Slutrapport

Projekttitel
Nutritions- och hälsoindikatorer inom livscykelanalyser (LCA) av livsmedel

Projektnummer: R-18-26-133

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Del 1: Utförlig sammanfattning

Kort beskrivning av syftet, metoder, huvudsakliga resultat och nytta för näringen samt rekommendationer. Sammanfattningen måste skrivas på engelska om rapporten är på svenska, och vice-versa.

Projektet syftade till att vidareutveckla området närings- och hälsoindikatorer för användning vid hållbarhetsbedömningar av livsmedel och koster, utifrån ett sedan tidigare identifierat behov av indikatorer för näringskvalitet av livsmedel som kan användas vid LCA av livsmedel. Projektet omfattade såväl vetenskaplig validering av ett näringstäthetsindex på kostnivå som diskussioner avseende användbarheten av de föreslagna metoderna, sett ur ett produktutvecklings- och kommunikationsperspektiv.

Genom detta projekt har flera viktiga steg framåt tagits, bland annat:

Projekt har fått finansiering genom:
Stiftelsen Lantbruksforskning

- Näringstäthetsindexet NRF (Nutrient Rich Food) har bekräftats som en lämplig indikator för nutritionskvalitet för användning i syfte att rangordna livsmedel i enlighet med kostråden. Resultaten visar att NRF-indexet har potential att vägleda till hälsosammare livsmedelsval.

- Näringstäthetsindexet NRF har också, genom tillämpning på kosten i en svensk befolkningsgrupp (VIP, Västerbotten Intervention Program), visat sig vara en lämplig indikator för kostens hälsoeffekter, bedömd som total dödlighet.

- En variant av NRF-indexet – NRF11.3 – som är skräddarsydd för den svenska kostkontexten, har identifierats som den variant av NRF-indexet som har högst överensstämmelse med kostråden på en livsmedelsnivå. Denna variant av indexet visade sig också vara den variant som bäst korrelerade till dödlighet i VIP-befolkningen, dvs hög följsamhet till NRF11.3 korrelerade till lägre dödlighet. Indexet NRF11.3 baseras på innehållet av 11 ”kvalitativa” näringsämnen (protein, fiber, vitamin A, C, E, D, folat, Mg, Ca, Fe, K) och tre ”diskvalitativa” näringsämnen (Na, mättad fett, tillsatt socker).

  Effekten av viktiga metodval för beräkning av näringstätheten hos livsmedel, inklusive urval av näringsämnen, referensenhet (100 g, 100 kcal, portionsstorlek), capping och viktning utvärderades. Val av referensenhet och val av näringsämnen visade sig vara de metodval som påverkade rankningen av livsmedelsgrupper baserat på näringstäthet mest. Användning av capping och viktning hade däremot liten inverkan.

- Två potentiella sätt att koppla ihop näringskvalitet och klimatpåverkan av livsmedel har föreslagits, analyserats och diskuterats med projektets företagspartner ur ett användbarhetsperspektiv. Det ena sättet är att helt integrera de två bedömningarna till en faktor, genom att dividera klimatpåverkan (koldioxidekvivalenter) med näringstäthet (NRF). Det andra sättet är att parallellt plotta klimatpåverkan mot näringstäthet i en tvådimensionell graf.

- Projektet har även påbörjat kartläggningen av hälsoindikatorer som tillämpas i hållbarhetsstudier. Genom en systematisk litteraturöversikt har sex hälsoindikatorer identifierats, som används i kombination med miljöindikatorer.

Många av de ovanstående resultaten har diskuterats omfattande inom projektet och även presenterats öppet vid projektets slutseminarium, där cirka 80 deltagare från såväl livsmedelsbranschen, institut, myndigheter och akademin deltog. Diskussionerna har genererat frågor och ytterligare tankar, både ur ett vetenskapligt perspektiv och kring potentiell tillämpning av kunskapen inom livsmedelssektorn.
Resultaten från projektet möjliggör identifieringen av utvecklingsområden och prioriteringar för att driva utvecklingen av tvärvetenskapliga indikatorer som är robusta,

vetenskapligt validerade och tillgängliga för att mäta övergångar mot en hälsosammare och mer miljömässigt hållbar livsmedelsproduktion och konsumtion.

