhu et al., 2015), might be more relevant for mankind than the marine area needed for natural production of the fish. Finally, the presented approach does not directly cover biomass depletion as such, i.e. the effect of species harvest on species population is not directly assessed (Vázquez-Rowe and Benetto, 2014). However, this is indirectly done as the amount of NPP (in joules) or land that is available is limited and consequently when comparing this to the total available amounts, overconsumption can be characterized.

A third relevant finding is that all the ingredients besides the main ingredient can be as important, especially if the main ingredient has a low weight share. For example, tomato concentrate has an EF similar to that of chicken meat, making its presence as relevant in 'chicken leg ratatouille'. For 'salmon steak gratino', salmon only contributes a third of the carbon footprint while salmon is estimated to comprise about 80% of the weight. The rest of the carbon footprint is associated with cheese, sun dried tomatoes and oils. For fried products, e.g. fries and croquettes, the use of frying oil (0.3 kg kg^{-1} product) is the main reason for their high impact for both CF (at 82%) and EF (at 93%) compared to other starch components, keeping in mind the lower portion size for croquettes. Regarding vegetable and fruit components, a crucial finding is that these of which a considerable global share is cultivated in greenhouses, have a considerably higher impact (e.g. tomato and green bell pepper, implying a higher impact for the respective soups). This is mainly because fossil fuels are (indirectly) burned for heating the greenhouses, leading to fossil CO_2 emissions. Even though at a more local level low-carbon footprint practices might have been applied, this was not valid for the considered global market mixes. Moreover, concentrated or dried vegetables and fruits, e.g. tomato concentrate with an EF of 19 m^2*year kg^{-1}, have high EFs per weight due to the particular concentration effect.

Striking is also the higher EF for the considered legume vegetables, e.g. a portion French peas has the highest EF (1.5 m^2*year per portion) for all vegetables (Figure 1), due to their low areal productivity (“FAOSTAT,” 2015). Of the vegetarian meal components, those with considerable amounts of animal-based products score higher since they also need animal production (e.g. cheese present in the ‘veg. apple-brie pie’ at 1.4 m^2*year and the ‘pumpkin burger’ at 1.0 m^2*year per portion). The EF is also higher for energy-intensively produced products (e.g. quorn) (Sturtewagen et al., 2016). To summarize, the following products besides meat and fish lead to a relatively higher score: other animal based products, oils or fats, concentrated fruit or vegetables, greenhouse vegetables and products with low productivity (e.g. peas) or energy-intensive production (e.g. quorn).
Another conclusion is that the influence of portion size on the impact can be considerable, which is relevant for meat, vegetarian and fish components as these may vary considerably in weight. For other meal components this is considered to remain constant. For example, the beef in ‘Ghent stew’ has a high EF (31 m^2*year kg^{-1}) but only comprises 48% of the weight. Nevertheless due to the size of the portion, 250 g, it has the highest EF of all meat products at 4.1 m^2*year per portion. However, per kg, cordon bleu has a 10% higher EF even though it does not contain beef. Regarding final transportation, the long transoceanic transport of about 10 000 km of pangasius only induces 6 and 19% of the EF and CF respectively, and this while their total scores are relatively low at 0.90 m^2*year and 0.11 kg CO_2 eq. per portion, respectively. For vegetables or fruits, transportation can comprise a considerable share of the impact (e.g. >50%). This underscores the statement of Nemecek et al. (2016) that the influence of transportation depends on the product, way of transportation and distance. Only considering the so called ‘food miles’ is a clear shortcoming.



590

591 *Figure 1. Carbon footprint (CF) and ecological footprint (EF), with alteration (see*
592 *section 3.1) of the 39 meal components of the considered week at the Ghent*
593 *University canteen. Conventional meals are composed out of a (1) meat, fish or*
594 *vegetarian; (2) a vegetable and (3) a starch component. The ecological score*

intervals are shown above the chart in green. The three full meals ("Ravioli pesto", "Spaghetti bolognaise" and "Vegetarian spaghetti") for which exact values have been obtained, are not presented in this figure, as they cannot be directly compared with meal components, but values are presented in the supporting information.

