National Institute for Public Health
and the Environment
*Ministry of Health, Welfare and Sport*

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*Quality of the diet*

RIVM Letter Report 350123001/2011
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# Colophon



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# Rapport in het kort

Een voeding die minder vlees en zuivel bevat en meer duurzame plantaardige voedingsmiddelen kan voldoende eiwitten, mineralen en vitaminen leveren. Daarvoor is het wel nodig gevarieerd te kiezen uit plantaardige producten. De belangrijkste bronnen van plantaardige eiwitbronnen zijn noten, peulvruchten en volkoren graanproducten. Peulvruchten en noten worden nu echter nauwelijks gegeten als vervanger van dierlijke producten. Voor bepaalde vitaminen en mineralen (ijzer, calcium, vitaminen B2 en B12) kunnen ook verrijkte vlees- en zuivelvervangers een goede bron zijn. Dit geldt vooral voor B12, aangezien deze vitamine niet in plantaardige voedingsmiddelen zit.

Dit blijkt uit verkennend onderzoek van het RIVM. Hierin is onderzocht wat een verschuiving in een menu van de traditionele, dierlijke eiwitbronnen naar meer duurzamere plantaardige betekent voor de inname van eiwitten, en een selectie van vitaminen en mineralen.

Vlees en zuivel leveren in Nederland ongeveer de helft van de eiwitconsumptie. Mensen die geen vlees consumeren, eten meestal wel zuivelproducten. Voor hen zijn zuivel- en graanproducten momenteel de belangrijkste bronnen van eiwit. Daarnaast dragen vlees en zuivel in belangrijke mate bij aan de inname van de vitamines A, B1, B2, en B12 en de mineralen calcium, ijzer, fosfor, selenium en zink. Aanvullend onderzoek is nodig om de inname van voedingsstoffen bij verschillende consumptiepatronen met minder vlees en zuivel, verder te kwantificeren.

## Abstract

Diets with less meat and dairy and more sustainable plant based foods can provide enough protein, minerals and vitamins, provided that a varied choice of plant foods is consumed. Main sources of plant proteins are nuts, pulses, and whole grain cereals. Current consumption of pulses and nuts as a replacer of meat is low. Fortified meat and dairy substitutes can also be a source of certain vitamins and minerals (iron, calcium, vitamins B2 en B12). This is especially true for vitamin B12, since it cannot be supplied by plant sources.

RIVM carried out an exploratory study on the nutritional consequences of a shift from conventional animal to (more) sustainable protein rich plant foods. The focus was on protein, amino acids and selected micronutrients. In the Netherlands, meat and dairy deliver half of the daily protein intake. People consuming no meat typically do consume dairy products. In addition to dairy, grains are the main source of protein for them. Meat and dairy are major sources of vitamins A, B1, B2, en B12 and minerals calcium, iron, phosphorus, selenium en zinc. Further studies are needed to quantify the effects of different dietary patterns in which meat and dairy intake is reduced.

# Summary


## Replacement of meat and dairy by more sustainable protein sources in the Netherlands – Quality of the diet

A reduction in the consumption of animal protein rich foods is an efficient and possibly unavoidable way to reduce the negative impact of human behaviour on the environment. In this letter report, the nutritional consequences of a shift from conventional animal to (more) sustainable protein rich plant and insect foods are explored. Focus is on protein, amino acids, selected micronutrients and allergens.

Animal foods contain high quality protein. Protein rich plant-based foods are legumes, grains, nuts and ready-made meat and dairy replacers. The current ready-made meat and dairy replacers are based on wheat, soy, rice, pea, lupin, or a combination thereof. They also contain differing degrees of animal products such as egg protein and milk protein. Soy and lupin, more than the other plant based protein sources, have an amino acid composition of quite high quality.

As can be seen from the Dutch National Food Consumption Survey (DNFCS), protein consumption in the Netherlands is mainly provided by meat, dairy and grain products. Almost the whole population meets the recommendations for protein intake and nutritionally there is room to replace animal protein by plant protein. Those persons in the DNFCS that do not consume meat, consume a large part of their protein from grains and dairy products. Currently, legumes and nuts are not consumed frequently in the Netherlands. It will be beneficial to increase their consumption, in light of a varied intake of plant protein sources. This will secure sufficient protein quality, especially when intake of both meat and dairy products is reduced.

Micronutrients that are currently provided mainly by meat or dairy, and that could possibly be of potential concern when intake of meat and/or dairy is lowered, are heme iron, selenium, vitamin B1, vitamin B12, and zinc (meat), and calcium, vitamin B2, vitamin B12, phosphorus, vitamin A and zinc (dairy). For vitamin A, vitamin B1, iron and zinc, intake may already be too low in certain population subgroups. Legumes, nuts and *whole* grains can contribute importantly to micronutrient intake, and this becomes more important when intake of dairy products is also reduced. Fortified ready-made meat and dairy replacers can, in an easy way, ensure sufficient intake of iron, calcium, vitamin

B2 and especially vitamin B12; the latter of which cannot be provided by plant sources.

In terms of allergy, no significant adverse effects are expected to occur when animal protein sources are replaced by plant protein sources. One issue to monitor is cross-reactivity.

It is recommended to update the Dutch Food Composition Table in terms of both sustainable food types and nutrients; and to systematically review the consequences of a protein shift in terms of health and disease.

Key words:
healthy, sustainable, food, nutrition, protein

## Samenvatting

# Vervanging van vlees en zuivel door duurzamere eiwitbronnen in Nederland – Kwaliteit van de voeding

Een vermindering in de consumptie van voedingsmiddelen van dierlijke oorsprong is een efficiënte en mogelijk onvermijdelijke manier om de schadelijke gevolgen van menselijk gedrag op het mileu te verkleinen. Dit briefrapport bevat een verkenning van de voedingskundige gevolgen van een verschuiving in eiwitbronnen, van conventioneel dierlijke voedingsmiddelen naar meer plantaardige voedingsmiddelen en insecten. We gaan hierbij vooral in op eiwit, aminozuren, een selectie van micronutriënten en allergenen.

Dierlijke voedingsmiddelen bevatten eiwit van hoge kwaliteit. Eiwitrijke voedingsmiddelen op plantaardige basis zijn peulvruchten, granen, noten en kant-en-klare vlees- en zuivelvervangers. De huidige vlees- en zuivelvervangers zijn gemaakt op basis van tarwe, soja, rijst, erwt, lupine, of een combinatie hiervan. Ze bevatten ook, in verschillende mate, dierlijke producten zoals ei-eiwit en melkeiwit. Soja en lupine hebben, meer dan de andere plantaardige bronnen die nu gebruikt worden, een aminozuursamenstelling van hoge kwaliteit.

De voedselconsumptiepeiling (VCP) laat zien dat eiwit in Nederland vooral gegeten wordt in de vorm van vlees, zuivel en granen. Vrijwel de gehele bevolking voldoet aan de eiwitaanbevelingen en voedingskundig is er ruimte om dierlijk eiwit te vervangen door plantaardig eiwit. Diegenen in de VCP die geen vlees eten, krijgen hun eiwit in belangrijke mate binnen via zuivel en granen. De huidige consumptie van peulvruchten en noten is laag. Een toename in hun consumptie zal gunstig zijn in het kader van een gevarieerde consumptie van plantaardige bronnen; dit zal een voldoende hoge eiwitkwaliteit garanderen, vooral als zowel de consumptie van vlees als van zuivel verminderd wordt.

Micronutriënten die op dit moment voornamelijk via vlees en zuivel geleverd worden, en mogelijk in het gedrang zouden kunnen komen als de consumptie van vlees en zuivel wordt verminderd, zijn: heem-ijzer, selenium, vitamine B1, vitamine B12 en zink (vlees), en calcium, vitamine B2, vitamine B12, fosfor, vitamine A en zink (zuivel). Voor vitamine A, vitamine B1, ijzer en zink, is de inneming mogelijk al wat laag in bepaalde groepen in de bevolking. Peulvruchten, noten en *volkoren* granen kunnen in belangrijke mate bijdragen

een de inneming van micronutriënten. Dit wordt belangrijker naarmate ook de consumptie van zuivel wordt beperkt. Verrijkte kant-en-klare vlees- en zuivelvervangers kunnen, gemakshalve, zorgen voor een voldoende inneming van ijzer, calcium, vitamine B2 en vooral vitamine B12; plantaardige bronnen kunnen niet voorzien in deze laatste.

Wat betreft allergie, worden geen belangrijke nadelige effecten verwacht wanneer dierlijke voedingsmiddelen vervangen worden door plantaardige. Er moet wel op kruisreactiviteit gelet worden.

Geadviseerd wordt om het Nederlandse Voedingsstoffenbestand te updaten met meer soorten duurzame voedingsmiddelen alsook met voedingsstoffen die zij bevatten; en om systematisch de gevolgen van een eiwitverschuiving in kaart te brengen in termen van ziekte en gezondheid.

Trefwoorden:
gezond, duurzaam, voeding, voedsel, eiwit

# Contents

**Terms and definitions in this report**

| | |
|---|---|
| Ready-made meat replacer | Product that is developed to replace meat (with or without added nutrients) |
| Ready-made dairy replacer | Product that is developed to replace milk, cheese or yoghurt (with or without added nutrients) |

# 1 Introduction

Protein is an essential nutrient for the human body. It provides building blocks, and has a large number of regulatory functions, and can also serve as a fuel source (Millward et al., 2008, WHO, 2007). Protein consists of chains of amino acids.

Currently, about half of the protein consumed by the Dutch is derived from animal sources, i.e. meat and dairy products. However, the production of meat and dairy is rather inefficient and negatively affects the ecosystem when used on a large scale (Blonk et al., 2008, FAO, 2006). The World population is increasing, with an expected number of 9 billion people in 2050. Following current production and consumption patterns, the ecosystem is and will increasingly be overly pressured and future food security is endangered.

An effective option to reduce the environmental burden is to eat less meat and dairy and to shift towards more sustainable protein food sources (see Box 1), such as grains, legumes, nuts and insects. However, such a change may also affect nutritional intakes and human health. Animal protein is of high quality, i.e. its amino acid composition suits the human body well. It also provides valuable micronutrients. Both plant and animal protein can elicit allergic reactions, among certain individuals. In this report, we consider these nutritional issues.

Several different ways exist to fill the place of meat and dairy in the diet, which face different challenges, e.g. from technological or consumer (Schosler et al., 2011) perspectives:

1) Replacement of meat or dairy products by more sustainable imitations of the product and its role in the current diet: ready-made meat or dairy replacers or hybrid meat. Ready-made meat or dairy replacers are mostly based on plant constituents (see section 2.1.1). In hybrid meat products, a percentage of the fat or meat content is replaced by protein-rich plant components.
2) Increased daily consumption of sustainable protein-rich basic commodities that need to be considered in the diet as a whole, both in terms of nutrition and of eating habits: grains, legumes, nuts.
3) Meat replacement via "new" or "novel" protein-rich sources, such as algae and insects.

There are developments in improving the animal product chain (Coenraadts & Cornelissen, 2011) or culturing meat cells (Tuomisto & de Mattos, 2011), but this is beyond our scope. In this report we focus on plant foods and insects.

An exploration of the relation between health and sustainability in human diets is in full progress (see Box 2). Many foods are both healthy and environmentally sustainable. Those that are not, need to be addressed.

Within the above context and developments, in this report we explore the effects of replacing meat and dairy by more sustainable protein sources on dietary quality in the Netherlands. More specifically, we consider the adequacy of protein quantity and quality, the adequacy of micronutrient intake and the occurrence of food allergy of plant foods and insects. Our aim is to support policy makers in their knowledge of the nutritional effects of consuming more sustainable protein sources. In addition, this report contributes to a weighing of benefit and harm, both nutritionally and ecologically, of the shift from conventional animal to more sustainable protein sources.

