An exploration of the sustainability of dinner recipes

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Abstract

Background: Our current food system and dietary habits not only contribute to malnutrition and ill health, but also have a damaging environmental impact. A potential source of inspiration for food choice is recipes, but little is known about how well recipes adhere to healthy dietary principles or their environmental sustainability. Here I have explored the healthiness and environmental impact of recipes from three different countries, and the relationship between healthiness, environmental impact and country of origin.

Methods: Recipes from online recipe sites of Norway (n = 400) and the United States (US, n = 100), and recipes from United Kingdom (UK) chef's recipe books (n = 100) were included in the analysis. Recipe's healthiness was calculated by comparing their nutrient content to the World Health Organization and the Nordic Nutrition Recommendations for macronutrient intake, the Norwegian recommended daily intake of micronutrients for adult women, and the food labels UK Food Standard Agency multiple traffic light system and the French Nutriscore. The SHARP Indicator database was used to calculate environmental impact. A cross-country analysis was performed by comparing the healthiness scores, nutrient content and environmental impact between countries using the Kruskal Wallis test with a *post-hoc* Dunn's test. Relationship between healthiness and environmental impact was explored by using Spearman's rho to look at correlation between healthiness indicators and environmental impact and the correlation between individual nutrients and environmental impact, and by comparing the environmental impact of recipes that used foods encouraged in dietary guidelines with those that used foods dietary guidelines recommend to limit.

Results: Small but significant differences (p-value <0.05) were found between countries on the healthiness indicators. Recipes from the UK scored significantly higher on three out of four healthiness indicators than recipes from Norway and the US. Recipes scored more favorably on healthiness when assessed with food labels than with the macronutrient criteria. Recipes from the US had a significantly (p-value <0.05) higher environmental impact than recipes from the UK. All healthiness indicators were positively correlated with each other (rho >0.4) and negatively correlated with environmental impact (rho <-0.3). Iron and zinc were positively correlated with environmental impact (rho >0.4). The majority of recipes used red meat as a source of protein, with seafood or poultry being the second most used protein source depending on country. There were few vegetarian or vegan recipes. Recipes that used ruminant meat as a source of protein had a higher environmental impact than most other recipes.

Conclusion: The type of healthiness indicator used can influence if a recipe is classified as healthy or not. Small but statistically significant differences were found between recipe healthiness, environmental impact and country of origin. Regardless of healthiness indicator used, healthier recipes had lower environmental impact, but lower environmental impact was also associated with a reduction in important nutrients such as iron and zinc. Despite dietary guidelines recommending that red meat intake should be limited, while simultaneously encouraging the intake of seafood or plant-based food, red meat was the most used protein source.

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List of Abbreviations

Abbreviation	Explanation
E%	Percentage of energy
FAO	Food and Agriculture Organization of the United Nations
FBDG	Food Based Dietary Guideline
FSA MTL	Food Standard Agency Multiple Traffic Light
GHGE	Greenhouse gas emissions
HEAS	Australian Healthy Eating Advisory Service traffic light system
LCA	Life Cycle Assesment
LL	Australian LiveLighter traffic light system
MJ	Megajoule
NNR	Nordic Nutrition Recommendations
OPP	One Planet Plate Concept
RDI	Recommended Dietary Intake
WHO	World Health Organization

Chapter 1

Background

Not only are unhealthy diets that lead to malnutrition believed to be responsible for one in five adult deaths and 15% of the total adult disability adjusted life years globally (1), but our current food system, i.e. how we produce, distribute and process food items, is also taking its toll on the environment. Globally, food production accounts for 70% of fresh water resources (2)(p5), 42-61% of land resources (2)(p6) and 21-37% of total greenhouse gas emissions (GHGE) (3). Additionally, there is growing awareness of how food production negatively impacts biodiversity, increases soil degradation and pollutes air, water and land (4–7). This is made even worse by the fact that about a third of all food produced in the world is either lost or wasted through the supply chain or at the consumer level. Food waste is the third largest contributor to the world's GHGEs (8), and accounts for 23-24% of freshwater, land and fertilizer used in food production (9). The EAT-Lancet Commission on Food, Planet, Health states that food production is the largest cause of global environmental change (10). With a growing human population, if current trends in production and consumption patterns continue, more people will end up malnourished and the stress on the environment will increase.

This is the background for the need to develop diets that are both healthy and environmentally sustainable, so called "Sustainable Healthy Diets". The World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO) define 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." (11)

1.1 The environmental impact of our food

An environmentally sustainable food system is defined by FAO as a system whose effects "on the surrounding natural environment are neutral or positive, taking into consideration biodiversity, water, soil, animal and plant health, the carbon footprint, the water footprint, food loss and waste, and toxicity." (12)

Most research that has been done on the environmental impact of different foods have focused on GHGE. Increased GHGE cause climate change, which with various degrees of certainty will result in sea level rise, ocean acidification, increased temperature and more extreme weather events such as floods and droughts (13). Among the many issues this can cause, is poorer yield and nutrition value of crops and livestock products, and in turn worse nutrition status of humans (14,15). It follows then that an unsustainable food system by itself can contribute to decreased food security in the future, that is the physical and economical access individuals have to nutritious and safe foods (2,16).

The environmental impact of foods are commonly found through life cycle assessments (LCAs), a "compilation and evaluation of the inputs, outputs, and potential environmental impacts of a product system throughout its life cycle." (17) The input in an LCA for a food product could be the raw materials used to produce farm equipment, the energy source used for heating a greenhouse or powering a tractor, the resources used to make fertilizer or feed, and how the food is packaged, distributed, processed and finally how any waste produced is handled. The result is the environmental impact (GHGE, land use, water footprint, eutrophication, acidification and/or others) per output functional unit of the food. The functional unit varies, but could be the kilo of food produced at the farm, or that reaches the consumer. Other functional units used are amounts of energy, protein and various micronutrients produced, or hectares of land used to produce a given amount of product. There are no standardised method to perform an LCA of a food, so it can be difficult to compare results between studies that have performed LCAs with various inputs, outputs and assessment of different environmental impacts.

In general, production at the farm contributes the most to a food's environmental impact, while distribution, packaging, processing, preparation and waste removal is less important (3,18,19).

There are however huge variations both within and between the same foods and food groups (see **Figure** 1.1). Details such as geographical location and available local resources, seasonality, outdoor or indoor production system, energy sources used for production, type of fertilizer and/or pest control used for crops, herd size and type of breed of animals and type of feed used for animals can all influence the environmental impact of a given food. For example, vegetables produced locally may have lower environmental impact than imported produce when in season and grown in fields, but out of season the vegetables might be grown in heated greenhouses that have a higher environmental cost than transportation from a region where they are produced in season. A food could also be environmentally sustainable when looking at one type of environmental impact, but harmful when looking at another. For example, nuts have a high water footprint while their GHGE is relatively low.

1.1.1 Difference between food groups

Multiple studies have found that industrial meat production from ruminants (beef, sheep) is the largest contributor to GHGE and land use in the agriculture sector (20,24,25). Per kilo produced, median GHGE from beef is 71 times higher than in season field grown vegetables, 53 times higher than cereals and legumes, 22 times higher than tree nuts, eight times higher than fish, seven times higher than chicken, five times higher than pork, three times higher than shrimps and prawns, and about similar to lamb (20).

The situation is more nuanced when it comes to the water footprint. There are three types of water that must be taken into account when looking at the water footprint of a food, namely blue water (surface- and groundwater), green water (rainwater) and gray water (surface- and groundwater that has been polluted) (26). Around the world, the availability of blue

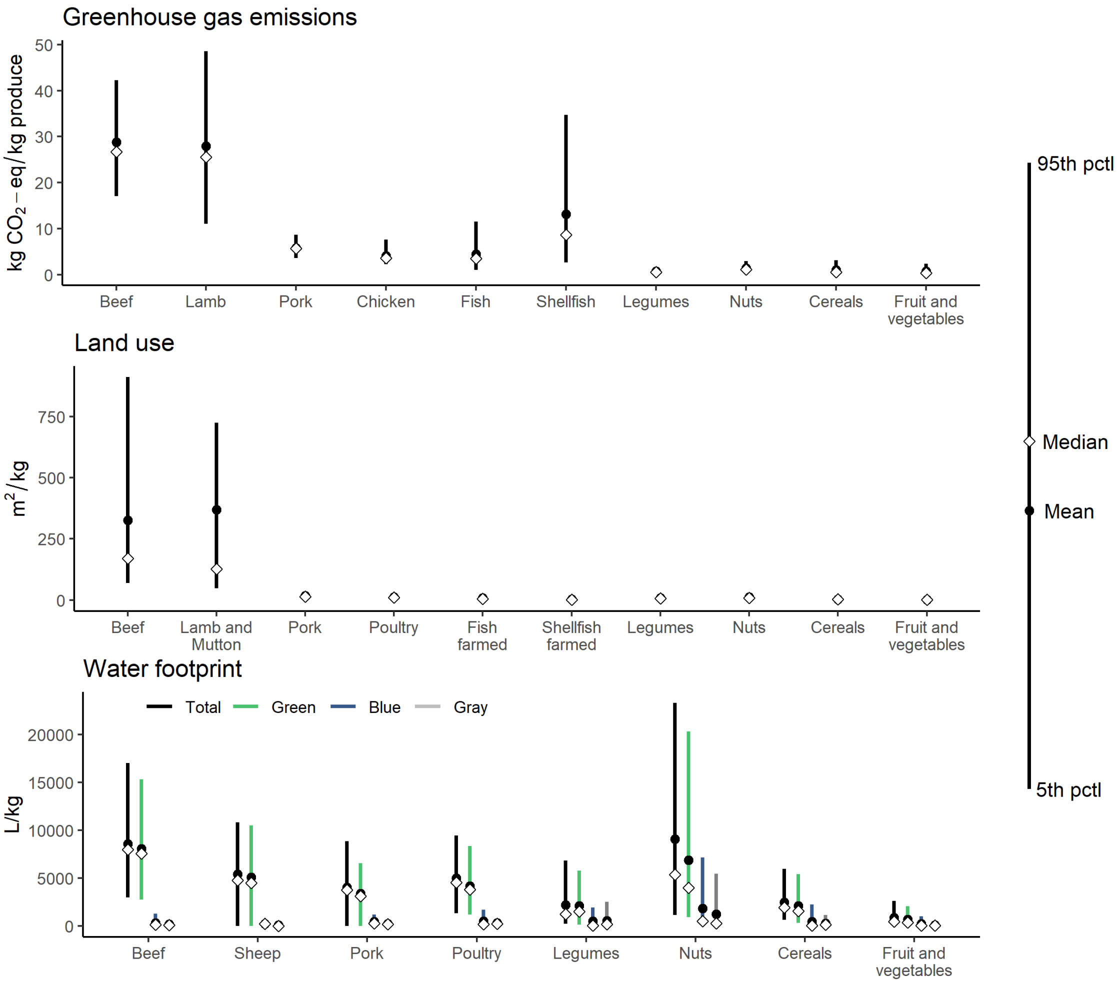

Figure 1.1: Greenhouse gas emissions (20), land (21) and water use (22,23) of various food groups.

and green water varies (27,28), and depending on the region in which food is produced it may overtax available resources. While the global average total water footprint of beef per kilo produced is higher than for other animals (2.6 times more than pork, 3.6 times more than chicken (22)), if green water is excluded the water footprint of beef is similar to that of pork and chicken (26). The global average total water footprint per kilo produced of beef is 21.8 times higher than vegetables, 9.4 times higher than cereals, 3.8 times higher than pulses and 1.7 times higher than nuts. When removing green water, beef has 5.4 times the water footprint of vegetables, 2.4 times the water footprint of cereals, about the same water footprint as pulses, and half the water footprint of nuts (22,23). There is a lack of water footprint analyses of seafood, but aquaculture in China has been found to have a similar blue and green water footprint to global levels for chicken (29).

Of land used for agriculture, about 75% is used for pastures, while the remaining 25% is used for croplands (2)(p6). The median area of land used to produce one kilo of fat and bone free meat of beef is 568 times higher than a kg of assorted vegetables, 30.4 times that of farmed fish, 19.6 times more than nuts, 15.5 times that of poultry, 14 times that of pulses, 12.7 that of pork and 1.3 times that of lamb (21).

Turning natural land into croplands or pasture is the principal cause of habitat loss for wild species, which in turn is associated with loss of biodiversity (4). The expanding use of natural lands by humans may lead to an increased exposure to infectious pathogens from animals, in the worst case leading to future pandemics (30–33). Water used for farming also shunts water away from natural ecosystems. Runoff, excess nutrients from fertilizer, can cause overgrowth of algae in rivers and other water systems at the expense of other species in a process known as eutrophication. The use of pesticides to grow crops is also associated with loss of biodiversity (4).

Organic farming practices have been shown to be less damaging to biodiversity than conventional farming, but produce lower yields so that per functional unit produced GHGE, water footprint and land use is higher (34). However, concerns have been raised that typical LCAs fail to adequately assess the full environmental impact of organic farming, and that results may be to overestimate acidification, eutrophication and global warming potential while downplaying the benefits (35).

It is important to note that looking at the environmental impact per kilo produced of a food does not take into account the amount and type of nutrients the food provides. A food could have a high environmental impact per kilo, but only be needed in small amounts to supply the necessary nutrients for good health, such as meat and dairy products. For these foods their high environmental impact per kilo may be at least partly offset by their nutrient density (36). Conversely, a food can have a low environmental impact per kilo but be of low nutrient quality, such as white sugar.

Included in LCAs of livestock production, which also entails farmed seafood, is the environmental impact of growing feed. Currently, a third of all crops grown are used to feed livestock. While some argue these crops should be used to feed humans, only about 14% of the crops used to feed livestock are fit for human consumption (37). Depending on type of lifestock, this number could be either increased or decreased. Non-ruminant (pork, poultry and farmed fish) feed consists of more human edible cereals than ruminant feed, as ruminants can be fed roughage that are not edible for humans (37–39). The rise of fish farming means that more crops will be grown for fish feed in the future, likely leading to an increase of farmed fish's water and land footprint (39). On the other hand, the increased use of crops in fish feed has come about in part due to overfishing of marine ingredients used in the feed, and the use of crops reduce the strain on these marine resources.

Additional concerns not mentioned here, but still important for sustainable farming systems, are farm worker and animal welfare, and cultural and socioeconomic aspects of food choices (40).

Returning to the broader definition of sustainable diets, a diet must not only be environmentally sustainable but also promote an individual's health and well being, while being both accessible and culturally acceptable. To various degrees, health, accessibility and acceptability have all been part of the development of so-called food based dietary guidelines (FBDGs) that provide nutritional advice for how to eat to get adequate energy and nutrients to stay healthy. More than 100 countries either have or are developing a FBDG for their population (41,42).

1.2 Dietary guidelines

Even though there are differences between countries and regions, FBDGs around the world share similarities such as qualitative recommendations to eat high quality whole foods within one's energy requirements, include a variety of colorful vegetables (starchy roots and tubers are generally not counted as a vegetable in these instances) and fruit and other fiber rich foods such as whole grain cereals, legumes and nuts, consume fish and dairy foods, and have a low intake of processed foods, saturated fat, added sugar and salt (41). This is also true of other healthy dietary patterns, such as the Mediterranean diet (43) or the New Nordic diet

(44). To make it easier to know how much to consume to eat a healthy diet, recommendations can also be quantitative by defining the number of portions and/or portion sizes. A well known example is to eat five portions of fruits and vegetables a day. In high income countries, it is also common to include a maximum red meat intake, like <500 grams/week (41). A few countries advise that home cooking and cooking skills are beneficial for healthy dietary habits (45–47).

FBDGs are often presented to consumers with images that show various food groups and their proportion in relation to each other in a healthy diet. An example is the Norwegian "diet circle" that can be seen in **Figure** 1.2.

Figure 1.2: The Norwegian diet circle, an illustration of how various food groups should contribute to a healthy Norwegian diet (48).

The largest food groups in such visualizations are starchy staples like grains and grain-based products, starchy roots and tubers, fruit and vegetables and legumes (41). These food groups provide, among a multitude of beneficial micronutrients and other compounds, carbohydrates to the diet in the form of starch, sugar and fiber. The importance of these foods is also reflected in different guidelines recommendations for macronutrient intake, where recommended percentage of energy intake (E%) from carbohydrate is relatively high compared to the other energy-providing macronutrients protein and fat (49).

Recently FBDGs have started to address environmental sustainability. FBDGs from Brazil (45), Canada (47), Denmark (50), France (51), Germany (52), Netherlands (53), Sweden (54), and Qatar (55) include advice on how to eat not only for individual health, but also in an environmentally sustainable manner. Environmental impact will also be included in the new Nordic Nutrition Recommendations (NNR) for 2022, that will be used as a basis for FBDGs in the Nordic and Baltic countries (56). It is likely that even more countries are working on this.

Following a predominantly plant-based diet rich in whole grains, legumes, nuts, fruit and vegetables with low to moderate consumption of animal sourced foods is an advice commonly given to consumers that want to be environmentally friendly, while still eating healthy (10,50,53–55). In the case of water footprint, total water footprint might decrease by reducing the intake of animal sourced foods, but this could come at the cost of a higher blue water footprint (57), putting strain on water scarce areas. This is especially true when animal sourced foods are reduced while intake of water intensive nuts, fruits or cereals are increased, made worse by the fact that these foods may be grown in areas with water scarcity (57,58).

Animal sourced foods are generally nutrient dense, and they are not required in large amounts in the diet to provide necessary nutrients for good health (10). If eliminating animal sourced foods completely, as when following a vegan diet, special focus must be placed on vitamin B12, vitamin B2, vitamin D, iodine, zinc, calcium and selenium as these nutrients are either not present in plant-based foods (vitamin B12) or more difficult to obtain (59). Other advice presented in FBDGs that include environmental impact is to eat local, seasonal produce and choose organic if possible, and to reduce intake of discretionary and nutrient poor foods such as confectionery.

By following national FBDGs, an individual should meet their recommended dietary intake

(RDI) of all nutrients, and thus support their good health and well-being. Unfortunately, many studies have found that adherence to FBDGs is low, especially when it comes to intake of healthy and relatively sustainable foods such as fruit and vegetables, legumes, whole grain cereals, nuts and seeds, fish and dairy, and for unhealthy foods high in sugar, salt and/or saturated fat (60–68). This pattern is seen in all age groups, genders and socioeconomic groups, but lower adherence to FBDGs is more prevalent in lower socioeconomic groups. Low adherence is associated with increased risk of malnutrition and associated diseases. In 2013 FAO estimated that the costs of malnutrition in the world could be as high as US $3.5 trillion (69).

There is wide consensus that a higher adherence to healthy dietary habits such as following national FBDGs would lower disease burden of individuals globally and substantially decrease health costs (70–72). The Institute for Health Metrics and Evaluation has in their Global Burden of Disease series quantified how low adherence to different advice found in FBDGs contribute to mortality and disease risk in 195 countries (1). Both globally and in most of the included countries, the leading causes of diet related mortality and disability adjusted life years were high salt intake and low intake of whole grain cereals, fruit, nuts and seeds and vegetables. Additionally, on a global level the consumption of meat is higher than what is needed for good health (62). However, while many high-income countries would benefit from a lower intake of meat, in other parts of the world an increase in meat intake could be beneficial due to poor nutritional status in the population (10,73). It is clear that by improving adherence to dietary guidelines the environmental impact of our diets would decrease, as it would mean an increased intake of foods with a low environmental impact at the expense of high environmental impact foods (74,75).

