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Abstract

Contrary to food ingredients, little is known about recipes' healthiness or environmental impact. Here we examine 600 dinner recipes from Norway, United Kingdom (UK) and the United States of America (USA) retrieved from cookbooks and the internet. Recipe healthiness was assessed by their adherence to dietary guidelines and aggregate health indicators based on front-of-pack nutrient labels, while environmental impact was assessed through greenhouse gas emissions and land use. Results revealed that recipe healthiness strongly depends on the healthiness indicator used, with more than 70% of the recipes being classified as healthy for at least one front-of-pack label but less than 1% comply with all dietary guidelines. All healthiness indicators correlated positively with each other and negatively with environmental impact. Recipes from the USA, found to use more red meat, have a higher environmental impact than those from Norway and the UK.

1 Main

Unhealthy diets that lead to malnutrition are believed to be responsible for one in five adult deaths and to account for 15% of the total adult disability-adjusted life years [1]. On top of these issues, our current food system is taking its toll on the environment. Globally, food production accounts for 70% of freshwater use [2, p.7], 42-61% of ice-free land use [2, p.8] and 21-37% of anthropogenic greenhouse gas emissions (GHGE) [3]. Through destruction of habitats and production of agricultural runoff and atmospheric fine particulate matter, food production negatively impacts biodiversity, increases soil degradation and pollutes air, water and land [4–7]. This has led to calls from organizations such as The World Health Organization (WHO) to develop diets that are both healthy and environmentally sustainable, so-called "Sustainable Healthy Diets". WHO and the Food and Agriculture Organization of the United Nations (FAO) have defined sustainable healthy diets as dietary patterns that "promote all dimensions of individuals' health and well-being; have low environmental pressure and impact; are accessible, affordable, safe and equitable; and are culturally acceptable." [8].

To this end, many countries and regions have developed their own food-based dietary guidelines (FBDGs) [9, 10]. These guidelines share many similarities, such as recommending a whole foods diet with a variety of fruit and vegetables, as well as other fibre-rich foods. Typically, this also includes whole-grain cereals, legumes and nuts, and high-quality protein, often from animal-sourced foods [10]. FBDGs are sometimes quantified in terms of a recommended number of portions per day or week, as well as in terms of serving sizes, which is thought to help the public to attain a healthier dietary intake [11, p.319].

Recently, FBDGs have also started to address environmental sustainability, as observed in Sweden [12], Denmark [13] and Qatar [14]. These FBDGs emphasize the importance of following a plant-based diet with a low to moderate amount of animal sourced foods, as plant-based foods generally have a low environmental impact per kilo produced, and animal sourced foods with a high environmental impact are not required in high amounts in the diet due to their nutrient density [10, 15].

A systematic review has found the adherence to FBDGs to be low [16]. This particularly applies to the intake of healthy foods such as fruit and vegetables, legumes, whole grain cereals, nuts, fish and dairy, but also unhealthy foods high in sugar, salt and/or saturated fat. At a global level, intake of meat is also higher than what is necessary for good health [16].

A source of information that could influence an individual's food choices are recipes. Analysis of specific food and nutrient content in recipes have previously been suggested as a low-burden method to follow food trends and dietary patterns in a population [17, 18], and to monitor the relationship between food consumption and health [19]. Similarly, recipes could be used to monitor environmental impact of dietary patterns and to find meals that are in line with broader sustainable dietary principles [20].

To date, several studies on recipes from different sources including cookbooks [21–23], supermarket magazines [24], food blogs [25–27] and other Internet recipe sites [23, 28, 29] have found that recipes rarely comply with healthy dietary principles. Recipes that are plant-based have been found to have lower environmental impact than recipes that use animal sourced protein, but few studies have looked at environmental impact of recipes [30, 31].

Previous works have largely examined single aspects of sustainable diets, such as studying healthiness and environmental impact in isolation. In this study, we explore the healthiness and environmental impact of a selection of recipes from the United Kingdom (UK), Norway and the United States of America (USA), consulting cookbooks (UK) and the Internet (Norway, USA). We compare two domains of sustainable diets, namely health and environmental impact. More specifically, we ask to what extent (i) recipes from Norway, the UK and the USA comply with healthy dietary guideline principles, (ii) a recipe's healthiness and environmental impact depend on country of origin, and (iii) a recipe's environmental impact is related to its healthiness.

2 Results

2.1 Data completeness

Among the 600 recipes in the dataset, 586 recipes were included in the analyses. One Norwegian recipe was excluded from analysis as it contained no ingredients for which the amount in weight could be obtained, while five additional Norwegian recipes were excluded as they were not dinner recipes. Eight recipes (six Norwegian, two USA) were not included in the analysis as >10% of their ingredients in weight could not be mapped to the nutrient or SHARP Indicators database. These ingredients included sheep head, marrow bones and plantains, ingredients that would be expected to impact either the health or environmental sustainability outcomes.