In Chapter 2, we start with an inventory of protein-rich foods and their nutritional characteristics. Then, in Chapter 3, we describe current dietary intake, focusing on protein-rich food sources and their most characteristic micronutrients. Also, we describe the expected nutritional consequences of a shift to more sustainable protein-rich food sources. In Chapter 4, we describe allergy-related issues. In Chapter 5 we elaborate further on some selected issues.

**Box 1: sustainability**

This letter report builds on the evidence-based premise that replacing animal protein sources by plant- and/or insect-based protein sources within our current dietary pattern benefits sustainability. It contains no quantitative consideration of sustainability parameters.

The most common parameters to measure sustainability are ecological parameters, i.e.: biodiversity, land use, greenhouse gas emissions, use of non-renewable resources, disturbances in the nitrogen and phosphate cycles, water use and soil quality (explained in Box 2.1). However, it may also include parameters related to animal welfare and social welfare. Two definitions of sustainability are specifically mentioned here:

1) "sustainability means production and consumption with respect for people, animals and environment" (LNV, 2009).

In the renowned so-called 'Bruntland report' this specifically also includes future generations:

2) "In essence, sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations" (WCED, 1987).

**Box 2: health and sustainability combined**

Recently, the **Health Council of the Netherlands** considered the Dutch dietary guidelines (Health Council of the Netherlands, 2006) from an ecological perspective (Health Council of the Netherlands, 2011). It distinguished:
-***win-win guidelines***, which deliver both health benefits and ecological benefits in terms of land use and green house gas emissions:
- -***less animal-based, more plant based diet***
- -lower energy intake

-*guideline conferring health benefit, but detrimental ecological impact*:
- -fish twice a week, including oily fish once

-*ecological benefit, neutral health effects*:
- -reduce food waste

The Health Council advises to take these ecological perspectives into account when establishing the new guidelines for good nutrition, and mentions specifically less animal-based and more plant-based dietary patterns, as well as a reconsideration of the recommendation for fish, especially since there are indications that fatty fish once a week will suffice for prevention of cardiovascular disease. Ideally, all perspectives (health and ecological and potentially other) should be weighed against each other.

New food-based dietary guidelines based on incorporation of ecological perspectives are under development in other countries, for example:
*In the UK, the **Rowett Institute of Nutrition and Health**, as commissioned by **WWF-UK**, defined a sustainable diet that is nutritionally viable (MacDiarmid et al., 2011). They adapted the current governmental eating advice – the Eatwell plate – to include the environmental aspects and meet the 2020 Green House Gas Emissions target of 25% reduction. The result was called the **Livewell plate**. To achieve the 2050 target of 70% reduction would be much more difficult based on current diet and would require a radical shift in food consumption. A 2050 diet could include food such as meat and dairy, but in very much smaller amounts than the current diet (MacDiarmid et al., 2011).
The general Livewell 2020 principles are:
*1)* ***Eat more plants****;* 2) Waste less food; *3)* ***Eat less meat****;* 4) Eat less processed food; and 5) Where available, buy food that meets a credible certified standard.
In addition, a 7 day sample menu, including a shopping list that corresponds to this menu, has been created, see wwf.org.uk/livewell2020.

*Also, (traditional) regional diets are being promoted as being both healthful and sustainable. Some examples are mentioned here. In Norway, a diet based on locally available products has been proposed, containing: 1) native berries; 2) cabbage; 3) native fish and other seafood; 4) wild (and pasture-fed) land-based animals; 5) rapeseed oil; 6) oat/barley/rye (Bere & Brug, 2009, EFSA, 2012). Similarly, the Mediterranean diet is based on a variety of diversified local traditional foods strictly linked to the Mediterranean environment (Burlingame & Dernini, 2011), i.e. Greece, Italy, Spain and Morocco (http://www.unesco.org/culture/ich/en/RL/00394).

# 2 Composition of sustainable protein-rich foods and commodities

In this section, we describe the nutritional composition of available options of foods that can be consumed as alternatives for meat and dairy. Focus is on amino acids and micronutrients that are characteristic for animal-based protein sources.

For background information on protein quantity and quality, see Appendix 1. Dutch translations and food composition codes for the foods mentioned in this chapter are presented in Appendix 2 and 3, respectively.

## 2.1 Available options for sustainable protein-rich foods and commodities in the Netherlands

Protein-rich options are ready-made meat and dairy replacers based on soy, wheat and pea protein; tahoe and tempé; seitan; quorn; tahin, hummus and falafel, nuts and seeds; and legumes. These are all good protein sources (see section 2.2.1), but often lack in one or more of the other nutrients, compared to meat (see section 2.2.2). However, nutrients that meat and dairy provide can be provided by different kinds of foods. And thus, it needs to be kept in mind that it is the whole diet that determines (in)adequate intake.

### *2.1.1 Ready-made meat replacers and hybrid meats*

Several companies produce ready-made (vegetarian) ready-made meat replacers in the Netherlands (some commonly available brands are Tivall, Vivera, GoodBite, Quorn, and Valess). Most products contain a combination of wheat, soy, and egg proteins, some also contain cow's milk proteins. Quorn is a fungal protein (mycoprotein) extracted from the *Fusarium venenatum*.

Innovations in the field of meat-replacement products are
-increased use of lupin and different types of legumes as more locally produced protein sources and
-increased attention for a more meat-like 'bite' of the product (www.devegetarischeslager.nl; http://www.likemeat.eu/) and
-development of hybrid products. Products based on beef and containing ~30% plant components have been available in Dutch supermarkets since 2010.

The above developments are being combined. Beeter® (www.eetbeeter.nl) is a 100% plant-derived basic product for replacement of meat and fish that focuses on an attractive 'bite'. It is currently sold on a soy-basis, but a lupin version is being developed for better sustainability. Meatless (www.meatless.nl) is a 100% plant-based product that comes in three varieties: wheat-based, which scores best on sustainability and is mostly used in hybrid products; rice-based, which an allergen-free alternative, also mostly used in hybrid products; and lupin-based, which has the best nutritional value and is (therefore) mostly used in vegetarian products.  A new development is hybrid meat with pea protein.

In general, the less animal-based the product is, the lower its impact on sustainability parameters (Marinussen et al., 2010, Blonk et al., 2008), see Box 3. For example, Valess is made of dairy and is therefore not considered as a sustainable replacer of meat (Blonk et al., 2008). In quorn and other ready-made meat replacers, egg-white protein extracts are used, which unfavourably influences their environmental impact. With respect to the plant components, soy scores relatively unfavourably in Europe compared to for example wheat or lupin (Blonk et al., 2008, Broekema & Blonk, 2009), which can be grown in Northwestern Europe. It has to be noted, that differences exist in the production of soy; producers of meat and dairy replacers often adhere to sustainability standards, which influence the sustainability score (Blonk et al., 2008).

### 2.1.2 *Dairy replacers*

Soy-based drinks and soy-based yoghurt are the most available dairy replacers. However, there is a movement away from total reliance on soy towards the broader promotion of plant-based diets. For example, major European producer of soy-based drinks Alpro has recently changed its soy-based logo to a sun and green leaf accompanied by the words 'Enjoy Plant Power' . Two new (fortified) drink products are introduced based on almond and hazelnut. Compared to cow's milk, soy drink scores relatively favourably with respect to green house gasses, but land use in South America and fossil energy use is relatively unfavourable (Marinussen et al., 2010, Blonk et al., 2008).

Cheese scores relatively unfavourably on all sustainability parameters, but replacement options are few in the Netherlands.

**Box 3: major sustainability parameters explained**

| |
|---|
| The major sustainability parameters are:<br>-Emission of greenhouse gasses. This includes carbondioxide ($CO_2$), nitric oxide ($N_2O$), methane ($CH_4$). These are integrated into one measure: $CO_2$-equivalents per 100 years, based on internationally agrees values (IPCC GWP-100).<br>-Use of fossil fuels. This entails use for transport, storage, processing, etc. It can be expressed as the caloric value of the primary fossil fuels (KJp).<br>- Land use. This describes the how much land is being used for the production of a product and is expressed in $m^2$ per year. Key in this measure is the quality of the land that remains, in terms of biodiversity and contribution to the Life Support System. The degree to which natural land is converted to agricultural land for a product can be expressed as the 'land use and land use change' (LULUC). Loss of biodiversity can also be quantified. Different types of land can be differentiated, for example 'land use in South East Asia and South America'. Furthermore, water use can be incorporated in the form of irrigated land use.<br>- Other effects are: water use in the entire production chain; and production and translocation of minerals, resulting in local excess or deficiency.<br>When presenting sustainability calculations, it is important to demarcate which method is followed and what is and is not included. An often used method is Life Cycle Analysis (LCA). This method quantifies selected parameters over the entire production chain. |

### 2.1.3 *Basic plant commodities*

Basic protein-rich plant commodities are legumes, nuts and grains. The sustainability potential of nuts and legumes varies. For example, cashew nuts score unfavorably on land use in South East Asia and South America and in production and use of fertilizers; And brown beans in glass score unfavorably in processing, i.e. drying or cooking, and packaging (Blonk et al., 2008).

### 2.1.4 *Insects*

People in many parts of the world eat insects and more than 1300 different edible types have been found (Verkerk et al., 2007). Here, we focus on those insects currently produced and marketed for human consumption in the Netherlands. These are: mealworms, buffalo worms and locusts. These insects have been freeze-dried and are marketed via wholesale (www.ruig.nl). Insects are a sustainable source of protein as their yield is higher and they producte less greenhouse gasses and ammonia than conventional livestock (Oonincx et al., 2010). Another line of development is the extraction of insect protein that can be used in 'regular' products.

## 2.2 Nutritional composition of sustainable protein-rich foods and commodities

### *2.2.1 Protein content and amino acid composition*

The protein content of a selection of meat and dairy and its replacers is shown in Table 1. Total protein content of (ready-made) meat replacers varies from ~ 7-22 g per 100 g (the range in around 150 different products by different producers as reported via the internet). The total protein content of basic commodities such as legumes is around 8 g/100 g cooked weight. Soy (21 g/100 g cooked weight) and lupin (16 g/100 g cooked weight) have a higher protein content. The most consumed types of meat in the Netherlands are beef, pork and chicken. These three types contain similar amounts of high quality protein of around 20 g per 100 g. Chicken egg, both the white and the yolk, contains high quality protein, approximately 12 g/100 g for the whole egg.

Dairy products differ in protein content, cheese being more concentrated (20-25 g protein/100 g) than cow's milk and yoghurt (~4 g protein/100 g), the quality of all being high. Soy drink contains ~3-4 g protein/100 g.

Nutritional data for many insects are available, but are scarce for the specific genus that are marketed in the Netherlands. The protein content of insects varies highly between and within type (Bukkens, 1997, Verkerk et al., 2007). In general, protein content is comparable to conventional meats (Bukkens, 1997). For mealworms, it is almost 20 g/100 g edible insect. Amino acid composition and thus protein quality also varies, but is generally good (Bukkens, 1997, FAO, 2010, Finke, 2002, Ramos-Elorduy et al., 1997). For some (e.g. silkworm pupae, not in Table 1) protein quality is very high, see also Appendix 1 (FAO, 2010).

