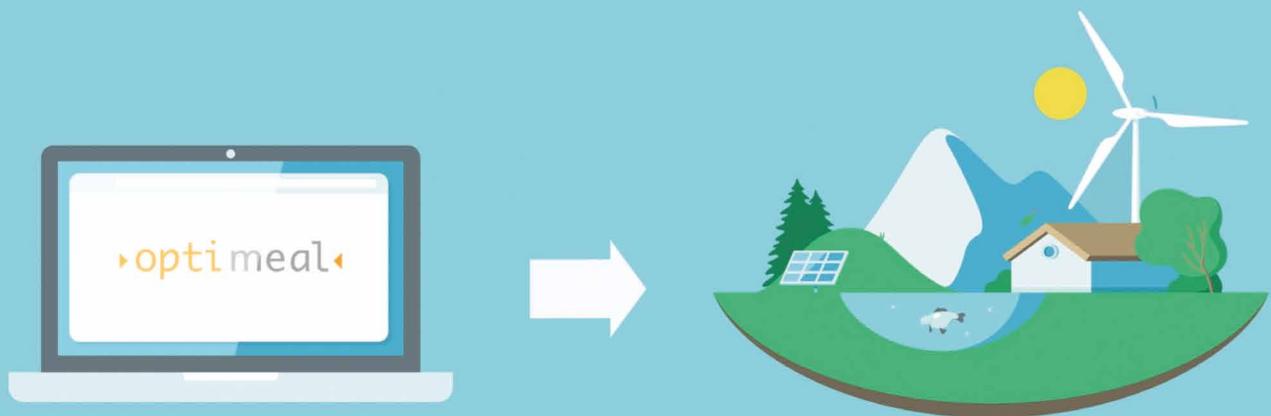


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The calculations are based on LCA-analyses, prices and food compositions of products from the Netherlands.

The place of animal products in a more sustainable diet



Replacing animal-based foods with plant-based foods does not necessarily lower a diet's carbon footprint. The nutritional value of food should be taken into account, as well as affordability. Modeling with the quadratic program Optimeal® helps to understand the ecological impact of changing food choices in a healthy diet, and the impact on food prices.

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It is often assumed that you can reduce the negative effects of your diet on the environment by eating more plant-based products and less animal-based products. This rule does not always apply, because it does not take sufficient account of the health aspects of your diet. This may sound contradictory, because eating more vegetable products is more beneficial to our health. But animal products also play an important role in our health. In conse-

quence, simply leaving out animal products can lead to nutrient deficiencies. Moreover, the change towards a more plant-based diet can also have significant consequences for the costs of your groceries. In this article, we explain how this works.

Cradle to grave

Scientists and policy-makers have long held on to the paradigm “eat more plant-based and less animal-based”. This rule arose mainly as a result of calculations of emissi-

ons per kilogram of product on the basis of life-cycle analyses. Using a LCA, the CO₂ emissions of a product in all phases of its life cycle are mapped out. This includes the raw materials used, packaging, transport, storage, consumer maintenance and waste disposal. This is also called the “cradle-to-grave” analysis, the environmental impact of a product from its inception to its end. For each phase of a product’s life, aspects of the environmental impact can be calculated, such as land use, water use and CO₂ >



emissions. The ultimate LCA value of a food product is the sum of the CO₂ (or other ecological variable) footprint of each stage in the life cycle of a food product.

CO₂ emissions per kg of product

Based on LCAs, an overview can be made of the carbon footprint of food products. These are often expressed in terms of CO₂ emissions per kilogram of product (figure 1). The figure shows that products of animal origin are responsible for most of the CO₂ emissions per kilogram of product. However, a representation of CO₂ emissions per kilogram of product does not take into account the quantity and quality of nutrients in the product.

This means the CO₂ emissions of a food does not tell the whole story, because the nutritional value is not taken into account. Reducing or eliminating animal-based foods from your diet can have negative consequences on nutrient intake. To avoid deficiencies, those nutrients must be compensated for by other foods.