2.2 Nutrients, recipe healthiness and environmental impact

2.2.1 Cross-country comparison

We assessed cross-country differences for 35 healthiness and environmental sustainability indicators and nutrients. Kruskal-Wallis tests revealed 19 out of 35 of them to be significantly different (adjusted p-value <0.05) between at least two countries. To this end, *post-hoc* Dunn test were performed. All significantly different features on the Kruskal-wallis test are described in **Table 1**; for all features, see the supplementary materials.

We observed differences regarding the adherence to different nutritional guidelines. These were significant for the NNR guidelines (UK > Norway: p-value <0.01; UK > USA: p-value <0.001, Norway > USA: p-value <0.05), WHO guidelines (UK > Norway: p-value <0.05; UK > USA: p-value <0.01) and the inverted Nutriscore (UK > Norway: p-value <0.05; UK > USA: p-value <0.05). Few recipes complied with WHO and NNR guideline criteria for carbohydrates, but recipes were more compliant with NNR than WHO criteria. In a similar manner, more recipes were compliant with protein and total fat recommendations of the NNR than WHO. As the guideline recommendations for dietary fibre, saturated fat and added sugar were identical, there were no differences in adherence. Furthermore, protein contributed most to the qualifying scores on the Nutriscore, with the median score for protein being higher than the total median score of the disqualifying components. For the scores for each component of the healthiness indicators by country, see **ED Fig. 1**, **ED Fig. 2** and **ED Fig. 3** for the guidelines, Nutriscore and the MTL respectively.

Environmental impact indicators also varied between countries, including to GHGE, expressed in kg CO_2 equivalents (USA > UK: p-value <0.001; USA > Norway: p-value <0.05; Norway > UK: p-value <0.05), and land requirements (USA > UK: p-value <0.01; USA > Norway: p-value <0.01).

In terms of individual nutrients, there were significant differences between countries on dietary fibre content (UK > USA: p-value <0.001; UK > Norway: p-value <0.001), vitamin C (UK > USA: p-value <0.001; UK > Norway: p-value <0.01; Norway > USA: p-value <0.05) and protein (USA > UK: p-value <0.01; USA > Norway: p-value <0.05). While there were other statistically significantly different micronutrients, the differences between countries in absolute numbers were negligible.

In general, recipes adhered better to the front-of-pack label (FOPL) healthiness criteria than to the macronutrient guidelines. Only 10.5% and 7% recipes scored >4 on the NNR and WHO guidelines respectively, while 71% received an inverted Nutriscore > -2 and 99% scored >7 on the FSA-MTL. The percentage of recipes from each country and all countries pooled that received a specific score can be seen in **ED Tables 1** and **2**.

2.2.2 Protein sources

Red meat (beef, lamb, game and pork) were the most used sources of protein in the recipes from all countries. Seafood (lean fish, oily fish and shellfish) were the second most used in the recipes from the UK and Norway, while white meat (poultry) was the second most used in USA recipes. Few recipes were vegan; the UK recipes had the most vegetarian ones (**Fig.** 1 a). Per 100 grams, recipes from the USA had the most meat and meat based products (**Fig.** 1 b).

A recipe's protein source affected the GHGE and land use indicators. Recipes with beef, lamb, game and shellfish had the highest environmental impact, while vegetarian and vegan recipes had the lowest impact. Recipes with pork, poultry, lean and oily fish fell in between. The vegetarian recipes with the highest impact were on level with the non-ruminant meat based recipes and the lowest ruminant meat recipes (**Fig.** 1 c).

2.2.3 Healthiness indicators and environmental impact indicators

All four healthiness indicators were positively correlated with each other (significant BH tests: p-value <0.001). We found a moderate correlation between the two FOPLs ($\rho = 0.68$), and a strong correlation between the two dietary guidelines ($\rho = 0.78$). In contrast, the correlation between the FOPLs and the dietary guidelines were weaker. The two sustainability indicators were strongly and positively correlated ($\rho = 0.84$, BH p <0.001).

All four healthiness indicators were found to be negatively correlated with the two environmental sustainability indicators (BH p <0.001). This was strongest for the two dietary guidelines, while NNR had a slightly stronger correlation with both GHGE and land use than WHO did, and Nutriscore showed the weakest correlation with land use. The correlation between healthiness indicators and environmental impact tended to be weakest for the Norwegian recipes, and strongest for the recipes from the USA, as shown in **Fig.** 2.