3.1.2 A case-specific ecological scoring system

As outlined in section 2.1.1, based on the findings of the LCA results and on some other criteria an ecological score system has been developed specifically for served canteen meals. The score system should be applicable to other offered meal (components) in a relatively easy manner, given the outcomes of the thorough study of 42 meal components (one week) and the amount of data that is readily available to the canteen for the other offered meal components, in this case: a component sample or picture, an ingredient list with only an exact content amount of the main ingredient and, for fish products, mentioning if they are produced via aquaculture.

Some choices needed to be made, i.e. the proposed ecological score system is based on partially subjective decisions, though argued, and has its limitations. Moreover, the demand for a simple and fully reliable system is not possible to ideally achieve as there is no single-score sound impact method that covers all aspects (see section 2.2). The score system is though chiefly based on the outcomes of the ecological footprint (EF) impact method given its adequacy (see section 2.2), yet, the outcomes of the carbon footprint (CF) are also kept in mind. The result is an ecological scoring system that assigns single scores to the meal components from 1 to 8 primarily based on EF-values which are represented in Table 2 and Figure 1.

Table 2. The values for the ecological scoring system

Ecological footprint (m^2*year)	**Ecological score**
0-0.25	1
0.25-0.5	2
0.5-1	3
1-1.5	4
1.5-2	5
2-3	6
3-4	7
> 4	8

The intervals are smaller for lower scores to allow the customer to make a difference but also because the absolute uncertainty range is most likely smaller for lower EF. A score of 8 is assigned if the EF> 4 m^2*yr. The main reason for this is to cover the discrepancy between, on one hand, caught fish with a very high EF and relatively low

CF and, on the other hand, the (red) meat products with high CF due to non-CO_2 greenhouse gases not accounted for in the relatively low EF (see section 3.1.1). Mathematical approaches exist to cluster outcomes into different classes or scores (Marvuglia et al., 2016), and can be used in other cases. However, in our case there are too much relevant non-numerical factors to apply such a mathematical approach.

To obtain scores for full meals, these of the separate meals may be added (as presented for some in Figure 2). However, such a summed score should be approached with care due to the simplistic nature of the score system. For example a meal with a double as high score might not have an exactly double as high impact. Moreover, the scores are for meal components of a tripartite meal, consisting of (1) a meat fish or vegetarian; (2) a vegetable and (3) a starch component. Hence, for full meals such as spaghetti bolognaise they first need to be subdivided in these three different components, given a score for these and then these separate scores need to be added, for example: 'Veg. spaghetti': 8 = 2 (soy & cheese; EF=0.5 m^2*yr) +4 (vegetables; EF= 1.2 m^2*yr) + 2 (pasta; EF= 0.4 m^2*yr); 'Spaghetti bolognaise' 11 = 6 (meat and cheese; EF= 2.5 m^2*yr) +3 (vegetables; EF=0.9 m^2*yr)+2 (pasta; EF=0.4 m^2*yr). Alternatively the average EF per category could be used as a scoring system (Figure 1). This would provide a more concrete and correct, especially when summing, approach. However, the decimal values seem to us much more complex to directly process by the customer than integer values. Finally, besides the specific outcomes of the week, additional guidelines were set up, based on these, to allow to relatively easily score other meal components (see SI section H). As this is a rough attribution of a score, a robust scoring system based on integer values, and not decimal values, seemed appropriate. Furthermore the customer should at best have the possibility to estimate the environmental score of the meal, to this end, he or she should be relatively easily able to aggregate the scores of the separate selected meal components. Using numbers allows to give an estimation for the score of the complete meal by summing them, this mental arithmetic is facilitated by only considering integer numbers from 1 to 8 instead of non-integer values. This all underscores the selection of integer values. As an example, these scoring system were applied to all other meals and meal components served during the academic year 2014-2015 (see SI section I). The numbers are eventually presented in colours, from green for 1 to red for 8, as a survey in the respective canteen showed that it is good to combine labelling numerical values with colours (Hoefkens et al., 2012). The customer will be presented with the ecological scores at the counter but exact scores and scale of the scoring system should be made available through online reports and flyers or leaflets on the tables, as advised by Spaargaren et al. (2013).