To make good dietary choices, the population must have nutritional literacy: "the ability to critically analyze nutrition information, increase awareness and participate in action to address barriers to healthy eating behaviors." (76,77). Low nutritional literacy, which typically includes difficulty finding and interpreting reliable nutrition information, has been associated with low adherence to healthy dietary habits (78–81). Concerns have been raised that contradictory messaging on diet and health, for example in news media, cause confusion and lower intentions to follow healthy dietary advice (82–85). These concerns could also apply to making food choices with low environmental impact, especially as consumers tend to associate healthiness with environmental sustainability (86–89).

It is beyond the scope of this thesis to include a comprehensive review of the literature on the systemic and individual factors that underlie food choice that in turn influence the healthiness and sustainability of ones diet, but for a more thorough discussion of the science, read the review by Chen and Antonelli (90). In short, the availability, accessibility and affordability of healthy foods in the environment, together with individual food preferences, cultural norms and knowledge of the relationship between diet and health all play a role.

An interesting environmental factor that could influence which foods are consumed is recipes (91). Analysis of food and nutrient content in recipes have been suggested as a way to follow food trends and dietary patterns in a population (92,93), and to monitor the relationship between food consumption and health (94). This could also be true for the other domains of sustainable diets. Using recipes could be a less resource intensive method to gather dietary information than typically used food-frequency questionnaires, dietary interviews or food diaries.

1.3 Recipes in nutritional research

Cooking dinners at home has been associated with improved dietary quality and higher adherence to healthy dietary patterns like FBDGs (95–97), although clinical relevance is uncertain. Still, in a recent European survey with more than 27 000 respondents, more than 40% of European consumers believe cooking at home is part of a sustainable diet (87). Meal planning, of which recipes can be an integral part, is also a tool consumers can use to reduce their food waste, and by that reduce the environmental impact and cost of their diets making it more sustainable (98).

While cooking at home and meal planning can be part of sustainable diet habits, this will depend on the type of meals that are prepared. Consumers find inspiration for what meals to cook in various sources, such as cookbooks and on the Internet (91). Recipes from cookbooks, internet recipe sites, blogs and retailer magazines have garnered attention as they have a large reach, and could potentially influence the food choices of many.

Several studies have looked at how well recipes found in cookbooks (99–101), supermarket magazines (102), food blogs (103–105) or other Internet recipe sites (101,106,107) compare to dietary guidelines and/or other classification schemes for healthy meals such as various front-of-pack nutrition labeling systems. A limitation of these studies is the lack of micronutrient content analysis besides sodium, and little mention of the food based dietary advice found in FBDGs such as intake of whole grains or lean fish. Still, results are sobering as most recipes studied do not comply with healthy dietary principles as defined in the studies. Less is known about how recipes align with the other domains of sustainable diets.

1.4 Thesis aims

This thesis aim to explore a selection of recipes from the United Kingdom (UK), Norway and the United States of America (US), from cookbooks (UK) and the Internet (Norway, US), and compare two domains of sustainable diets, namely health and environmental sustainability. To build on previous studies on recipe's healthiness, a comprehensive analysis of recipe's nutrient content and inclusion of foods encouraged in FBDGs will be included.

The following research questions are asked:

1: To what extent do recipes from Norway, the UK and the US comply with healthy dietary guideline principles, and to what extent does environmental sustainability relate to healthiness?

2: To what extent does a recipe's healthiness and environmental sustainability depend on country of origin?

Chapter 2

Methods

2.1 Data

To assess how well recipes comply with healthy dietary guideline principles and to what extent a recipe's healthiness is related to its environmental impact, 400 recipes from Norway, and 100 from each of the US and the UK were analysed. Recipes from different countries were used to make a cross-country comparison of recipe healthiness and environmental impact.

Recipes from Norway and the US came from a recipe database collected previously as described in Trattner et al (108) and is available from Christoph Trattner. For this database Norwegian recipes had been collected between June-September 2018, and US recipes in the Summer of 2015. The 400 Norwegian recipes used in this thesis came from Klikk.no (n = 100), Tine.no (n = 100), Aperitif.no (n = 100) and Kolonial.no (n = 100)[1]. Recipes from the US came from Allrecipes.com (n = 100). The UK recipes came from a random selection of UK celebrity chef's recipe books previously used to study the healthiness of television chef's recipes (100): 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).

[1]Since recipe collection Kolonial has been renamed Oda.

2.2 Calculating nutritional content and environmental impact of the recipes

The dataset used included information about each recipe's energy, macronutrient and sodium content. However, for a more detailed macro-and-micronutrient comparison between the countries, and correlation analysis between healthiness, nutrients and environmental impact, the ingredients from each recipe were mapped to the 2020 Norwegian Food Composition Datatable Matvaretabellen (109), that contains information about the macro- and micronutrient content per 100 grams of commonly consumed foods in Norway. The nutrients included in the analyses were all macronutrients, excluding alcohol but including saturated fat and added sugar, and also all minerals and vitamins listed in Matvaretabellen If an ingredient in a recipe was not listed in Matvaretabellen the US equivalent, Agricultural Research Service FoodData Central food database (110), was used. If the ingredient could not be found in either database it was exchanged for a similar ingredient, for example beef liver was used instead of veal liver.

To explore potential beneficial amounts of nutrients in the recipes, the nutrient content was compared to the European Union commissions nutrition claims legislation (111). For micronutrients, a recipe was considered a source of the nutrient if it contained >15% of the RDI of an adult Norwegian woman (112), and a good source if it contained >30% of the RDI per 100 grams. For protein the amounts were 12 and 20 E% respectively, and for dietary fibre 3 and 6 grams/megajoule (MJ).

To calculate a recipe's environmental impact, the SHARP Indicators database was used (25). The SHARP Indicators database is a public database of certain environmental impacts of different foods, namely greenhouse gas emissions (in kilo CO_2 equivalents) and land use (in m^2 pr year) per kg of an ingredient/food. The database includes information on 944 foods commonly consumed in the four European countries Denmark, Czech Republic, Italy and France. The environmental impact in the database comes from life-cycle inventory data on 182 primary products, and many composite foods based on these primary products. These LCAs included the environmental impacts of primary production of the food, and the impact of its packaging, transport to supermarket/consumer, storage at the supermarket/consumer, final preparation and any waste produced throughout.

The nutrient content and environmental impact of each recipe was found by summing the values for all ingredients in the recipe. Nutrient content and environmental impact was also calculated separately for recipes using different sources of protein: Beef, lamb, game, pork, poultry, lean fish, oily fish, shellfish, vegetarian or vegan. This was done as dietary guidelines often recommend protein sources, such as encouraging fish intake while advising a limited intake of red meat. Recipes were grouped into the different categories using the food groups from the SHARP indicators database and individual ingredient names. Recipes that contained no ingredients that were of animal origin were labeled "Vegan", recipes that contained eggs and/or dairy but no other animal sourced ingredients were labeled "Vegetarian", while recipes that contained a majority of one animal source of protein was labeled as such. For example a recipe might contain cod and a smaller amount of bacon, and be labeled as "lean fish".

Some ingredients were listed in the recipe with either volume units or number of pieces. Before calculating the nutritional content and environmental impact of these ingredients, standardised weight equivalent was found by primarily using the "Weights, measures and portion sizes for foods" database from The Norwegian Directorate of Health (113). If the ingredient was not in this database the U.S. Department of Agriculture, Agricultural Research Service FoodData Central food database (110) was used, the ingredient was found in the online shops of Meny, Kolonial or COOP, or measured at home.

Some recipes included composite ingredients, such as pastry or pizza dough, not present in either nutrient databases or the SHARP Indicator database. For these ingredients a recipe was found through an online search, similar to how the inventors of the SHARP Indicator database looked up composite foods (25). Nutrient content, CO_2 emission and land use were calculated for the composite ingredient and normalised to per 100 grams of the ingredient, before being added to the recipe like any other ingredient.

For both the environmental sustainability indicators and nutritional information, values were normalised to per 100 grams of a recipe.

2.3 Recipe healthiness

Recipes were scored on how well they adhered to the dietary guidelines macronutrient ranges supplied by the WHO (114) and the NNR (115), see **Table** 2.1. The WHO guidelines have been used in previous studies (100,101,103–107), and the NNR were chosen as they are used in Norway and are closer to the dietary guidelines from the UK (116) (p7) and the US (117) (p135) than the WHO guidelines. A recipe would receive one point for each recommendation in the guideline it adhered to, giving a total score between 0-6. For example a recipe could score one point for having between 15-30 E% coming from fat. A higher score indicates higher adherence to the guideline.

Table 2.1: Scoring system for the dietary guidelines from World Health Organization and the Nordic countries.

	Dietary guidelines	
Nutrient	World Health Organization	Nordic Nutrition Recommendation
Fat	15-30 E%	25-40 E%
Saturated fat	<10 E%	<10 E%
Carbohydrate	55-75 E%	45-60 E%
Added sugar	<10 E%	<10 E%
Dietary fibre	≥3 g/MJ	≥3 g/MJ
Protein	10-15 E%	10-20 E%

Note:
Abbreviations used: E% = Energy percent, MJ = Megajoule.

For these analyses, energy providing nutrients fat, saturated fat, carbohydrates, added sugar and protein were recalculated to E%, and dietary fibre to grams/MJ, from the original raw values of grams found in the nutrient databases.

Energy percentage of each of the nutrients were found by first calculating the amount of kilocalories provided by each nutrient: multiplying the amount in grams of fat and saturated fat by nine, and for carbohydrates, sugar added sugar and protein by four. This was then divided by the total amount of kilocalories per 100 grams and multiplied by 100. Grams of fibre per MJ was found by dividing the amount of fibre in grams by the energy in MJ.

Additionally, the recipes were assessed as to how well they adhered to the UK Food Standard

Agency multiple traffic light system (FSA MTL), and the French Nutriscore system (used in several countries in Europe). These scoring systems are front-of-pack nutrition labels, that have been created to provide consumers at-a-glance information about a single food's nutrient qualities and guide healthier food choices. The FSA MTL looks at a food's fat, saturated fat, sugar and salt content, and gives each category a score between green "low", amber "medium" and red "high" depending on how much of the nutrient the food contains per 100 grams, see **Table** 2.2. Consumers are advised to choose foods with more green and amber than red (118). Foods with mostly green is a "healthier choice", foods with all or mostly amber can be eaten "most of the time", and foods with mostly red should be eaten less often and in low amounts. In a previous study by Howard et al. (100) the FSA MTL was turned into a numeric score by using a score of 1 for "low", 2 for "medium" and 3 for "high", and a food could score between 4-12, with a lower score being a healthier choice. To be in line with the dietary guideline recommendations where a higher score indicates better adherence, the scoring system by Howard et al. was inverted for this thesis. This means that a total score of seven or more will correspond to a food having mostly amber colored nutrients (three amber and one red) and can be eaten "most of the time".

Table 2.2: Scoring system for the UK Food Standard Agency multiple traffic light system

	Green/Low	Amber/Medium	Red/High
Nutrient	Healthier choice	Can be eaten most of the time	Eat less often
Salt	≤0.3g/100g	>0.3g to ≤1.5g/100g	>1.5g/100g
Fat	≤3.0g/100 g	>3.0g to ≤17.5g/100g	>17.5g/100g
Saturated fat	≤1.5g/100g	>1.5g to ≤5.0g/100g	>5.0g/100g
Added sugar	≤5.0g/100g	>5.0g to ≤22.5g/100g	>22.5g/100g

The Nutriscore is similar, but it builds on the FSA MTL by also taking into account the amount of energy and protein in a food, in addition to the amount of fibre, fruit, vegetables, pulses and nuts and the healthy fats olive oil, rapeseed oil and walnut oil (119,120). In the Nutriscore system, a food can receive between 0-10 points for each of the "disqualifying" categories energy, added sugar, saturated fat and sodium, and 0-5 points for the "qualifying" categories of protein, fibre, and the percentage of fruit, vegetables, pulses and nuts and the healthy fats olive oil, rapeseed oil and walnut oil per 100 grams of the food (121). In contrast to the FSA MTL, the Nutriscore is a summary score and does not provide the consumer with the individual scores from each category.

The points from the qualifying categories are subtracted from the points from the disqualifying categories, see **Table** 2.3, giving a total score between -15 to +40, and a lower score indicates a more healthy and nutritious food. The points correspond to a colored grading system between a dark green A (most healthy) and a dark orange E (least healthy). Consumption of foods that score green/A, is encouraged, while consumption of foods that score dark orange/E is advised to be limited (122). As with the FSA MTL, an inverted scoring system is used in the analyses in this thesis. An inverted score of minus two or more, corresponding to a light green B or dark green A, was chosen as the cut-off for a food that could be eaten often as part of a healthy diet. This score has also previously been used to study if the Nutriscore is in alignment with national FBDGs (123).

Table 2.3: Scoring system for Nutriscore.

	Disqualifying				Qualifying		
Points	Energy density	Added sugars	Saturated fat	Sodium	Fruits, vegetables, pulses, nuts and rapeseed, walnut and olive oils	Dietary fibre	Protein
0	$\leq$ 335 kJ	$\leq$ 4.5 g	$\leq$ 1 g	$\leq$ 90 mg	$\leq$ 40 %	$\leq$ 0.9 g	$\leq$ 1.6 g
1	> 335 kJ	> 4.5 g	> 1 g	> 90 mg	> 40 %	> 0.9 g	> 1.6 g
2	> 670 kJ	> 9 g	> 2 g	> 180 mg	> 60 %	> 1.9 g	> 3.2 g
3	> 1005 kJ	> 13.5 g	> 3 g	> 270 mg	-	> 2.8 g	> 4.8 g
4	> 1340 kJ	> 18 g	> 4 g	> 360 mg	-	> 3.7 g	> 6.4 g
5	> 1675 kJ	> 22.5 g	> 5 g	> 450 mg	> 80 %	> 4.7 g	> 8.0 g
6	> 2010 kJ	> 27 g	> 6 g	> 540 mg	-	-	-
7	> 2345 kJ	> 31 g	> 7 g	> 630 mg	-	-	-
8	> 2680 kJ	> 36 g	> 8 g	> 720 mg	-	-	-
9	> 3015 kJ	> 40 g	> 9 g	> 810 mg	-	-	-
10	> 3350 kJ	> 45 g	> 10 g	> 900 mg	-	-	-

The percentage of fruit, vegetables, pulses, nuts and healthy fats were found by summing the amounts of ingredients found in the food groups “Fruit and fruit products”, “Vegetable and vegetable products”, “Fruit/vegetable juice and nectar” and “Legumes, nuts, seeds” from the SHARP Indicator database, in addition to the amounts of olive, rapeseed and walnut oil per 100 grams of the recipe.

2.4 Statistical analyses

2.4.1 Missing data

Ingredients with no amounts were replaced with the mean value of that ingredient in all other recipes, normalised to per 100 grams of the recipe. If this was not possible, ingredients were left out of the analyses. Ingredients that could not be found in the food composition or environmental 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 or SHARP Indicators database, the recipe was left out.

2.4.2 Significant differences between countries

Significant differences in energy per 100 grams, macronutrient content in percentage of energy, micronutrient content in percentage of the RDI of an adult woman in Norway (112), healthiness scores and environmental sustainability indicators between recipes from the different countries were assessed using the Kruskal-Wallis test. The Kruskal-Wallis test is a non-parametric test to look for differences between more than two groups (124). A significant result means that there is a significant difference between at least two groups, but the test cannot say which groups. To identify the groups that were different from each other a *post-hoc* pair-wise comparison was done using the Dunn’s test (125). To account for multiple testing the Benjamini Hochberg (BH) method was used (126). An adjusted p-value < 0.05 was considered significant.

All tests were done using the rstatix package v. 0.7.0 (127).

2.4.3 Network analysis of co-occurring nutrients

A healthy diet contains adequate amounts of all the nutrients the body needs. To achieve this dietary guidelines often recommend a varied diet as different food groups contribute different nutrients to the diet. To explore which nutrients that could be found together in a recipe, multiple graphs were built using tidygraph v. 1.2.0 (128). A graph is an object that contains nodes and edges, where nodes are variables and edges the connection between them. The edges may be directed or undirected, depending on if the relationship between the nodes are bidirectional or not (129). For this analysis, the nodes in the graph were nutrients that a recipe was either a source or a good source of, with undirected edges connecting nutrients that were found in the same recipe. One graph was constructed for each of the recipe categories: Beef, lamb, game, pork, poultry, lean fish, oily fish, shellfish, vegetarian or vegan, and the number of recipes that were considered a source was normalised to the number of recipes in the recipe category. The graph objects were visualised using ggraph v. 2.0.5 (130), using the default “stress” layout.

2.4.4 Correlation analysis

To explore possible correlation between variables, the nonparametric test Spearman’s rho (131) was calculated using the Psych library v. 2.1.6 (132) corr.test function. 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 and an adjusted p-value < 0.05 was considered significant.

Chapter 3

Results

3.1 Data completeness

Of 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. This was a recipe for “Fresh mackerel”. Five additional Norwegian recipes were excluded as they were not dinner recipes.

For all three countries, the median percentage of the weight of the recipe that was mapped to a nutrient database or the SHARP Indicators database was 100, and the interquartile range was 100, 100. See **Appendix Figure** A.1.

Eight recipes (six Norwegian, two US) were not included in the analysis as >10% of their ingredients in weight could not be mapped to the nutrient or SHARP Indicators database. The ingredients that contributed to this were sheep head, marrow bones, fish bones, bananas, plantains, pure gluten flour and tamarind juice, ingredients which would be expected to impact either the health or environmental sustainability outcomes.

3.2 Recipes healthiness and environmental impact

Recipes scored better on the front-of-pack labeling criteria than the dietary guidelines. Only 7% and 10.5% of recipes complied with four or more of the WHO and NNR guideline criteria respectively, while 71% received an inverted Nutriscore > -2 and 99% scored >7 on the inverted FSA MTL. Table A.1 and Table A.2 show the number of recipes that received a specific score on either front-of-pack label or dietary guidelines respectively. The median score for WHO guideline compliance was 1 (IQR 1, 2), for NNR 2 (IQR 1, 3), inverted Nutriscore 0 (IQR -3, 2) and for the inverted MTL 9 (IQR 8, 10), see **Figure** 3.1A. The median kg CO_2 equivalent emissions were 0.5 (IQR 0.3, 0.9) and the median m^2 land used per year were 0.6 (IQR 0.3, 1.2), see **Figure** 3.1B.