2.2.4 Nutrients and environmental impact

Various individual nutrients correlated significantly with environmental impact. Nutrients found exclusively in plants such as carbohydrates, dietary fibre and the pre-vitamin A beta-carotene were weakly, negatively correlated with environmental impact. Carbohydrates had the strongest correlation of these nutrients. The nutrients saturated fat, protein, iron and zinc that could be found in both plant-based and animal-sourced foods were positively correlated with environmental impact. The strength of the correlation for all nutrients varied between countries, shown in **Fig.** 3.

3 Methods

3.1 Data

To assess the association between different recipes in terms of health and environmental impact, we analysed 600 recipes. 400 recipes were from Norway, and 100 recipes were each from the UK and the USA. A larger Norwegian sample was collected, as we had also planned a within-country analysis, but little differences were observed. Since omitting part of these recipes would not significantly affect the results, we decided to retain all 400.

Recipes from Norway and the USA came from databases of online recipes collected previously. A randomized selection of these recipes had been chosen for nutritional analyses previously [32] and were reused for this study. Norwegian recipes were obtained from Klikk.no (n = 100), Tine.no (n = 100), Aperitif.no (n = 100), Kolonial.no (n = 100), and USA-based recipes from Allrecipes.com (n = 100). Since recipe collection Kolonial has been renamed Oda. The UK recipes were selected randomly from an assortment of UK celebrity chef's recipe books, previously used to study the healthiness of television chef's recipes [22]: Baking Made Easy (n = 7), River Cottage Everyday (n = 21), Jamie's Ministry of Food ($n = 22$), Jamie's 30 Minute Meals ($n = 25$) and Nigella's Kitchen ($n = 25$). A list of all recipe names and their sources is provided in the supplementary material.

3.2 Recipes' nutritional content and environmental impact

The nutrient content of the recipes was calculated by mapping the ingredients to the 2020 Norwegian Food Composition Database Matvaretabellen [33]. We leveraged information about the macro- and micronutrient content per 100 g of commonly consumed foods in Norway. Nutrients included comprised all macronutrients except alcohol, and all vitamins and minerals found in the Norwegian Food Composition Database. If an ingredient was not found in the Norwegian database, the equivalent USA food database, Agricultural Research Service FoodData Central [34], was used. The names of the nutrients included are described in supplementary Tables 3 and 5.

Each recipe's environmental impact was computed using the public SHARP Indicators Database [35]. This included greenhouse gas emissions (in kilo CO_2 equivalents) and land use (in m^2 pr year) of ˜900 foods. The environmental impact in the database stemmed from life-cycle inventory data on 182 primary products and many composite foods based on these primary products. These life cycle analyses included the environmental impacts of primary production of the food, its packaging, transport to supermarket/consumer, storage at the supermarket/consumer, final preparation, and any waste produced throughout.

Standardized weight measures from the "Weights, measures and portion sizes for foods" database from The Norwegian Directorate of Health [36] were used to calculate the weight of ingredients with volume units. If the ingredient was not found in this Norwegian database, we resorted to the U.S. food database FoodData Central [34]. If it would still be missing, we would look it up in the online shops of Meny, Kolonial or COOP, or measured it at home. For composite ingredients not present in Matvaretabellen or SHARP Indicators Database, we searched online for similar ingredients and used their nutrient content and environmental impact; this procedure was similar to that used by the creators of the SHARP Indicator Database [35]. The nutrient content and environmental impact *of the composite ingredients* was calculated separately and standardized to [per 100g], before being used in the analyses. Moreover, the nutrient content and environmental impact *of the recipes* from the different countries were all standardised to [per 100g] of the recipe.

3.3 Recipe's healthiness

Four indicators were used to assess a recipe's healthiness. This included two dietary guidelines: the WHO [37] and the NNR [38], and two FOPL systems: the UK FSA-MTL [39] and the French Nutriscore [40]. The two dietary guidelines defined macronutrient ranges for daily diets, with the WHO recommending a higher carbohydrate intake, and lower fat and protein intakes than the NNR. Similar to Howard et al. [22], a health score was created based on the content for carbohydrates, sugar, dietary fibre, fat, saturated fat and protein, attributing a score of 1 for adherence to the guideline and 0 for non-adherence giving a total score of 0-6, where 0 was unhealthiest and 6 healthiest. A cutoff of 4 was used for "healthy".

The FSA-MTL considered four nutrients: Salt, fat, saturated fat and sugar. Each nutrient was scored between 1 and 3; a score of 3 was awarded for "green"/"low", 2 for "amber"/"medium" and 1 for "red"/"high", resulting in a range between 4-12, where a higher score indicated healthier foods. This is an inversion of the scoring system used by other authors [22, 41], to create a consistent 'higher is healthier' score across all dietary guidelines. According to the FSA, a food can be eaten "most of the time" if it has a majority of amber lights, with a score ≥ 7 [39].