**Table 1: protein content and amino acid composition of plant-based protein sources, insects, meat, dairy and egg**

| | | Protein content | | Amino acid composition[1] in mg/g protein | | | |
|---|---|---|---|---|---|---|---|
| | | g/100g edible food (c/d/r)[2] | specific NCF[3] | Lysine | Methionine + Cysteine | Threonine | Tryptophan |
| *Scoring Pattern*[4] | *Children (3-10 yrs)* | | | *48.0* | *24.0* | *25.0* | *6.6* |
| | *Adults* | | | *45.0* | *22.0* | *23.0* | *6.0* |
| **Plant sources** | | | | | | | |
| Legumes | Brown beans | 8.0 (c); 20 (d) | 6.25 | 72.0 | 15.7 | 41.6 | 12.5 |
| | White beans | 8.0 (c); 20 (d) | 6.25 | 68.8 | 25.9 | 41.6 | 11.8 |
| | Green peas | 8.4 (c); 21 (d) | 6.25 | 60.8 | 18.6 | 41.6 | 11.0 |
| | Lentils | 8.8 (c); 21 (d) | 6.25 | 72.0 | 17.6 | 40.0 | 9.6 |
| | Mung beans | 7.0 (c); 23.9 (d) | 6.25 | 70.4 | 20.8 | 32.0 | 10.9 |
| | Chickpeas | 7.6 (c); 19.3 (d) | 6.25 | 68.8 | 27.2 | 38.4 | 8.0 |
| | Lupin | 15.6 (c); 36.2 (d) | 6.25 | 53.4 | 19.4 | 36.8 | 8.0 |
| | Soya beans | 21.5 (c); 35.9 (d) | 5.71 | 69.9 | 28.4 | 42.2 | 14.0 |
| | Soya flour | 38 | 5.71 | 70.1 | 31.5 | 42.0 | 14.0 |
| Grains | Wheat flour, white | 12.6 | 5.83 | 24.0 | 32.8 | 27.4 | 11.1 |
| | Wheat flour, brown | 10 | 5.83 | 34.3 | 32.4 | 32.6 | 13.7 |
| | Rice, polished | 3.2 (c); 7 (r) | 5.95 | 36.9 | 35.2 | 33.6 | 14.1 |
| | Rice, brown | 3.1 (c); 8.3 (r) | 5.95 | 37.0 | 35.3 | 33.6 | 14.1 |
| | Corn flour | 9 | 6.25 | 27.6 | 34.9 | 36.4 | 6.4 |
| | Rolled oats | 13 | 5.83 | 44.0 | 46.2 | 35.8 | 13.4 |
| Nuts | Hazel nuts | 14 | 5.3 | 28.1 | 33.2 | 33.2 | 12.8 |
| | Brazil nuts | 15 | 5.46 | 34.8 | 98.9 | 27.5 | 10.8 |
| | Cashew nuts | 21.2 | 5.3 | 52.8 | 36.4 | 37.7 | 15.5 |
| | Walnuts | 15.9 | 5.3 | 34.0 | 33.6 | 37.7 | 11.5 |
| | Macademia nuts | 7.8 | 5.3 | 2.3 | 3.6 | 46.8 | 8.5 |
| **Plant sources, meat replacers** | | | | | | | |
| | Tahoe | 11.6 | 5.71 | 65.8 | 26.6 | 40.8 | 15.6 |
| | Quorn (mycoprotein) | 14.5 | 6.25 | 57.3 | 14.4[5] | 37.9 | 11.0 |
| | Vegetarian nuggets[6] | 15 | 6.25 | 56.4 | 36.8 | 38.9 | 13.6 |
| | Vegetarian schnitzel | 16 | 6.25 | 60.9 | 39.2 | 40.3 | 13.5 |
| **Plant sources, milk replacers** | | | | | | | |
| | Soy-based drink (fresh) | 3.0 | 5.71 | 69.9 | 28.4 | 42.2 | 14.0 |
| **Animal sources** | | | | | | | |
| Meat | Beef (<5% fat) | 21.8 (r) | 6.25 | 83.2 | 31.2 | 41.6 | 11.4 |
| | Pork (5-14% fat) | 21.1 (r) | 6.25 | 89.6 | 32.3 | 41.6 | 10.7 |
| | Chicken | 20.5 (r) | 6.25 | 89.6 | 32.0 | 40.0 | 10.4 |
| Dairy | Cow's milk (full fat) | 3.3 | 6.38 | 89.3 | 32.8 | 42.3 | 13.5 |
| | Yoghurt (reduced fat) | 4.5 | 6.38 | 89.3 | 31.7 | 42.3 | 13.6 |
| | Cheese 48+ | 22.8 | 6.38 | 106.4 | 39.0 | 37.3 | 14.1 |
| Egg | Egg chicken whole | 12.3 (r); 46 (d) | 6.25 | 72.0 | 54.4 | 48.0 | 12.2 |
| | Egg chicken white raw | 10.5 | 6.32 | 77.5 | 68.0 | 47.5 | 15.2 |
| | Egg chicken yolk raw | 16.7 | 6.12 | 81.7 | 41.2 | 50.7 | 13.1 |
| | Egg chicken white[7] | 81.1 (d) | 6.32 | 68.0 | 60.1 | 44.3 | 12.2 |
| **Insects** | | | | | | | |
| Mealworms | Tenebrio molitor larvae[8] | 18.7 (r) | | 55 | 21 | 41 | 8 |
| | | 67.9 (d) | | 57 | 35 | 34 | 16 |
| Buffalo worms | Alphitobius laevigatu | NA | | NA | NA | NA | NA |
| Locusts | Locusta migratoria[9] | 55.5-64.9 (d) | | NA | NA | NA | NA |

[1]Based on amino acid databases from Denmark (Saxholt et al., 2008), USA (USDA, 2011), UK (McCance & Widdowson, 2006), Germany (Souci et al., 2008) and FAO (FAO, 1970); [2]food composition codes are presented in appendix 3; where applicable: c=cooked, d=dried, r=raw (amino acid composition remains the same); [3]standard nitrogen conversion factor (NCF, 6.25) to translate nitrogen content into protein content is used in NEVO for all products, except for dairy products (6.38); NCF lower than 6.25 means that in reality protein content is proportionally lower than indicated in first column. Specific NCF is used for calculation of amino acid pattern; source for specific NCFs is the Danisch Food Composition Table (Saxholt et al., 2008) [4]according to latest EFSA report (EFSA, 2012); plant protein sources and insects with an exoskeleton (such as locusts) have lower protein digestibility;[5]methionine only, data on cysteine lacking; source: www.mycoprotein.org;[6]basic recipe for meat replacers in NEVO; amount of protein available, but information lacks on (exact proportion of) protein sources, see also chapter 5;[7]used in vegetarian products, but not available in NEVO; [8]marketed as triobolo worms; source for raw values Finke 2002, source for dry values: Despins 1995; [9]source for dry weight: Ooníncx 2011, dry weight is approximately 1/3 of fresh weight; NA: not available

Plant protein sources in general have lower digestibility than animal-based sources, approximately 80% compared to 95% for animal sourced food and some plant protein isolates (Millward & Garnett, 2010). Also, their amino acid composition differs compared to animal-based sources. When comparing against the amino acid score (see Table 1, and Appendix 1 for explanation) the lower digestibility needs to be taken into account. As is visible from Table 1, grains tend to be relatively low in lysine, and legumes relatively low in the sulfur amino acids methionine and cysteine. Nuts and seeds tend to be low in lysine, but are high in methionine and cysteine. The values in Table 1 are consistent with those reported by Young and Pellett (Young & Pellett, 1994), albeit that for nuts and seeds they report a higher tryptophan content. However, within these groups, there are also differences in the content of the individual amino acids (Woolf et al., 2011). Lupin is relatively complete with respect to amino acid content. Soy protein, especially with increased digestibility as with concentrates, is a high quality protein.

### 2.2.2 *Micronutrient content*

The micronutrient content of a selection of meat and dairy products and its replacers is shown in Table 2.  The choice of micronutrients is based on the most recent Dutch food composition tables (NEVO, 2011) and the products are meant as an illustration.

Ready-made meat replacers available via supermarkets are often fortified with vitamin B12 en iron to be a full meat substitute (see also Chapter 5). Tahoe and some replacers are not fortified with vitamins and minerals.

The most consumed types of meat in the Netherlands (beef, pork and chicken) vary in some of the micronutrients. Beef contains relatively high amounts of iron and vitamin B12, and pork is relatively high in vitamin B1. Compared to meat in general, ready-made meat replacers in general may contain lower concentrations of selenium and zinc and similar concentrations of vitamin B1 and B2 (based on current estimates, see Chapter 5). In quorn, the concentration of selenium and zinc is higher than the content in meat, but it contains very little iron. The micronutrient composition of new products such as Beeter® and Meatless® is not known from the most recent Dutch food composition table (NEVO, 2011) and producers’ information.

Many of the dairy replacers are fortified with calcium, vitamin B2 and vitamin B12. The content of zinc and vitamin A of soy drink is lower than of cow’s milk.