Del 2: Rapporten (max 10 sidor)

Introduction

The study of the environmental impact of foods and dietary patterns in relation to their nutrition quality and health effects is of recent development and great interest for both nutrition and environmental scientists. Preliminary research has been conducted on the potential application of nutrition indexes as complementary functional units (FUs) in the life cycle assessment (LCA) of foods, as an alternative method to capture one of the most important functions of food, as compared to the mass unit traditionally used.

An increasing number of studies has related the environmental impact of foods to the nutritional value expressed as nutrient density (Scherer at al., 2019; González-García et al., 2018). However, no recommendation exists on which nutrient density method ranks foods more correctly, leaving it open for LCA researchers to choose among many different indexes, with the consequence of results difficult to compare and interpret.

Building on a recent literature review conducted by this group (Hallström et al., 2018), the Nutrient Rich Food (NRF) index (Fulgoni et al., 2009) was identified among many nutrient density indices as a robust, versatile and validated method, suitable for incorporation in environmental assessments, and therefore selected as base indicator for use in this project.

Although work has been done to refine and validate NRF and other methods, the perspective of application in LCA has been rarely included. Therefore, as pointed out by Hallström et al., (2018), more work needs to be done in the area of development, testing and validation of indexes for a combined use in environmental impact assessments of products and diets.

Importantly, these methods should be optimized for their level of coherence with the dietary recommendations, in order to include the public health perspective and avoid conflicting indications. Furthermore, nutrient quality indicators applied to whole diets should also be validated for their ability to predict health outcomes.

The aim of this project was to further develop the field of nutrition and health indicators for use in sustainability studies, with a special focus to the methodological aspects of nutrition quality indicators in the effort to identify the indexes best suited to be used in comparative food LCA studies.

Specific aims of this project were:

i. To systematically assess the methodological variables related to the nutrient density index NRF with the aim to identify the variant that ranked foods with highest coherence to the dietary guidelines.

ii. To assess the separate and combined nutritional and climate impact effects of diets on total mortality in a population-based prospective study in northern Sweden.

iii. To apply the identified NRF index in combined nutrition and environment assessments of food products, and analyse its suitability and usability as a tool for product development and consumer communication.

iv. To compile a systematic review of health metrics currently used in environmental assessments of foods and diets.

The outcome of this project constitutes a basis for future recommendations on how nutrition and health metrics can be used in combination with environmental metrics by different stakeholders in the food system to drive a global shift towards more sustainable and healthy food consumption patterns.

Materials and Methods

Assessment of methodological variables and selection of a nutrient density index at a food product level

Nutrient density was calculated for 118 food products, from different food categories, representative of the Swedish diet, according to different variants of the base indicator NRF9.3 index (Eq 1) (Fulgoni et al., 2009):

$$NRF = \sum_{i=1}^{x} \frac{Nutrient\ i}{DRI\ i} - \sum_{j=1}^{y} \frac{Nutrient\ j}{MRI\ j} \qquad \text{(Eq 1)}$$

Where x is the number of desirable nutrients (nine for NRF9.3), y is the number of non-desirable nutrients (three for NRF9.3), nutrient i/j is the content of nutrient i or j per reference unit of the food product, DRI is the dietary reference intake of desirable nutrient i and MRI is the maximum recommended intake of non-desirable nutrient j. DRIs and MRIs were obtained from the Nordic Nutrition Recommendations 2012 (NCM, 2014). Nutrient composition was derived from the Swedish Food Agency Food Composition Database (version 20171215). Portion sizes were retrieved from the same database, or, if not available, from the US Department of Agriculture (USDA) Food Composition Database.

Forty-five different NRF variants were assessed for their ability to rank foods clustered in 53 subgroups (analysis between food groups) and within three food groups (i.e. cereal products, dairy products and meat). The indicator variants differed in reference unit (100 g, 100 kcal, portion size), number and choice of desirable nutrients (9, 11 and 21), and the application of capping and/or weighting. Capping to 100% of DRI was applied when

nutrient content per reference unit exceeded DRI values, in order to avoid crediting overconsumption of nutrients in the NRF calculation. Weighting was applied to correct the weight of the individual nutrients in the NRF formula based on the nutritional status of the studied population (Amcoff et al., 2012).
For each variant, the level of coherence with the Swedish food-based dietary guidelines (SFA, 2017), was assessed in the highest quintile (Q1) of nutrient density. Specifically, the percentage of healthy foods (foods which should be eaten more or considered healthier alternatives) and the representation of healthy food groups emphasized by the guidelines (vegetables and legumes, nuts and seeds, fruit and berries, seafood) were calculated for Q1.