The Nutriscore differed from the other healthiness indicators in that it balanced healthy and unhealthy components of a food [42]. It awarded points to both categories and subtracting one from the other. It was calculated according to the guideline documentation [40]. Instead of using the original scale between 40 and -15, where -15 was the healthiest, an inverted score was used to be in line with other 'higher is healthier' indicators. An inverted score of $\geq$ -2 was chosen as the cut-off for a food that could be eaten often as part of a healthy diet, as this was previously used to assess the alignment between the Nutriscore and national dietary guidelines [42]. To calculate the percentage of fruits, vegetables, legumes and healthy oils in a recipe for the Nutriscore, the food groups from the SHARP Indicator Database were used to classify ingredients as either a fruit, vegetable or legume, while individual ingredient names were used for the healthy oils. The nutrient thresholds for each healthiness indicator can be seen in supplementary tables 8-10.

Protein sources used

We also compared the environmental impact of different recipes based on the main source of protein they contained (e.g. seafood, poultry, vegan). Food-based dietary guidelines in different countries often included recommendations for various protein sources, such as encouraging fish intake [9, 10]. Recipes that contained no ingredients of animal origin were labeled "Vegan", recipes that contained eggs or dairy but no other animal-sourced ingredients were labeled "Vegetarian", while recipes that contained a majority of one animal source of protein by mass were labeled accordingly.

3.4 Statistical analysis

3.4.1 Missing data

Ingredients with no quantities specified were replaced with the mean value of that ingredient in all other recipes, normalized to per 100 g of the recipe. If this was not possible, ingredients were left out of the analyses. Ingredients that could not be found in the nutrient or sustainability databases were if possible exchanged for a similar ingredient, or left out. If more than 10% of the recipe in weight could not be mapped to either the food composition databases or SHARP Indicators database, the recipe was left out.

3.4.2 Cross-country comparison

Significant differences in energy per 100 g, macronutrient content in percentage of energy, micronutrient content in percentage of the RDI of an adult woman in Norway [43], healthiness indicator scores and sustainability indicators between recipes from the different countries were assessed using the Kruskal-Wallis test. A Dunn's test was performed *post-hoc*, and to account for multiple testing the Benjamini Hochberg (BH) method was used.

All tests were done using the rstatix package v. 0.7.0 [44].

3.4.3 Correlation analysis

To explore possible correlation between variables Spearman's rho were calculated using the corr.test function from the Psych library v.2.1.6 [45]. This was done for the recipes from each country individually and for the pooled data from all countries. P-values were calculated and corrected for multiple testing using the BH method. For all analyses, an adjusted p-value < 0.05 was considered to be statistically significant (i.e., $\alpha = 0.05$).

4 Discussion

This study has sought to determine the environmental impact and healthiness of dinner recipes, and to compare them across different countries of origin. For health, we have done so by examining their adherence to different dietary intake and FOPL criteria. Moreover, we have examined to what extent a recipe's healthiness and environmental impact are related.

4.1 Healthiness and environmental impact

In line with previous studies on recipe healthiness, the recipes in this study show low compliance to dietary guideline macronutrient criteria from the WHO [22, 23, 25–29]. However, the adherence of the recipes examined in our study depends strongly on the used guidelines or FOPLs. Recipes scored slightly better on the NNR criteria that allow for more fat and protein and less carbohydrates. Moreover, nearly all recipes could be considered as a food that could be eaten "most of the time" when using the FSA-MTL criteria, while 71% of recipes are considered healthy according to the Nutriscore criteria. This contrasts with previous work where low adherence with WHO criteria is reflected in the FSA-MTL scores [27]. This discrepancy might stem from a difference in the interpretation of the FSA-MTL by Dickinson et al. [27]: Both amber and red lights are labeled unhealthy, while in this study a recipe could be seen as healthy if it had mostly amber lights. The FSA states that "If a food contains mostly amber, you can eat it most of the time" [39], suggesting that consumers should consider these foods healthy. Discrepancies with other studies on recipe healthiness that use MTL could stem from the use of the Australian Healthy Eating Advise Service MTL [21] and the Australian Live Lighter MTL [24], the latter having more stringent nutrient criteria than the FSA-MTL.