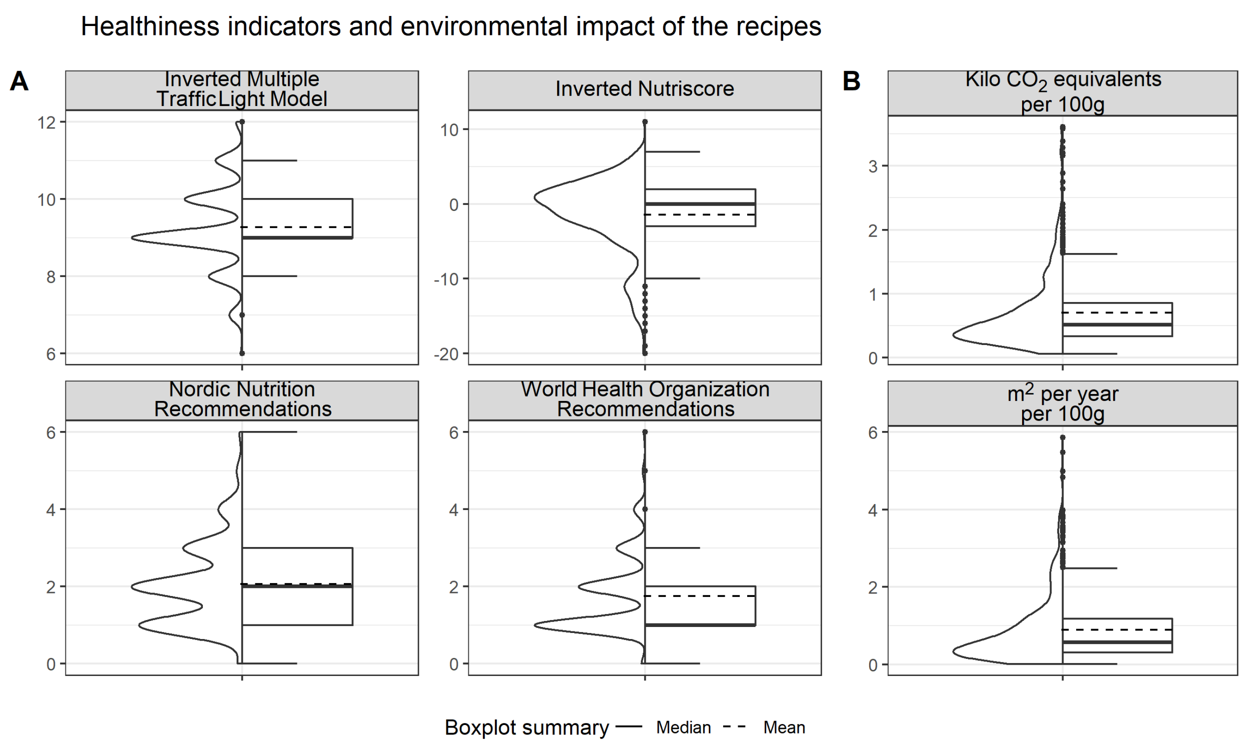

Figure 3.1: (A) The recipe's scores on the healthiness indicators the inverted French Nutriscore and UK Multiple Traffic Light system, in addition to the dietary guidelines from the World Health Organization and the Nordic Nutrition Recommendations. (B) The environmental impact of the recipes in kilo CO_2 equivalents and m^2 per year. All values are per 100 grams of the recipes.

Figure 3.2 show the variables used to calculate the guideline scores: energy content, percentage of energy from each macronutrient and the amount of dietary fibre in g/MJ for the recipes. For all but sugar content, the median percentage of energy or density per MJ of these nutrients were outside the recommended intake range for both the WHO and NNR guidelines. The median energy content in kilocalories per 100 grams was 141 (IQR 105.7, 184.6). The macronutrient that contributed most to energy content was total fat, with a median percentage of energy of 47.4 (IQR 35.1, 58.7), followed by protein (median 23.4, IQR 18.1, 30.4) and carbohydrates (median 22.2, IQR 12.6, 35.8). The median percentage of energy from saturated fat was 16.3 (IQR 9.8, 22.9).

The energy contribution of added sugar was negligible in most recipes, but were >25% in a handful, while the median dietary fibre in grams/MJ were 1.9 (IQR 1.1, 3.0). In regards to dietary fibre, few recipes that had grains as an ingredient specified that whole grains should be used (not shown).

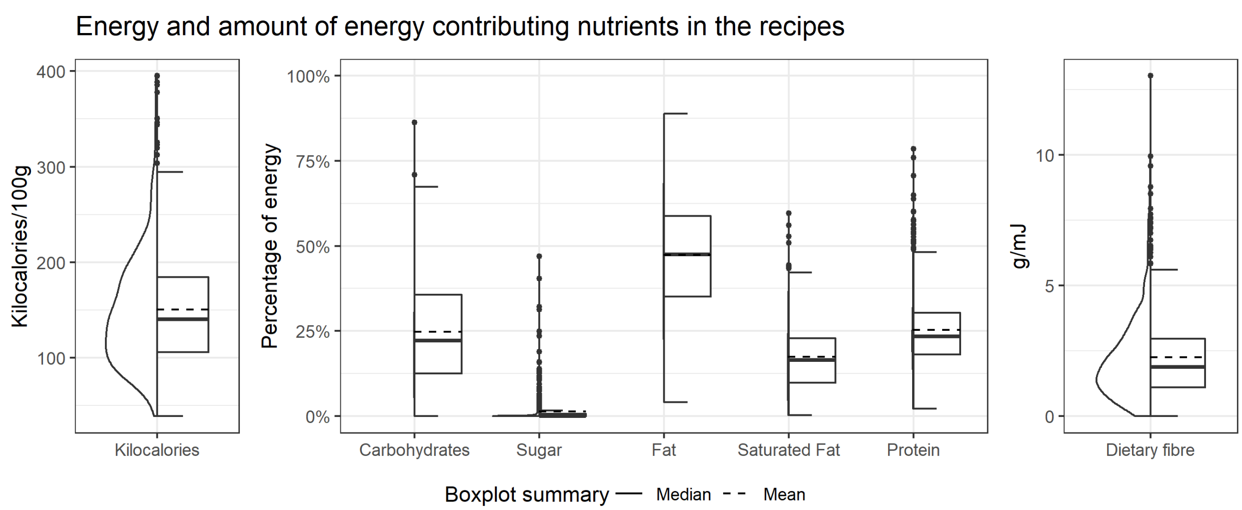

Figure 3.2: Energy content per 100 grams and the contributions of each of the macronutrients in addition to fiber content in the recipes.

In terms of micronutrients, per 100 grams the recipes contributed most to the percentage of RDI of vitamin B12 (median 25, IQR 10, 48), phosphorus (median 19, IQR 15, 23) and vitamin B6 (median 14, IQR 9, 20). On the other end, recipes contributed least to percentage of RDI of vitamin D (median 2, IQR 1, 7), iodine (median, 3 IQR 1, 5) and calcium (median 3, IQR 2, 6). Recipes contained more vitamin A in the form of retinol than beta-carotene. For the micronutrients copper, iodine, selenium, sodium, phosphorus, vitamin A, D, E, B2 (riboflavin), B9 (folate) and B12 a handful of recipes could deliver more than the RDI per 100 grams. See **Figure** 3.3.

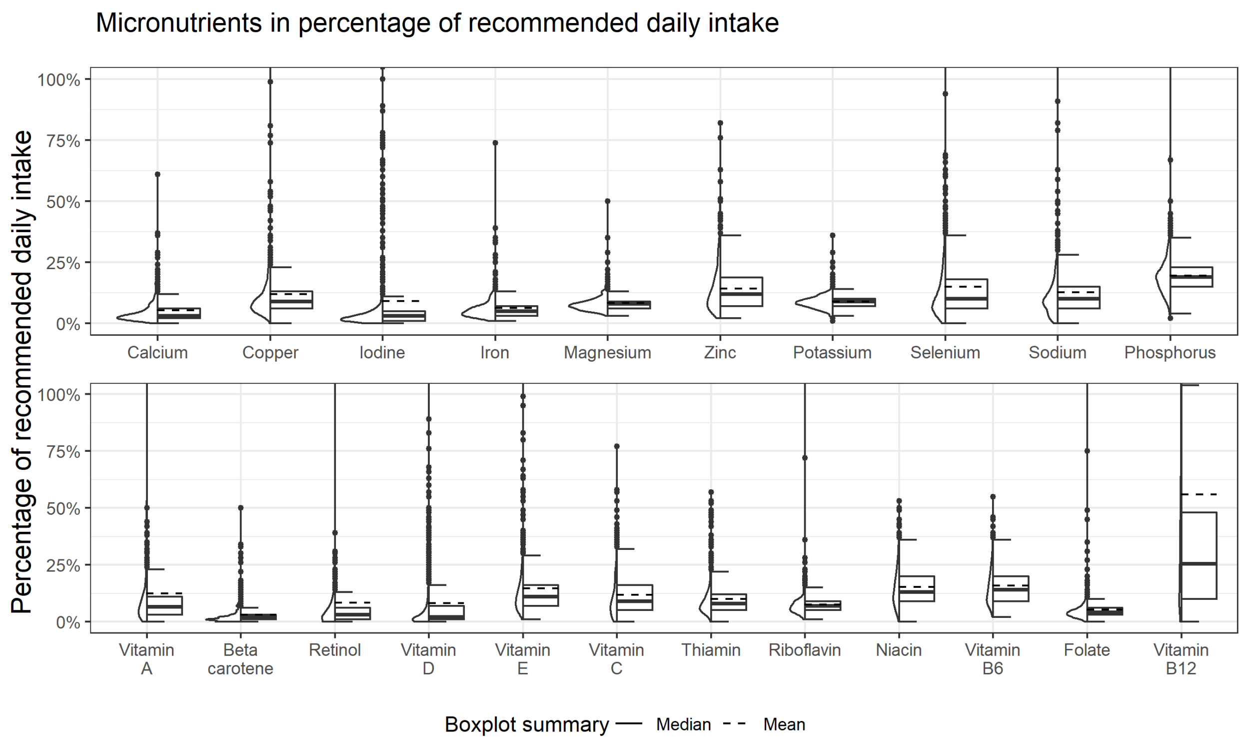

Figure 3.3: Micronutrient content in the recipes per 100 grams, in percentage of recommended daily intake.

3.2.1 Comparison between countries

Of the 35 variables assessed, 19 were significantly different (adjusted p-value <0.05) between at least two countries in the Kruskal-Wallis test, so a *post-hoc* Dunn test was performed.

3.2.1.1 Healthiness indicators

As seen in **Figure** 3.4, significant differences between countries were found in three of the four healthiness indicators assessed: the inverted Nutriscore (UK > Norway: adjusted p-value <0.05; UK > US: adjusted p-value <0.05), the NNR guideline criteria (UK > Norway: adjusted p-value <0.01; UK > US: adjusted p-value <0.001; Norway > US: adjusted p-value

< 0.05) and the WHO guideline criteria (UK > Norway: adjusted p-value <0.05; UK > US: adjusted p-value <0.01).

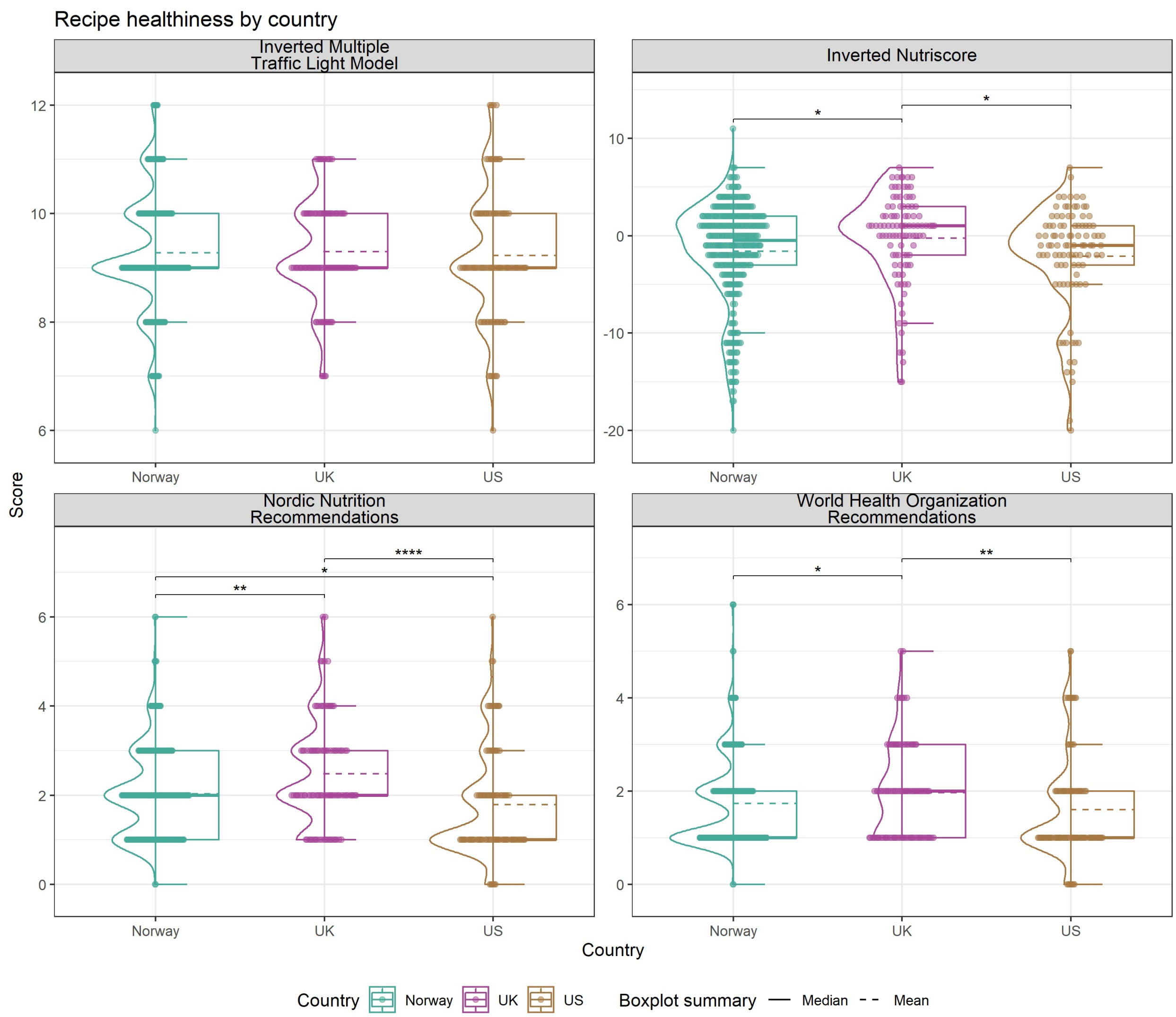

Figure 3.4: The healthiness of the recipes based on the dietary guidelines from the World Health Organization and Nordic Nutritional Recommendations, and the inverted Multiple Traffic Light model from the UK and the inverted Nutriscore from France.

Only a few recipes complied with WHO and NNR guideline criteria for carbohydrates, but more were 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. For dietary fibre, saturated fat and added sugar the guideline recommendations are identical so there are no differences in adherence. Protein contributed most to the qualifying scores on the Nutriscore for recipes from all countries. Recipes from the UK did better on dietary fibre criteria on both dietary guidelines and the Nutriscore than recipes from other countries. For the scores for each component of the healthiness indicators by country, see **Figure** A.3, **Figure** A.2 and **Figure** A.4 for the guidelines, Nutriscore and the MTL respectively.

3.2.1.2 Environmental impact

Significant differences between countries were also found for the environmental impact indicators: kilo CO_2 emissions (US > UK: adjusted p-value <0.001; US > Norway: adjusted p-value <0.05; Norway > UK: adjusted p-value <0.05), and land use (US > UK: adjusted p-value <0.01; US > Norway: adjusted p-value <0.01), See **Figure** 3.5

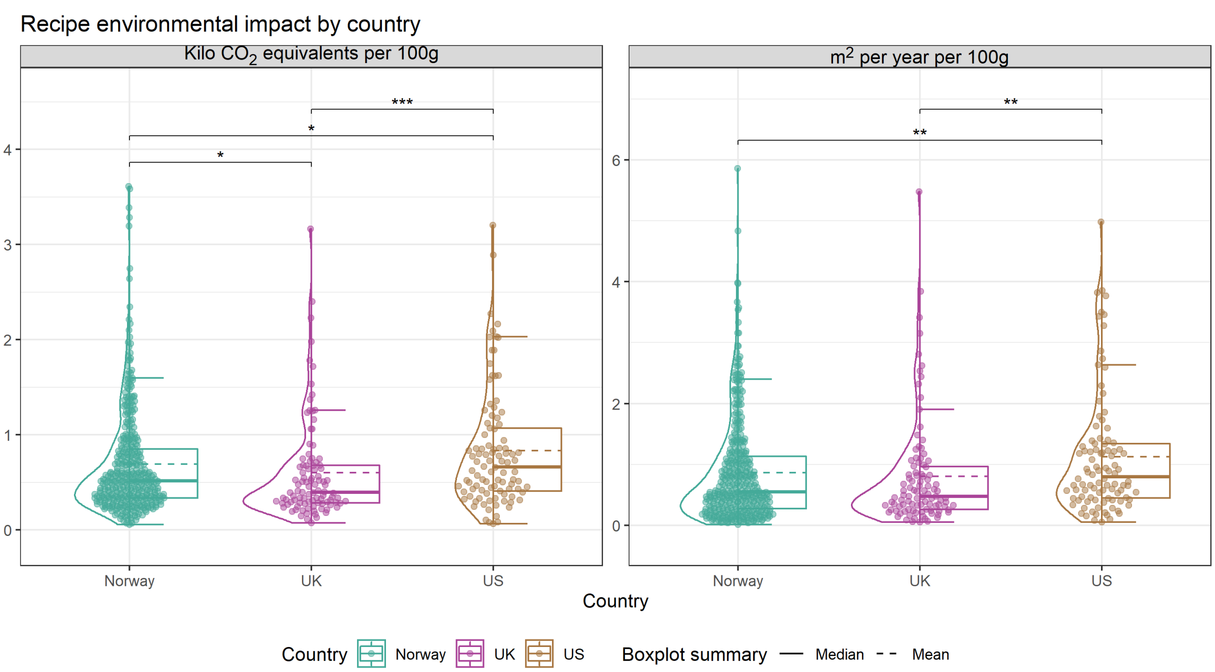

Figure 3.5: The environmental impact in kilo CO_2 equivalents and m^2 used per year per 100 grams of the recipes.

3.2.1.3 Individual nutrients

In terms of individual nutrients, significant differences were seen for dietary fibre (UK > US: adjusted p-value <0.001; UK > Norway: adjusted p-value <0.001), vitamin C (UK > US: adjusted p-value <0.001; UK > Norway: adjusted p-value <0.01; Norway > US: adjusted

p-value <0.05), protein (US > UK: adjusted p-value <0.01; US > Norway: adjusted p-value < 0.05) and vitamin B12 content (Norway > UK: adjusted p-value < 0.05; Norway > US: adjusted p-value < 0.05). While there were other statistically significantly different micronutrients, in absolute numbers the difference between countries were negligible, see **Table** 3.1.

Table 3.1: Kruskal Wallis and Dunn test results.