Less animal-based foods: compensation

In an average Dutch person's diet, animal products are an important source of protein, minerals and vitamins (figures 2 and 3). Animal products contribute significantly to the intake of important nutrients, such as high-quality protein, vitamins A, B2 and B12, calcium, magnesium, zinc and

(in the case of meat) heme iron. These nutrients are not naturally, or often, found in plant products. Omitting animal products from the diet therefore can have major consequences for nutrient intake.

Plant-based alternatives

On first sight, a way to eat more sustainably is to replace animal products with plant-based products that are positioned as alternatives. For example: replacing meat with a meat substitute and milk with plant-based drinks that are marketed as possible alternatives. This seems plausible because a number of these alternatives are enriched with vitamins and minerals. Nevertheless, the one-to-one replacement of animal products with plant-based alter- ➤

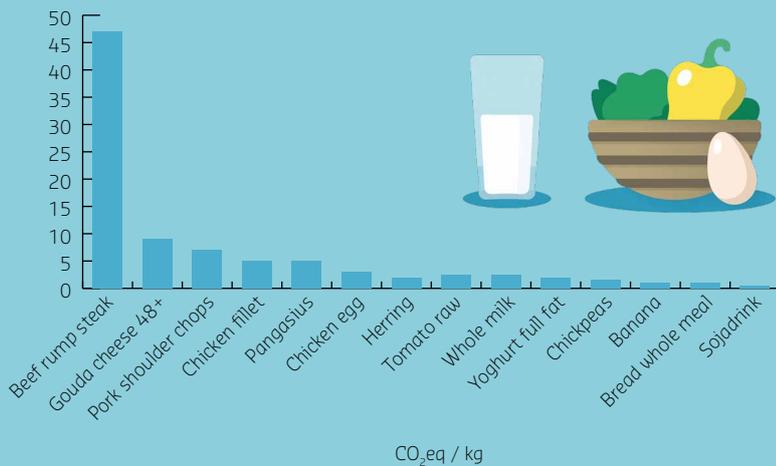


Figure 1: Carbon footprint per kilogram of food product.

Key messages

- Replacing animal products with plant-based alternatives does not automatically result in a healthy alternative diet
- Eating according to the food-based dietary guidelines can increase grocery costs by 20%
- Eating less meat can reduce the carbon footprint by 20%, but grocery costs increase by up to 10%
- Eating less dairy can reduce the carbon footprint by maximal 7%, but grocery costs increase by 35%
- Eating more bread reduces both the carbon footprint and the costs on groceries

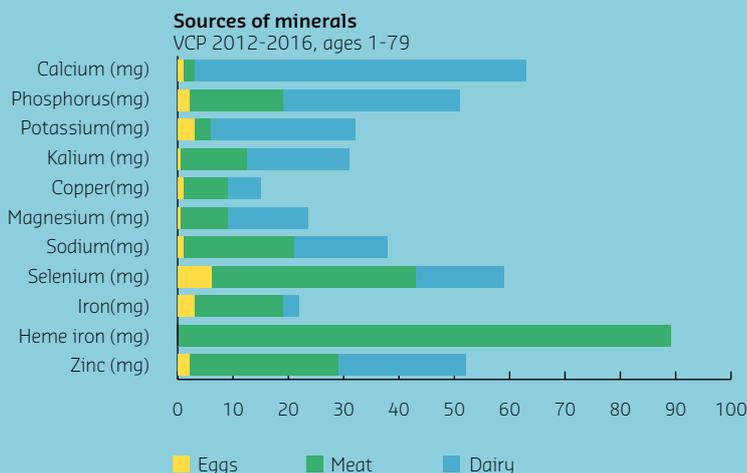


Figure 2. Share of eggs, meat and dairy in the mineral intake of the average Dutch person, according to the Dutch Food Consumption Survey 2012-2016 1-79 year olds.