3.2 Case study: Nutritional analysis and scoring

In addition to the life cycle assessments and ecological scoring, a nutritional evaluation and scoring was performed as well, using the approach explained in section 2.1.2. Currently, there are no official nutritional criteria or limits to judge hot main meals in Belgium, but the guidelines for main meals from Notte-De Ruyter (1997) were developed by Ghent university for the local population and, therefore, regarded as representative for the canteen customers. For saturated fat and salt, national nutrition recommendations were used (Hoge Gezondheidsraad, 2009). Though other guidelines exist, these were selected because of their specificity for the majority of the clientele: the local population. These published guidelines outline a certain energy content and specific amounts of macro nutrients (g) which are ideal for the average adult. In our study, these criteria were converted to specific amounts of macro nutrients (g) per unit of energy content (100 kcal) in order to obtain criteria which are independent of the meal size and of the average consumer's personal daily energy requirement. For the energy amount, the daily energy amount of average male and female students with low activity is multiplied with 0.35, the share of energy to be provided by the main hot meal, to provide an optimal average range (Notte-De Ruyter, 1(1997). See Table 3. The seven respective macronutrients were also selected based on the fact that these should be mandatory declared towards consumers in Europe. See article 30 of the European regulation document EU 1169/2011, which came into complete force from 13 December 2016 onwards. Finally, it is acknowledged that other factors, such as share in red meat and fibres, and micronutrients, e.g. vitamins and minerals, are also very relevant for human health, but these were not taken into account because they will not for sure be mentioned on food labels (EU 1169/2011) and due to lack of available data regarding these.

Table 3. Nutritional criteria for the hot canteen meals (Hoge Gezondheidsraad, 2009; Notte-De Ruyter, 1997).

Nutrients	**riteria**	**meal**	**meal**
1. Energy	750[1] to 950[2] kcal per meal	≤ 750 kcal	≤ 950 kcal
2. Protein	≤ 4.0 g per 100 kcal	≤ 30 g	≤ 38 g
3. Fat	per 100 kcal		≤ 35 g
4. Saturated fat	≤ 1.1 g per 100 kcal	≤ 8 g	≤ 10 g
5. Carbohydrates	≥ 12.6 g per 100 kcal	≥ 95 g	≥ 120 g
6. Sugar	≤ 2.5 g per 100 kcal	≤ 19 g	≤ 24 g
7. Salt (NaCl)[3]	g per meal	g	

[1]Small meal size: 35 % of the daily energy requirement of the average female student with low activity (2150 kcal/day) = 750 kcal
[2]Large meal size: 35 % of the daily energy requirement of the average male student with low activity (2713 kcal/day) = 950 kcal
[3]Since salt is not an energy source for the body, this is not normalized per total energy content.

The nutritional composition and information was provided by the supplier of the product. In some exceptional cases the information was not complete, and then the nutritional composition was estimated based on the ingredient composition from the suppliers and the corresponding nutritional data from Internubel (http://www.internubel.be/). A study on the respective canteen revealed that in order to satisfy most customers' information needs, a nutrition label that contains basic guideline daily amount-type of numerical information is advised (Hoefkens et al., 2012). Our scoring system does not directly present such data but is based on it. The nutritional score system is more precisely based on equation 1 and Table 3, leading to a score range from 1 to 8. A meal with score 8 failed on all criteria, while a meal with score 1 meets all criteria for the investigated nutritional parameters. The nutritional parameters were calculated for each complete meal in the selected week, i.e. all possible combinations the consumer could make with all offered meal components. Some are presented in Figure 2.

Concerning the results, it is striking that no meal combination existed in the whole week with a perfect nutritional score, i.e. a score of 1. Meals with highest scores contained mostly lot of vegetables and were vegetarian or fish dishes with rice or cooked potatoes. Though meals with meat and fries have on average a lower score, they can be part of high-scoring meals as well, e.g. chicken with fries and tajine vegetables was the best choice on one day with a score of 3 (Table S15). An analysis was also performed of all meal components of the year 2014-2015. Latter analysis excludes though energy, saturated fat and sugar content as criteria, leading to a score system from 1 to 5, because of data limitation. After new regulation (EU 1169/2011) has induced bringing more detailed information to the canteens and consumers, it is recommended to though include latter macronutrients into all future evaluations. This information will thus in the future be demanded of suppliers.

The hot main meals often provided an appropriate amount of energy but the relative amount of nutrients was not optimal: they contained on average too much protein, too much fat, too much salt and too little carbohydrates. Especially the issue of excessive salt content is wide-spread in all the canteen meals. Due to its high salt content, addition of soup always led to non-fulfilment of the respective criterion. Interestingly, our results are very similar to those from a prior study in 2004 of the same canteen, only focused on fat, salt and vegetable content (Lachat et al., 2009). For a thorough elaboration, see SI section L and the report of Ceuppens et al. (2016).