**Table 2: selected micronutrient composition of plant-based protein sources, insects, meat, dairy and egg**

| | product (c/d/r)[2] | calcium (mg) | phosphorus (mg) | iron (mg) | selenium (µg) | zinc (mg) | RAE[3] (µg) | vit B1 (mg) | vit B2 (mg) | vit B12 (µg) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Plant sources** | | | | | | | | | | |
| Legumes | Brown/white beans (c/d) | 38/80 | 170/400 | 2.0/5.0 | 2.0/9.0 | 1.0/2.0 | 0/0 | 0.11/0.60 | 0.05/0.10 | 0/0 |
| | Green peas (c/d) | 36/80 | 160/400 | 2.0/5.0 | 1.0/3.0 | 1.4/3.5 | 0/0 | 0.44/1.10 | 0.04/0.10 | 0/0 |
| | Lentils (c/d) | 23/80 | 160/400 | 2.9/5.0 | 42/105.0 | 1.4/3.9 | 0/0 | 0.19/0.41 | 0.05/0.10 | 0/0 |
| | Mung beans (c/d) | 27/88 | 99/395 | 1.4/6.7 | NA/8.8 | 0.84/2.7 | 1/5.7 | 0.164/0.62 | 0.061/0.23 | 0/0 |
| | Chickpeas (c/d) | 46/105 | 83/366 | 1.8/6.24 | 1.0/NA | 1.7/3.43 | 2.0/3 | 0.05/0.477 | 0.03/0.212 | 0/0 |
| | Lupin (c/d) | 51/176 | 128/440 | 1.2/4.36 | NA/8.2 | 1.38/4.8 | 0/1.0 | 0.134/0.64 | 0.053/0.22 | 0/0 |
| | Soya beans (c/d) | 138/225 | 333/555 | 5.0/8.4 | 8.0/4.0 | 1.8/3.0 | 19/32 | 0.66/1.10 | 0.19/0.31 | 0/0 |
| | Soya flour | 220 | 590 | 6.9 | 11.0 | 5.0 | 0 | 0.64 | 0.35 | 0 |
| Grains | Wheat flour, white | 23 | 103 | 0.8 | 5.0 | 0.64 | 0 | 0.07 | 0.04 | 0 |
| | Wheat flour, brown | 30 | 370 | 4.0 | 4.0 | 2.9 | 0 | 0.40 | 0.15 | 0 |
| | Rice, polished (c/r) | 12/10 | 42/100 | 0.2/0.4 | 1.0/13 | 0.75/1.8 | 0/0 | 0.02/0.04 | 0.01/0.03 | 0/0 |
| | Rice, brown (c/r) | 16/12 | 105/300 | 0.3/1.3 | 9.0/10 | 0.81/0.8 | 0/0 | 0.09/0.34 | 0.01/0.03 | 0/0 |
| | Corn flour | 20 | 180 | 3.3 | NA | 2.5 | 0 | 0.26 | 0.08 | 0 |
| | Rolled oats | 70 | 400 | 4.0 | 7.0 | 3.0 | 0 | 0.60 | 0.05 | 0 |
| Nuts | Hazel nuts | 200 | 300 | 3.0 | 2.0 | 2.1 | 0 | 0.40 | 0.07 | 0 |
| | Brazil nuts | 175 | 600 | 4.0 | 254 | 4.2 | 0 | 1.00 | 0.04 | 0 |
| | Cashew nuts | 44 | 607 | 6.7 | 37 | 5.8 | 1.0 | 0.23 | 0.13 | 0 |
| | Walnuts | 117 | 520 | 3.4 | 12 | 3.4 | 2.0 | 0.29 | 0.11 | 0 |
| | Macademia nuts | 70 | 198 | 2.6 | 12 | 1.3 | 0 | 0.71 | 0.09 | 0 |
| **Plant sources, meat replacers** | | | | | | | | | | |
| | Tahoe | 188 | 130 | 2.2 | NA | 1.1 | 19 | 0.07 | 0.02 | 0 |
| | Quorn (mycoprotein) | 30 | 204 | 0.3 | 30 | 5.6 | 0 | 0.10 | 0.30 | 0.1 |
| | Vegetarian nuggets[5] | 67 | 157 | 2.1* | 3 | 0.1 | 0 | 0.11 | 0.14 | 0.15* |
| | Vegetarian schnitzel | 0 | 140 | 2.1* | 3 | 0.1 | 0 | 0.10 | 0.15 | 0.26* |
| **Plant sources, milk replacers** | | | | | | | | | | |
| | Soy-based drink (fresh) | 120* | 82 | 0.4 | NA | 0.25 | 1 | 0.02 | 0.21* | 0.38* |
| **Animal sources** | | | | | | | | | | |
| Meat | Beef (<5%, r) | 5 | 219 | 2.2 | 10 | 4.4 | 6.0 | 0.05 | 0.16 | 1.9 |
| | Pork (5-14%, r) | 7 | 218 | 0.7 | 12 | 2.4 | 5.0 | 0.66 | 0.15 | 0.5 |
| | Chicken (r) | 10 | 156 | 0.8 | 18 | 1.8 | 0 | 0.07 | 0.11 | 0.2 |
| Dairy | Cow's milk (full fat) | 123 | 102 | 0.0 | 1.0 | 0.46 | 35 | 0.03 | 0.18 | 0.4 |
| | Cow's milk (semi-skimmed) | 122 | 102 | 0.0 | 1.0 | 0.41 | 16 | 0.03 | 0.18 | 0.44 |
| | Yoghurt | 143 | 115 | 0.1 | 1.0 | 0.45 | 16 | 0.03 | 0.17 | 0.5 |
| | Cheese 48+ | 815 | 538 | 0.2 | 12 | 3.47 | 332 | 0.01 | 0.29 | 1.97 |
| Egg | Egg chicken whole, raw | 57 | 229 | 2.2 | 17 | 1.6 | 194 | 0.05 | 0.38 | 1.5 |
| | Egg chicken whole, dried | 225 | 900 | 11.0 | 42 | 5.0 | 768 | 0.40 | 1.00 | 10 |
| | Egg chicken white raw | 12 | 12 | 0.1 | 6 | 0.09 | 0 | 0.03 | 0.35 | 0.7 |
| | Egg chicken yolk raw | 150 | 619 | 5.9 | 20 | 4.3 | 537 | 0.20 | 0.50 | 3.8 |
| | Egg chicken white dried[6] | 62 | 111 | 0.2 | NA | 0.10 | 0 | 0.01 | 2.53 | 0.2 |
| **Insects** | | | | | | | | | | |
| Mealworms | Tenebrio molitor larvae[7] (r/d) | 16.9/30 | 285/900 | 2.06/21.8 | 25/nd | 5.2/26.8 | <100 IU/ NA | 0.24/ NA | 0.81/ NA | 0.47/ NA |
| Buffalo worms | Alphitobius laevigatu | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Locusts | Locusta migratoria[8] (d) | 52-77 | 555-652 | 15.1-21.7 | NA | NA | 11-16 | NA | NA | NA |

[1]selection based on contribution of meat and dairy to intake of these nutrients of Dutch population (see chapter 3); [2]food composition codes are presented in appendix 3; where applicable: c=cooked, d=dried, r=raw; [3]retinol activity equivalents; [4]data for cooked rice is recent, for dried rice it is dated; [5]basic recipe for meat replacers in NEVO; protein content available, but info lacks on (exact proportion of) protein sources, see also chapter 5; [6]used in vegetarian products, but not available in NEVO; [7]marketed as triobolo worms; source for raw values: Finke 2002, source for dry values: Despins 1995;[8]source: Oonincx, 2011; *fortified; NA: not available

Table 2 shows that the micronutrient values of the basic plant protein sources is quite variable. Protein-rich plant sources of calcium are soy and some types of nuts. Legumes and nuts in general are sources of phosporus and of iron. Different types of legumes, grains and nuts are sources of selenium, vitamin A-precursors (carotenoids), vitamin B1 and vitamin B2. All plant commodities naturally do not contain B12. Table 2 also shows that brown rice and whole wheat provide higher levels of micronutrients than their refined counterparts.

In egg, the yolk contains the large majority of the micronutrients. This is relevant as often only part of the egg is used as an ingredient.

In general, edible insects can be good sources of calcium, phosphorus, iron, selenium, zinc, vitamin A, B1, and B2 (Yhoung-aree, 2010, Banjo et al., 2006, Bukkens, 1997, Finke, 2002, Ramos-Elorduy et al., 1997). This can also be seen from the (scarce) data that are available for the insects available in the Netherlands, summarized in Table 2.

### *2.2.3 Other nutritional characteristics*

Energy content of ready-made meat replacers varies from ~150-300 kcal per 100 g, which is higher than for meat. Plant foods in general are high in fibre, whereas meat and dairy do not contain fibre. The fat content of meat and dairy depends on the part of the animal that is used or the method of processing. Saturated fat is high for especially cheese (see Appendix 4). Nuts in general are also high in fat, but the proportion of saturated fat is relatively small.

The fat content of insects can be relatively high and they contain fibre (Yhoung-aree, 2010, Banjo et al., 2006, Bukkens, 1997, Finke, 2002, Ramos-Elorduy et al., 1997).

## 2.3 Summary

In short, protein-rich plant-based foods, i.e.. legumes, whole grains, nuts and ready-made meat and dairy replacers, can provide valuable nutrients. Fortified ready-made meat replacers can contribute specifically to iron, calcium, vitamin B2 and B12; the latter of which cannot be supplied by plant sources. In addition, new protein sources, such as insects, can also provide valuable nutrients. A transition to protein sources will influence people’s daily diets. Innovations to facilitate this, such as hybrid meat or a better texture of meat replacers are ongoing.

# 3 Intake of protein-rich foods and related nutrients

In this section, we describe how animal protein sources currently contribute to protein and micronutrient intake in the Netherlands and explore the current role of plant protein sources. Also, we explore the expected nutritional changes when meat and dairy are replaced by more sustainable sources.

## 3.1 Current intake of protein-rich foods, protein and selected nutrients

Meat and dairy products contribute on average 52% to total protein intake as reported in the most recent Dutch National Food Consumption Survey (DNFCS) (Van Rossum et al., 2011). Of the total protein consumption, the largest part (45%) is consumed during dinner (Table 3). Of the total animal protein, 55% is consumed during dinner (data not shown). Dinner is the main occasion where meat and meat products contribute to protein intake, on average 74% (see Table 3). For dairy products, the contribution to protein intake by meal occasion is more evenly divided. For cereals and cereal products (including bread), lunch is the most important food occasion (42% of protein intake).

**Table 3: Top 3 contribution (mean %*) to the intake of protein among the Dutch population (7-69 yrs), weighted for socio-demographic factors, season and day of the week (n=3819) and shown by meal occasion**

| Source[1] | Protein[2] | Meal occasions | | | | |
|---|---|---|---|---|---|---|
| | Mean | | Breakfast | Lunch | Dinner | In-between |
| Total | | 100%: | 14% | 24% | 45% | 17% |
| 1. Meat and meat products | 29% | 100%: | 3% | 14% | 74% | 5% |
| 2. Dairy products | 23% | 100%: | 24% | 31% | 26% | 18% |
| 3. Cereal grains and their products[3] | 22% | 100%: | 26% | 42% | 20% | 12% |

*there is large variation within the population; [1]EPIC-soft food groups; [2] Total protein; [3]Cereal products contain virtually no animal protein, therefore the first two categories equal animal protein and the latter equals plant protein

Grain consumption consists mainly of wheat, in the form of bread (Van Rossum et al., 2011). Other protein-rich products, such as nuts, legumes and soy products, currently are an insignificant source of protein in the Dutch diet (Van Rossum et al., 2011).

In the most recent DNFCS, the median habitual protein intake was 61-98 g/d for men and 60-75 g/d for women and above the EAR for almost the whole population (Van Rossum et al., 2011). In all age groups the median habitual amount of animal protein was higher than of vegetable protein. For animal protein, the median habitual intake ranged from 36-62 g/day for men and 36-47 g/day for women. For vegetable protein this was 25-37 g/d for men and 23-28 g/d for women (Van Rossum et al., 2011). The median habitual intake of protein as a proportion of energy intake ranged from 12-16 en% and did not exceed the upper bound of 25 en% (Van Rossum et al., 2011).

Expressed by kg of body weight, the habitual protein intake ranged from 2.2 to 1.1 for men and 2.1 to 1.0 for women with increasing age (see Table 4). The percentage of the age/sex groups with intakes below the EAR was close to zero. Adult females could be an exception, 3-4 % of the females 19 years and older were below the EAR. This increased to around 7% when compared to more recent estimations of average requirement by EFSA (EFSA, 2012). However, measurement uncertainties interfere with the lower (and higher) percentages. Therefore, percentages below 10% are generally not considered to indicate a public health problem (Table 8.1 in the most recent DNFCS food consumption survey report (Van Rossum et al., 2011)).

As noted before, intake of protein is mainly through animal sources, i.e. meat and dairy products (see Table 3). These sources have a high content of indispensable amino acids (see Appendix 1 for background information on amino acids) and most Dutch people will have intakes of indispensable amino acids above requirements (EFSA, 2012). Excess of indispensable amino acids will be converted to dispensable amino acids or are directly oxidized (EFSA, 2012). The human body needs both indispensable and dispensable amino acids, their main distinction is in the ability of the human body to generate them.