Sustainable diets

natives still leads to potential shortages of various nutrients. The Dutch Institute of Public Health (RIVM) has made model calculations for this purpose. Figure 4 shows the effects on nutrient intake when dairy and meat are replaced by products that are recommended as alternatives in nutritional advice or are available in the supermarket (figure 4). The RIVM came to the following conclusions:^{1,2}

1. 30% substitution of animal products can lead to a 14% reduction in the CO₂-eq footprint and 100% substitution leads to a 40% reduction in the CO₂-eq footprint;
2. Replacing animal products with “plant-based alternatives” can lead to a potential shortage in intake of zinc, vitamin B1 (thiamine), A and B12 and calcium.

In short, simply leaving out animal products leads to potential nutrient deficiencies and replacing animal products with plant-based alternatives does not automatically lead to a healthy alternative diet. The substitution is not as “nutrient neutral” as one might expect.

Ideally, model calculations should show how you can fully compensate for the missed nutrients with other foods, when you reduce or omit certain products from your diet. If the calculated alternative diet ensures

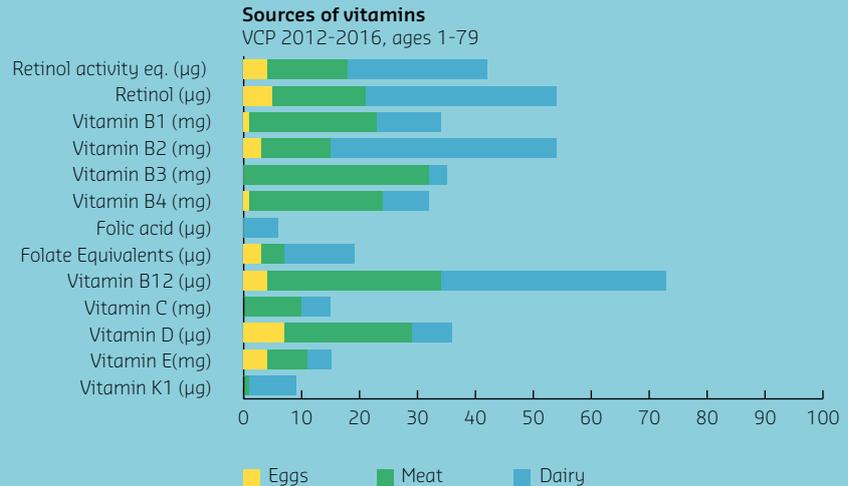


Figure 3. Share of eggs, meat and dairy in the intake of vitamins by the average Dutch person, according to the Dutch Food Consumption Survey 2012-2016 1-79 year olds.

that all nutrients are compensated for, a more nutritionally complete picture is generated of changes in the diet. Programming with Optimeal® offers this unique option.

Calculating with Optimeal®

Based on quadratic programming in the Optimeal® program, the effects of increasing or decreasing products or product groups (of animal or vegetable origin) on CO₂ emissions can be calculated. Optimeal® can also be used to calculate the effect of a change in diet on the costs of groceries. In its calculations, Optimeal® uses different datasets of 208 commonly

consumed foods in the Netherlands and combines them:

- Nutrient composition
- Supermarket price
- CO₂ equivalent (CO₂-eq) impact based on life-cycle analyses (LCAs)

Optimizing for health

Optimeal® is a mathematical program that makes calculations using quadratic programming. In simple terms, this means that the LCA data of 208 products are combined with their nutrient composition. In our calculations, Optimeal® depicts the dietary pattern by subdividing these 208 products into 12 product groups. The starting amount of each product group in grams is approximately what the average Dutch person eats (according to the Food Consumption Survey of the Dutch Institute of Public Health, RIVM). The first step is to “optimize” this starting diet. Once optimized, the starting diet will meet all recommendations for vitamins, minerals, saturated fat, salt, etc. as set out in the Dutch food-based dietary guidelines. This optimized diet creates an optimal starting point. Optimeal® can then calculate an alternative healthy diet when increasing or decreasing the quantity of a product group.