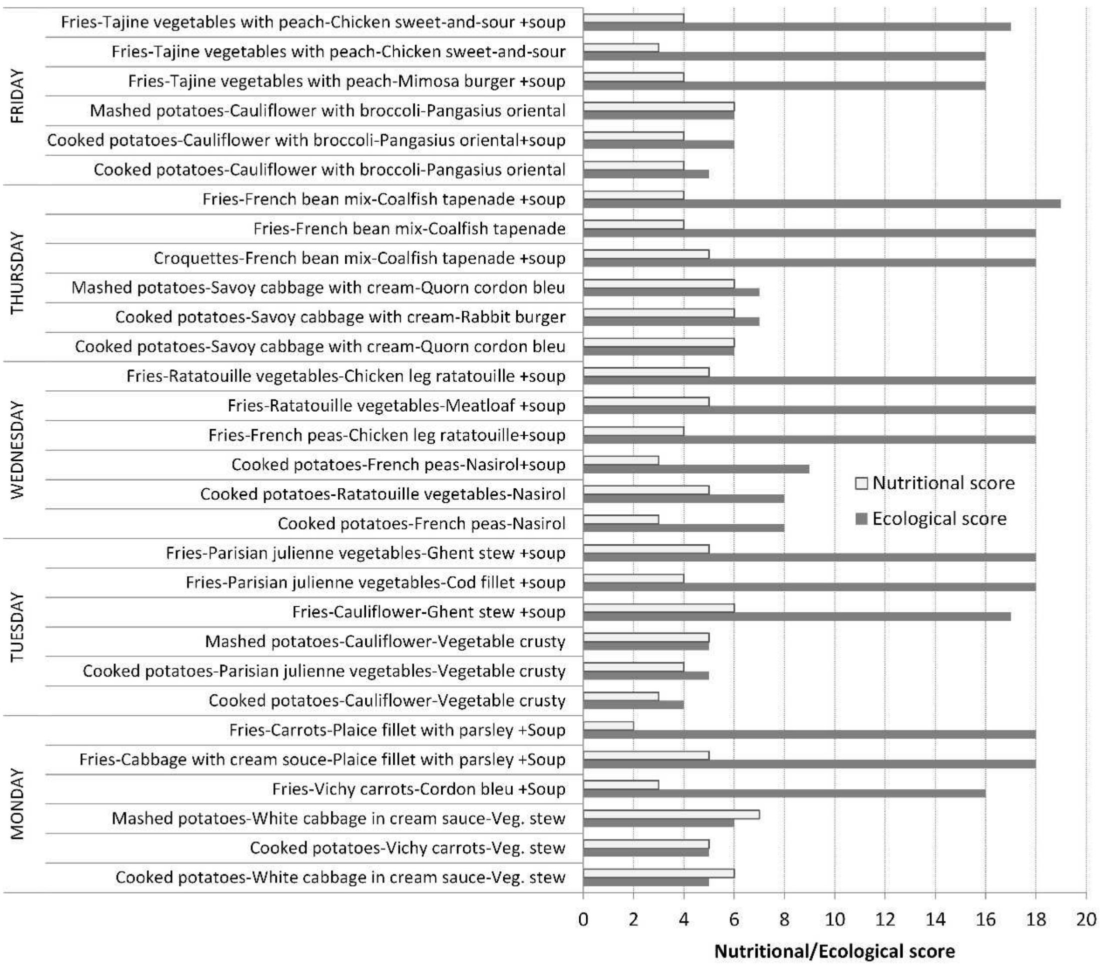


Figure 2. Summed ecological scores, based on the ecological footprint (EF), and nutritional score (between 1 and 8) for the three best and three worst combinations concerning the EF, this for the studied week of the Ghent University canteen. Lower scores are better.