	Median (IQR)			Kruskal-Wallis test, BH corrected		Dunn test, BH corrected	
	Norway	UK	US	Adj. p-value	Effect size (95% ci)	Pairwise	Adj. p-value
Environmental impact							
kg CO_2 equivalents	0.5 (0.3, 0.9)	0.4 (0.3, 0.7)	0.7 (0.4, 1.1)	<0.01	0.02 (0-0.05)	Norway - UK	<0.05
						Norway - US	<0.05
						UK - US	<0.001
Landuse m^2/year	0.6 (0.3, 1.1)	0.5 (0.3, 1)	0.8 (0.4, 1.3)	<0.01	0.02 (0-0.05)	Norway - US	<0.01
						UK - US	<0.01
Healthiness indicators							
Inv. Nutriscore	-0.5 (-3, 2)	1 (-2, 3)	-1 (-3, 1)	<0.05	0.01 (0-0.04)	Norway - UK	<0.05
						UK - US	<0.05
NNR Score	2 (1, 3)	2 (2, 3)	1 (1, 2)	<0.001	0.04 (0.01-0.08)	Norway - UK	<0.01
						Norway - US	<0.05
						UK - US	<0.001
WHO Score	1 (1, 2)	2 (1, 3)	1 (1, 2)	<0.05	0.01 (0-0.05)	Norway - UK	<0.05
						UK - US	<0.01
Macronutrients							
Protein E%	23.1 (18.1, 29.7)	20.9 (17.3, 29.9)	25.8 (21.2, 32)	<0.05	0.01 (0-0.04)	Norway - US	<0.05
						UK - US	<0.01
Dietary fibre g/MJ	1.8 (1.1, 2.8)	2.6 (1.5, 3.7)	1.4 (0.7, 2.7)	<0.001	0.04 (0.02-0.09)	Norway - UK	<0.001
						UK - US	<0.001
Sugar E%	0 (0, 0.5)	0 (0, 0.5)	0.1 (0, 1.8)	<0.05	0.01 (0-0.04)	Norway - US	<0.05
						UK - US	<0.05
Vitamins							
Vitamin D % of RDI	2.5 (1, 9)	1 (0, 3)	2 (1, 5.8)	<0.001	0.04 (0.01-0.08)	Norway - UK	<0.001
						UK - US	<0.05
Vitamin C % of RDI	8 (5, 15)	13 (7, 21)	6.5 (3, 12)	<0.001	0.04 (0.01-0.08)	Norway - UK	<0.01
						Norway - US	<0.05
						UK - US	<0.001
Thiamin % of RDI	7 (5, 11)	9 (6.8, 12)	9 (5, 14)	<0.05	0.01 (0-0.04)	Norway - UK	<0.05
Niacin % of RDI	13 (9, 20)	11 (8, 18)	15 (9, 23)	<0.05	0.01 (0-0.04)	UK - US	<0.05
Folate % of RDI	4 (3, 6)	5 (3, 8)	3 (2, 4)	<0.001	0.06 (0.03-0.11)	Norway - UK	<0.01
						Norway - US	<0.001
						UK - US	<0.001
Vitamin B12 % of RDI	30 (11, 51)	22.5 (6, 43)	17.5 (9.2, 38)	<0.05	0.01 (0-0.04)	Norway - UK	<0.05
						Norway - US	<0.05
Minerals							
Copper % of RDI	8.5 (6, 13)	11 (7.8, 18.2)	7 (5, 11)	<0.001	0.04 (0.01-0.08)	Norway - UK	<0.001
						UK - US	<0.001
Iodine % of RDI	3 (2, 6)	2 (1, 5)	2 (1, 4)	<0.05	0.01 (0-0.04)	Norway - US	<0.05
Iron % of RDI	5 (3, 7)	6 (4, 8)	5 (4, 7.8)	<0.01	0.02 (0-0.05)	Norway - UK	<0.01
Potassium % of RDI	8.5 (7, 10)	9 (7.8, 11)	8 (6, 10)	<0.05	0.01 (0-0.04)	Norway - UK	<0.05
						UK - US	<0.05
Selenium % of RDI	10.5 (6, 19)	7 (5, 15)	10 (6, 14)	<0.05	0.01 (0-0.04)	Norway - UK	<0.05

Note:
Abbreviations used: Inv = Inverted, NNR = Nordic Nutrition Recommendations, WHO = World Health Organization, E% = Percentage of energy, MJ = Megajoule, RDI = Recommended daily intake.

3.2.2 Protein sources and amounts of different ingredients

Red meat (beef, lamb, game and pork) were the most used sources of protein in the recipes from all countries, while seafood (lean fish, oily fish and shellfish) were the second most used in the recipes from the UK and Norway and white meat (poultry) the second most used in the recipes from the US. Few recipes were vegan, and the UK had the most vegetarian recipes (**Figure** 3.6).

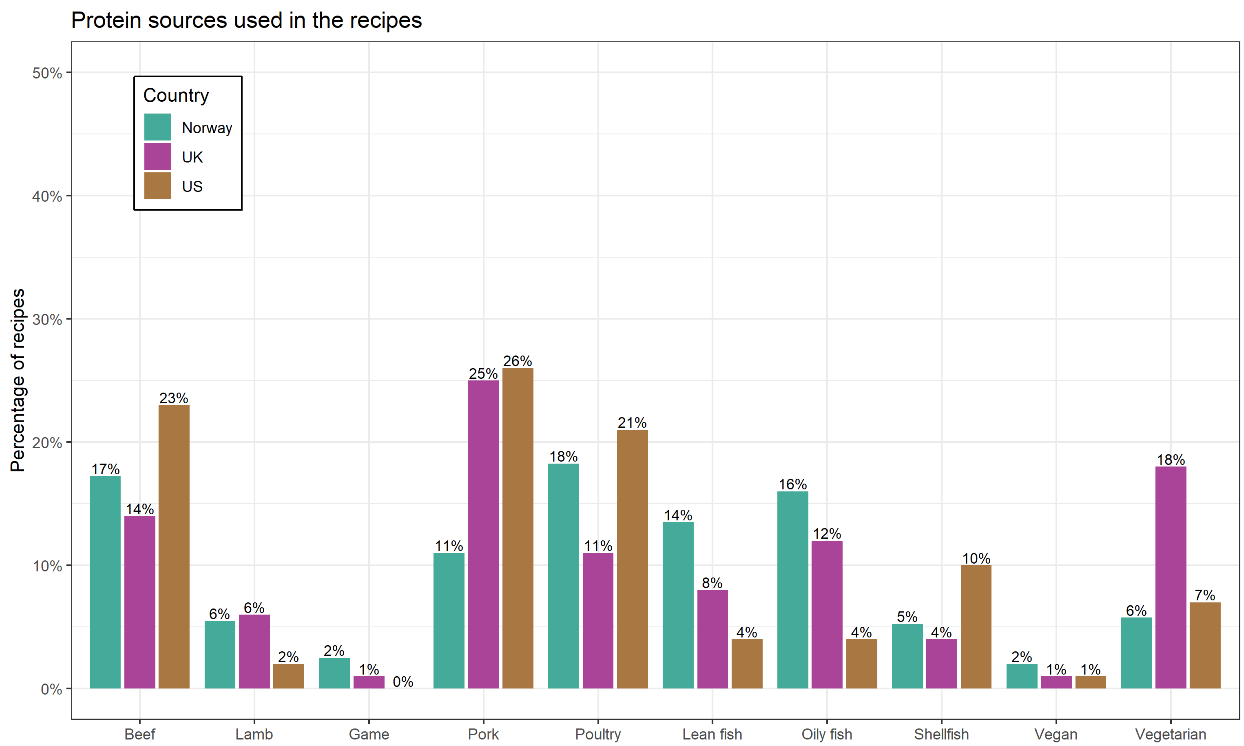

Figure 3.6: Percentage of recipes that used various animal protein sources, or were vegan or vegetarian.

Depending on protein source, the GHGE and land use for the recipes varied. Recipes with beef, lamb, game and shellfish had the highest environmental impact. Vegetarian and vegan recipes had the lowest environmental impact. Recipes with pork, poultry, lean and oily fish were 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 (**Figure** 3.7).

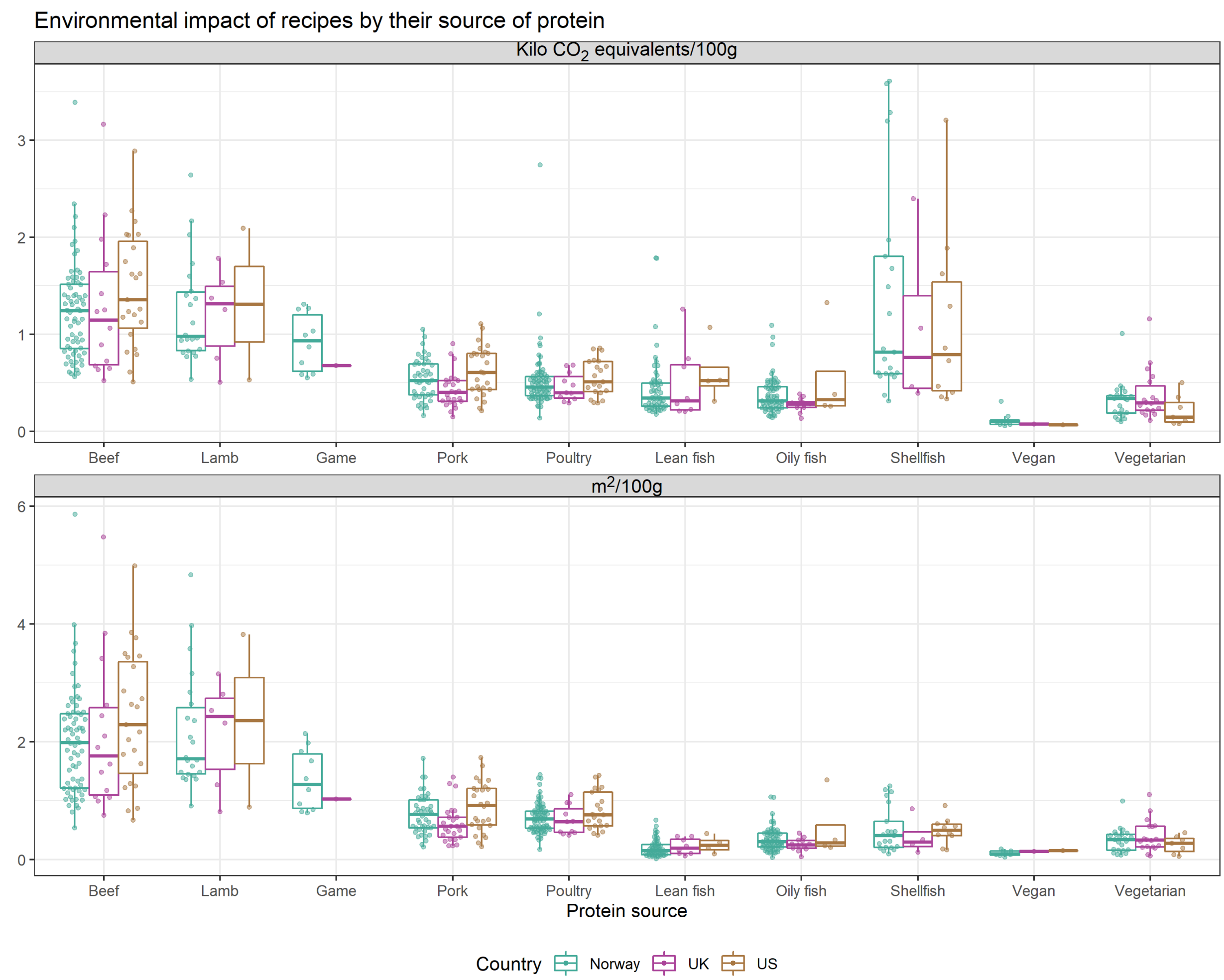

Figure 3.7: Environmental impact in kilo CO_2 equivalents and land use in m^2 per 100 grams in recipes with various protein sources.

Meat and meat products, seafood, vegetables and starchy roots and tubers made up most of the weight of the recipes in which they were included. For recipes that included meat based products or vegetable products, recipes from the UK tended to include less meat and more vegetables than recipes from Norway and the US. There were small differences for other food groups, see **Figure** 3.8.

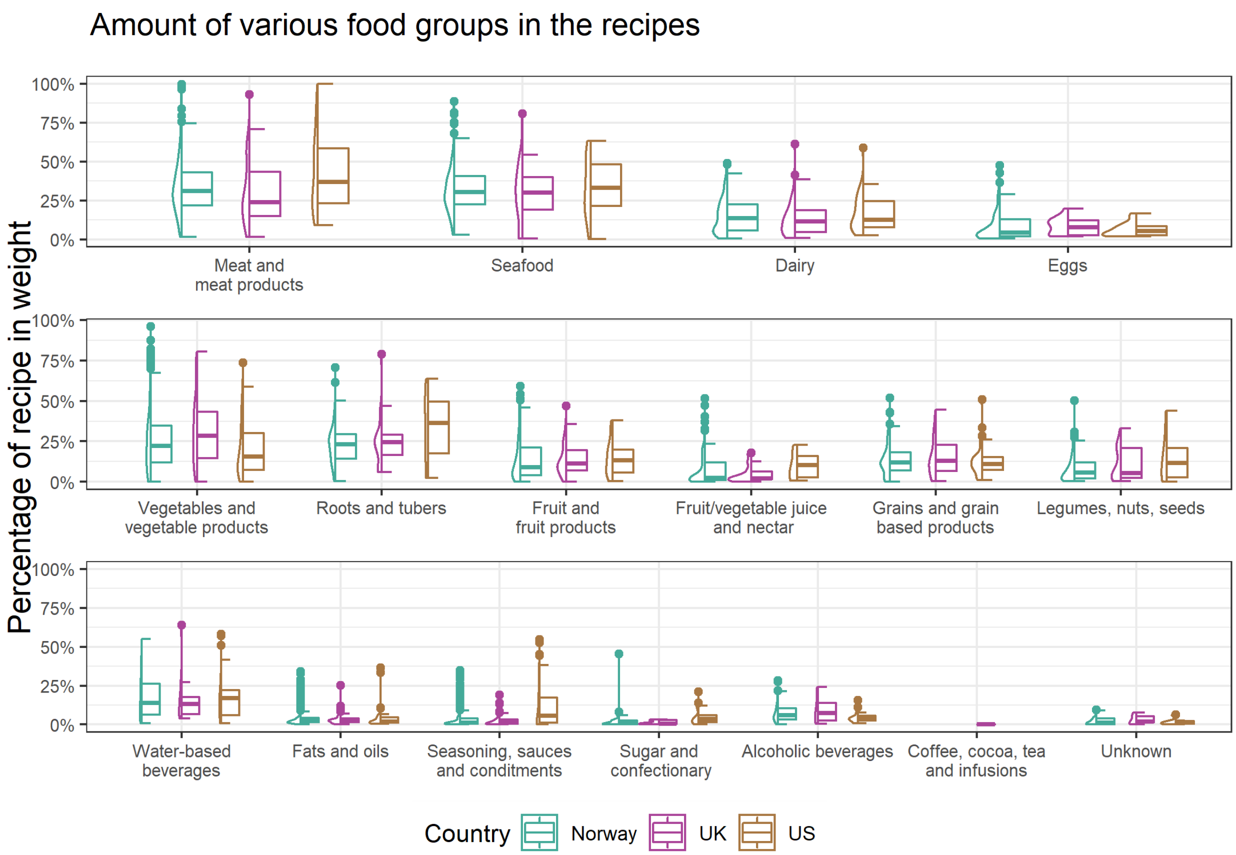

Figure 3.8: How much various food groups contributed to the weight of the recipes they were included in in percent.

3.2.3 Dinner meals as a source of nutrients

Table 3.2 show the percentage of recipes that were a source or a good source of a particular nutrient. The majority of recipes were a source of at least one nutrient, with the most common nutrient being protein. Nearly all recipes from each country were considered a source of protein, and the majority were considered good sources of protein. Most recipes were also a source of phosphorus, and more than half of the recipes in each country were a source of vitamin B12.

For some nutrients, there were large differences between countries on the percentage of recipes that were considered sources. About twice the percentage of recipes from the UK were considered a source or a good source of dietary fibre compared to recipes from Norway or the US. This is also true for the recipes from the UK that were sources of Vitamin A, in the form of both retinol and beta-carotene, vitamin C, folate, iron, and magnesium, although the percentage of recipes that were good sources of these were more similar between countries. Norway had more than twice the percentage of recipes than the UK or the US that were either a source or a good source of iodine, and also a higher percentage of recipes that were sources of selenium and Vitamin D.

Less than 10% of recipes from any country were sources of retinol, beta-carotene, riboflavin, folate, iron or potassium.

3.3 Nutrients that occur together

The percentage of recipes that were good sources of the various nutrients varied by the type of protein used, and this was also the case for the pattern of nutrients that occurred together (**Figure** 3.9).

Recipes that were vegan or used game meat as a source of protein had the fewest number of nutrients that occurred simultaneously in such amounts that a recipe was considered a good source. In recipes that used ruminant meat or seafood as a source protein, protein and vitamin B12 were the highest co-occurring nutrients, while there were slight differences for which additional nutrients that a recipe was a good source of. Many beef recipes that were good sources of protein and B12, were also good sources of zinc. For recipes that contained oily fish, protein, vitamin B12 and vitamin D were found together. Lean fish and shellfish recipes were good sources of protein, vitamin B12, iodine and selenium. For poultry, more recipes were good sources of vitamin B3 and B6 than B12, while for pork more recipes were good sources of vitamin B1 and B6 than B12. For vegetarian recipes, most that were good sources of protein were also good sources of fibre or phosphorus. For vegan recipes, only fibre and vitamin C occurred together in a recipe in such amounts as to be considered good sources.

More nutrients that were only sources, not good sources, could be found occurring together, see **Appendix Figure** A.5.

Table 3.2: The percentage of recipes from each country that could be classified as a source of a specific nutrient, with the percentage of recipes that were classified as a good source in parantheses.

	Norway	UK	US	All countries
Macronutrients				
Protein[a]	93% (68%)	88% (59%)	95% (79%)	92% (68%)
Dietary fibre[b]	21% (3%)	40% (9%)	21% (4%)	24% (4%)
Fat soluble vitamins				
Vitamin A[c]	12% (2%)	22% (7%)	16% (4%)	15% (3%)
Retinol[c]	5% (1%)	8% (2%)	2% (1%)	5% (1%)
Beta-carotene[c]	2% (0%)	6% (2%)	2% (1%)	3% (1%)
Vitamin D[c]	19% (8%)	9% (6%)	11% (5%)	16% (7%)
Vitamin E[c]	32% (7%)	37% (4%)	30% (5%)	33% (6%)
Water soluble vitamins				
Vitamin C[c]	27% (7%)	44% (9%)	18% (6%)	28% (8%)
Thiamin[c]	11% (2%)	20% (4%)	24% (11%)	15% (4%)
Riboflavin[c]	5% (0%)	6% (2%)	3% (0%)	5% (1%)
Niacin[c]	46% (7%)	38% (4%)	53% (11%)	46% (7%)
Vitamin B6[c]	48% (6%)	44% (6%)	50% (15%)	48% (7%)
Folate[c]	1% (0%)	7% (3%)	4% (2%)	3% (1%)
Vitamin B12[c]	69% (50%)	59% (37%)	56% (34%)	65% (45%)
Minerals				
Calcium[c]	5% (1%)	10% (1%)	11% (0%)	7% (1%)
Iron[c]	4% (1%)	8% (2%)	5% (1%)	5% (1%)
Zinc[c]	35% (6%)	34% (8%)	42% (10%)	36% (7%)
Magnesium[c]	4% (0%)	11% (1%)	4% (1%)	5% (0%)
Potassium[c]	2% (0%)	6% (1%)	5% (0%)	3% (0%)
Selenium[c]	36% (10%)	27% (7%)	22% (12%)	32% (10%)
Iodine[c]	14% (10%)	6% (4%)	4% (3%)	11% (8%)
Sodium[c]	26% (6%)	19% (2%)	31% (5%)	25% (5%)
Phosphorus[c]	75% (8%)	80% (8%)	76% (11%)	76% (9%)
Copper[c]	20% (3%)	38% (8%)	11% (4%)	22% (4%)

Note:

A recipe is a source or a good source of a nutrient if it contains respectively:

[a] >12 or >20 % energy from the nutrient.

[b] >3 or >6 g/MJ.

[c] >15 or >30 % recommended daily intake of the nutrient.