Despite the variety in recipe healthiness based on the indicators used, we have found all healthiness indicators to correlate positively with each other, as well as negatively with the two environmental impact indicators. This suggests that the healthiness indicators pick up on similar properties in the recipes, also indicating that healthier foods tend to be more environmentally sustainable, regardless of the healthiness indicator used. The different correlational strengths between environmental impact and both healthiness indicators and nutrient content in the different countries show that different food combinations can provide the same healthiness and nutrient content at different costs to the environment. While there are significant differences between countries on the healthiness indicators and individual nutrient content, the absolute differences were small and are unlikely to be of clinical relevance.

The two dietary guidelines are found to have a stronger negative correlation with environmental impact than the two FOPLs. This is likely due to differences in design between the two types of indicators (guidelines vs FOPLs), in terms of how nutrients predominantly found in either plant-based or animal sourced foods are scored. The guidelines 'reward' a moderate-to-high content of carbohydrates and a high content of dietary fibre, nutrients found in plant-based foods with a low environmental impact. At the same time, a high content of protein and saturated fat, nutrients found predominantly in high environmental impact animal-sourced foods, are penalized. In contrast, the FSA-MTL includes no plant-based specific nutrients, while the Nutriscore only reward plant-based foods rich in fibre. Both the FSA-MTL and the Nutriscore penalize a higher content of saturated fat, but neither penalize a high protein content. In fact, higher protein content leads to a higher Nutriscore.

The observed differences likely stem from the different purposes of dietary guidelines and FOPL. Dietary guidelines are designed to be used to measure the nutrient quality of whole diets, where several meals complement each other. On the other hand, FOPLs are designed to provide at-a-glance information about a specific food product, and help consumers to make the healthier choice. Several studies have found that foods that score A/B on the Nutriscore are foods that are encouraged in FBDGs, and that if consumers choose these foods, dietary quality is likely to improve [42, 46–48], although for combination dishes such as ready meals that are comparable to the dinner recipes in this study, the alignment with dietary guidelines have been found to be lower than for other food categories [42, 49].

FBDGs from all three countries have specific recommendations for certain food groups. These include recommendations to choose whole-grain products instead of refined grains, chose lean animal sourced foods, consume at least "five a day" of fruit and vegetables and consume a minimum of seafood throughout the week [50–52]. The FBDGs from Norway and the UK recommend to keep red meat intake <500 grams/week, while the USA has a recommendation to keep all meat <700 grams/week [50–52]. All country's FBDGs recommend a predominantly plant-based diet.

Interestingly, we have observed a similar pattern in the recipes in this study as Leme et al. [16] identify in whole diets. Few of the recipes include wholegrain ingredients, and few recipes score high on fruit, vegetable, legume and nut content for the Nutriscore. Also, relatively few recipes include seafood compared to red meat, despite the recommendations for seafood in the FBDGs being subject to a lower limit, contrasting with the upper limit for red meat. This is not only unfortunate for health, but also for environmental impact, for vegetarian, vegan, and fish-based recipes are found to have a relatively low environmental impact.

We have found a higher amount of plant-based foods in our UK recipes, compared to Norway and the USA. This likely explain why UK-based recipes could provide iron and zinc at a lower environmental cost, for these nutrients are found in both plant-based and animal-sourced foods. These results must be interpreted with caution as plant-based sources of iron and zinc have a lower bio-availability than animal sources [43].

Country-specific FBDGs reflect what is found in our recipes. Norway has the highest percentage of seafood recipes, as the recommended weekly seafood intake is highest in their FBDGs. USA-based recipes have the highest percentage of red meat recipes and include a higher proportion of red meat or meat-based products, reflecting the lack of a recommended upper limit in the USA FBDGs for red meat and higher allowed protein intake. This is also consistent with USA recipes scoring significantly higher on environmental impact, as the proportion of red meat and total amount of meat explains most of the variance in the environmental impact of European diets [53].

Our work falls in line with studies that examined diets across different countries (cf. [53]). We have shown that recipes can pick up on dietary trends that can influence the healthiness and environmental impact of diets, which are otherwise also shown through studies on whole diets.

4.2 Strengths, limitations and future work

The main strength of this study lie in the assessment of multiple healthiness indicators across three countries makes our findings applicable beyond the countries of origin of the recipes analyzed, as well as the wide range of nutrients assessed.

Yet the data used includes only two aspects of what would be called a "sustainable diet" (namely healthiness and environmental impact) and a limited number of indicators for each. No indicator for recipe healthiness from the USA was used as the USA currently does not have a government approved FOPL that can be operationalised with a score similar to the FSA-MTL or the Nutriscore, and that besides from the higher allowance of protein USA macronutrient criteria overlap with WHO and NNR criteria. The recipes from the UK are from celebrity chefs' recipe books, which could possibly be different than UK recipes found online. For example, it is possible that the higher content of fibre and lower content of protein in the UK recipes is due to chefs' recipes aiming to be healthier by including more fibre-rich foods, such as whole grain bread, which incidentally also made them more environmentally sustainable.