3.3 Case study: scoring of supplier sustainability

As mentioned in the introduction, the ecological scoring system is not specific for the particular suppliers' production chains of the meal components but based on generic supply chains and does also not address certain other sustainability aspects. Therefore, a scoring system of the specific sustainability aspects of suppliers was developed, called 'supplier scoring'. In the past, a scoring system for fish products was already implemented and is outlined in SI section J. A first version of our supplier scoring system was presented towards a group of stakeholders (18 in total), of which about 80% actual suppliers for the Ghent University canteen itself, and discussed with them to obtain a scoring system, set in dialogue with the suppliers. Since it is the canteen that selects the meal components and then picks a supplier for it, not the overall impact but only supplier-specific aspects that are considerably changeable by them and for which enough information is available, are considered. Likewise, nutritional scores are not included. Additional adequate food safety and nutritional labelling is still required. Moreover, overall nutritional requirements, e.g. salt quantity lower than a certain amount, can be implemented but are regarded as prerequisites.

In the scoring system, scores are appointed for specific sustainability criteria and summed. These indicators are at present a new matter for suppliers to take into account when filling out public tenders to deliver meal components to the university canteen. Many of these suppliers are small & medium enterprises, not having access or having available numerical data, and consequently criteria are often defined in a semi-quantitative or qualitative manner with potential for the supplier to shortly elaborate on how he complies with the criterion and provide documentation. This does imply some subjectivity in the scoring of the supplier sustainability status but may in due time help to further build the system with information collected in the start-up phase. This particular scoring system is also implementable in the selection system for suppliers, next to the current selection criteria such as cost price and assessment of supplied meal components' sensorial quality. These supplier scores are not intended to be presented to the customer (see Table 1). The selected indicators and scores for these are shown in Table 4.

Table 4. Supplier sustainability scoring for the Ghent university canteen, developed in dialogue with suppliers, encompassing indicators and score criteria

	4 points	3 points	2 points	1 point	0 points
Origin of fruits and vegetables (if representing the major part of a meal component) taking into account that the sourcing location is not only a matter of environmental impact of transport distance but it also may affect social sustainability (Pelletier, 2015)	within 80 km radius	if further than 80 km but from neighbouring countries	from other EU-countries	outside EU but with fair trade label	not any of the above cases or unknown
Way of production for seasonal fruits and vegetables (if representing a major part of a meal component). The present study highlighted the impact of greenhouse production and Jungbluth et al. (2015) showcased that for their studied vegetables deep-frozen ones produced in open field have a lower carbon footprint than produced in greenhouses using fossil heating	open field production with extra efforts to lower environmental score	/	open field	production in greenhouses with environmentally friendly energy source for heating	none of the above or unknown
Water usage by the supplier (for amounts, ony >10% difference in m^3 water per kg product output compared to other suppliers will be considered)	prevention of water usage	reuse of water	usage of alternative sources of water (e.g. grey water)	/	business as usual; no plans
Energy usage by supplier (for amounts, only >10% difference of Joules energy kg product output compared to other suppliers will be considered)	prevention of energy usage	own (more sustainable) energy production or collaboration with neighboring companies to do so	purchase of sustainable energy	/	business as usual; no plans
Solid waste disposal by the supplier (for amounts, only >10% difference per kg product compared to other suppliers will be considered)	prevention of generating solid waste	(partial) reuse of solid waste	disposal of solid waste in an env-ironmentally friendly manner (e.g. burning with exhaust gas purification)	/	no waste management or disposal in non-environmentally friendly manner (e.g. dumping)
(intention for) **corporate sustainability initiatives** or implementation of environmental management schemes	life cycle assessment and management	initiatives in compliance to defined standards (e.g. ISO 26000, UN Global compact, CO_2 performance ladder, Global Reporting Initiative)	own initiative with reporting and with external support of the relevant industry association or consultant (i.e. under the four eyes principle)	own initiative with reporting	business as usual; no plans

3.4 Other non-scored sustainability aspects

Some other aspects (sustainability labels, organic farming, Genetically Modified Organisms (GMO), animal welfare and bioplastic packaging) are of relevance and were raised by the stakeholders, but cannot be in general directly included in the scoring systems as they are case dependent or further research is still needed. No general (dis)favoring of these aspects is advised. These are shortly documented with reference to a specialist in the university's report (Uyttendaele et al., 2016b). Here, they are briefly discussed. Nevertheless, to present stakeholders with the statement that no general conclusions can be made is also presenting them with information.