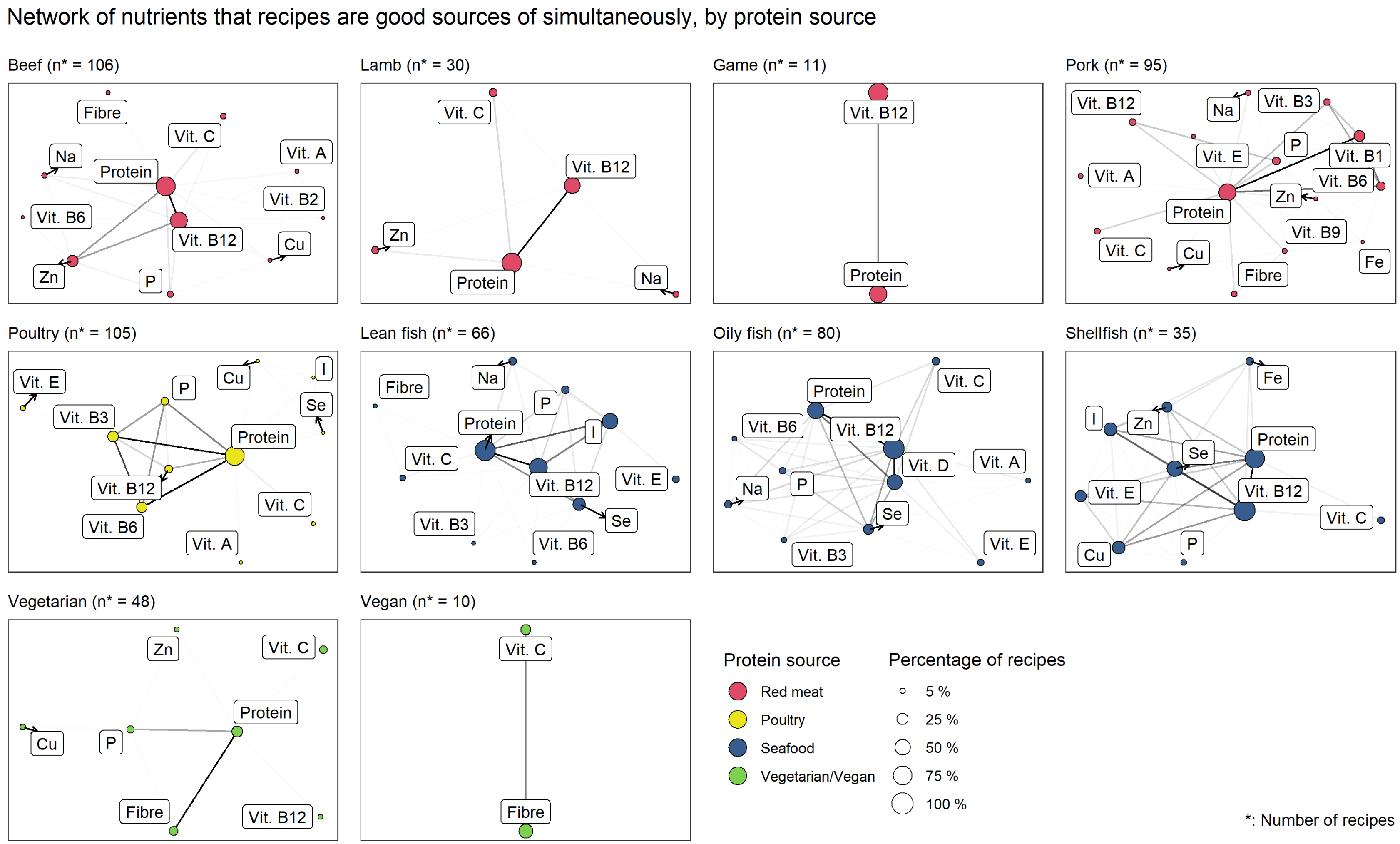

Figure 3.9: Nutrients that occur together in the recipes, in such amounts that the recipe is considered a good source. A larger circle indicates a higher percentage of recipes that is a good source of the nutrient, scaled by the number of recipes that used a particular source of protein, and a stronger line indicate a higher number of co-occurrences.

3.4 Correlation analyses

3.4.1 Healthiness indicators and environmental sustainability indicators

Results from the Spearman correlation showed a significant (adjusted p-value <0.001) positive correlation between all the four healthiness indicators. There was a strong correlation between the two front-of-pack labels (rho 0.68), and a strong correlation between the two dietary guidelines (rho 0.78), while the correlation between the front-of-pack labels and the dietary guidelines were weaker. The two environmental sustainability indicators had a significantly strong positive correlation (rho 0.84, adjusted p-value <0.001).

All four healthiness indicators were significantly (adjusted p-value <0.001) negatively correlated with the two environmental sustainability indicators, with the two dietary guidelines being more strongly correlated with both GHGE and land use than the FSA MTL and Nutriscore. NNR had a slightly stronger correlation with both GHGE and land use than WHO guidelines, while the Nutriscore had a weaker correlation with land use than the FSA MTL. Slight differences were seen between countries, with recipes from Norway consistently having a weaker correlation between healthiness and environmental sustainability indicators, this can be seen in **Figure** 3.10 that show scatterplots of the various healthiness and environmental sustainability indicators, and the correlation between them for each country and all countries pooled.

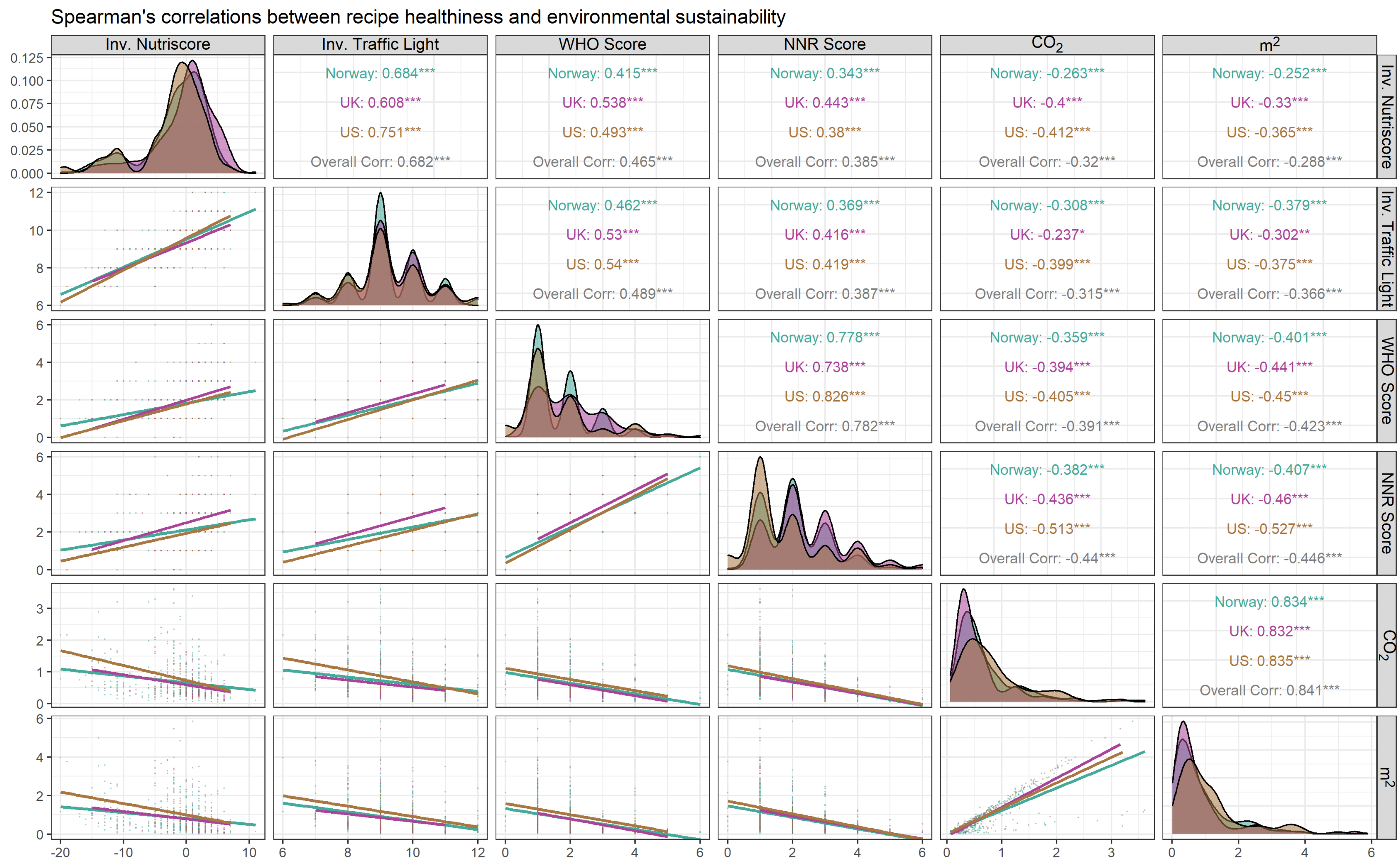

Figure 3.10: Spearman's Rho between CO_2 equivalents (kg), land use (m^2/year) and the inverted Nutriscore, inverted Food Standard Agency's multiple traffic light score, World Health Organization dietary guideline score and the Nordic Nutrition Recommendation score.

3.4.2 Environmental sustainability indicators and energy providing nutrients

Figure 3.11 show the correlations between energy and macronutrient content of a recipe and its environmental sustainability. For all countries pooled, there was a very weak positive correlation between GHGE and total energy content in kilocalories (rho 0.12, adjusted *p*-value <0.01), a weak positive correlation between GHGE and total fat (rho 0.24, adjusted *p*-value <0.001) and protein (rho 0.34, adjusted *p*-value <0.001), and a moderate positive correlation between GHGE and saturated fat (rho 0.43, adjusted *p*-value < 0.001). These associations did not reach statistical significance in all countries separately.

Sugar had a very weak (rho 0.1) positive correlation with both environmental sustainability indicators in the pooled recipe data (adjusted *p*-value <0.01). In both cases this was driven by recipes from the US, where sugar was used in many meat-based recipes as part of a condiment (not shown).

GHGE had a moderate negative correlation with carbohydrates (rho -0.47, adjusted *p*-value <0.001) and a weak negative correlation with dietary fibre (rho -0.38, adjusted *p*-value <0.001). Land use had a moderate negative correlation with carbohydrates (rho -0.42, adjusted *p*-value <0.001) and a weak negative correlation with dietary fibre (rho -0.32, adjusted *p*-value <0.001).

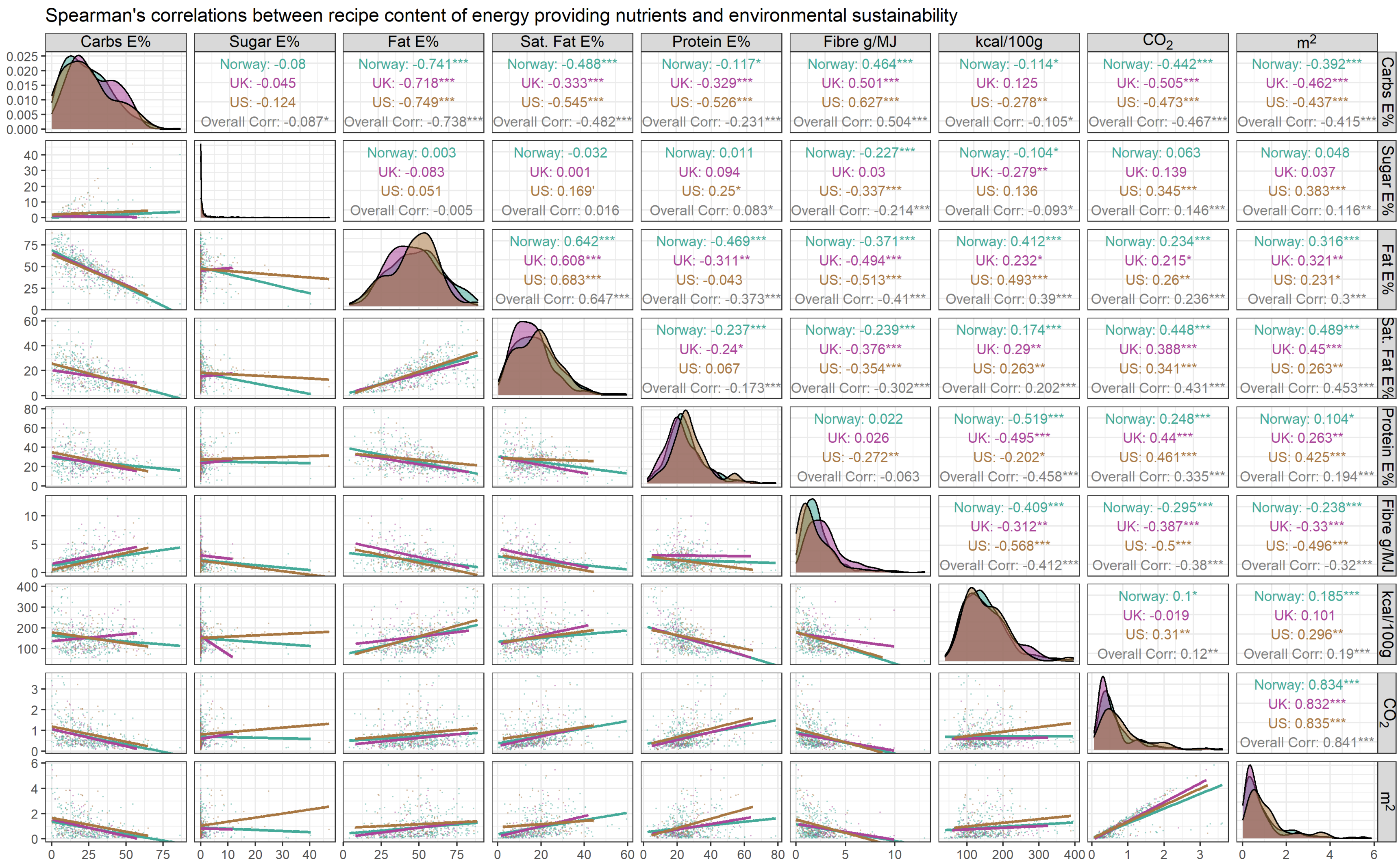

Figure 3.11: Spearman's Rho between CO_2 equivalents (kg), land use (m^2/year), energy content and energy providing nutrients.

3.4.3 Environmental sustainability indicators and mineral content

Many minerals were correlated with the environmental sustainability indicators, but the strength and significance of the correlations varied between countries, see **Figure** 3.12 and **Figure** 3.13.

There was a very weak negative correlation between GHGE and both copper (rho -0.08, BH-adjusted p-value <0.05) and calcium (rho -0.09, adjusted p-value <0.05). GHGE were weakly positively correlated with Iron (rho 0.39, adjusted p-value <0.001), phosphorus (rho 0.21, adjusted p-value <0.001) and strongly positively correlated with zinc (rho 0.68, adjusted p-value <0.001). For copper the correlation was driven by recipes from the US, while for calcium it was driven by recipes from the UK. With iron and zinc the correlation was weaker for recipes from the UK than recipes from the US and Norway.

Land use had a very weak negative correlation with copper (rho -0.17, adjusted p-value <0.001) and calcium (rho -0.15, adjusted p-value <0.001), and a weak negative correlation with iodine (rho -0.3, adjusted p-value <0.001). As with GHGE, the correlation between land use and copper was driven by recipes from the US. Zinc had a strong positive correlation with land use (rho 0.7, adjusted p-value <0.001), while the corellation between land use and iron and phosphorus were moderate (rho 0.45, adjusted p-value <0.001) and weak (rho 0.16, adjusted p-value <0.001) respectively. As with the correlations with GHGE, the correlation between land use and both iron and zinc were weakest in the UK recipes.

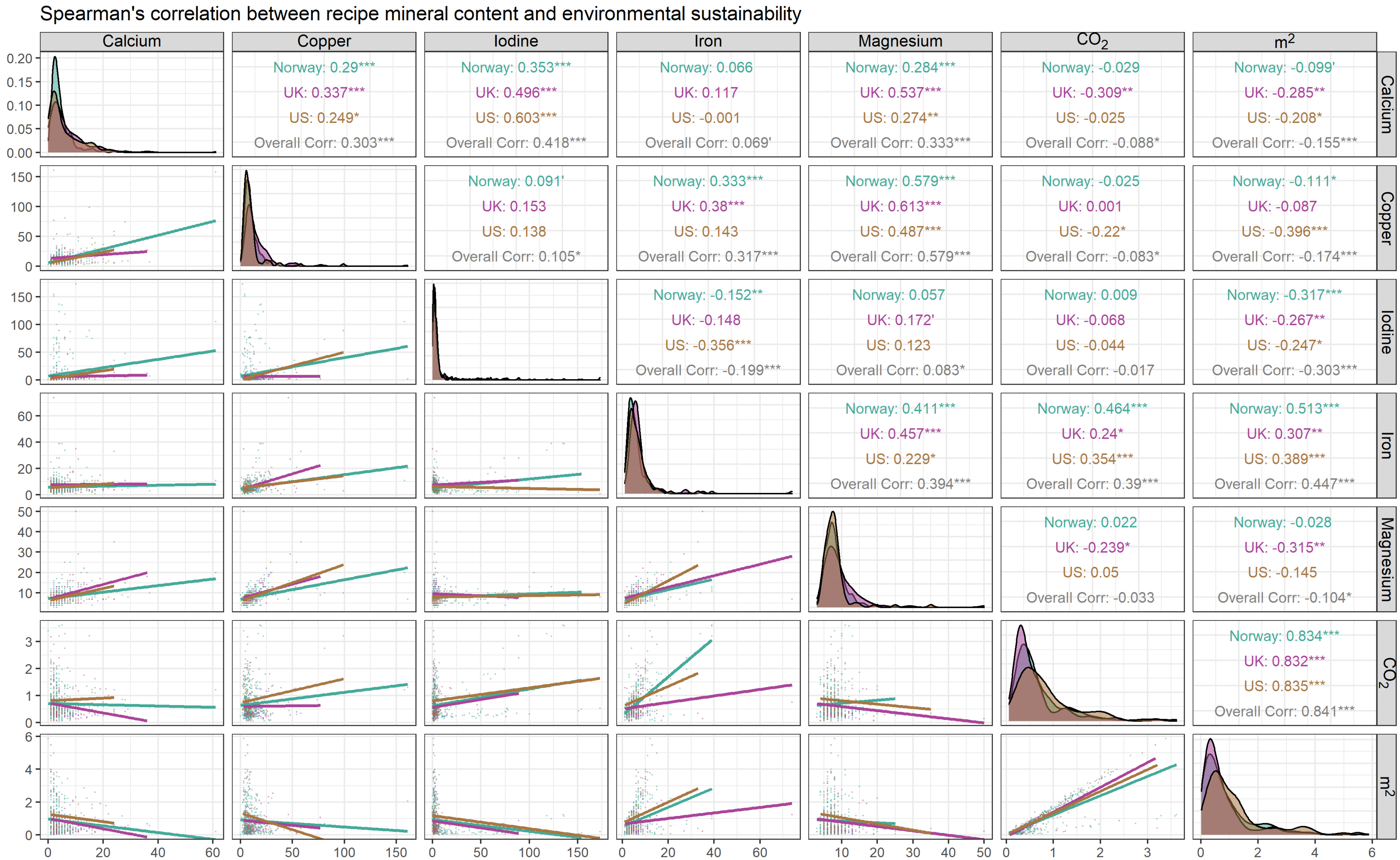

Figure 3.12: Spearman's Rho between CO_2 equivalents (kg), land use (m^2/year) and mineral content (% of recommended daily intake).