Finally, healthiness, nutrient content and environmental impact have been calculated per 100 grams, as not all recipes provided their suggested number of portions. This may have limited the applicability of the results, as portion sizes are typically larger than 100 grams. However, while portion sizes supplied in recipes are likely to be used as guidelines for consumers, actual portion sizes consumed are likely to vary depending on the needs of the individual. Standardising per 100 grams allows for comparison between foods regardless of the quantity consumed.

5 Conclusion

The type of measurement and country of origin affects whether a recipe tends to be classified as healthy. While cross-country differences are found too small for overall recipe healthiness, GHGE and land use, nutritional differences were observed in terms of the recipes examined. Across Norway, the UK, and USA, few recipes are still either vegetarian, vegan, or included whole grains or seafood, even though all countries encourage the intake of plant-based foods, whole grains and seafood in their FBDGs.

The trends we have found in recipe composition mirror the trends observed in whole diets, strengthening the belief that recipes could be a useful tool for monitoring dietary trends. Knowledge of recipe composition could further be used by clinicians when advising clients where to find recipes that follow healthy dietary principles, and what types of alteration that could improve their healthiness. For all four healthiness indicators, we find a negative correlation with both environmental impact indicators, indicating these indicators may also be used by consumers to choose more environmentally sustainable foods.

Differences in recipe healthiness based on the healthiness indicator used suggest that further studies should aim to find the most suitable healthiness indicator for recipes. The Nutriscore is advantageous in that it should be used on single food products comparable to recipes, balances healthy and unhealthy nutrients and the inclusion of foods recommended in FBDGs provide a higher score. Further studies should include additional aspects of dietary sustainability, such as water use or availability, and their comparison should be done relative to portion sizes to check if portion size differences explain the differences observed between countries.

Data availability

All data besides the UK recipes' ingredient lists are available in the repository sustainableRecipes[54].

Code availability

All code can be found in the repository sustainableRecipes[54].

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Contributions

AA and CT conceptualized and designed the study. AA and CT were involved in data collection for the study. AA conducted the analyses. All authors were involved in the interpretation of the results of the analysis. AA drafted the manuscript and CT, and AS revised the article. All authors reviewed the final manuscript and approved it for submission.

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Competing interests

All authors declare that they have no competing interests.

Tables

Table 1 Dunn test results, BH corrected, of the features that were significantly different on the Kruskal-Wallis test. Abbreviations used: E% = Percentage of energy, GHGE = Greenhouse gas emissions, IQR = Interquartile range (25th - 75th percentile), MJ = Megajoule, RDI = Recommended daily intake. Significant differences on the pairwise Dunn's test in bold. * = p-value ≤ 0.05, ** = p-value ≤ 0.01, *** = p-value ≤ 0.001.

