Nutrient based functional unit for meals

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ABSTRACT
The goal of this study was to compare the environmental impact of meals and their ingredients and to analyse the influence of the functional unit on the results. For this study all relevant life cycle phases were considered. The functional units we compared: 1 meal (about 450g); adjusted by the nutrient density score (NDS); adjusted by the nutrient rich food index (NRF9.3). A comparison of the different meals per plate or adjusted by the NRF9.3 method shows that the most relevant impact comes from meat. If the results are weighted by the NDS method, beef still shows a high impact but is not as dominant due to its high nutrient density. Using this method whether the ingredients are regionally or seasonally produced becomes much more relevant. Taking the uncertainty into account a meal with vegetables out of season can but must not have a significant lower environmental impact than a meat meal. The different outcomes due to the three different functional units used show the importance to take into account the adequate circumstances when defining the functional unit. What is adequate to compare - the amount of food, the nutritional value of food or the nutritional health of food? Otherwise, the functional unit and the results may not answer the questions.

Keywords: LCA, meal, nutritional value, functional unit

1. Introduction
In the European Union more than a quarter of the environmental impact is estimated to come from the food chain. There is an on-going discussion on how to reduce the environmental impact along the food production and supply chain. One of the most widely spread proposition is to alter food consumption patterns by replacing animal foods with plant-based foods. And of course there is a big difference between the environmental impacts of the production of 1kg vegetables and 1 kg meat. However, nutritional values or nutritional health of food are seldom considered in such comparisons. It is important to use a functional unit that is relevant from a nutritional perspective.

2. Methods
2.1. Goal and scope
The goal of this study was to compare the environmental impact of real restaurant meals and their ingredients and to show the influence of the functional unit on the results. The following meal combinations were compared (among others): proteins (beef vs. poultry vs. mushrooms) with potatoes and green beans (fresh beans Switzerland vs. fresh beans Egypt vs. fresh beans greenhouse grown).

For this study all relevant life cycle phases were considered including production, further processing, transportation, packaging and cooking of the meals.

The functional units we compared:
- 1 meal (about 450g).
- 1 meal adjusted by the nutrient density score (NDS).
- 1 meal adjusted by the nutrient rich food index (NRF9.3)

2.2. Nutrient density score (NDS) and nutrient rich food index (NRF9.3)
In this study, the NDS was calculated according to Drewnowski (2005). The sum of proteins, carbohydrates, fats, 10 vitamins and 8 trace elements were considered and each weighted according to the recommended daily intake meaning the higher the nutrient density the more valuable the food was. Nutrient contents were taken from the USDA National Nutrient Database for Standard Reference (2011). The nutrient density of an ingredient was calculated as follows:

Nutrient density (NDS) = ∑PNR x PropN
• PNR: Percentage of nutrient recommendation
  \( = 100 \times \left( \frac{\text{content of nutrient } i \text{ in 100g of edible portion}}{\text{recommended daily value of nutrient } i} \right) \)

• PropN: Proportion number of nutrients >5% of recommended daily value
  \( = \frac{\text{number of nutrients in 100g of edible portion >5% of recommended daily value divided by 21}}{\text{amount of considered nutrients}} \)

The nutrient rich food index (NRF) was calculated according to Drewnowski (2009). The NRF9.3 was chosen because it best correlates to a healthy diet (Drewnowski 2009). The NRF9.3 contains nine nutrients to encourage (protein, fibre, Vitamins A, C and E, Minerals Ca, Fe, Mg, K) and 3 nutrients to limit (saturated fat, added sugar, Na). Nutrient contents were taken from the USDA National Nutrient Database for Standard Reference (2011). The nutrient rich food index was calculated as follows:

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\text{Nutrient rich food index (NRF9.3)} = \sum \text{NE} - \sum \text{LIM}
\]

• NE: Nutrients to encourage
  \( = 100 \times \left( \frac{\text{content of nutrient } i \text{ in 100g of edible portion}}{\text{recommended daily value of nutrient } i} \right) \)