Sustainability labels, among which environmental labels, are used to highlight (presumed) more sustainable production practices. Goossens et al. (2017) highlight the limitations regarding transparency and full coverage of environmental sustainability in eco-labels, this specifically for fresh products in Flanders, the region in which Ghent University is situated. A diversity of labels exist and not all need independent third-party certification, making their credibility sometimes questionable. An issue is that auditing and membership cost money and time and that producers because of those reasons may not apply for such certification or labelling (Bush et al., 2013). Hence, it can be that non-certified products meet all the criteria or even have for some impact categories a lower environmental impact, as exemplified by Nhu et al. (2016). In addition, these labels differ considerably and some of their criteria can be questioned. Consequently each label needs to be separately judged. In our particular case, besides the Fair trade label (see above section), some sustainable fish-labels (e.g. ASC and MSC) were already deemed relevant by the university and this information was yet accounted for in the supplier selection, as has already been done in the past, and brought forward to the customer. Moreover, labels cover aspects which are not included in LCA, e.g. the MSC-label directly accounts for social sustainability and the effect on fish stocks, though the latter is charted to be addressed in LCA (Vázquez-Rowe and Benetto, 2014).

Concerning organic farming, a main aspect of it is a restriction in usage of chemical substances. The fact that this type of farming is more sustainable can be debated and is case dependent. For example while using less synthetic fungicides is more environmentally friendly, the use of copper-based alternatives to deal with late blight for organic potato cultivation is also harmful (Meier et al., 2015; Saling et al., 2012). Even though studies show that the impact per area farmed are usually less in organic systems, related to the quantity produced, impacts are often higher (Meier et al., 2015). This would be mainly due to a lower yield (Meier et al., 2015), which induces a larger demand of land, a larger EF, and thus among else an associated prevention in natural plant growth and prevalence of biodiversity. To the contrary, Antonini and Argilés-Bosch (2017) report a negative correlation between increasing farm intensification and economic and environmental sustainability. Further research is needed to improve the comparison (Meier et al., 2015). For example the crucial characterization of fungicides and other similar products on soil quality, going beyond first-order toxicity, in LCA does, to the best of our knowledge, not exist yet (Garrigues et al., 2012). Moreover, models that simulate soil emissions are also not that well adapted for organic fertilizers (Meier et al., 2015). Further research is needed to improve soil modelling and its applicability in LCA (Vidal Legaz et al., 2017). From a nutritional and toxicological point of view, a difference is also questionable, e.g.

organic vegetables and potatoes in general might not be significantly better than the conventional ones (Hoefkens et al., 2009a), even though it is often perceived otherwise (Hoefkens et al., 2009b; Olson, 2017). Similarly free range husbandry may increase animal welfare but can decrease areal productivity. Moreover, the sustainability of animal welfare is not enough assessed within larger sustainability assessment studies to present a fair comparison.

GMO products are another debated topic. According to Carpenter et al. (2010), GMO crops had a positive impact on biodiversity and sustainability over the period 1995-2010 by improving yields, lowering insecticide usage etc. Regarding food safety, no substantiated evidence that foods from GMO crops were less safe than foods from non-GMO crops has been found, as mentioned in a recent elaborate report (National Academies of Sciences, Engineering, and Medicine, 2016). Nevertheless, as genetic modification can be done for various reasons, it is also too case dependent to make any general statement on the sustainability of GMO. Regarding the usage of bioplastics in packaging, the fact that biological resources are used instead of fossil-based is not estimated to always lead to more environmentally friendly packaging, as exemplified by Alvarenga et al. (2013a), and is consequently also case dependent. The fact that plastics are biodegradable though seems a good feature in itself, at first sight. In the future, if adequate scientific information becomes available for specific cases, these sustainability aspects could be scored, potentially using expert judgement, but this seems not yet the case.

3.5. A path forward

The canteen management has a central role in using the information, outcomes and framework in their daily practice and policy. Specific guidelines are discussed in supporting information (SI) section M. The supplier scoring system, only brought forward to canteen and suppliers, supports the canteen in the selection of their suppliers by the potential to include apart from cost price and sensorial quality, also sustainability criteria in the tenders. Spaargaren et al. (2013) showcase that customers do not like to have to digest too much information prior to the register and that a more elaborate explanation afterwards seems more suited. Hence, it is here proposed to only mention the ecological scores for all meal components at the selection counter. The ecological scores can be shown, this through showing the numbers with a colour scaling. A colour scaling from green (best) to red (worst) score seems advised (Hoefkens et al., 2012) to point out that higher values are worse. The three best and worst nutritional scores of possible meals can be posted on a poster, also at the selection counter, and a flyer or leaflet with more explanation on the canteen tables to provide needed background information. This is in line with advise from literature, especially the advice to not present too much information prior to the register (Pulkkinen et al., 2015; Spaargaren et al., 2013). Background reports would then be available online, with all the results for all meals and meal components. An app could also be developed as discussed by Price et al. (2017). Through an app, nutritional scores could also be presented that are more specific and based on user input such as gender, weight etc.