Validation of a nutrient density index at a diet level and suitability to predict mortality

Dietary data obtained with a 64-food items FFQ from 75 501 women and 71 162 men aged 35-65 years in the population-based prospective study Västerbotten Intervention Programme (Sweden) was used. Greenhouse gas emissions (GHGE) were estimated using data from LCA provided by Research Institutes of Sweden (RISE) (RISE Food Climate Database 2019; 2018). Fifteen variants of NRF index (see method description in the first paragraph) were evaluated and the index that best predicted mortality was used to estimate the participants' diet quality. GHGE and nutrient density were adjusted for energy intakes. Total mortality risk was estimated by Cox proportional hazards regression and hazard ratios (HRs) with 95% confidence interval (95% CI) for four groups of women and men, respectively, i.e., high nutrient density, low climate impact (HNutr/LClim); high nutrient density, high climate impact (HNutr/HClim); low nutrient density, low climate impact (LNutr/LClim); and low nutrient density, high climate impact (LNutr/HClim, reference group).

Combined nutrient density and climate impact of foods

The best performing NRF variant was identified from the previous phases of the project as the index which harmonized the most with the dietary guidelines when food products were examined, and that most successfully predicted a decreased risk of premature death when diet was evaluated. NRF11.3 per 100 kcal with the application of weighting and per portion size, the variants identified to rank foods with highest coherence to the dietary guidelines, was calculated for the 53 analyzed food subgroups. The climate impact of the analyzed foods was based on data from RISE Food Climate Database (RISE, 2019; 2018, Florén et al., 2017). Climate impact was expressed as kg of CO_2 equivalents per kg food, including greenhouse gas emissions from primary production to industry gate. For imported foods, a generally assumed transport impact was included. Climate impact from packaging and land use change were not included. In order to do a combined evaluation of the nutrient density and climate impact of the included food products two different methods were used: an integrated index where NRF was used as complementary FU (results not presented); and parallel assessment of the two outcomes illustrated in a two-axis graph with the nutrient density score on one axis and the environmental impact on the other.

Systematic literature review on health metrics used in combination with food environmental assessments

A systematic literature review was performed to identify health metrics used in combination with environmental assessment of foods. The review is an important basis for further methodological work aiming to provide guidance on the suitability of different health metrics to be used in combination with food LCA.

The literature search was performed in February 2020. Eligible articles to be included in the review were those published in peer-reviewed scientific journals between 2010 and February 2020, written in English and including the following analyses:

i. Quantitative assessment of the environmental impact of foods, meals or diets.
ii. Quantitative assessment of the intake of food and/or nutrient intake of foods, meals or diets.
iii. Assessment of the health impact of foods, meals or diets based on health scores.

Studies only including assessment of nutritional content or quality as a health impact was excluded, due to a recent review of such methods (Hallström et al., 2018).

Results and Discussion

Selection of a nutrient density index at a food product level

In order to gain better knowledge of the role of methodological variables and identify a nutrient metric suited to be used in LCA, we developed a new method to validate nutrient density indexes based on the level of coherence to the dietary guidelines. The assessment was performed both between food categories with different nutrient profiles and within three specific food groups: red and processed meat including egg and chicken, dairy products and cereal products. Most of NRF variants assessed ranked foods coherently with the dietary guidelines, confirming that nutrient density is indeed an indicator of food quality that can be used to guide consumers and product developers towards healthier options between different food groups. However, differences in methodological choices of reference unit, included nutrients and application of capping and/or weighting, had an impact on the way individual foods ranked. Among the NRF variants assessed, the index NRF11.3 ranked food subgroups with the highest level of coherence to the food-based guidelines (**Figure 1**). Q1 included the highest number of healthier foods and foods from all four groups emphasized by the dietary recommendations. The NRF11.3 indicator, as compared to the base NRF9.3 algorithm, includes two additional nutrients, vitamin D and folate, which are at risk for deficiency in the Swedish population. The same performance was obtained both if the index was calculated per portion size or per 100 kcal with the application of weighting. Whereas the index performed well in the assessment between food categories, results indicate that assessment within specific food groups may benefit from tailored method choices.