	Median (IQR)			Dunn test results, BH corrected
	Norway	UK	USA	Pairwise
Environmental impact				
GHGE in kg CO_2 equivalents	0.5 (0.3, 0.9)	0.4 (0.3, 0.7)	0.7 (0.4, 1.1)	**Norway - UK*** **Norway - USA*** **UK - USA*****
Landuse m^2/year	0.6 (0.3, 1.1)	0.5 (0.3, 1)	0.8 (0.4, 1.3)	Norway - UK **Norway - USA**** **UK - USA****
Healthiness indicators				
Inverted Nutriscore	-0.5 (-3, 2)	1 (-2, 3)	-1 (-3, 1)	**Norway - UK*** Norway - USA **UK - USA***
Nordic Nutrition Reccomendation Score	2 (1, 3)	2 (2, 3)	1 (1, 2)	**Norway - UK**** **Norway - USA*** **UK - USA*****
World Health Organization Score	1 (1, 2)	2 (1, 3)	1 (1, 2)	**Norway - UK*** Norway - USA **UK - USA****
Macronutrients				
Protein E%	23.1 (18.1, 29.8)	20.9 (17.3, 29.9)	25.8 (21.2, 32)	Norway - UK **Norway - USA*** **UK - USA****
Dietary fibre g/MJ	1.8 (1.1, 2.8)	2.6 (1.5, 3.7)	1.4 (0.7, 2.7)	**Norway - UK***** Norway - USA **UK - USA*****
Sugar E%	0 (0, 0.5)	0 (0, 0.5)	0.1 (0, 1.8)	Norway - UK **Norway - USA*** **UK - USA***
Vitamins				
Vitamin D % of RDI	3 (1, 9)	1 (0, 3)	2 (1, 5.8)	**Norway - UK***** Norway - USA **UK - USA***
Vitamin C % of RDI	8 (5, 15)	13 (7, 21)	6.5 (3, 12)	**Norway - UK**** **Norway - USA*** **UK - USA*****
Thiamin % of RDI	7 (5, 11)	9 (6.8, 12)	9 (5, 14)	**Norway - UK*** **Norway - USA*** UK - USA
Niacin % of RDI	13 (9, 20)	11 (8, 18)	15 (9, 23)	Norway - UK Norway - USA **UK - USA***
Folate % of RDI	4 (3, 6)	5 (3, 8)	3 (2, 4)	**Norway - UK**** **Norway - USA***** **UK - USA*****
Vitamin B12 % of RDI	30 (11, 51)	22.5 (6, 43)	17.5 (9.2, 38)	**Norway - UK*** **Norway - USA*** UK - USA
Minerals				
Copper % of RDI	8.5 (6, 13)	11 (7.8, 18.2)	7 (5, 11)	**Norway - UK***** Norway - USA **UK - USA*****
Iodine % of RDI	3 (2, 6)	2 (1, 5)	2 (1, 4)	Norway - UK **Norway - USA*** UK - USA
Iron % of RDI	5 (3, 7)	6 (4, 8)	5 (4, 7.8)	**Norway - UK**** Norway - USA UK - USA
Potassium % of RDI	8.5 (7, 10)	9 (7.8, 11)	8 (6, 10)	**Norway - UK*** Norway - USA **UK - USA***
Selenium % of RDI	10.5 (6, 19)	7 (5, 15)	10 (6, 14)	**Norway - UK*** Norway - USA UK - USA

Figure legends/captions

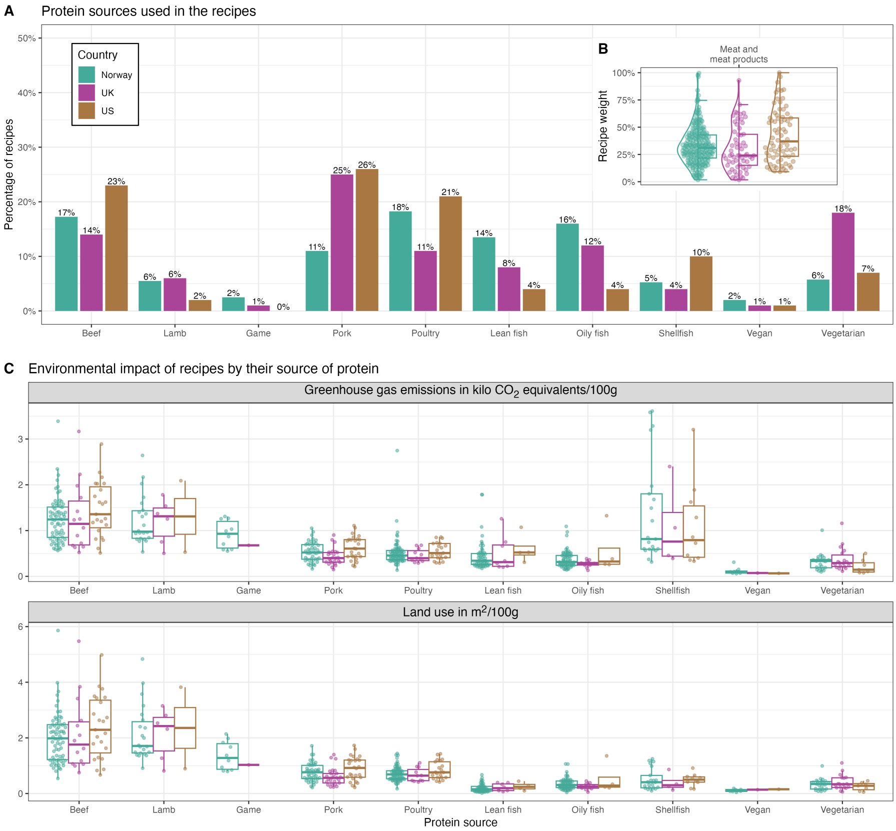

Fig. 1 Recipes' protein sources (A), amount of meat and meat based ingredients by weight (B) and environmental impact (C). A) Percentage of recipes that used various animal protein sources, or were vegan or vegetarian. B) Percentage in weight of meat or meat based products in recipes that contained meat. C) Greenhouse gas emissions and land use of recipes depending on protein source used, in kilo CO2 equivalents and m2 respectively. The lower and upper edges of the box show the 25th and 75th quartile respectively, with whiskers extending to the value no further than 1.5 times away from the quartile value. The thick line inside the box is the median.