To show how this works in practice, we will take meat as an example. In the Netherlands, the Dutch eat about 150 grams of meat per day (sum of all types of meat) on average. If we reduce the amount of meat in Optimeal®, the program calculates which nutrients you lose. In the >



Figure 4. Percentage change in nutrient intake after replacing 30% and 100% dairy and meat with plant-based alternatives.



case of meat, this is a decrease in, among other nutrients, protein, vitamin B12 and iron. To compensate for these lost nutrients, Optimeal® looks for products in the other foods in the 11 groups that can provide these nutrients. Optimeal® selects these foods and, using quadratic programming, strives to find an alternative diet that is as similar as possible to the starting diet. Working in this way Optimeal® ensures that the alternative diet always complies with the dietary guidelines and that it is recognizable and acceptable to the average Dutch person. Decreasing meat in the diet and compensating for it using Optimeal® results in a decrease of the CO₂-footprint of the diet, but it makes the diet also more expensive.



dietary guidelines, he or she will spend about 20% more on groceries than they do currently.

CO₂ emissions and price effects

With Optimeal® we can calculate an alternative diet in a nutritionally sound way and see the effect of that change in the carbon footprint and price of the supermarket groceries. The results in table 1 show results of calculation with

when it is not.

The most important results are:

- Eating less meat results in a diet with a lower carbon footprint of 20%, but the costs in the supermarket increase by up to 10%.
- Eating less fruit and vegetables reduces the carbon footprint by up to 5%. Doubling fruit and vegetable intake increases the CO₂ footprint by 7% and grocery costs by 8% (not shown in table 1).

Optimeal® ensures that the alternative diet always complies with the dietary guidelines

First results

On average, the Dutch do not eat according to the food-based dietary guidelines. In order to make good calculations within Optimeal®, we first “optimized” the average Dutch diet to a healthy diet that meets all recommendations for vitamins, minerals, macro nutrients and saturated fat, among others, according to the food-based dietary guidelines. This optimized diet had the same CO₂ footprint as the average Dutch diet. Interestingly enough, this optimized diet is 20% more expensive than the average Dutch diet. In other words: if the average Dutch person eats according to the food-based

Optimeal® in which the amount of the given food group was reduced by 33%, 66% and 100% respectively. In these calculations, the lost nutrients were compensated for according to the principle of quadratic programming.

Results from Optimeal®

We started this article with the question of whether it is ecologically better to eat fewer animal products and more vegetable products. The results from the calculations with Optimeal® in table 1 clearly and reliably show when this is the case and

- Reducing dairy intake reduces the carbon footprint by maximal 7%, but grocery shopping becomes more expensive by 35%.
- Eating less bread and whole grain products increases the carbon footprint up to 5%, but grocery costs also rise by around one-fifth. Conversely (not shown in table 1), eating more bread reduces both the carbon footprint and the costs. Similar calculations have been carried out previous.³ Our calculations were similar but with more product groups and added grocery prices.

	CO ₂ emissions per % decrease in product group			Grocery price per % decrease in product group		
	33%	66%	100%	33%	66%	100%
Vegetables	-1	-2	-2	-1	-1	-1
Fruit	-2	-3	-5	-2	-4	-5
Meat	-11	-18	-21	0	+3	+10
Fish	+1	+3	+6	-1	-2	-1
Dairy	-2	-4	-7	+4	+17	+35
Beans/legumes	0	-1	-1	0	0	1
Nuts/seeds	-1	-1	-2	0	0	0
Bread/whole grain	+1	+3	+5	+5	+16	+18
Potatoes/rice/pasta	-1	-1	-2	0	+1	+1
Fats	+1	+5	+9	+1	+2	+3
Candy/snacks	+1	+3	+9	+3	+6	+17
Beverages (excl. milk)	-2	-3	-4	-1	-2	-3

Table 1. Effect on CO₂ emissions and the price of groceries when reducing the quantity of a product group and compensating for it based on quadratic programming with Optimeal®.