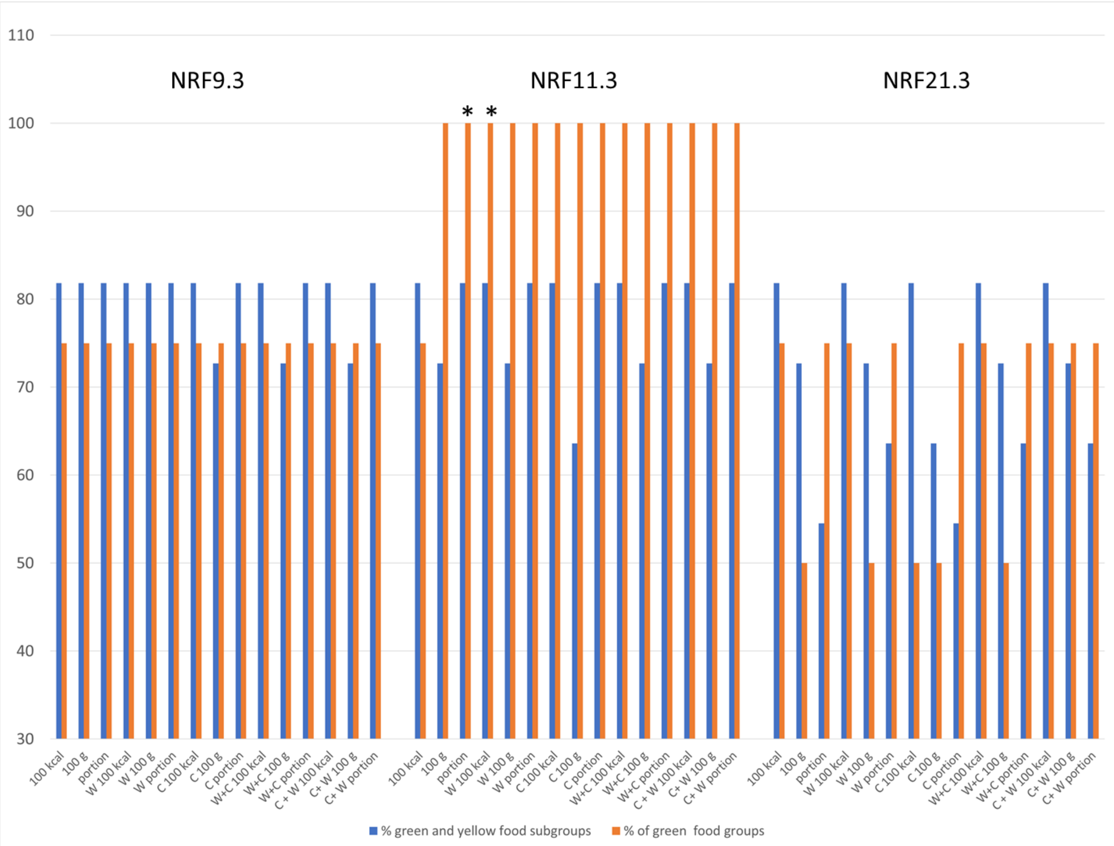

Figure 1: Level of coherence to the dietary guidelines in the highest quintile for nutrient density of food subgroups ranked according to 45 variants of NRF index. Variants are calculated per different reference unit (100 kcal, 100 g, and portion size), choice of nutrients (9.3, 11.3, 21.3) and the application of weighting (W) and/or capping (C). * indicates the index variants based on the simplest calculation algorithm that gave the best results. Green and yellow food subgroups refer to foods which we should consume more of (green) or that are healthier alternatives (yellow). Green food groups are: fruit and berries, nuts and seeds, vegetables and legumes, fish and seafood.

Validation of a nutrient density index at diet level

The separate and combined effects of diet quality and climate impact on mortality were examined in a population-based prospective cohort of women and men in northern Sweden to evaluate variants of the nutrient density index NRF to find the index that best predict total mortality, and to evaluate if a nutritious diet with low climate impact also would be considered good for human health. HR for the 15 alternative versions of NRFn.3 are summarized in **Table 1**. For men none of the various NRFn.3 versions proved better, whereas for women NRF11.3 was identified as the version with most consistent HR patterns. Applying capping to NRF11.3 improved HR and p-values for both women and men but adding weighting after capping only improved the results marginally. Based on these results, NRF11.3 with capping was identified as the diet quality index best predicting total mortality in the population, and was the method used in analyses of combined effects of diet quality and climate impact on total mortality.