The search for environmentally friendly and healthy meals, is a difficult one. This study is one of the few that focuses on canteen meals and not just diets (Pulkkinen et al. 2015; Benvenuti et al. 2016; Spaargaren et al. 2013; Jungbluth et al. 2015; Ribal et al. 2015). Its prominent aspects are: (1) more thorough selection of environmental impact methods for food products, (2) improved comparison of aquaculture and fishery products through characterisation of the ecological footprint of caught fish, (3) application to a manifold of meals and (4) a novel pragmatic framework usable by canteens that encompasses ecological scoring, nutritional scoring, supplier scoring and discussion of other aspects not covered by the latter scoring approaches. Caputo et al. (2017) also present an interesting framework for catering but do not present latter improvements, except the third one, and their selection of their respective three indicators is quite limited, though they more explicitly cover economic costs and the linkage between local production and consumption at a regional level.

As a prominent finding, Figure 2 reveals that meals that have a low ecological score do not necessarily have a high nutritional score, and vice versa. Especially caught fish is a difficult case since it has a relatively high environmental impact but dishes with these were among the most nutritionally adequate in our study (table S15). However, for cultivated fish environmental impact is considerably lower. Every casus should be regarded separately, and one should look beyond the product itself and consider its life cycle (Pelletier, 2015). General considerations that environmental impact is the inverse of its nutritional value (Nemecek et al., 2016; Tilman and Clark, 2014), are not always valid. Nevertheless, for every day of the meal servings of the studied week in the university's canteen, a meal with a reasonably good ecological score (≤ 8) and good nutritional score (≤ 6) is available which could be regarded as the 'best choice'. Keep in mind that the ecological score for a meal is considered the sum of three scores between 1 and 8, namely that of a (1) meat vegetarian or fish, (2) vegetable and (3) starch component (see section 3.1.2). Uncertainty analysis was not conducted, since this is not executable by the canteen itself as uncertainty values are not consistently presented on the technical notes of the meals and it seems not presentable to the customer due to its complexity. Specifically for LCA, this should ideally be done pairwise when comparing products to eliminate correlation (Henriksson et al., 2015; Nhu et al., 2016). This seems though infeasible in this case given the amount of possible combinations. Our approach could be applied to other canteens and even to other restaurants and retailers (see section 2). The case study can be used as a template but case specific aspects that should be possibly adapted for other applications are: (1) the ecological scoring system, i.e. the complexity and selection of intervals; (2) dietary guidelines on which to base the nutritional score and (3) the supplier sustainability scoring system, which is best checked regarding feasibility by suppliers. Canteens can in fact differ considerably in their meal service. For example some allow one to freely choose portion sizes and base pricing on weight, implying an environmental scoring per weight is more suited than per portion. Another example is the provision of full meals instead of meal components, for which it would be not needed to present the current lower ecological scores. Yet, the same strategies can be applied and our scoring systems provide a basis from which to start.