**Table 4. Current habitual[1] protein-by-weight[2] intake distribution in the Dutch population (weighted; n=3817[3])**

| Protein | 7-8 years | | 9-13 years | | 14-18 years | | 19-30 years | | 31-50 years | | 51-70 years | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| g/kg/d | male n=153 | female n=151 | male n=351 | female n=351 | male n=352 | female n=354 | male n=356 | female n=347 | male n=348 | female n=350 | male n=351 | female n=353 |
| **Total** | | | | | | | | | | | | |
| p5 | 1.5 | 1.4 | 1.1 | 0.9 | 0.9 | 0.7 | 0.8 | 0.6 | 0.7 | 0.6 | 0.7 | 0.6 |
| p25 | 1.9 | 1.8 | 1.4 | 1.2 | 1.2 | 1.0 | 1.0 | 0.9 | 0.9 | 0.8 | 0.9 | 0.8 |
| p50 | 2.2 | 2.1 | 1.7 | 1.5 | 1.4 | 1.2 | 1.2 | 1.0 | 1.1 | 1.0 | 1.1 | 1.0 |
| p75 | 2.6 | 2.4 | 2.0 | 1.7 | 1.6 | 1.4 | 1.4 | 1.2 | 1.3 | 1.2 | 1.3 | 1.2 |
| P95 | 3.1 | 3.0 | 2.4 | 2.2 | 2.0 | 1.7 | 1.8 | 1.5 | 1.6 | 1.5 | 1.6 | 1.5 |
| EAR (g/kg/d) (HCN, 2011)[4] | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 |
| %<EAR | 0 | 0 | 0 | 0.5 | 0.5 | 1 | 0.5 | 3 | 1 | 4.0 | 1.1 | 3.5 |
| EAR (g/kg/d) (EFSA, 2012) | 0.74 | 0.74 | 0.75 | 0.75 | 0.72 | 0.70 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 | 0.66 |
| %<EAR | 0 | 0 | 0.1 | 0.66 | 0.5 | 2.67 | 1.2 | 5.71 | 2.4 | 7.36 | 2.5 | 6.55 |
| | | | | | | | | | | | | |
| **Vegetable** | | | | | | | | | | | | |
| p5 | 0.6 | 0.5 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| p25 | 0.7 | 0.7 | 0.6 | 0.5 | 0.5 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| p50 | 0.9 | 0.8 | 0.7 | 0.6 | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| p75 | 1.0 | 0.9 | 0.8 | 0.7 | 0.7 | 0.6 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 |
| P95 | 1.3 | 1.1 | 1.0 | 0.9 | 0.7 | 0.7 | 0.7 | 0.6 | 0.7 | 0.6 | 0.6 | 0.6 |
| **Animal** | | | | | | | | | | | | |
| p5 | 0.8 | 0.8 | 0.6 | 0.5 | 0.5 | 0.4 | 0.4 | 0.3 | 0.4 | 0.3 | 0.4 | 0.4 |
| p25 | 1.1 | 1.0 | 0.8 | 0.7 | 0.7 | 0.6 | 0.6 | 0.5 | 0.6 | 0.5 | 0.6 | 0.5 |
| p50 | 1.3 | 1.3 | 1.0 | 0.9 | 0.8 | 0.7 | 0.7 | 0.6 | 0.7 | 0.6 | 0.7 | 0.6 |
| p75 | 1.5 | 1.5 | 1.2 | 1.1 | 1.0 | 0.9 | 0.9 | 0.8 | 0.9 | 0.7 | 0.9 | 0.8 |
| P95 | 1.9 | 1.9 | 1.5 | 1.4 | 1.3 | 1.1 | 1.1 | 1.0 | 1.1 | 1.0 | 1.1 | 1.1 |

[1]calculated using SPADE (statistical program to assess dietary exposure) (Souverein et al., 2011);[2]self-reported; [3]for 2 subjects, weight is missing; [4]Health Council of the Netherlands, 2001

Besides high quality protein, animal sources provide valuable micronutrients, see Table 5. Meat most significantly contributes to intake of heme iron, selenium, vitamin B12, zinc, and vitamin B1. Dairy products most significantly contribute to intake of calcium, vitamin B2, vitamin B12, phosphorus, vitamin A and zinc. When replacing meat and dairy products, these micronutrients need to be considered. In the remainder of this section we will focus on these micronutrients.

**Table 5: Top mean contribution (%) of dairy and meat to micronutrient intake among the Dutch population (7-69 yrs), weighted for socio-demographic factors, season and day of the week (n=3819) (Van Rossum et al., 2011)**

| Dairy[1] | | | Meat | |
|---|---|---|---|---|
| Calcium | 58 | 1 | Heme Iron[2] | 85 |
| Vitamin B2 | 39 | 2 | Selenium | 31 |
| Vitamin B12 | 38 | 3 | Vitamin B12 | 30 |
| Phosphorus | 32 | 4 | Zinc | 28 |
| RAE[3,4] ; Zinc[4] | 23 | 5 | Vitamin B1 | 24 |

[1]Dairy also contributes importantly to iodine intake, but this nutrient requires special attention and is outside the scope of this report. It is added to salt.; [2]Most iron is consumed as non-heme iron, but heme iron has better absorbability; largest source of non-heme iron in the Netherlands are cereals and cereal products; [3]Retinol activity equivalents; [4]equal contribution

Some population subgroups may have difficulty to meet the recommendations for some of the micronutrients for which meat and dairy products are important sources. For vitamin B1 this concerns adult women below 50 years, where 15-19% may have inadequate intakes (Van Rossum et al., 2011); For iron, there is indication that some groups, especially women of childbearing age, have relatively low intakes (estimated proportions are expected to be an underestimation). Inadequacy also exists for zinc, for 1-24% of children and 5-14% of adults (Van Rossum et al., 2011). For vitamin A, intake appears to be inadequate for 15-30% of almost all subgroups. For vitamin A, vitamin B1, iron and zinc, it is unknown what the health consequences of lower intakes are (Van Rossum et al., 2011).

Knowing that a) intakes of the above nutrients may already be suboptimal and b) meat and dairy products are major sources of these nutrients, these nutrients require extra attention when reducing meat and dairy consumption.

## 3.2 Current dietary intake on meat-free and fish-free days

To get an idea of the influence of a reduction in meat and fish consumption on current nutrient and food intake, we grouped the most recent DNFCS population, covering males and females in the age of 7 to 69 years, according to consumption of meat and fish and calculated their intake. The DNFCS measures food consumption on two independent days. We differentiated three groups: those consuming no meat or fish on the two measurement days (n=77, or 2% of the DNFCS population), those consuming meat or fish on one of the two measurement days (n=434, or 11%) and those consuming meat or fish on both measurement days. Table 6 and 7 show their selected nutrient and food intakes and some characteristics. As fish does not contribute significantly to protein intake in the Dutch population, we will omit the word 'fish' in the further description for better readability (though it is taken into account). It is noted that these data represent observed consumption (which is suitable for this expolorative purpose), and not long term mean (habitual) intake.

In the DNFCS, adults not consuming meat (on both days or one day) are more often female (see Table 7). For both children and adults, BMI appears to be lower for those not consuming meat (Table 6 and 7). Both children and adults not consuming meat (on both days or one day) had lower energy intakes; for example, for adults this was approximately 1900 kcal/d versus approximately 2300 kcal/d on meat consumption days. Fat intake was also lower, although the percentage of energy provided by saturated fat did not appear to differ; for both adults and children this was 12-13 en%. This is probably due to the generally higher intake of dairy among those not consuming meat (see below).

Protein intake is higher among those consuming meat (Table 6 and 7). As the percentage of males and females differs between the groups, the best comparison can be made on a 'protein by kg body weight' basis or within the group that consumes meat on one day. For those that do not and those that do consume meat on two days, respective protein intakes are approximately 0.8 versus 1.1 g/kg bw for adults and 1.3 versus 1.5 g/kg bw for children. For those that do not and those that do consume meat on one day, protein intake is approximately 60 versus 85 g for adults or 50 versus 65 g for children. On meat-free days, adults and children consumed approximately half the amount of animal protein (with dairy as the main source, Figure 1) of those who do consume meat (Table 6 and 7). However, the absolute amount of vegetable protein is only slightly higher on meat-free days. The main plant source is cereal grains (Figure 1.). Thus, on meat-free days, there are two main sources of protein (see Figure 1.): dairy products and cereal grains; these contribute to total protein intake by somewhat higher percentages than on days of meat consumption, where meat contributes most. Notable is the low contribution, both in a relative and absolute sense, of legumes. This is visible both on meat and meat-free days.

**Table 6: Nutrient and food intakes and basic characteristics of youth (7-18 years) in the Dutch National Food Consumption Survey 2007-2010 differentiated by their consumption of meat or fish on zero, one or two days, unweighted**

| Characteristic | Group | No meat or fish[1] on both days[2] | | No meat or fish on one day | | | | Meat or fish on both days[2] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | n=31 | | n=203 | | | | n=1479 | | |
| | | | | Day w/out | | Day with | | | | |
| Age (years) | | 13.1 ± 3.6 | | 11.7 ± 3.6 | | | | 12.5 ± 3.4 | | |
| | 7-8 (n)<br>9-13 (n)<br>14-18 (n) | 4<br>11<br>16 | | | 49<br>84<br>70 | | | 251<br>608<br>620 | | |
| Sex (n / % female) | | 15 / 48% | | 108 / 53% | | | | 734 / 50% | | |
| BMI | | 18.1 ± 3.1 | | 18.3 ± 3.3 | | | | 19.2 ± 3.6 | | |
| | | *Mean ± sd* | *p50* | *Mean ± sd* | *p50* | *Mean ± sd* | *p50* | *Mean ± sd* | *p50* | |
| *Energy intake* | kcal/d;<br>kJ/d | 2054 ± 804;<br>8628 ± 3365 | 1966;<br>8266 | 1967 ± 671;<br>8269 ± 2820 | 1915;<br>8046 | 2132 ± 593;<br>8952 ± 2484 | 2042;<br>8582 | 2229 ± 628;<br>9358 ± 2628 | 2145;<br>9020 | |
| *Nutrient intake* | | *Mean ± sd* | *p50* | *Mean ± sd* | *p50* | *Mean ± sd* | *p50* | *Mean ± sd* | *p50* | % *inadequacy in DNFCS*[3] |
| Protein (g/d) | | 58 ± 19 | 57 | 52 ± 22 | 50 | 68 ± 23 | 65 | 74 ± 23 | 69 | < 1% |
| | animal;<br>vegetable | 25 ± 13;<br>32 ± 13 | 23;<br>30 | 25 ± 15;<br>28 ± 12 | 23;<br>25 | 41 ± 19;<br>26 ± 9.3 | 38;<br>25 | 45 ± 18;<br>28 ± 9.6 | 41;<br>27 | |
| | by kg body weight | 1.34 ± 0.51 | 1.24 | 1.31 ± 0.63 | 1.20 | 1.73 ± 0.86 | 1.55 | 1.61 ± 0.62 | 1.53 | not determined (see Table 4) |
| Fat (g/d) | | 75 ± 40 | 73 | 67 ± 30 | 66 | 81 ± 32 | 75 | 84 ± 31 | 80 | |
| | saturated g/d;<br>saturated en% | 29 ± 16;<br>12.1 ± 3.4 | 26;<br>12.4 | 27 ± 13;<br>12.2 ± 4.4 | 25;<br>11.8 | 30 ± 12;<br>12.7 ± 3.1 | 28;<br>12.4 | 31 ± 12;<br>12.5 ± 2.7 | 30;<br>12.4 | [% too high: 86-87] |
| Carbohydrates (g/d) | | 275 ± 99 | 262 | 279 ± 101 | 267 | 272 ± 81 | 257 | 280 ± 77 | 271 | girls 9-18 yr: 15-29 |
| Fibre (g/d) | | 19 ± 8.5 | 17 | 16 ± 8 | 15 | 17 ± 6 | 16 | 18 ± 6 | 17 | unclear, even p95 below guidelines |
| Vitamin A (RAE[4] ; µg/d) | | 644 ± 414 | 504 | 503 ± 404 | 438 | 598 ± 636 | 414 | 683 ± 688 | 514 | 6-34% |
| Vitamin B1 (mg/d) | | 0.84 ± 0.41 | 0.68 | 0.76 ± 0.91 | 0.57 | 1.0 ± 0.58 | 0.88 | 1.1 ± 0.51 | 0.95 | ≤13 yr low, >13 yr unclear |
| Vitamin B2 (mg/d) | | 1.4 ± 0.61 | 1.4 | 1.5 ± 1.2 | 1.3 | 1.4 ± 0.74 | 1.3 | 1.5 ± 0.69 | 1.3 | low |
| Vitamin B12 (µg/d) | | 2.5 ± 1.3 | 2.2 | 2.7 ± 1.7 | 2.4 | 3.4 ± 1.9 | 3.1 | 3.8 ± 2.1 | 3.3 | low |
| Calcium (mg/d) | | 1075 ± 441 | 897 | 1000 ± 547 | 911 | 948 ± 461 | 917 | 935 ± 416 | 870 | ≤13 yr low, >13 yr unclear |
| Iron (mg/d) | | 9.1 ± 3.3 | 8.0 | 7.6 ± 3.7 | 7.1 | 8.6 ± 3.2 | 8.0 | 9.1 ± 2.9 | 8.6 | ≤10 yrs low, >10 yr unclear |
| | heme;<br>non-heme | 0.058 ± 0.15;<br>9.0 ± 3.3 | 0.01;<br>7.8 | 0.090 ± 0.24;<br>7.5 ± 3.6 | 0.02;<br>6.9 | 0.87 ± 0.89;<br>7.8 ± 2.9 | 0.61;<br>7.2 | 1.0 ± 0.75;<br>8.1 ± 2.7 | 0.83;<br>7.7 | |
| Phosporus (mg/d) | | 1278 ± 449 | 1098 | 1162 ± 548 | 1110 | 1304 ± 444 | 1292 | 1354 ± 446 | 1279 | low (HCN);<br>≤ 8 yr low, >8 yr 5-28% (IOM) |
| Selenium (mg/d) | | 33 ± 19 | 30 | 24 ± 11 | 22 | 35 ± 16 | 33 | 38 ± 15 | 35 | low/unclear (HCN); 11-75% (IOM) |
| Zinc (mg/d) | | 7.9 ± 3.5 | 7.4 | 6.4 ± 2.9 | 6.1 | 8.7 ± 3.5 | 8.4 | 9.2 ± 3.2 | 8.6 | 1-24% |
| *Amount* of protein from product category (g/d) | | *Mean ± sd* | *p50* | *Mean ± sd* | *p50* | *Mean ± sd* | *p50* | *Mean ± sd* | *p50* | |
| | Meat and meat products | 0 | 0 | 0 | 0 | 19 ± 16 | 18 | 23 ± 14 | 20 | |
| | Dairy products | 19 ± 13 | 19 | 19 ± 15 | 17 | 18 ± 13 | 17 | 17 ± 11 | 15 | |
| | Legumes<br>(*on consumption days*) | 2.8 ± 0.005<br>(n=2) | - | 13.3 ± 2.3<br>(n=2) | - | 5.2 ± 3.2<br>(n=4) | - | 6.7 ± 3.7<br>(n=66) | 5.9 | |
| | Nuts<br>(*on consumption days*) | 5.9 ± 4.1<br>(n=16) | 3.7 | 7.4 ± 6.7<br>(n=41) | 4.4 | 8.2 ± 5.9<br>(n=36) | 6.4 | 6.9 ± 6.1<br>(n=547) | 4.4 | |
| | Meat and dairy replacers[5]<br>(*on consumption days*) | 13.8 ± 8.1<br>(n=13) | 14.1 | 9.5 ± 4.9<br>(n=12) | 9.2 | 5.6 ± 3.0<br>(n=4) | - | 10 ± 7.0<br>(n=51) | 8.3 | |