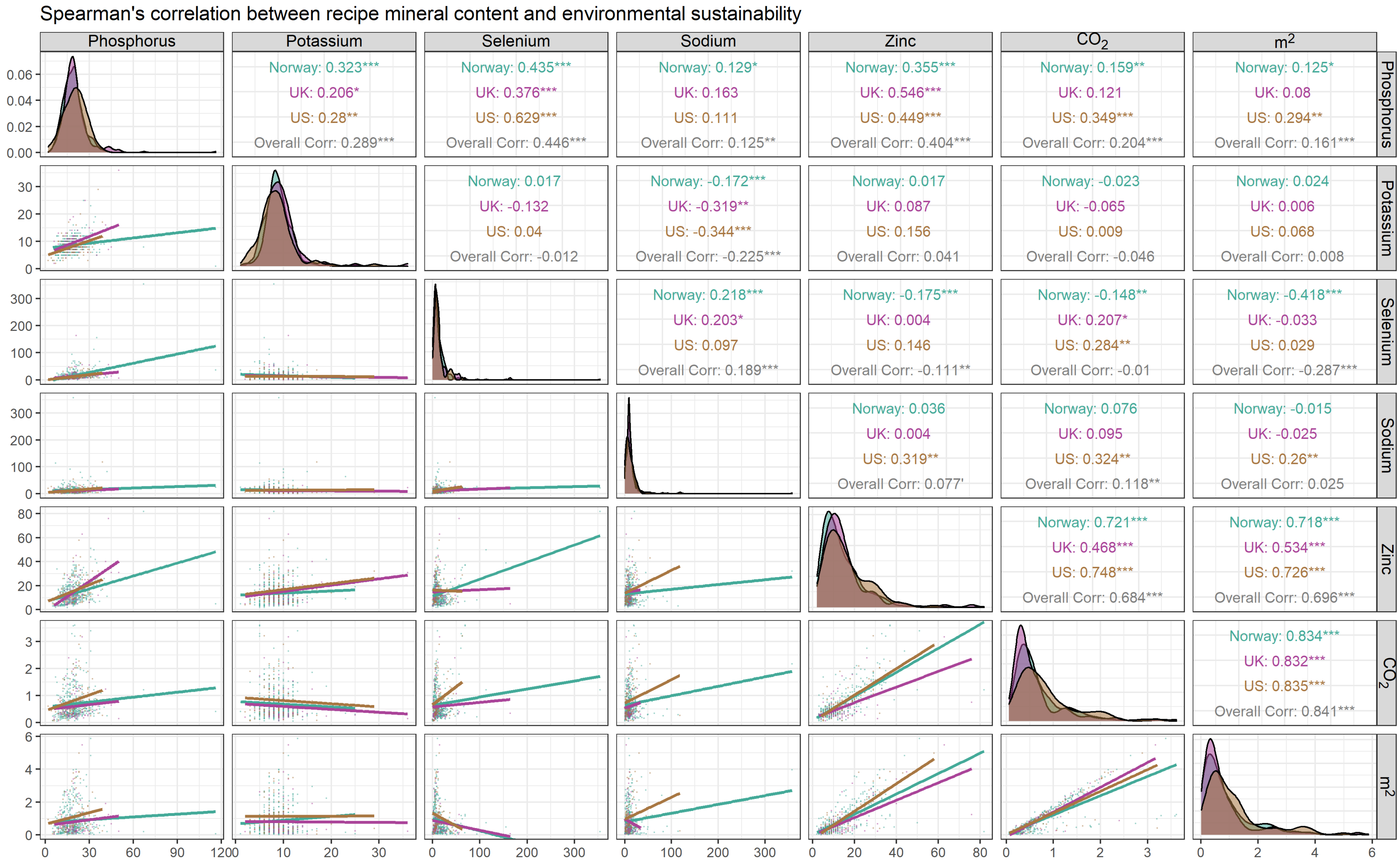

Figure 3.13: Spearman's Rho between CO_2 equivalents (kg), land use (m^2/year) and mineral content (% of recommended daily intake).

3.4.4 Environmental sustainability indicators and vitamin content

As with minerals, there were many vitamins that correlated with the environmental sustainability indicators, to various degrees of strength and significance, see **Figure** 3.14 and **Figure** 3.15.

GHGE had a very weak negative correlation with thiamine (rho -0.1, adjusted *p*-value <0.05), beta-carotene (rho -0.19, adjusted *p*-value <0.001), and a weak negative correlation with folate (rho -0.27, adjusted *p*-value <0.001) and vitamin C (rho -0.23, adjusted *p*-value <0.001). For thiamine, the correlation was only significant in the pooled data. In all countries, there was a very weak positive correlation between GHGE and retinol (rho 0.17, adjusted *p*-value <0.001), and a weak correlation between GHGE and niacin (rho 0.25, adjusted *p*-value <0.001), riboflavin (rho 0.37, adjusted *p*-value <0.01) and vitamin B12 (rho 0.35, adjusted *p*-value <0.001).

Correlation between the different vitamins and land use generally followed the same pattern, but there was also a weak negative correlation between land use and vitamin D content (rho -0.25, adjusted *p*-value <0.001), mostly driven by the Norwegian recipes

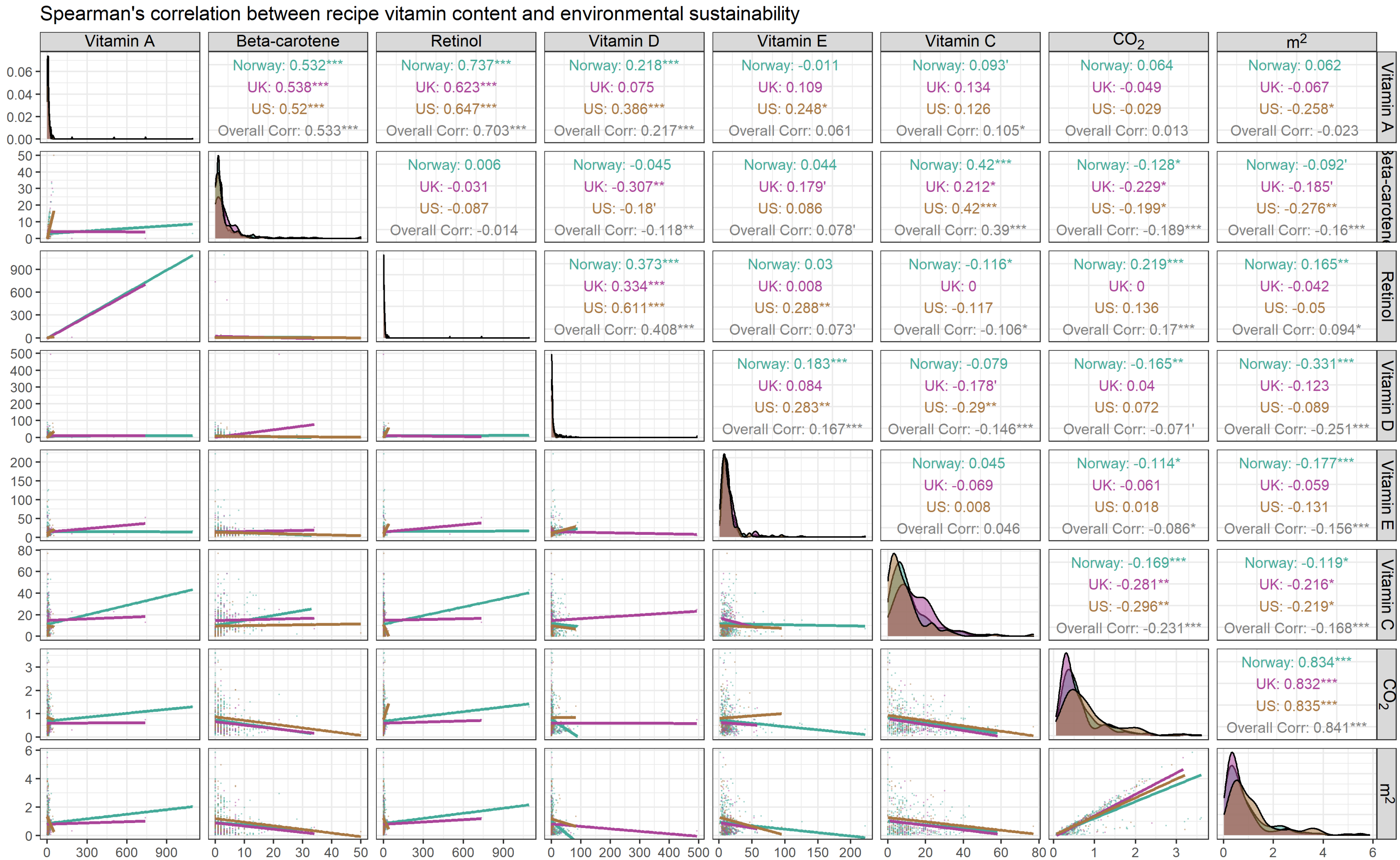

Figure 3.14: Spearman's Rho between CO_2 equivalents (kg), land use (m^2/year) and vitamin content (% of recommended daily intake).

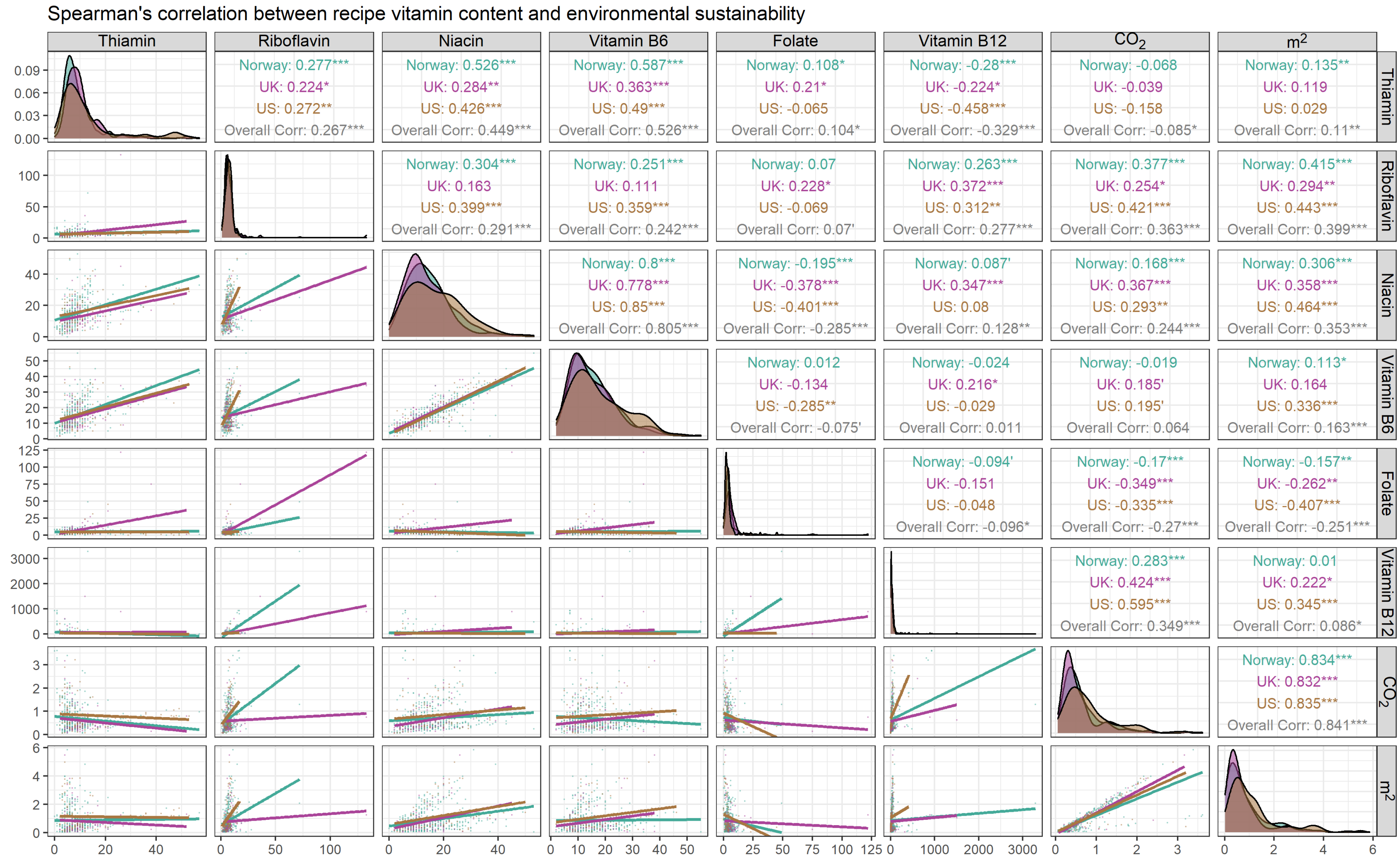

Figure 3.15: Spearman's Rho between CO_2 equivalents (kg), land use (m^2/year) and vitamin content (% of recommended daily intake).

Chapter 4

Discussion

The purpose of this thesis was to explore the sustainability of dinner recipes found on Internet recipe sites or in recipe books, from Norway, the UK and the US, and explore the potential relationship between a recipe's adherence to healthy dietary guideline principles and its environmental sustainability, and if there were any cross-country differences.

4.1 Healthiness and environmental impact

In line with previous studies on recipe healthiness that looked at compliance with the WHO macronutrient dietary guidelines (100,101,103–107), the results from this thesis showed that only a small percentage of recipes were compliant. The macronutrient content of the Norwegian dinner recipes varied slightly from a previous study of the nutrient content of Norwegian dinners, based on data from the Norwegian national diet survey Norkost 3 that was performed in 2010/2011 (133). Compared to dinners in Norkost 3, the Norwegian recipes in this thesis had a lower E% from carbohydrates and added sugar, a higher E% of total fat, while the E% from saturated fat and protein and the amount of dietary fibre were similar. This could suggest that in the recipes ingredients that contribute to carbohydrate content have been exchanged for ingredients that contribute fat, specifically unsaturated fats as there was little difference in saturated fat content. A possible explanation could be that the recipes from Norway are of a newer date, and follow the trend of a decreased E%

from carbohydrate and increased E% from fat that has been seen in Norwegian diets since Norkost 3 was performed (134) (p37). This pattern of decreased intake of carbohydrates and increased intake of fat has also been observed in the US (135).

Fewer recipes were compliant with the WHO than the NNR guidelines, which allows for less carbohydrates and more fat. When looking at the front-of-pack labels, the FSA MTL and the Nutriscore, the majority of recipes were classified as foods that could be consumed most of the time as part of a healthy diet. That the front-of-pack labels showed that most recipes could be consumed often, while the same recipes were not compliant with the dietary guidelines, is likely due to the different design and purpose of these indicators, that will be discussed in more detail later. There were statistically significant differences between countries on the total score of the healthiness indicators, but these differences were small and are unlikely to have clinical relevance. That said, it is problematic that all the indicators used gives the same weight to each component of the indicator when total score is calculated as it is unlikely that the individual components have the same health impact (136). The Nutriscore gives the qualifying components lower weights than the disqualifying components, but within these categories the components still carry the same weight.

The FSA MTL findings from this thesis are different from other studies that have used a traffic light system to classify recipes and found that their nutritional qualities are low (99,102,105). This is likely due to a difference in interpretation of the FSA MTL, and the use of other traffic light systems with different threshold values for nutrients and different interpretations of the traffic light colors. Dickinson et al. (105) found that recipes on clean eating blogs did not comply well with WHO criteria, and that this was reflected in the recipes also having amber-red lights on the FSA MTL. However, in the guide to interpretation of the FSA MTL (118), it is said that a food that has mostly amber colored lights can be eaten “most of the time”, which suggests it is not exactly unhealthy. In line with this, a recipe that had mostly amber lights, which could mean three amber and one red light, were not considered unhealthy in this thesis. Irwin et al. (99) found that few recipes were healthy when using the Australian Healthy Eating Advisory Service traffic light system (HEAS) where an amber light does not mean “can be eaten most of the time” as in the FSA MTL, but rather “consume in moderation” (137). The same is true for the study by Wademan et al. (102) that used the Australian LiveLighter traffic light system (LL), where amber means the food is “okay sometimes”. Additionally the LL has more stringent nutrients criteria than the FSA MTL, with the amber criteria from FSA MTL overlapping with the red criteria from the LL. If this is true for the HEAS as well is difficult to say as in contrast to the FSA MTL and the LL criteria, the HEAS varies depending on the type of food, including different types of dinner main and side dishes.

The World Wide Fund for Nature’s “One Planet Plate” concept (OPP) (138), which was the basis behind classifying the menu items at the 26th UN Climate Change Conference of the Parties in Glasgow 2021 (139) into “low”, “moderate” or “high” emission meals, uses 0.5 kg CO_2 as the upper limit for a sustainable or low CO_2 emission for a single meal. A “moderate” emission meal according to the OPP causes between 0.5-1.8 kg CO_2 emission, and a high emission meal causes >1.8 kg CO_2 emissions. These CO_2 emissions, in contrast to the SHARP indicator database, does not include acidification or emissions related to preparation and cooking of the food, making it difficult to compare the results from this thesis with the OPP. Additionally, they are based on portion sizes that were not available for the recipes used in this thesis. Still, based on the standard portion sizes for protein food and starchy staples by Dalane et al. (113), a dinner portion is about 400 grams, which would suggest that the majority of recipes in this thesis would be in the high emission category as the median GHGE per 100 grams for all recipes pooled were 0.5 kg. For all countries, a 400 grams portion of the recipe at the 25th quartile would be in the moderate category, while for the UK recipes this is also true for the median GHGE recipe.

4.1.1 Nutrient content and specific food recommendations

A diet is not sustainable if it cannot provide the nutrients needed to promote an individual’s health and wellbeing.

FBDGs from all three countries have specific recommendations for certain food groups. These include recommendations to choose whole grain products instead of refined grains and vegetable oils over butter, consume at least “five a day” of fruit and vegetables, and consume a minimum amount of seafood throughout the week. Norway and the UK also recommend to limit red meat intake to <500 grams/week, corresponding to about two-three dinners and some meat based cold-cuts according to the Norwegian FBDG (140), while the US recommends to limit all land-based animals to <700 grams/week corresponding to three-four dinners (117,140,141). The Nutriscore is the only one of the healthiness indicators used that reward specific foods that many FBDGs encourage an increased intake of, namely fruits, vegetables, legumes, nuts and the unsaturated fats olive oil, walnut oil and rapeseed oil.

Nearly all dinner recipes were sources of protein, with most also being a source of phosphorus which is commonly found in protein rich foods such as cheese, fish and meat. This is also the case for vitamin B12 (109). While few recipes were sources of either retinol or beta-carotene, both of these nutrients can be utilised by the body as vitamin A, and more recipes contained enough of both to be considered sources of vitamin A.

Few recipes included whole grain ingredients, and few recipes had high scores for fruit, vegetable, legume and nut content on the Nutriscore. It is therefore not surprising, though still unfortunate, that few recipes were sources of nutrients found in these foods, such as beta-carotene, folate, magnesium, iron and potassium (109). More recipes from the UK, that tended to include more vegetables than recipes from Norway and the US, were sources of these nutrients. Additionally more recipes from the UK were sources of dietary fibre that is also found in these foods, and vitamin C that is found in vegetables and fruit specifically. This is likely contributing to recipes from the UK performing slightly better on the Nutriscore than recipes from the other two countries, and having more recipes that scored favorably on dietary fibre criteria from the dietary guidelines.

That few recipes were sources of iodine reflects that few recipes included white lean fish, one of the few dietary sources of this mineral (109). If the low use of lean fish as an ingredient in this sample is reflective of dinner recipes from these sources overall, it is unfortunate as mild to moderate iodine deficiency could be a problem for vulnerable groups, especially pregnant women, in all the three countries the recipes are sourced from (142–144).