Table 1. Hazard ratios (HR) and 95% confidence intervals (CI) for total mortality[1] of women and men (n=146 663) participating in the Västerbotten Intervention Programme (VIP) during 1990-2016 divided into quintiles according to diet quality calculated by various versions of the nutrient density score NRF. The lowest quintile is the reference category.

	Women (n=75 501)			**Men (n=71 162)**		
	NRF9.3[2]	**NRF11.3[2]**	**NRF21.3[2]**	**NRF9.3[2]**	**NRF11.3[2]**	**NRF21.3[2]**
Neither capped nor weighted						
Q1	1.00	1.00	1.00	1.00	1.00	1.00
Q5, HR mortality (95% CI)	0.86 (0.77, 0.96)	0.85 (0.76, 0.95)	0.94 (0.84, 1.04)	0.97 (0.88, 1.07)	0.96 (0.87, 1.05)	1.04 (0.95, 1.14)
Capped						
Q1	1.00	1.00	1.00	1.00	1.00	1.00
Q5, HR mortality (95% CI)	0.83 (0.74, 0.93)	0.81 (0.72, 0.90)	0.86 (0.77, 0.97)	0.85 (0.78, 0.93)	0.85 (0.78, 0.93)	0.89 (0.81, 0.98)
Weighted						
Q1	1.00	1.00	1.00	1.00	1.00	1.00
Q5, HR mortality (95% CI)	0.85 (0.76, 0.94)	0.87 (0.78, 0.97)	0.91 (0.82, 1.01)	0.94 (0.86, 1.04)	0.92 (0.83, 1.01)	0.98 (0.90, 1.07)
Capped and weighted						
Q1	1.00	1.00	1.00	1.00	1.00	1.00
Q5, HR mortality (95% CI)	0.81 (0.73, 0.91)	0.80 (0.72, 0.89)	0.87 (0.78, 0.98)	0.85 (0.77, 0.93)	0.83 (0.76, 0.91)	0.87 (0.79, 0.96)
Weighted and capped						
Q1	1.00	1.00	1.00	1.00	1.00	1.00
Q5, HR mortality (95% CI)	0.81 (0.73, 0.91)	0.81 (0.73, 0.91)	0.86 (0.77, 0.96)	0.88 (0.81, 0.97)	0.88 (0.80, 0.97)	0.94 (0.86, 1.03)

Ranking into quintiles adjusted by age groups. Q1 is the low quintile and Q5 the high quintile. [1]Examined by Cox proportional hazards regression. [2]Adjusted for age, age squared, BMI, physical activity, educational level, smoking status and year of participation. Abbreviations: BMI, body mass index; CI, confidence intervals; HR, Hazard Ratio; NRF, Nutrient Rich Foods index; VIP, Västerbotten Intervention Programme; Q, quartile.

In women, statistically significantly lower hazards for total mortality were found for the two groups characterized by high diet quality, i.e., HNutr/LClim [HR 0.87 (95% CI: 0.79, 0.96); p=0.006] and HNutr/HClim [HR 0.87 (95% CI: 0.78, 0.98); p=0.016], compared to the reference LNutr/HClim. The hazard for LNutr/LClim did not differ statistically significantly from the reference group. In men, a statistically significantly higher hazard for total mortality was found in LNutr/LClim compared to the reference group LNutr/HClim [HR 1.11 (95% CI: 1.02, 1.23); p=0.013]. For HNutr/LClim and HNutr/HClim the risk for total mortality did not differ statistically significantly from the reference group LNutr/HClim.

The results confirm that nutrient density indexes are valid to predict risk of total mortality. The Sweden-adapted index turned out superior, suggesting that nutrient density indexes should be adapted to the specific population of study. Women with high diet quality and either a high or a low climate impact had a lower risk of total mortality suggesting that a diet benefiting both health and climate is possible. The same conclusion could not be reached for men. This advocates for further studies of how men can transition into more climate-sustainable and healthy diets. Among both sexes, a diet of low nutrient density and low climate impact was associated with higher mortality than was a diet of low nutrient density and high climate impact, highlighting that dietary patterns with low climate impact can have both positive and negative impact on risk of total mortality.