[1]defined as no consumption from epic soft food group 07 (meat and meat products), 08 (fish and shellfish) or a selection of food group 17 03 (snacks: manual selection of predominantly meat-based snacks, where animal protein >50% of total protein); [2]mean of 2 days; [3]As compared to guidelines by the Health Council of the Netherlands (HCN) and in some cases also the Institute of Medicine (IOM, USA); With respect to micronutrients, DNFCS 2007-2010 reported 'no public health problem' for vitamin B2 and vitamin B12. For other micronutrients, more information is wanted; DNFCS 2007-2010 recommends the performance of nutritional status research and research on health effects for vitamin A, B1, calcium; research on health effects for iron and zinc; and re-evaluation of the reference values for phosphorus and selenium; [4]retinol activity equivalents; [5]defined as consumption from food group 17 00 and 17 01

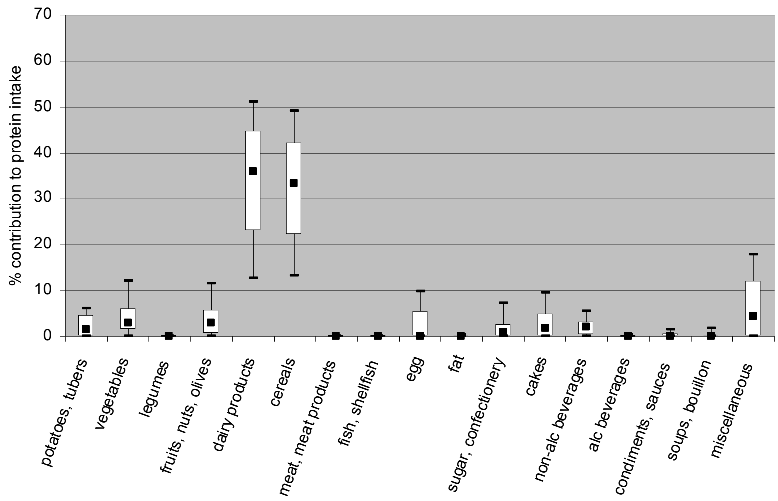
**Table 7: Nutrient and food intakes and basic characteristics of adults (19-69 years) in the Dutch National Food Consumption Survey 2007-2010 differentiated by their consumption of meat or fish on zero, one or two days, unweighted**

| Characteristic | Group | No meat or fish[1] on both days[2] | | No meat or fish on one day | | | | Meat or fish on both days[2] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | n=46 | | n= 220 | | | | n=1840 | | |
| | | | | Day w/out | | Day with | | | | |
| Age (years) | | 43.6 ± 15.1 | | 40.3 ± 14.7 | | | | 42.3 ± 15.0 | | |
| | 19-30 (n)<br>31-50 (n)<br>51-70 (n) | 15<br>14<br>17 | | | 90<br>67<br>63 | | | 598<br>618<br>624 | | |
| Sex (n / % female) | | 33 / 72% | | 134 / 61% | | | | 884 /48% | | |
| BMI | | 24.6 ± 5.7 | | 25.2 ± 5.4 | | | | 26.1 ± 4.9 | | |
| | | *Mean ± sd* | *p50* | *Mean ± sd* | *p50* | *Mean ± sd* | *p50* | *Mean ± sd* | *p50* | |
| *Energy intake* | kcal/d;<br>kJ/d | 1892 ± 647;<br>7941 ± 2713 | 1853;<br>7784 | 1857 ± 822;<br>7794 ± 3450 | 1865;<br>7835 | 2294 ± 927;<br>9619 ± 3882 | 2122;<br>8940 | 2330 ± 739<br>9770 ± 3092 | 2233;<br>9357 | |
| *Nutrient intake* | | *Mean ± sd* | *p50* | *Mean ± sd* | *p50* | *Mean ± sd* | *p50* | *Mean ± sd* | *p50* | *% inadequacy in DNFCS[3]* |
| Protein (g/d) | | 60 ± 18 | 61 | 59 ± 28 | 59 | 86 ± 34 | 80 | 88 ± 28 | 84 | <1% |
| | animal;<br>vegetable | 25 ± 12;<br>34 ± 14 | 25;<br>33 | 28 ± 19;<br>31 ± 15 | 25;<br>30 | 54 ± 27;<br>32 ± 15 | 48;<br>30 | 56 ± 23;<br>32 ± 11 | 52;<br>30 | |
| | by kg body weight | 0.86 ± 0.31 | 0.84 | 0.81 ± 0.42 | 0.78 | 1.2 ± 0.51 | 1.0 | 1.1 ± 0.40 | 1.1 | not determined (see Table 4) |
| Fat (g/d) | | 68 ± 32 | 67 | 65 ± 36 | 61 | 86 ± 43 | 79 | 91 ± 36 | 86 | |
| | saturated g/d;<br>saturated en% | 26 ± 13;<br>12.0 ± 4.0 | 25;<br>11.7 | 27 ± 16;<br>12.8 ± 4.8 | 24;<br>12.0 | 33 ± 16;<br>12.9 ± 4.1 | 29;<br>12.7 | 34 ± 14;<br>12.8 ± 3.1 | 32;<br>12.6 | [% too high: 88-91] |
| Carbohydrates (g/d) | | 238 ± 88 | 248 | 232 ± 111 | 227 | 256 ± 117 | 242 | 253 ± 87 | 240 | women: 21-49 |
| Fibre (g/d) | | 23 ± 9.3 | 21 | 19 ± 10 | 18 | 21 ± 9.9 | 20 | 21 ± 7.1 | 20 | unclear, even p95 below guidelines |
| Vitamin A (RAE[4]; µg/d) | | 685 ± 465 | 573 | 550 ± 385 | 469 | 948 ± 2346 | 575 | 873 ± 928 | 634 | 16-30 |
| Vitamin B1 (mg/d) | | 0.84 ± 0.37 | 0.76 | 0.77 ± 0.52 | 0.65 | 1.2 ± 1.3 | 0.97 | 1.3 ± 0.66 | 1.1 | men: ≤50 yr 4%, >50 yr low;<br>women ≤50 yr 15-19%, >50 yr low |
| Vitamin B2 (mg/d) | | 1.3 ± 0.52 | 1.4 | 1.5 ± 0.97 | 1.3 | 1.7 ± 1.6 | 1.4 | 1.7 ± 0.77 | 1.5 | <10% |
| Vitamin B12 (µg/d) | | 2.3 ± 1.3 | 2.1 | 2.8 ± 2.0 | 2.6 | 5.0 ± 5.0 | 3.6 | 5.1 ± 3.86 | 4.3 | <10% |
| Calcium (mg/d) | | 1138 ± 431 | 1094 | 1103 ± 650 | 998 | 1080 ± 550 | 972 | 1060 ± 455 | 1003 | low; unclear |
| Iron (mg/d) | | 10 ± 3.3 | 9.8 | 9.0 ± 4.6 | 8.8 | 11 ± 4.8 | 10 | 11 ± 3.6 | 10 | men: low;<br>women: ≤50 yr unclear, >50 yr low |
| | heme;<br>non-heme | 0.05 ± 0.16;<br>10 ± 3.4 | 0.00;<br>9.8 | 0.12 ± 0.36;<br>8.9 ± 4.6 | 0.01;<br>8.4 | 1.1 ± 1.1;<br>9.9 ± 4.5 | 0.74;<br>9.0 | 1.3 ± 1.0;<br>9.7 ± 3.2 | 1.1;<br>9.2 | |
| Phosporus (mg/d) | | 1326 ± 467 | 1279 | 1298 ± 658 | 1238 | 1595 ± 655 | 1483 | 1603 ± 515 | 1550 | low (HCN); 0% (IOM) |
| Selenium (mg/d) | | 31 ± 16 | 29 | 30 ± 18 | 26 | 50 ± 27 | 44 | 50 ± 22 | 46 | men: low (HCN)/21-28% (IOM);<br>women: unclear (HCN)/46-58% (IOM) |
| Zinc (mg/d) | | 8.3 ± 2.6 | 8.2 | 7.7 ± 4.1 | 7.2 | 11 ± 4.5 | 10 | 11 ± 3.9 | 11 | 5-14% |
| *Amount* of protein from product category (g/d) | | *Mean ± sd* | *p50* | *Mean ± sd* | *p50* | *Mean ± sd* | *p50* | *Mean ± sd* | *p50* | |
| | Meat and meat products | 0 | 0 | 0 | 0 | 25 ± 22 | 21 | 29 ± 20 | 25 | |
| | Dairy products | 20 ± 11 | 21 | 21 ± 17 | 18 | 20 ± 15 | 18 | 20 ± 12 | 18 | |
| | Legumes<br>(*on consumption days*) | 16 ± 0.9<br>(n=2) | - | 6.8 ± 4.9<br>(n=8) | - | 7.5 ± 5.5<br>(n=9) | 5.8 | 8.6 ± 6.3<br>(n=83) | 7.5 | |
| | Nuts<br>(*on consumption days*) | 7.3 ± 4.9<br>(n=22) | 5.9 | 6.8 ± 5.8<br>(n=48) | 5.3 | 8.8 ± 9.6<br>(n=52) | 4.5 | 8.5 ± 8.3<br>(n=731) | 6.8 | |
| | Meat and dairy replacers[5]<br>(*on consumption days*) | 10 ± 6.1<br>(n=30) | 9.4 | 11 ± 6.4<br>(n=22) | 10.2 | 9.2 ± 6.4<br>(n=6) | - | 8.4 ± 6.4<br>(n=79) | 6.5 | |