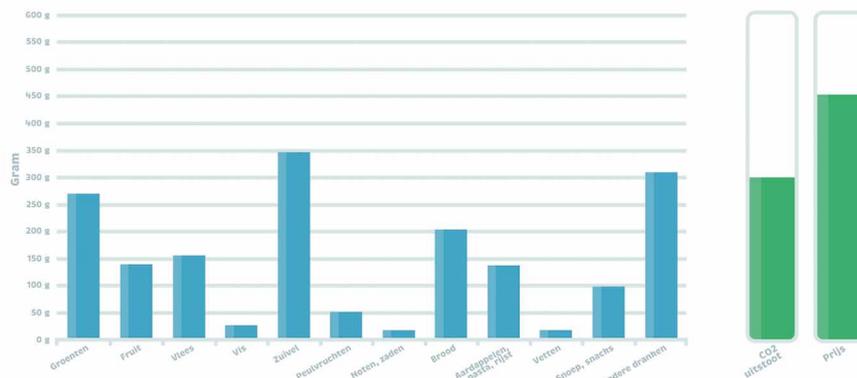
Discussion

According to the Food and Agriculture Organization of the United Nations (FAO), there are four important preconditions for a sustainable change in diet. Any new diet must be *i* healthy, *ii* affordable, *iii* acceptable and *iv* ecologically beneficial. There is a very complex correlation between these factors. For a desired change to be successful, a balance must be found between these four preconditions. Calculations with Optimeal® bring together these factors, because it calculates alternative diets that are as *i* healthy (i.e. they contain as many nutrients) as the starting diet. It then provides insight into the *ii* price and *iii* ecological effects. Through the principle of quadratic programming, the mathematical model ensures that the calculated alternative dietary pattern comes as close as possible to what the consumer is used to, making it the most *iv* cultural acceptable alternative.

Based on the calculations, the paradigm “eat less animal- and more plant-based products” can also be tested. The calculations show that the paradigm is too general and does not always apply. The fact that

Interactive tool

The effect on CO₂ emissions and grocery costs when reducing a food group by 33%, 66% and 100%, while compensating for lost nutrients through quadratic programming, is shown in table 1. With the online tool at <https://www.nzo.nl/en/nutrition/sustainable-diets/> more calculations with Optimeal® can be viewed. By moving the cursor up or down a food group in the interactive tool, an alternative food pattern is shown that is just as healthy, calculated with Optimeal®. The columns on the right of the figure show the effect on the carbon footprint and the costs of groceries.



of calcium. If dairy were to be completely omitted from the diet, calculations with Optimeal® show that the consumer would need to consume 538 grams of vegetables every day.

one-to-one basis. To determine a more sustainable diet, it is necessary to take into account the quantity and quality of nutrients in food. This can be done with the Optimeal® calculation program. Through quadratic programming, Optimeal® combines the LCA data (including carbon footprint) with the nutrient composition and the supermarket price of 208 products. Calculations with Optimeal® show that eating less meat has a favorable effect on environmental impact and that grocery costs for the consumer increase slightly. Eating less dairy hardly reduces the carbon footprint, and groceries become significantly more expensive. The conclusion is that policy and nutritional advice on more sustainable eating must be based on both CO₂ emissions and health aspects. In addition, advice on sustainable dietary changes should take consumer costs into account. <

When replacing dairy, the consumer would need to consume 538 grams of vegetables every day

fewer animal products cause less environmental impact of the diet is true for meat, but not for dairy and fish. That more vegetable products cause less environmental impact applies to bread/whole grain products, but not to fruit and vegetables. The impact of dietary changes can be viewed in the interactive online tool (see box). In these calculations using quadratic programming, no food groups were excluded as alternatives. This means that Optimeal® can choose any possible alternative (also animal based) to replace a food group to achieve a healthy diet that is as sustainable as possible. For example, when replacing dairy, Optimeal® mainly chooses vegetables as an alternative, because after dairy, vegetables are the most important source



Conclusion

The paradigm “eat fewer animal products and more vegetable products” is of little use to anyone who strives for a more sustainable diet that is also healthy. Animal products contain many nutrients and cannot be replaced by plant-based products on a

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