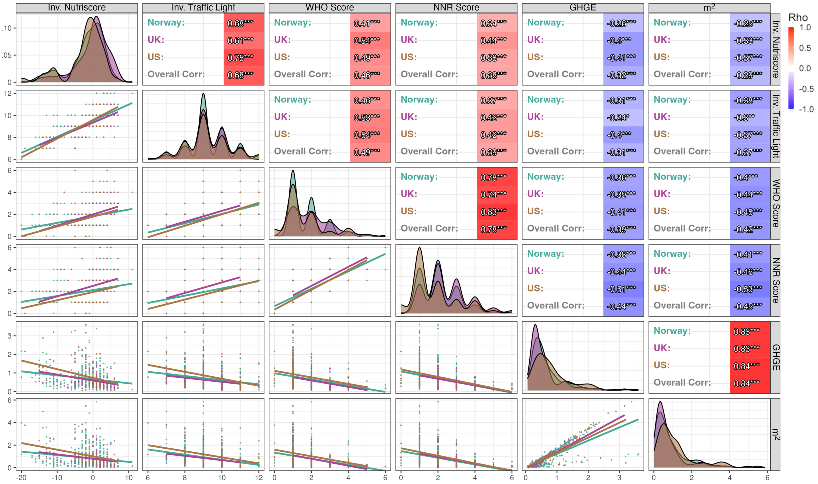

Fig. 2 Correlation between environmental impact and healthiness. Spearman's Rho between Greenhouse gas emissions (in kg CO2 equivalents), landuse (m2/year) and the inverted Nutriscore, inverted Food Standard Agency's multiple traffic light score, World Health Organization dietary guideline score and the Nordic Nutrition Recommendation score. Hot and cold colors show the strength and direction of the correlations.

Supplementary information

Supplementary Table 1: The IDs from the Norwegian Food Composition Database and FoodData Central that ingredients were mapped to.
Supplementary Table 2: The IDs from the Sharp Indicator Database that ingredients were mapped to.
Supplementary Table 3: The raw nutrient and environmental impact values for each recipe.
Supplementary Table 4: The raw nutrient values used to calculate the healthiness scores for each recipe.
Supplementary Table 5: The percentage of the recommended daily intake of each nutrient in the individual recipes per 100 grams.
Supplementary Table 6: The individual healthiness indicator scores for each recipe.
Supplementary Table 7: The urls of the recipes collected online.
Supplementary Table 8: The scoring system for the dietary guidelines from the World Health Organization and the Nordic countries.
Supplementary Table 9: The scoring system for the UK Food Standard Agency multiple traffic light system.
Supplementary Table 10: The scoring system for the Nutriscore.
Supplementary Table 11: Full statistics table.

Source Materials

Source Data Fig. 1a
Source Data Fig. 1b

Source Data Fig. 1c
Source Data Fig. 2
Source Data Fig. 3

Extended data

ED Table 1

ED Table 2

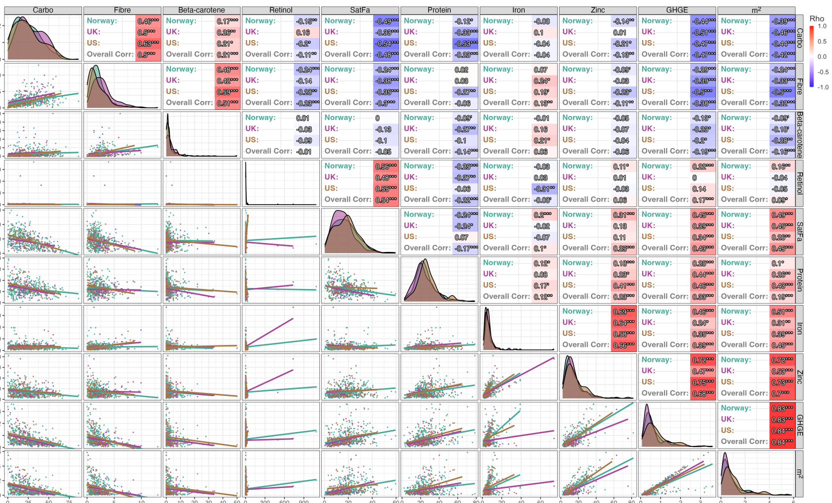

Fig. 3 Correlation between environmental impact and individual nutrients. Spearman's Rho between Greenhouse gas emissions (in kg CO2 equivalents), landuse (m2/year) and a selection of nutrients. Carbo = Carbohydrates, SatFa = Saturated fat. Hot and cold colors show the strength and direction of the correlations.