Our framework is, on the one hand, to a certain extent scientific novel and robust but, on the other hand, limitations are present and also arbitrary choices and assumptions have been made in its development, which is inevitable in any sustainability assessment. These choices and assumptions have though been avoided as much as possible and, if not avoidable, are though clearly brought forward and argued, even though inevitably partially subjective. Various needed to be made to obtain a pragmatic framework that is comprehensible, user friendly, applicable to a large range of meals and not too costly and time-intensive for the canteen and its stakeholders, in our opinion. The next step is to apply this framework in the respective canteen and research how it is received by the audience, adapt if necessary and assess whether customers change their behaviour. Methods can in the future be improved if more data becomes available and scientific advancements have been achieved. Ideally, though not here the case, a single analysis and scoring system should have been developed that covers all aspects mentioned in the introduction, from specific supplier sustainability to consumer health benefit, and can be brought forward to all stakeholders (Schaubroeck and Rugani, 2017). However, due to practical limitations, aspects needed to be covered separately. An ideal single sustainability scoring system that is specific for the meal components and their particular supply chains is not yet feasible on a large scale. A first requirement is easy provision of inventory data, i.e. transparency of the life cycle. Life cycle data on food products is getting more available though it is still an obstacle (Nemecek et al., 2016). There is a need for a system and policy to relatively easily collect and transfer such data on a need-to-know basis, and this not only for food systems. Regarding the characterization of the environmental impact of food products, in this paper the ecological footprint (EF) method is discussed to be the most appropriate, especially including the introduced adaptation to cover the EF of caught fish or animals in general. However, this method is flawed and does especially not cover two relevant aspects of food production impact: water consumption and other greenhouse gases besides carbon dioxide. Some improvements are presented and tested in section K of the SI. Nonetheless, such a method does not consider or would not relatively easily consider nutritional benefits of food products, i.e. integrating nutritional and ecological scoring. There are some statistical approaches that base this integration on the correlation among nutrition and environmental impact (van Dooren et al., 2017). These can be questioned since such a correlation is not always valid for each food product (van Dooren et al., 2017), as also mentioned above. As discussed in literature (Heller et al., 2013; Sturtewagen et al., 2016) and applied by Stylianou et al. (2015), both the benefit through nutrition and damage to human health because of the production system can be considered, resulting in the net impact on human health. In practice impact on human health can be expressed as disability adjusted life years (DALY), using e.g. the ReCiPe method, and the nutritional benefit as negative DALY amounts (Sturtewagen et al., 2016; Stylianou et al., 2015). However, it can be debated whether the approach of Stylianou et al. (2015) considers the benefit of food as such, for example the provision of exergy for the body as studied by Rodriguez-Illera et al. (2017), since their framework considers only epidemiological effects that would occur when selecting another food product. Additionally, impact on human health does not cover all environmental impact. DALY was quantified, using ReCiPe, in our study and correlated well with other methods (see SI section F), but there is no direct link between the impact of land occupation and human health, besides also not covering the impact of fish harvest. Though this could be addressed using the approach of Pfister et al. (2014) which introduces an interesting approach to link human health loss in DALY due to land occupation. Latter approach is though not fully operational yet; not enough characterization factors, linked with inventory databases, have been defined. LCA is in general a limited methodology, that’s why it needs to be complemented, as done in our work, with other approaches for policy support (Castellani et al., 2017), with a lot of choices that have a high influence on the outcome, necessitating further improvement to result in a holistic sustainability tool (Notarnicola et al., 2017a; Schaubroeck and Rugani, 2017). It is also relevant to consider consequential effects, but this is especially relevant for dietary changes at large scale (Aleksandrowicz et al., 2016; Schader et al., 2015). Other sustainability aspects, such as enjoy of eating and cost, should not be overlooked (Price et al., 2016) and future frameworks should address these all. Further research is thus needed and the authors hope to have somewhat cleared the mist surrounding the path forward.

4. Acknowledgements

This project was mainly financed by the Ghent University. The authors are especially grateful towards the Ghent University departments ‘Maaltijdvoorzieningen’ (mainly Vera Putteman) and ‘Duurzaamheidskantoor’ (mainly dr. Riet van de Velde and dr. ir David Van der ha) for their support. Gratitude also goes out to ir. Wiam el Karouni and Msc. Leen Michels for collection of information regarding ingredient composition of meal components. The authors would also like to thank the companies that confidentially shared latter data with us. Gratitude also goes towards suppliers that have provided feedback on our study and particular our supplier scoring system. Following persons have also provided relevant advice and feedback: prof. Jo Dewulf, prof. Patrick Sorgeloos, Prof. Peter Bossier, dr. Peter de Schryver, prof. Stefaan De Smet and prof. John Van Camp, all being affiliated to the Faculty of Bio-Science Engineering, Ghent University, Belgium. The authors declare a conflict of interest since they conducted a study of the canteen of Ghent University, the (previous) employer of most of them.

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A pragmatic framework to score and inform about the environmental sustainability and nutritional profile of canteen meals, a case study on a university canteen

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Highlights

- Ecological footprint was assessed for caught fish and 2-15 times that of cultivated
- A framework of indicators is provided to inform canteen stakeholders
- The ecological score per meal component, from 1 to 8, based on the EF
- Caught fish scored higher for the ecological, while meat for the carbon footprint
- The nutritional score per meal, from 1 to 8, based on meeting nutritional criteria