• LIM: Nutrients to limit
  \( = 100 \times \left( \frac{\text{content of limiting nutrient } i \text{ in 100g of edible portion}}{\text{maximum recommended daily value of nutrient } i} \right) \)

2.3. Inventory data

Production data for beef and poultry (integrated production, Switzerland) were based on Jungbluth (2000) updated by the Wirz handbook (LBL 2005) and own data inventories. Potato production (integrated production, Switzerland) was taken from the ecoinvent report No. 15 (Nemecek & Kägi 2007). Data for bean production (good agricultural practice, Germany) was based on Lattauschke (2002) and data for mushroom production (conventional, Poland) was taken from Hessische Landesfachgruppe (2002). Data for the further processing of the ingredients and preparing of meals was based on Dinkel et al. (2006). Data for meals was based on real restaurant dishes. The ecoinvent inventory V2.2 database (ecoinvent 2010) was used for other secondary data (fertiliser production, transportation and other) and emission factors.

2.4. Impact assessment

The LCA was performed using the software EMIS 5.7 (Environmental Management and Information System) developed by Carbotech (Dinkel 2011).

For valuation of the environmental footprint the ecological scarcity method (Frischknecht et al. 2009) was used. The method represents the environmental policy of Switzerland and evaluates the emissions and their environmental impacts according to a “distance-to-target”-approach. For evaluation of processes of which the emissions are generated outside of Switzerland it is assumed, that the relative importance of the emission factors is similar. The Eco-indicator 99 method (Goedkoop and Spriensma 2001) was used as a second method for the evaluation of the environmental footprint.

2.5. Uncertainty considerations

To describe the uncertainty of data and model calculations distribution functions like normal or lognormal distribution are used. Especially for emissions where the distributions typically are not symmetric the lognormal distribution is a better approximation than the normal distribution. But the advantage of normal distributions is that there are analytic functions to calculate the uncertainty propagation over the process chain if it is assumed that the uncertainties are independent of each other which is of course not always the case. Due to this shortcoming an overestimation of the uncertainties may be obtained. By using normal distributions the results can be calculated within seconds instead of hours. This is one of the main reasons why in the EMIS software a simplified uncertainty calculation using normal distribution function is used. This means that the uncertainty propagation will be calculated and the user always gets an estimation of the confidence intervals of the LCA results. Even today there are few LCA studies giving the uncertainties of the results even if there are leading software tools giving the opportunity to do an uncertainty calculation with Monte Carlo simulation.

The methodological uncertainties were assumed to be around 20%. Considering the appropriateness of the data being used, uncertainties of the in– and output processes were taken into account. These uncertain-
ties were defined according to the pedigree matrix used in ecoinvent (2010). The uncertainty intervals are presented on the 68% level (standard deviation).

3. Results

The comparison of the environmental impacts of the meals depends on the functional unit we choose.

A comparison of the environmental impact in reference to one meal shows as expected that the most relevant impact comes from meat (figure 1). Meals with beef have a significantly higher environmental impact than meals with poultry whilst vegetarian meals show the lowest environmental impact. All other inputs are of secondary relevance compared to meat.

If the results are weighted by the NDS in order to compare the environmental impact of the meals in reference to their nutritional value, meat (especially beef) still shows a high impact but is not as dominant due to its high nutrient density (figure 2). Other ingredients such as potatoes and beans also contribute significantly especially if the ecological scarcity method is considered. This is because the nutrient density of meat is much higher than the nutrient density of vegetables. Using this NDS adjusted functional unit whether the ingredients are regionally or seasonally produced becomes much more relevant. Taking the uncertainty into account a meal with vegetables out of season can but must not have a significant lower environmental impact than a meat meal.

If the results are weighted by the NRF9.3 in order to compare the environmental impact of the meals in reference to their nutritional health, meat (especially beef) shows an even higher impact than in the comparison per meal. All other inputs are of secondary relevance compared to meat.