Combined nutrient density and climate impact of foods

The results indicate that positive synergies benefiting both climate and health exist for a wide range of food groups that should be encouraged in dietary guidelines for more sustainable diets. Food groups with high climate impact and low nutrient density of which consumption should be restricted are highlighted. Indicated trade-offs between the climate and nutritional performance of foods can provide guidance for prioritizing efforts within product development for increased nutritional quality and initiatives for reduced environmental impact from production systems. See **Figure 2** for the food groups with synergies and trade-offs between climate impact and health. The two alternative methods evaluated enable a quantitative combined assessment of the climate and nutritional performance of foods. Methods and indicators for such integrated assessments are currently lacking and in high demand in order to provide guidance towards more sustainable dietary choices. The methods presented include both opportunities and limitations and it is important to dwell on how the results should be interpreted and acted upon and for what purposes they are best suited for.

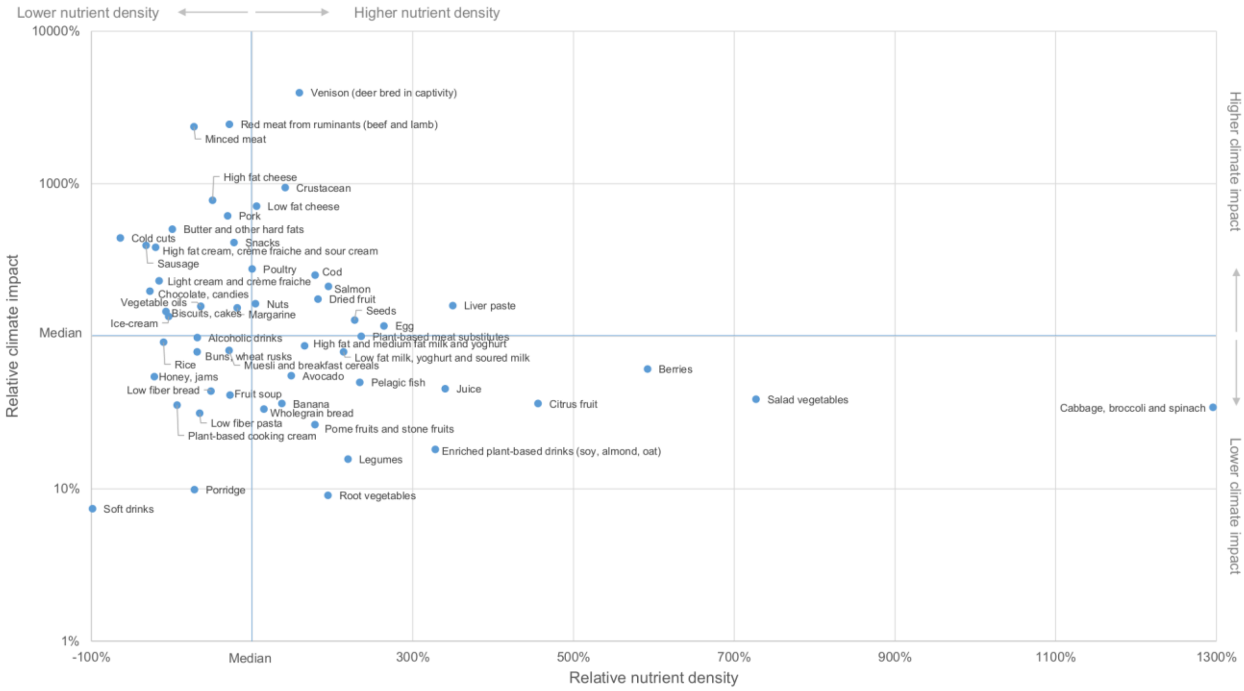

Figure 2. A combined analysis of climate impact and nutrient density of 53 food subgroups. Nutrient density is calculated by NRF11.3 per 100 kcal with weighting and climate impact by kg CO_2e/kg food subgroup. Log transformed climate data scaled around average representing the median of all subgroups. The blue lines represent the median of all food subgroups included. Nutritional information was taken

from version 20171215 of the Swedish food composition database. Abbreviations: NRF, Nutrient Rich Foods index; CO_2e, carbon dioxide equivalents.

Health Metrics used in combination with environmental assessment studies

The systematic literature search identified a total of 22 articles to be included in a systematic review. The different food exposures assessed from a nutritional and environmental perspective could be divided into four categories; food groups (change of intake of certain food group, eg reduced meat intake), total diet (total diet assessed without any changes), dietary patterns (specific dietary pattern, eg vegetarian diet) and food products (single food product, eg fluid milk). In total 14 health metrics used in combination with environmental metrics were identified. The most commonly used health metric was reduced risk (RR) of disease (12 studies). Other health metrics used in more than one study were YLL (years of life lost, 7 studies), DALY (disability adjusted life years, 5 studies) and LE (life expectancy, 3 studies) (see Table 2). Common health outcomes, for which the health metrics were calculated, were total mortality, coronary heart diseases, type 2 diabetes and cancer.