For the Norwegian recipes, the percentage of recipes with fish is in line with the lower end of the national FBDG recommendation for fish intake, i.e. consumption of at least two-three fish dinners a week, corresponding to 28-43% of a week's dinners. The ratio between lean and oily fish, about 1:1, is also in line with the guidelines (140). For the UK recipes the percentage of recipes is below the recommended two portions of fish a week (141), but the ratio between lean and oily fish is close to the guideline recommendations of 1:1. Unlike the Norwegian and UK FBDGs, the US FBDG do not give specific advice for fish intake, but rather group fish and shellfish together into a seafood category and advice an intake of 227 grams/week (117), corresponding to a bit more than one portion from the UK or Norway. This is in line with the percentage of seafood recipes from the US.

The Norwegian recipes are in line with the national FBDG to limit red meat to two-three portions a week, while the UK recipes are slightly above. Similarly, the percentage of US recipes that use land-based meat is above the three-four/week national FBDG recommendation.

It is interesting to note how the percentage of recipes are close to the lower limit set for seafood intake in each country, while being close to or exceeding the upper limit for meat intake. It should be mentioned that for lean fish, there is no upper limit on intake in any of these countries' FBDGs, in contrast to how both Norway and the UK recommend to limit red meat intake, and the US recommends to limit intake of all land-based meat. That is, it seems the percentage of recipes that use certain ingredients are close to the absolute amounts described in the FBDGs, regardless of whether this number is a lower or upper limit.

Surprisingly, few recipes were considered sources of iron despite most recipes containing meat, that is commonly seen as a good source of this mineral, especially in the case of red meat. While surprising, this is not necessarily concerning as unlike iodine iron can be found in many other staple foods that are eaten throughout the day, such as grains and legumes (109). Additionally, the bioavailability of iron from meat is between 15-35% (145), while the RDI for iron is based on a bioavailability of 15% to account for lower bioavailability from plant-based sources (112). In this thesis the RDI for nutrients were based on the needs of adult women, who have higher iron requirements than men due to menstrual bleeding (112). It is likely more recipes would have been considered sources of iron for men.

Other nutrients that few dinners were sources of, such as riboflavin and calcium, can like iron be found in several other foods that are likely to be eaten throughout the day. A single meal such as a dinner does not have to be a source of all nutrients, but when planning a weekly menu it is important with variety so that all RDIs are met.

There were differences in which nutrients could be found together in one meal depending on the source of protein used. Recipes that used poultry and seafood stood out as being good sources of more nutrients simultaneously than recipes that used other sources of protein. Per 100 grams, more recipes that used animal based sources of protein were good sources of many nutrients simultaneously than plant-based recipes. However, there was only a small number of plant-based recipes, and this could skew results. Nutrients typically came from the protein source itself rather than side dishes, i.e. recipes with lean fish were good sources of protein, vitamin B12, iodine and selenium, all nutrients found in lean fish, while vegetarian recipes were good sources of protein and fibre, in line with how protein rich plant-based foods such as legumes also are rich in fibre (109). This is likely due to meat and seafood based products made up the bulk weight of the recipes they were used in. Recipes that used protein sources that FBDGs encourage an increased intake of, such as fish-based or plant-based recipes, had a lower environmental impact than recipes that used ruminant meat that FBDGs recommend to limit the intake of.

Similar to how the proportion of red meat and total amount of meat could explain most of the variance in the environmental impact of European diets (146), recipes from the US that had more red meat and a higher amount of meat and meat based products also had the highest environmental impact. Additionally, there was a higher proportion of recipes from the US that used shellfish as an ingredient, which also has a high environmental impact. This shows that recipes can be used to find, and possibly track, dietary trends that influence the environmental sustainability of diets.

4.1.2 Nutrient content and environmental impact

Meeting RDIs should not put undue strain on the environment.

Nutrients found in high amounts in animal sourced foods, like saturated fat, protein, iron, zinc, phosphorus, retinol, vitamin B12 and riboflavin were the nutrients that were positively correlated with environmental sustainability. Interestingly, this varied a little by country. For zinc and iron, the correlation with GHGE were lower in the UK recipes than recipes from Norway and the US, suggesting that more zinc and iron in the UK recipes came from plant-based foods rather than animal sourced foods with a higher environmental impact. While iron content were significantly higher in the UK than the Norwegian recipes, the small difference in absolute numbers is likely clinically irrelevant.

While the UK recipes provided iron and zinc at a lower environmental cost, as already mentioned these minerals have lower bioavailability when they come from plant-based sources rather than animal sourced foods and so the amounts can not be directly compared (147). There are however ways to increase the bioavailability of these nutrients from plants, such as soaking, sprouting and combining plants with different nutrients that improve absorption, for example plant-based iron is easier absorbed if consumed together with an acid like vitamin C. It would have been interesting to see if any such strategies were used in the recipes to improve nutrient bioavailability. For vitamin B12 and protein, the correlation was stronger for GHGE than land use. Likely due to these nutrients being provided not only by meat but also seafood that has a lower land requirement than meat, but could still have the same GHGE, in the SHARP Indicators database. This could also explain the different strength of the correlation of the individual countries, as different types of seafood were used in the recipes from each country.

For the nutrients vitamin D and iodine, there was a negative correlation with land use but not GHGE. This is also likely due to these nutrients mainly being found in seafood.

For nutrients found more or less exclusively in plants, such as beta-carotene, vitamin C, carbohydrates and fibre there was a negative correlation with environmental impact. This was also the case for folate, but to a lesser extent. Possibly because folate is not exclusive to plants but can also be found in animal sourced foods, like liver and eggs. For sugar, which is also a plant-based food, there was a positive correlation with both GHGE and land use. This is likely an artifact due to sugar being used in marinades or sauces in meat based recipes.

That important micronutrients were positively correlated with GHGE and land use, underscore the importance of including micronutrient content when planning low environmental impact diets. The association between these nutrients and GHGE is likely the reason why in studies on self-selected diets, low GHGE does not always align with higher nutritional quality (148,149). Still, it is possible to design diets that are both nutrient dense and have a low environmental impact. In a recent modelling study Perignon et al. (150) showed that moderate GHGE reductions from diet (defined as $\leq 30\%$) were possible without compromising nutrient adequacy. Even larger reductions could be achieved, but would require non-trivial changes in food consumption patterns.

As with nutrient content, it is important to look at the whole diet over a period of time when looking at environmental impact. A high environmental impact of one meal could be offset by a lower environmental impact of another meal.

4.1.3 Differences between the front-of-pack labeling schemes and the dietary guidelines

Dietary guidelines for macronutrient intake are designed to to be used to assess the nutrient quality of whole diets, not single meals. Macronutrient guidelines alone do not ensure that a diet contains necessary micronutrients, which is why they are combined with advice on specific foods that should be included in a daily/weekly diet. On the other hand, the FSA MTL and the Nutriscore are designed to provide at-a-glance information about a specific product and help consumers make healthier food choices. That particular food by itself does not necessarily comply with all dietary guidelines, but by consistently buying the recommended foods within a varied set of food groups, dietary quality is likely to improve. The Nutriscore have consistently been shown to give A/B scores for foods which are encouraged in FBDGs (122,123,151,152), although for combination dishes such as ready meals that are comparable to the dinner recipes in this thesis, the alignment with dietary guidelines have been found to be lower than for other food categories (123,153). Unlike the other three indicators, the Nutriscore balance unhealthy disqualifying components of a food with healthy qualifying components. This means a food product can receive a healthy label if the score on the qualifying components outweigh the score of disqualifying components.

While the recipes defined as healthy or a meal that could be eaten often as part of a healthy diet varied between the healthiness indicators, the positive correlation between them indicate that they pick up on similar nutrient qualities in the recipes.

The differences between how the scores are calculated also likely explain why the dietary guidelines had a stronger correlation with environmental impact than the front-of-pack labels. All the healthiness indicators penalise a high content of saturated fats, found almost exclusively in high environmental impact animal sourced foods, but also a few vegetable fats such as coconut and palm oil (109). All but the FSA MTL reward higher dietary fibre content, found in low environmental foods such as whole grains, fruits and vegetables including starchy roots and tubers, legumes and nuts. The most important difference is likely between how total carbohydrates and protein content are scored, as carbohydrates are found in low environmental impact foods while most high protein foods are animal sourced and have a high environmental impact. The dietary guidelines reward a moderate to high total carbohydrate content and penalise a high protein content, while Nutriscore does not include total carbohydrates and protein is a qualifying component with no upper limit penalty, and the FSA MTL does not include either total carbohydrates or protein.

Effectively this means recipes with a higher score on the dietary guidelines would likely have a higher content of plant-based foods, while penalizing those recipes that contained a high amount of animal sourced foods. On the other hand, a recipe with a high score on the Nutriscore could still include high amounts of animal sourced foods, as long as it was a product low in saturated fat, which could give these recipes a higher environmental impact. For the specific recipes in this study, the median qualifying score from protein alone outweighed or neutralised the total median disqualifying scores on the Nutriscore, indicating that animal sourced foods contributed to the recipes scoring so favorably on the Nutriscore.

As the FSA MTL does not include either carbohydrates, fibre or protein content, a higher score is not as tied to a high content of low environmental ingredients as the dietary guidelines, but it is neither associated with a higher content of high environmental ingredients like the protein component in the Nutriscore.

Surprisingly, adherence to the NNR guidelines, with its lower carbohydrate and higher fat and protein allowances, was slightly stronger correlated to reduced environmental impact than adherence to the WHO guidelines. Since the WHO guideline recommends a higher intake of low environmental plant-based foods, it is likely that in reality this dietary pattern would have a lower environmental impact than the NNR. The surprising result could be because more recipes were awarded points for carbohydrate content with the NNR than the WHO criteria, influencing the correlation analysis as few recipes with a high score on the WHO received this score for their carbohydrate content.

4.2 Strengths, limitations and future work

To our knowledge, this is the first study to explore environmental impact of recipes from either the Internet or recipe books, the first study explore at the healthiness of recipes from Norwegian Internet recipe sites, and the first study on healthiness of recipes to use the NNR and Nutriscore and include a wide range of micronutrients. The healthiness indicators are used in many different countries, making the results of the healthiness and correlation analyses applicable outside of the countries of origin of the recipes included. All analyses and ingredient-to-database mapping are available as R scripts, and can easily be reproduced. A short summary of the data and scripts used can be seen in Appendix B.

There are several limitations of the data and methods used in this thesis. It was discovered that some online recipes would include additional ingredients in their description to be served with the recipe, not included in the ingredients list that had been added to the database used to calculate nutrient content and environmental impact. For example “serve with potatoes, rice or salad”. These are ingredients that would have altered the healthiness scores and lowered the environmental impact, by providing more carbohydrate and/or fibre rich foods, had they been included in the analyses. The recipes from the UK were from celebrity chef’s recipe books, which could possibly be different than recipes found online. Another issue with the online recipes were that not all recipes were classified correctly by meal type, as both desert, lunch and appetisers were found classified as dinner recipes. While this was a limited problem for this study, it is a limitation of collecting recipes from the Internet that could influence other similar studies.

Some ingredients that contributed to the nutrient calculations, and thus influenced healthiness scores, were ingredients that would not be eaten in full in the final recipe. For example oil in marinades or vegetables is some soup bases. This is only relevant for the healthiness of the recipes, and not the environmental impact, as the environmental impact of the ingredients used are the same regardless of if they are eaten or not. The final weight of soups, stews and recipes with certain sauces are likely inflated due to the inclusion of high amounts of water, that would have diluted the other ingredients when calculating nutrient content and environmental impact per 100 grams.

Analysing the nutrient content and environmental impact per 100 grams could limit the real world usefulness of the results, as a typical dinner is likely more than 100 grams. Using portion size could perhaps have been a better choice, but not all recipes provided the number of portions per recipe. This might have been solved by using standardised portion sizes of protein included in the recipe, but this approach does not take into account that portion sizes may vary by recipe, and this in itself could be a source of different nutrient content and environmental impact between different recipe sources.

The use of the SHARP Indicators database, that is based on LCAs from a handful of European countries, means that the results may not be relevant to inhabitants of the countries the recipes in this study comes from. Another issue with using the SHARP Indicators database is that a single group-level environmental impact measurement cannot reflect the in-group differences in environmental impact of various foods. Depending on the local situation, the foods available may be lower or higher in GHGE and land requirements than in the SHARP Indicators database. Nutrient content in food composition databases may also not accurately depict the nutrient content of foods available to the consumers, which could influence results of nutrient content analyses and the correlation of the various nutrients with environmental impact. The SHARP Indicators database also only include information about GHGE and land use, and not other indicators of environmental impact such as water use, eutrophication and impact on biodiversity.

Unfortunately, there was no data on the cost or acceptability of these recipes, which are also part of the sustainable diet concept by the WHO and FAO and would have been interesting to include.

While the aim of this thesis was to explore nutrient content and environmental impact of dinner recipes, future research should include other types of meals to see how nutrient composition and environmental impact varies depending on meal type. However looking at meals in isolation does not provide information about whole diets, where deficiencies or abundancies in one meal could be compensated for in another throughout the day or week. Looking at meal plans for one or more days would give a better picture of the sustainability of whole diets. If looking at single meals, portion sizes could give additional information than looking at per 100 grams of a recipe.

It would be important to take into account that some ingredients may not be mentioned in the recipe ingredient list, but rather in the text description, and that recipes may be misclassified, so that a dessert may be classified as a dinner. Including a large number of recipes of various meals could limit the effect this problem would have on the results, as it is likely most recipes will be correct. The discrepancies between dietary macronutrient reference guidelines and the front-of-pack label scores suggests that further studies should aim to find a healthiness indicator more suited to recipes. Macronutrient guidelines should not be used for analysing the healthiness of single meal type recipes, although they could be suitable for daily/weekly meal plans. If looking at meal plans, food based advice from dietary guidelines should be included, such as "eat fish two-three times a week" to ensure that also micronutrient content is taken into account. For single meals it would be useful to find better indicators for health. The Nutriscore has an advantage in that it includes foods that are encouraged in FBDGs and are likely to contribute important micronutrients: fruits, vegetables, nuts, legumes and healthy fats, but it may have some limitations with complex meals such as recipes used in this thesis. Another downside with the Nutriscore is that it is more difficult to compute than the dietary guideline scores and the FSA MTL. Similarly, further studies should find reference ranges for the environmental impact of recipes. Possibly the One Planet Plate concept could be a starting point.

Further, the last two domains of sustainable diets, cost and acceptability, should also be explored. For example cost could come from online stores, and some online recipe sources provide user ratings that could be used as a stand-in for acceptability. Additionally, it would have been interesting to include more environmental impact indicators in studies such as this. Thresholds for these indicators should be developed to find categories to describe the sustainability of meals, or found in the literature.

4.3 Conclusion

This thesis showed that the type of healthiness indicator used can influence if a recipe is classified as healthy or not, and country of origin had little impact on recipe healthiness, CO_2 emission or land use. Recipes scored worse on adherence to WHO and Nordic Nutrition Recommendation dietary guidelines for macronutrient intake than on the front-of-pack labels the UK's Food Standard Agency Multiple Traffic Light system and the Nutriscore. Nearly all recipes could be eaten often as classified by the Multiple Traffic Light System, whereas only around 10% of recipes were classified as healthy using the dietary guidelines. For all four healthiness indicators there was a negative correlation with environmental impact, with a stronger correlation being found between dietary guidelines and environmental impact than between the front-of-pack labels and environmental impact. Recipes that used protein sources encouraged in dietary guidelines, such as fish, had a lower environmental impact than recipes that used protein sources like ruminant meat that dietary guidelines advice to limit intake of. Nutrients predominantly found in animal sourced foods, including protein, vitamin B12, retinol, iron and zinc, were positively correlated with environmental impact, while nutrients found in plant-based foods, including carbohydrates, fibre and vitamin C, were negatively correlated with environmental impact. It was also found that relatively few recipes were either vegetarian, vegan, or included whole grains or seafood, even though dietary guidelines in all countries recipes were sourced from encourage the intake of plant-based foods, whole grains and seafood. This also likely contributed to few recipes being sources of the micronutrients beta-carotene, folate, magnesium, potassium, iodine and iron.

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Appendix A

Appendix

Table A.1: The percentage of recipes that received a specific score on each front-of-pack-label indicator.

Front of Pack Labels									
Inverted Multiple Traffic Light Model					Nutriscore				
Score	Norway	UK	US	All countries	Score	Norway	UK	US	All countries
12	2.6 %	0.0 %	4.1 %	2.4 %	**A**	41.5 %	54.0 %	32.7 %	42.2 %
11	10.8 %	11.0 %	10.2 %	10.8 %	**B**	28.1 %	23.0 %	37.8 %	28.8 %
10	22.4 %	28.0 %	21.4 %	23.2 %	**C**	20.1 %	18.0 %	16.3 %	19.1 %
9	45.6 %	45.0 %	40.8 %	44.7 %	**D**	10.1 %	5.0 %	11.2 %	9.4 %
8	13.1 %	12.0 %	16.3 %	13.5 %	**E**	0.3 %	0.0 %	2.0 %	0.5 %
7	5.2 %	4.0 %	6.1 %	5.1 %					
6	0.3 %	0.0 %	1.0 %	0.3 %					

Table A.2: The percentage of recipes that received a specific score on the dietary guideline indicators.

Dietary guidelines									
Nordic Nutritional Recommendations					World Health Organization Recommendations				
Score	Norway	UK	US	All countries	Score	Norway	UK	US	All countries
6	0.5 %	2.0 %	1.0 %	0.9 %	**6**	0.8 %	0.0 %	0.0 %	0.5 %
5	1.0 %	4.0 %	2.0 %	1.7 %	**5**	0.5 %	2.0 %	2.0 %	1.0 %
4	6.2 %	12.0 %	9.2 %	7.7 %	**4**	3.9 %	6.0 %	8.2 %	4.9 %
3	19.8 %	25.0 %	10.2 %	19.1 %	**3**	13.1 %	19.0 %	5.1 %	12.8 %
2	38.9 %	36.0 %	23.5 %	35.8 %	**2**	30.2 %	33.0 %	24.5 %	29.7 %
1	33.0 %	21.0 %	48.0 %	33.4 %	**1**	51.0 %	40.0 %	53.1 %	49.5 %
0	0.5 %	0.0 %	6.1 %	1.4 %	**0**	0.5 %	0.0 %	7.1 %	1.5 %

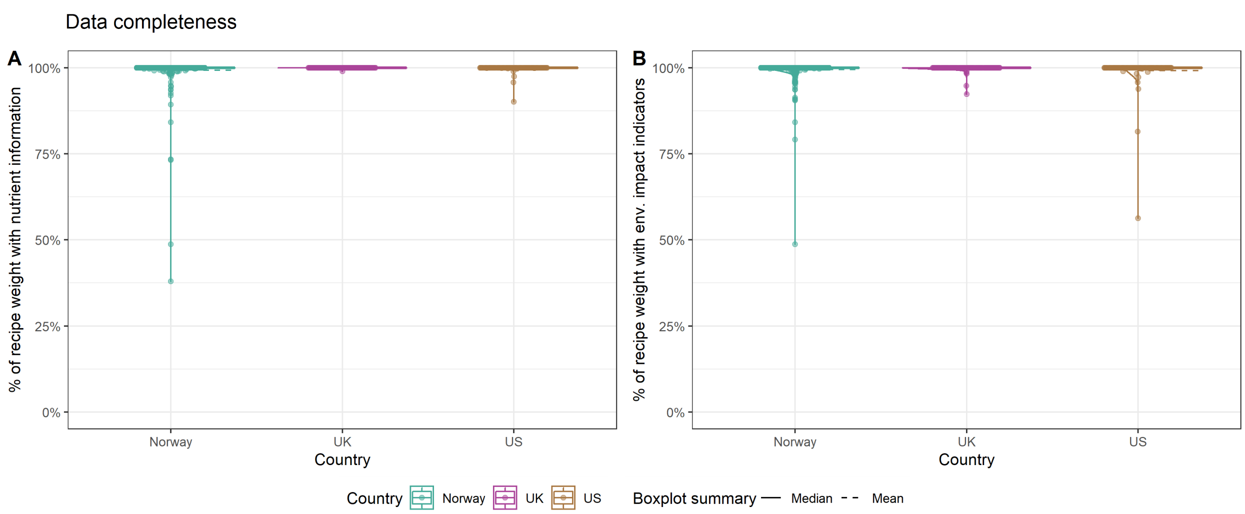

Figure A.1: Percentage of the recipe in weight not mapped to a nutrient database (A) and SHARP Indicators environmental impact database (B).