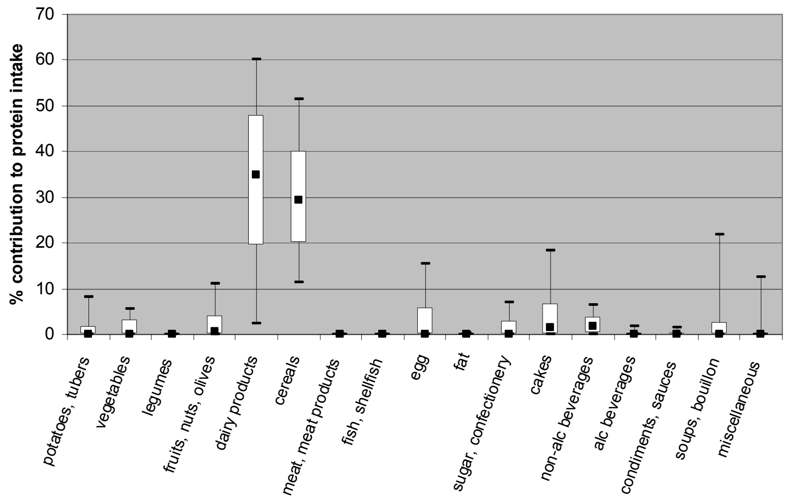
[1]defined as no consumption from epic soft food group 07 (meat and meat products), 08 (fish and shellfish) or a selection of food group 17 03 (snacks: manual selection of predominantly meat-based snacks, where animal protein >50% of total protein); [2]mean of 2 days; [3]As compared to guidelines by the Health Council of the Netherlands (HCN) and in some cases also the Institute of Medicine (IOM, USA); With respect to micronutrients, DNFCS 2007-2010 reported 'no public health problem' for vitamin B2 and vitamin B12. For other micronutrients, more information is wanted; DNFCS 2007-2010 recommends the performance of nutritional status research and research on health effects for vitamin A, B1, calcium; research on health effects for iron and zinc; and re-evaluation of the reference values for phosphorus and selenium; [4]retinol activity equivalents; [5]defined as consumption from food group 17 00 and 17 01

**Figure 1. Contribution of product groups to protein intake, for adults who do and do not consume meat or fish (bars represent percentiles 10, 25, 50 (the median), 75 and 90).**

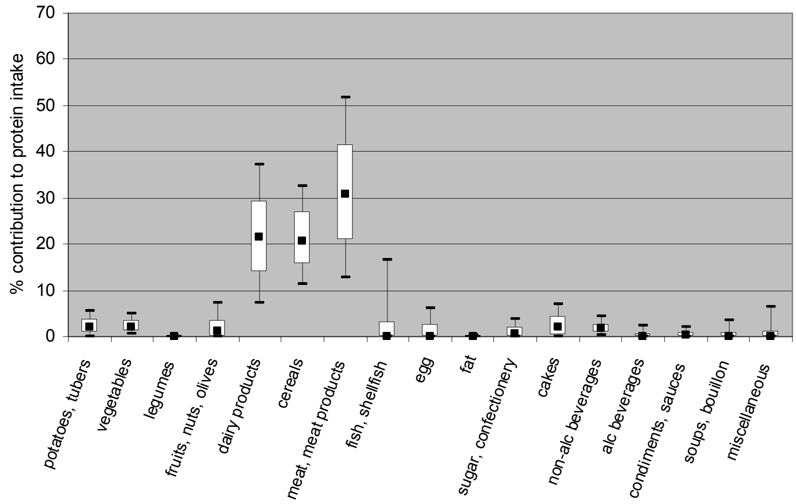
a) Adults consuming no meat (mean of two days), n=46




b) Adults consuming no meat (one day), n=220




c) Adults consuming meat (mean of two days), n=1840




Legume soups are not in group ‘legumes’ but in group ’soups, bouillon’; unfortunately, the type of legume cannot be differentiated.

Differences in micronutrient intake exist between days with and without meat consumption. Notably, intakes of vitamin A, vitamin B1, vitamin B12, selenium and zinc appear to be lower on meat-free days (Table 7). For children, the differences between meat-free and meat consumption days are smaller (Table 6). Intakes below the recommendations for some people have already been reported for vitamin A, vitamin B1, iron (women ≤50 yrs), zinc, and selenium (Van Rossum et al., 2011). However, as the DNFCS report noted, (large) differences exist between national and international guidelines and data on the association between intake and health effects is often lacking. The report recommended to perform more research on nutritional status and health effects of vitamin A, B1, calcium, iron and zinc; and to re-evaluate the reference values for phosphorus and selenium (Van Rossum et al., 2011). A lower intake on meat-free days as compared to meat consumption days signals that also in the context of sustainable food consumption, these nutrients may require some extra attention. In order to calculate the habitual intake and percentage below the reference value (estimated average requirement, EAR) a larger sample and at least two measurement days for those not consuming meat (or reduced meat/dairy) is needed.

It will be worthwhile to explore whether currently those leaving out meat replace this by the most nutritionally suitable sources. With regard to the type of products that are consumed in the DNFCS, legumes are eaten mostly as white beans (in tomato sauce), brown beans, marrowfat peas and chickpeas. The most consumed product from the nuts and seeds category, is peanut butter. Whole nuts that are consumed are almonds, brazil nuts, cashew nuts, peanuts, pistachio nuts, walnuts, mixed nuts and pine nuts. Seeds that are consumed are pumkin seeds, sesame seeds and sunflower seeds. In the category of meat and dairy replacers, the consumed products consist of: vegetarian ham, pate or sausage luncheon meat; vegetarian mincemeat, burger, sausages, balls or schnitzel based on soy, tahoe, quorn products, vegetable burger, valess; soy-based drink, soy-based deserts. Consumption of meat and dairy replacers in the group that consumed meat on both days consisted mainly of consumption of soy drink (related to self-reported lactose intolerance and cow's milk protein allergy).

Consumption of insects has not been reported in the DNFCS yet.

## 3.3 Expected change in dietary intake when the share of sustainable protein sources increases

### *3.3.1 Protein and amino acids*

Most plant-based food replacers used to replace meat and dairy contain less protein than meat and dairy. Total protein intake will thus decrease when portion sizes are kept the same. This is confirmed in the comparisons made for persons on meat (free) days in the previous section. Protein intake is higher among those consuming meat. However, there appears to be some room for a reduction in protein intake at a population level.

With respect to amino acid scores corrected for protein digestibility (PDAAS), the shift from an animal based diet towards a more plant based diet will increase intake of proteins with lower digestibility and lower completeness of indispensable amino acids. For a lacto-ovo vegetarian or vegan diet, the Health Council of the Netherlands assumes a PDAAS of 0,84 and 0,77, respectively, i.e. the requirements are 1.2 and 1.3 times higher (Health Council of the Netherlands, 2001). Practically, this means that when calculating the percentage inadequacy of a group of adults not consuming meat, group intake needs to be compared with 1.2 times 0.6 g/kg bw/d (=0.72 g/kg bw/d) or 1.2 times 45 g/d (54 g/d);

Two issues should be mentioned here. 1) High quality proteins, such as from dairy products, can compensate lower quality protein. One drawback for high quality proteins, however, is that when all amino acid values exceed the reference values, then this cannot be taken into account, as the score cannot exceed 1; these values are truncated and as such their ability to compensate other protein sources is not recognized (WHO, 2007). On the side of lower quality proteins, there is probably underestimation by this method, as it does not take into account the presence of antinutritional factors (Krishnan, 2005, Rozan et al., 1997). These factors, such as phytic acid, phenols, alkaloids and fibres, influence protein hydrolysis and thereby affect nutritional utilization. But, 2) Combining foods can improve the protein quality of the diet; this can be done most efficiently on an individual foods basis (Woolf et al., 2011). Excess indispensable amino acids can be minimized and also combinations of products can be found that require only small amounts to supply high quality total protein.

In a Western society, with affluence of food, even if plant-based, protein deficit is not likely. The most important message here with respect to protein and amino acids is to consider the *total diet* to make a sensible prediction about its protein quality.

### 3.3.2 *Micronutrients*

Meat and dairy are important sources for iron, zinc, calcium, selenium, vitamin B1, vitamin B2 and B12. The replacement foods or commodities determine how intakes in these micronutrients shift as compared with the requirements. Complicating the matter is that it is not always clear at what level deficiency will occur, meaning that lower intake is not always harmful (Van Rossum et al., 2011).

Currently, for participants in the DNFCS not consuming meat or fish, we see on average "normal" consumption of dairy products. Reducing meat consumption but not dairy consumption, is expected to cause most pronounced differences for vitamin B12 and zinc (see also Table 6 and 7); meat is currently on average a bigger source for these nutrients than dairy products. For vitamin B12, intake already appears to be more than sufficient. Also, ready-made meat and dairy replacers are fortified with vitamin B12 and thus no problems are expected here when either these replacement products or supplements are taken. Other nutrients characteristic for meat are heme iron, selenium and vitamin B1. Intake of heme iron will be lower when meat consumption is reduced (as can be seen in Table 6 and 7). The total consumption of iron is not expected to decrease, especially when ready-made meat replacers, which are fortified with iron, are consumed. However, the matrix of the meal will then determine how much of this non-heme iron is absorbed. A change in intake of vitamin B1, selenium and zinc, and its consequences may require additional research.

If the consumption of dairy products is also reduced, for better sustainability impact, it would be beneficial from a nutritional point of view to increase the intake of legumes. These not only supply protein with amino acids which can complement those from other plant-based products, but also vitamin B1, phosphorus and zinc (and many others, such as vitamin B6, folic acid, potassium and copper) (NEVO, 2011). Also important, for example for intake of vitamin B1, is the use of whole grain products instead of refined foods.

### 3.3.3 *Other nutrients or nutritional characteristics*

Energy intake can be expected to decrease when consumption of meat is decreased. When dairy consumption is also decreased, intake of saturated fat can also be expected to decrease. Fibre can be expected to increase, as meat and dairy do not contain fibre and the plant-based replacement protein sources all contain significant amounts of fibre.

## 3.4 Summary

In short, meat and dairy currently provide approximately half the protein consumption in the Dutch diet. Apart from high-quality protein, these sources also contribute importantly to the intake of vitamin A, B1, B2, B12, and minerals calcium, heme-iron, phosphor, selenium and zinc. Vitamin A, B1, selenium and zinc have been noted as potential problem nutrients in the general population in terms of too low intake; reducing intake of animal products may aggravate this. However, it is not clear what the health effects are of intakes lower than the current recommendations. Legumes, nuts, whole grains and ready-made meat and dairy replacers can also contribute to intake of these nutrients. All of the above sources are currently not consumed much.

# 4 Food allergy

Food allergy is an abnormal response of the immune system to otherwise harmless proteins in food. In this chapter we first give a brief overview of the major allergens and the prevalence and symptoms of the allergy they cause. Then, we describe the expected consequences of a shift towards more sustainable protein sources in relation to the risk of food allergy.