Figure 1. Environmental impact per meal, normalised to the maximum. Var 1: beef+potatoes+green beans CH, Var 2: poultry+potatoes+green beans ES, Var 3: poultry+potatoes+green beans CH, Var 4: mushrooms+potatoes+green beans greenhouse, Var 5: mushrooms+potatoes+green beans CH.

Figure 2. Environmental impact per meal, normalised to the maximum. Var 1: beef+potatoes+green beans CH, Var 2: poultry+potatoes+green beans ES, Var 3: poultry+potatoes+green beans CH, Var 4: mushrooms+potatoes+green beans greenhouse, Var 5: mushrooms+potatoes+green beans CH.
Figure 2. Environmental impact per nutritional value (NDS), normalised to the maximum. Var 1: beef+potatoes+green beans CH, Var 2: poultry+potatoes+green beans ES, Var 3: poultry+potatoes+green beans CH, Var 4: mushrooms+potatoes+green beans greenhouse, Var 5: mushrooms+potatoes+green beans CH.

Figure 3. Environmental impact per nutritional health (NRF9.3), normalised to the maximum. Var 1: beef+potatoes+green beans CH, Var 2: poultry+potatoes+green beans ES, Var 3: poultry+potatoes+green beans CH, Var 4: mushrooms+potatoes+green beans greenhouse, Var 5: mushrooms+potatoes+green beans CH.

4. Discussion

With increasing frequency, people and institutions draw conclusions on dietary recommendations from an environmental perspective without a comprehensive analysis of nutritional relevance. Using a functional unit involving only comparable menus in an average restaurant may lead to the conclusion that vegetable alternatives are always better than those of animal origin. There are few studies such as Kurppa et al. (2009) that already included nutritional aspects in environmental impact assessment of food. However, according to our knowledge, most previous studies did not take nutrient aspects into account when discussing the environmental impact of food choices and according to Swedman et al. (2010) environmental emissions have not been explicitly studied when making nutrition recommendations. It is thus important to use both knowledge in nutrition and environmental footprint to avoid simplistic and erroneous conclusions for food recommendations to mitigate the environmental footprint.

The question rises whether it is appropriate to consider nutrient aspects if comparing food choices as most persons choose their meal based on taste, appetite and economic considerations rather than on nutrients. However, there are many labels (e.g. weight watchers) that guide through the food offer on basis of nutrient considerations. On the one hand, although people are driven by appetite and taste, the main goal of eating is not to eat a certain amount of food or savouring good food but remains in providing the body with necessary nutrients. Considering this aspect, it is simply not enough to compare food per weight or per meal without including nutrient considerations. On the other hand, the NDS method does not consider the fact, that too much of nutrient rich food (e.g. meat) is unhealthy and is today a big problem especially in western civilisations. The NRF9.3 considers this aspect by punishing saturated fat, sodium and added sugar. It refers to the nutritional health of food. However, it seems dissatisfying that it does not include all vital nutrients (e.g. unsaturated fatty acids).

Regarding the three different functional units and their different outcomes (Results per NDS differ to the ones per NRF9.3 or per plate) it is of importance to clearly define the circumstances of the study and define the functional unit accordingly: what shall be compared - the amount of food, the nutritional value of food or the nutritional health of food? Otherwise, the choice of the functional will not lead to the adequate results answering the questions of the study. This result also shows that there is not one functional unit to be right for comparing meals but it has to be chosen carefully according to the circumstances. The right functional unit for one country, region or group of people may be the wrong one for other countries, regions or groups of people.
5. Conclusion

This study compared three different functional units for meals of which two considered nutritional aspects of food. Different conclusions may be derived based on the chosen functional unit leading to different food recommendations. The functional unit to be chosen depends not only on the goal of the study but also on the circumstances such as the cultural background or the measure of value of the stakeholder.

We are convinced that the consideration of nutrient density and nutritional health of food is important in the context of the environmental debate. Furthermore, environmental impacts of meals can be directly linked to nutritional considerations of meals.

6. References