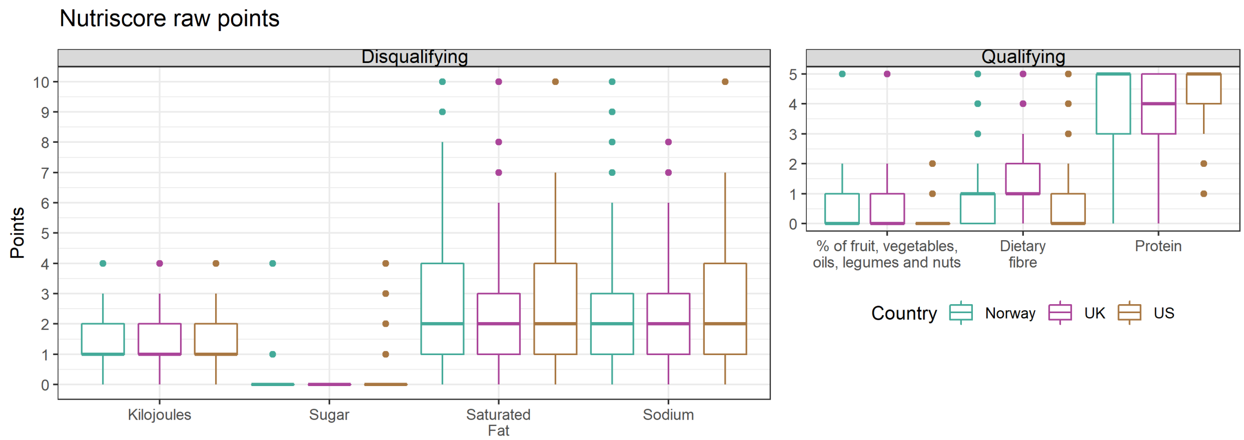

Figure A.2: The recipes' raw scores on disqualifying (1-10) and qualifying (1-5) components of the Nutriscore, by country.

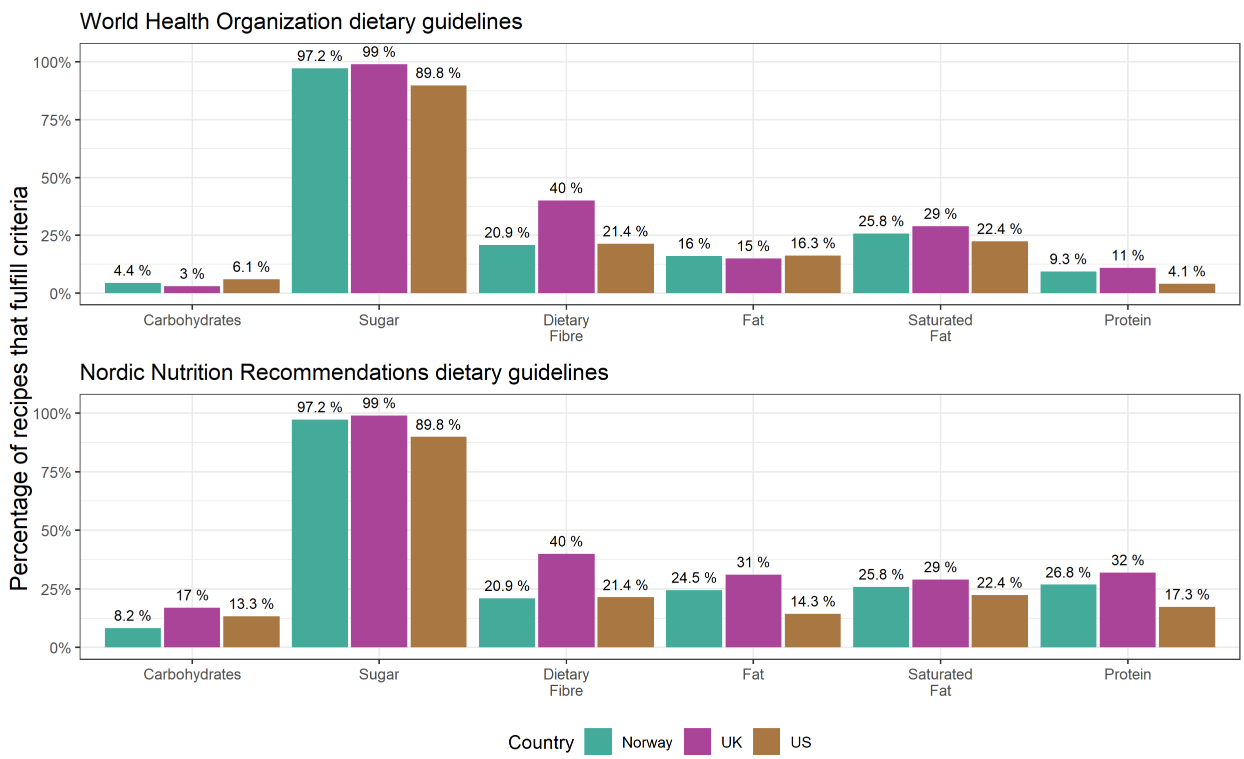

Figure A.3: The percentage of recipes that adhered to each of the criteria that made up the World Health Organization (top) and Nordic Nutritional Recommendations (bottom) dietary guidelines, by country.

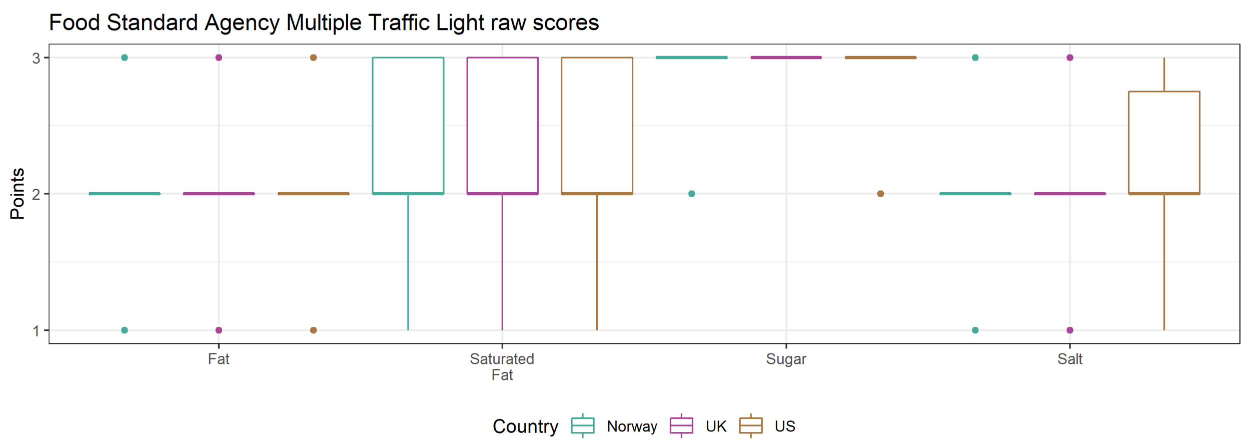

Figure A.4: The (inverted) individual scores from each component of the multiple traffic light system, by country.

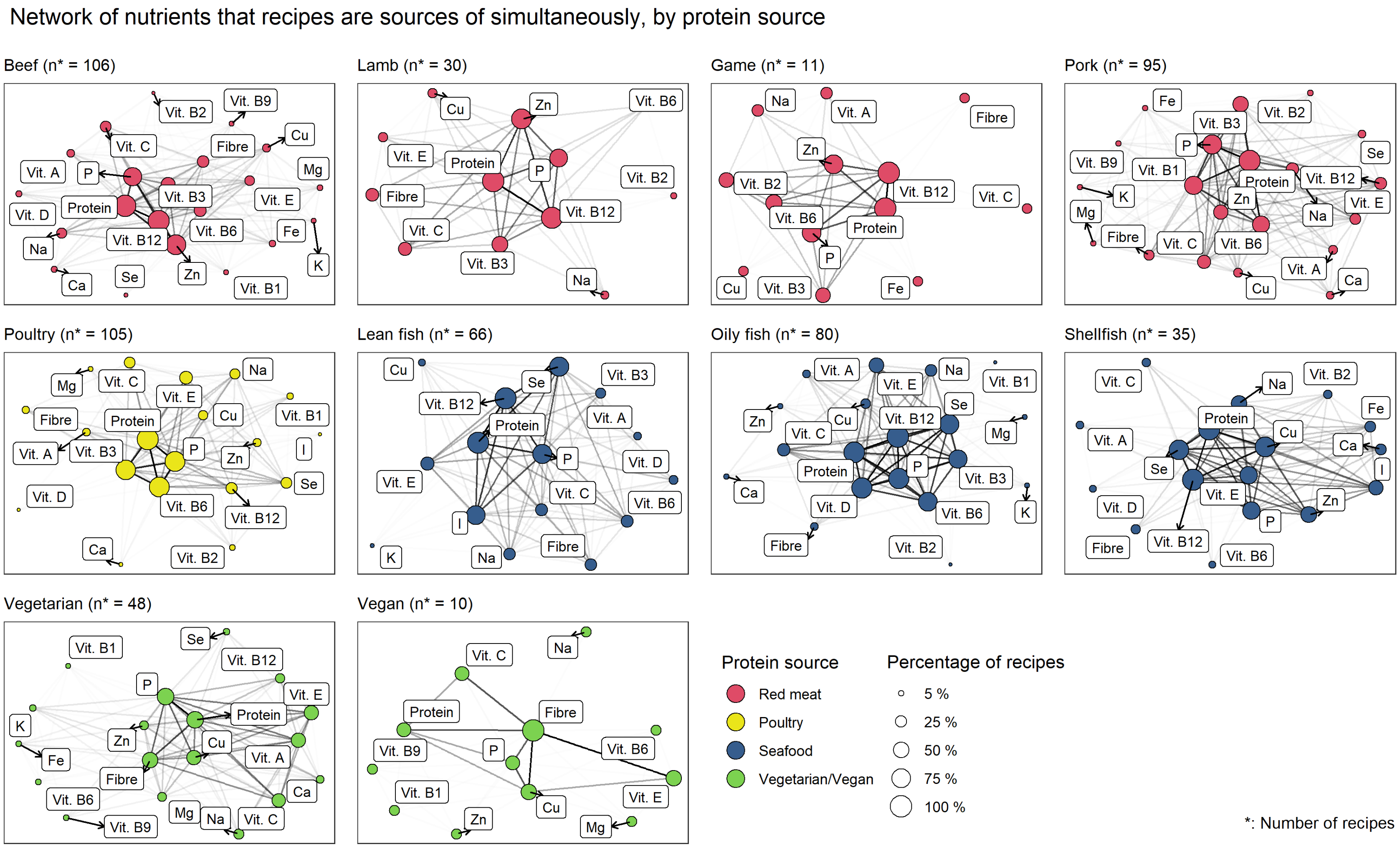

Figure A.5: Nutrients that occur together in the recipes, in such amounts that the recipe is considered a source. A larger circle indicates a higher percentage of recipes that is a source of the nutrient scaled by the number of recipes that used a particular source of protein, and a stronger line indicate a higher number of co-occurrences.

Appendix B

Appendix

B.1 Data summary

All the data and code used to write this thesis is available in the GitHub repository "sustainableRecipes" that will be made public after thesis evaluation. The code is able to recognise recipe ingredients, recalculate volume units into weight and calculate a recipe's nutrient content and environmental impact by using the respective databases "Weights, measures and portion sizes for foods" from the Norwegian Directory of Health, the Norwegian food composition datatable Matvaretabellen 2020 edition, and the SHARP Indicator database.

Nutrient content can be compared to the macronutrient criteria from the World Health Organization and the Nordic Nutrition Recommendations, and the front-of-pack labels the UK multiple traffic light and French Nutriscore.

Some volume/weight and nutrients were found from other sources than those listed which can be seen in the clean_database.R script.

Below is a short code example using a single recipe showing how the code is used and its output. Also included is the data structure of the GitHub repository and how to run the files within to replicate the results of the thesis.

B.2 Code example

B.2.1 Read in recipe data and standardise it

I have here used the "Bidos" recipe from the Norwegian dataset to illustrate how the code works. First Table B.1 shows how the recipe look before it will be standardised in terms of ingredient names and measurement units.

Table B.1: Original Bidos recipe data

recipe	Ingredients	Source	Country
Bidos	600 g of reindeer meat	Tine	Norway
Bidos	1 stk of onion	Tine	Norway
Bidos	2 tbsp tine dairy butter	Tine	Norway
Bidos	1.2 l water	Tine	Norway
Bidos	4 potatoes	Tine	Norway
Bidos	2 carrots	Tine	Norway

After being read, the recipe is standardised using the "standardiseRecipes" function. Here the amount and unit of an ingredient is taken from the "Ingredients" column and added to the respective "Amounts" and "unit" columns. All volume units are standardised to dl, weight units to kg, while ingredient names are standardised from plural forms to singular and to have the same spelling. The results after running this function are shown in Table B.2 (see how the two tablespoons of butter is now 0.3 dl and 600 g is 0.6 kg, and plural forms of potatoes and carrots have become singular). The recipe can now be mapped to the databases. I will illustrate with the volume/weight database as this recipe includes some ingredients where the amounts are listed in volume units.

```
#Standardise the recipes before calculating nutrient content
#and environmental impact
sample_standardised <- sample %>%
  standardiseRecipes()
```

Table B.2: Standardised Bidos recipe data

recipe	Ingredients	Amounts	unit	Source	Country
Bidos	reindeer	0.6	kg	Tine	Norway
Bidos	onion	1.0	stk	Tine	Norway
Bidos	butter	0.3	dl	Tine	Norway
Bidos	water	1.2	kg	Tine	Norway
Bidos	potato	4.0	stk	Tine	Norway
Bidos	carrot	2.0	stk	Tine	Norway

B.2.2 Map to databases

The function "checkRef" is used to map recipes to the different databases, using the "reference" argument to choose which database to use, here the volume/weight database is chosen.

```
#Find the ingredients with amounts not in weight already
  get_amounts_kg <- sample_standardised %>%
    filter(unit != 'kg')
#Map to volume/weight database
  temp <- checkRef(get_amounts_kg, reference = references$volume_weight)
```

The output of this function is a dataframe with the ingredient from the recipe and the food from the database it has been mapped to. After checking that there are no errors, the weight of one unit of the ingredient in grams is pulled from the database and the total amount in grams is calculated by multiplying the amount of units from the original recipe with the grams per unit from the database. Table B.3 show the dataframe before this calculation.

Table B.3: Result of mapping to volume/weight database.

recipe	Ingredients	db_reference	db_ID	unit	Amounts	gram_pr_unit
Bidos	bay leaf	bay leaf	1012	stk	2.0000000	0.20000
Bidos	black pepper	pepper ground	399	dl	0.0125000	33.35000
Bidos	bread	bread \	52	slice	4.0000000	42.50000
Bidos	butter	butter \	2514	dl	0.5997001	100.05000
Bidos	carrot	carrot \	181	stk	2.0000000	96.66667
Bidos	leek	leek \	433	stk	0.5000000	250.00000

This procedure is repeated with the nutrient and environmental impact databases, by changing the "reference" argument to the respective database. The end result is a dataframe with the recipe's nutrient content and environmental impact. An excerpt of this dataframe can be seen in Table B.4, where the results have been normalised to per 100 grams of the recipe.

Table B.4: Environmental impact and macronutrient content per 100 g of Bidos.

recipe	CO2 (kg)	Landuse (m2/year)	Fat (g)	Sat. fat (g)	Carb. (g)	Dietary fibre (g)	Sugar (g)	Protein (g)
Bidos	0.59	0.95	2.7	1.45	5.33	0.9	0.01	5.42

B.2.3 Healthiness assessment

With the nutrient content of the recipe, the healthiness assessment can be done, the result can be seen in Table B.5

```
#Calculate the various healthiness scores based on
#nutrient content of the recipe
healthiness_scores <- list(
  'nutriscore' = bidos_all_ingredients %>%
    calculateNutritionScore_nutriscore(),
  'multiple_traffic_light' = bidos_final %>%
    select(-group) %>%
    calculateNutritionScore_trafficlights(),
```

```
  'who_score' = bidos_final %>%
    calculateNutritionScore_who(),
  'nnr_score' = bidos_final %>%
    calculateNutritionScore_nnr()
) %>% reduce(full_join, by = c('sample_id'))
```

Table B.5: Healthiness assessment of the Bidos recipe.

recipe	Inv. Nutriscore	Nutriscore letter	Inv. Multiple Traffic Light	WHO Score	NNR Score
Bidos	1	A	12	2	3

Note:
Abbreviations used: Inv = Inverted, NNR = Nordic Nutrition Recommendations, WHO = World Health Organization

It is also possible to see the points awarded the individual components of the healthiness indicator. Doing so for the Nutriscore by including the argument "raw_scores = TRUE" in the function result in Table B.6. It should be noted this table has been cleaned up with improved column names for the sake of illustration.

```
bidos_nutriscores <- bidos_all_ingredients %>%
  calculateNutritionScore_nutriscore(raw_scores = TRUE)
```

Table B.6: Points awarded each component of the Nutriscore for the Bidos recipe.

recipe	Component	Points
Bidos	Dietary fibre	0
Bidos	Kilojoules	0
Bidos	Protein	3
Bidos	Saturated fat	1
Bidos	Sodium	1
Bidos	Sugar	0
Bidos	% of fruit, vegetables, oils, legumes and nuts	0

Note:
Abbreviations used: Inv = Inverted, NNR = Nordic Nutrition Recommendations, WHO = World Health Organization

B.3 Data structure

sustainableRecipes

all_recipes.R	
analyses.R	
clean_databases.R	
composite_ingredients.R	
Data	Contains the databases used, the nutrient criteria for the two dietary guidelines and the front-of-pack labels and the recipes.
DESCRIPTION	
man	Help-manuals for all functions written.
R	Functions written for the thesis.
README.md	
sustainableRecipes.Rproj	
thesis	Contains the individual chapter files and figures used in the thesis, in addition to the reference bibliography file.

B.4 How to run

B.4.1 Clean databases and add composite ingredients to the databases

Open clean_databases.R and block out the code for adding composite ingredients to the nutrient and environmental impact databases.

Run the code which will create two output files for each of the three databases used in the thesis. One output file is a shortened version of the database while the other is a set of reference words used to map recipe ingredients to the database.

Then run composite_ingredients.R and go back to clean_databases.R and include the code to add composite ingredients. This step must be done twice as some composite ingredients depend on other composite ingredients.

B.4.2 Calculate nutrient content and environmental impact of the recipes

After preparing the databases, run all_recipes.R to map the recipe ingredients to the databases and calculate the nutrient content and environmental impact per 100 grams of each recipe.

B.4.3 Calculate healthiness, run statistical tests, build plots and tables

Run analysis.R script.