Table. 2. Health metrics used in combination with environmental impact assessment

Health Metric	Description of metric
Relative risk (RR) [1]	Ratio of probability of incidence in a specific disease between an exposed group versus a non-exposed group
Years of life lost (YLL) [2]	An individual's loss of years before attaining predicted life expectancy
Disability adjusted life years (DALY) [2]	The sum of YLL and YLD. Measures the total time of years lived with disability and years lost before attaining ideal life expectancy
Life expectancy (LE) [2]	Expected life years a person from a specific age (e.g. birth) is expected to live when mortality rates for the same group of people, in the present year remain for the rest of the person's life

[1] Definition provided by GBD 2017 Risk Factor Collaborators.
[2] Definitions provided by Institute for Health Metrics and Evaluation (IHME 2019)

Regarding environmental metrics used in the selected studies greenhouse gas emissions was absolutely dominating, used in all studies but one. Land use (10 studies), water usage (8 studies) and biodiversity (6 studies) were other environmental metrics, used in more than one study. The results from the literature review will be further analyzed for a publication in a scientific journal during the Autumn 2020.

Applicability of combined nutrition/environment indicators in product development and communication

The five food companies participating in the project were asked to evaluate the suitability of the nutrient density index alone, and in combination with the climate impact, as a tool for the development of new products and the communication to the consumer.
The base index NRF9.3 was calculated for a product selection from their portfolios, and internal discussions allowed to analyze opportunities and limitations regarding the use of this index in combination with GHGE as a tool for the food sector.

The analysis highlighted both strengths and areas of improvement for this method. Specifically, the potential of a combined use of nutrition density and climate impact for both product design and consumer communication are considered promising, and particularly useful when these two variables are expressed separately rather than integrated in one score. However, the application of indexes like NRF9.3 or 11.3 as a measure of nutrition density in product design and communication can be challenging due to both lack of nutrient composition data and uncertainties on the legislative requirements related to nutritional statements on a product level.

As nutrient density indexes in general are not able to cover all aspects of the healthiness of a food product (i.e. whether enriched or naturally rich, other aspects of the food matrix), their use should be complemented by additional information on the nutrition and health benefits of a foods and diets.

Conclusions:

This study shows that nutrient density indicators are useful for guiding towards healthier foods and diets in accordance with dietary guidelines and that the method is suitable to incorporate nutritional aspects in environmental assessments of food.

The indications developed in this study are potentially relevant to researchers conducting food LCA, authorities and governmental bodies drafting future dietary guidelines for healthy and sustainable diets, to food producers and retailers working to offer more sustainable product portfolios.

This project raises a number of questions that need further research to be addressed and answered. A description of future research stemming from this project has been compiled in a document, titled “Kombinerade miljö- och hälsoeffekter av livsmedel: perspektiv på utvecklingen av närings-, hälso- och miljöindikatorer” (available at: https://www.slu.se/centrumbildningar-och-projekt/futurefood/forskning/temasidor-ny/sustainable-diets/seminariedokumentation/kost-naring-halsa-och-miljopaverkan--hur-tar-vi-hansyn-till-allt/).

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https://www.livsmedelsverket.se/globalassets/publikationsdatabas/broschyrer/kostraed_webb.pdf

Del 3: Resultatförmedling

Ange resultatförmedling av projektet, inklusive titel, referens, datum, författare/talare, och länk till presentation eller publikation om tillämpligt. Planerade publiceringar (med preliminära titlar) ska ingå i tabellen. Ytterligare rader kan läggas till i tabellen.

Vetenskapliga publiceringar	Bianchi, M., Strid, A., Lindroos, A-K., Sonesson, U., Winkvist, a., Hallstrom, E. Development of a nutrient density-based reference unit for food LCA studies. Sustainability, 2020.
	Strid, A., Johansson, I., Bianchi, M., Sonesson, U., Hallström, E., Lindahl, B., Winkvist, A. Diets benefiting health and climate relate to longevity in norther Sweden. Am. J. Clin. Nutr., accepted for publication.
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