## 4.1 Food allergy, important food allergens and celiac disease

Food allergy is in the majority of cases mediated by immunoglobulin E (IgE) that triggers the clinical manifestations of food allergy. In Westernized countries, the prevalence of IgE-mediated food allergy is estimated to be up to 6% in young children and 3-4% in adults (Wang & Sampson, 2011)..Food allergy can be caused by many allergenic proteins in food, but in more than 90% of the patients only eight food allergens are involved (Bush & Hefle, 1996). The most important food allergens in early infancy (< 1 year) are **cow's milk** and **egg**. These childhood allergies resolve in the majority of children between ages 3 and 5 years (Hattevig et al., 1984, Host, 2002). **Peanut, wheat** and **soy** allergy are food allergies that affect predominantly young children as well. Soy and wheat allergy disappear in most cases within a few years, but peanut allergy is in almost all cases a lifelong problem. Other important food allergens in adolescents and adults are **nuts**, **fish** and **shellfish** (FAO, 1995).

Food allergic reactions can affect different organs systems and can vary from mild to severe and potentially fatal symptoms. Classic food allergic symptoms can affect lips and/or mouth (itching, swelling), skin (hives, rash), gastrointestinal tract (vomiting, diarrhea), respiratory tract (wheeze, asthma) and the cardiovascular system. The most severe allergic reaction that can occur is anaphylaxis, which is a systemic allergic reaction that can lead to hypotension, dyspnea, collapse and heart problems. Without treatment this reaction can become fatal (Sampson, 1999). There is no cure for food allergy and allergic reactions can only be prevented by avoiding consumption of the food allergens.

Another adverse immune-mediated reaction that can be induced by food is celiac disease. This disease is induced by gluten, which are proteins present in wheat, rye and barley. Celiac disease has similarities with autoimmunity and food intolerances. The complaints are induced by gluten that trigger an inflammatory response in the small intestines. Symptoms are diarrhea, bowel damage and fatigue and the only way to avoid these is to avoid gluten-containing products. The prevalence is estimated to be between 0.5-1% (Catassi & Fasano, 2008).

## 4.2 Expected consequences for the prevalence of food allergy when the share of sustainable protein sources increases

Changing the diet to more sustainable protein sources will most probably lead to a different exposure pattern to known food allergens or introduce novel food allergens. Examples of known allergens relevant in this context are nuts and legumes (Zuidmeer et al., 2008). Additionally, ready-made meat replacers can contain food allergens such as soy, lupin and wheat. The prevalence rates of food allergies relevant for this report are summarized in Appendix 5.

According to the EU Labeling Directives (2000/13/EC, 2003/89/EC and 2007/68/EC), fourteen food allergens, including soy, lupin and wheat (see Box 4) have to be labelled on pre-packaged products. In this way, subjects allergic to these food allergens are able to avoid products that contain the allergen they are allergic to.

**Box 4 Food allergens that must be labelled on pre-packaged food.**

- Cereal grains containing gluten, (i.e. wheat, rye, barley, oats, spelt, kamut or their hybridized strains) and products thereof
- Crustaceans and products thereof
- Eggs and products thereof
- Fish and products thereof
- Peanuts and products thereof
- Soybeans and products thereof
- Milk and products thereof (including lactose)
- Nuts i.e. almonds, hazelnuts, walnuts, cashews, pecan nuts, Brazil nuts, pistachio nuts, macadamia nuts and Queensland nuts and products thereof
- Celery and products thereof
- Mustard and products thereof
- Sesame seeds and products thereof
- Lupin and products thereof
- Molluscs and products thereof
- Sulphur dioxide and sulphites at concentrations of more than 10 mg/kg or 10 mg/litre expressed as SO2.

Foods based on insects or fungi (i.e. Quorn) might contain novel proteins that are allergenic itself or cross-reactive towards other food allergens. Cross-reactive allergic reactions are explained by the fact that most plant and animal food allergens belong to very few protein families indicating that certain conserved structures play a role in the allergenic properties of a protein.

Proteins that are highly similar and share these conserved structures can cross-react. Peanut and lupin are able to cross-react, meaning that lupin can elicit allergic reactions in peanut-allergic subjects. Cross-reactivity can also occur between inhalation and food allergens, for example subjects allergic to birch pollen can respond with food allergic reactions to apple (Sicherer, 2001).

In summary, possible consequences of a shift towards more sustainable protein resources in relation to the risk on food allergy include:

1. Risk of food allergies due to increased exposure to known allergens;
2. Introduction of novel food proteins that are allergenic;
3. Risks of food allergic reactions due to cross reactivity in subjects with food allergy.

These possibilities are discussed further below.

### *4.2.1 Risk of food allergies due to increased exposure to known allergens*

Unlike toxic reactions that occur in every exposed individual at a sufficient exposure dose, food allergic reactions do not occur in every exposed individual. Exposure is of course necessary for the induction of food allergy, but the fact that the majority of the people can consume all food allergens without any problems illustrates that other factors determine the risk on food allergy. Genetic susceptibility is one important factor that determines this risk. Additionally, external factors (diet, lifestyle and environment) have an impact as well. As of yet it is unclear which external factors play a key role in the development of food allergy (Ezendam & Van Loveren, 2010). The current hypothesis that exposure early in life, during a window where tolerance can develop, is *protective* for the development of food allergy rather than a risk factor underlines that timing of exposure is an important factor rather than the exposure itself. There is no evidence that avoidance of food allergens early in life reduces the risk on food allergy (Hourihane et al., 2007). Remarkably, in Israel the prevalence of peanut allergy is very low compared to other countries, while peanut paste is frequently given in infancy (Du Toit et al., 2008). It has been hypothesized that exposure to food allergens during a critical period early in life exposure will lead to life-long immunological tolerance and in this way protects against food allergy, which has been confirmed in animal studies (Lopez-Exposito et al., 2009). It is therefore not expected that increased consumption of known food allergens will increase the risk on food allergy.
A transition from *processed* grains to *whole* grains will not affect the risk of coeliakie, as the amount of protein is not significantly different between the two.

### 4.2.2 *Introduction of "novel" food proteins in the Dutch diet: insects*

In the public literature, no evidence was found that insects can cause food allergy. This does not mean that insects might be involved, but could be a reflection of the low consumption rate of insects in Western countries. Concerns do exist, which was illustrated in a commentary in the Nutrition Bulletin that focused on eating insects. Insects could theoretically elicit allergic symptoms in subjects with shellfish allergies (*In: MacEvilly, C. 2000. Bugst in the system. Nutrition Bulletin, 25: 267-268).* The major allergen that has been identified in shellfish is tropomyosin, a muscle protein which is highly conserved among different species, including insects (Lopata et al., 2010). This means that due to cross-reactivity, subjects with a shellfish allergy may respond to the structurally similar tropomyosin of insects. In addition, tropomyosin of insects might act as a potential food allergen as well, although there is currently no evidence for this. Cross-reactivity towards other food or inhalation allergens has not been described, but this can never be excluded. It is currently unclear if insects will be considered as novel foods. If they are, insects have to be regulated under EU Directive 258/97 and according to this directive, the safety of the market introduction of novel foods and novel ingredients should be assessed. In this safety assessment, evaluation of the allergenicity of novel proteins, including their estimated homology to known allergens is mandatory. A more detailed description of this directive can be found in Appendix 6.

### 4.2.3 *Risks of food allergic reactions due to cross reactivity in subjects with food allergy: Quorn and lupin.*

One problem with "novel" foods is that they can contain structural similarities with known food allergens and as such elicit allergic reactions in those that react to the homologous proteins: a phenomenon known as cross reactivity. This may be the case for quorn and lupin.

Quorn has been on sale in Europe since the 1990s. In the USA, Quorn has the GRAS notification (Gras Notice No. GRN 000091), meaning that this food is generally regarded as safe. In the EU, Quorn is not considered to be a novel food, since it has been introduced before 1997 (see Appendix 6). Reported complaints induced after eating Quorn are adverse gastrointestinal reactions, such as cramps and vomiting. In a few cases allergic reactions were elicited, such as skin rash, swelling of the face, tongue and throat and anaphylactic reactions after eating Quorn (Jacobson, 2003). These allergic reactions were only elicited in subjects with an existing allergy for respiratory mould allergens (Katona & Kaminski, 2002, Tee et al., 1993, Hoff et al., 2003). The responsible allergen in Quorn was identified as a highly conserved protein present in a number of fungal species (Hoff et al., 2003). Therefore, it can be concluded that Quorn can give rise to problems in subjects allergic to respiratory moulds due to cross-reactivity. There is no evidence that Quorn can induce food allergy in non-allergic individuals.

Peanut and lupin contain homologous proteins and consumption of lupin can elicit severe allergic reactions due to cross-reactivity in peanut allergic patients (Moneret-Vautrin et al., 1999, Shaw et al., 2008, Sirtori et al., 2011). It has been shown that 35% of the peanut allergic patients developed allergic symptoms after consumption of lupin. These patients react to relatively low amounts of lupin. The lowest dose that induced mild oral symptoms was of 0.5 mg, whereas moderate symptoms such as rhinitis ('runny nose') and dyspnea ('shortness of breath') occurred at a dose of 1 gram of peanut protein. These concentrations are approximately five-fold lower than those identified for peanut, indicating that lupin flour has a significant allergenicity in a subset of peanut allergic patients (Peeters et al., 2009). The issue of cross-reactivity underlines that peanut allergic patients should become aware of possible risks associated with consumption of lupin-containing foods as well. Lupin is one of the fourteen food allergens that has to be labeled on pre-packaged food, but other allergenic legumes are not on this list. Cross-reactivity towards other legumes, however, does not seem to be a major problem, since they rarely induce allergic reactions in peanut allergic subjects (Sicherer, 2001).

## 4.3 Summary

In short, both plant and animal protein can elicit allergic reactions. A shift to more plant protein sources is not likely to have a significant adverse effect on allergy prevalence. Upon introduction of novel proteins, allergic consumers need to be aware of potential cross-reactivity.

# 5 Discussion

In this report, we explored the nutritional consequences of a shift from animal to (more) sustainable protein rich plant and insect foods, focusing on protein, amino acids, selected micronutrients and allergens.

In short, protein intake in the Netherlands is ample and satisfies population requirements. Both in terms of amount and type of protein, there is room to replace animal foods by plant foods. The important issue here is to consider the total diet and ensure enough variation in the source of protein, so that protein quality can be guaranteed.

Variation in the choice of foods to replace meat and dairy is also needed with respect to micronutrients. Legumes, nuts and *whole* grains can provide the micronutrients that are currently provided by meat and dairy products, except for vitamin B12. Ready-made meat and dairy replacers are often fortified with micronutrients and as such are easy suppliers of iron, calcium, vitamin B1, vitamin B2 and/or vitamin B12.

The prevalence of food allergy is not expected to rise with more consumption of sustainable food sources. Special attention is needed for cross-reactivity, for example lupin allergy may develop in those allergic to peanut.

Below we address some issues with respect to replacement foods, food composition data and monitoring of food intake, and consumer perspectives.

## 5.1 Foods replacing meat and dairy

*Basic commodities*

An increase in legumes and nuts will be beneficial from both a nutritional and sustainability point of view.

*Substitution products.*

The Netherlands Nutrition Center has formulated criteria that products need to fulfill to be recommended as a basic food, in the product group of meat and dairy and their substitutes (VCN, 2011). Per product group this concerns 3 nutrients (1 macronutrient and 2 micronutrients), which are selected based on their importance to the basic product group that supplies them, and which should include nutrients for which the DNFCS shows the intake is (close to) insufficient (e.g. iron) or that is dominantly contributed to by product group (e.g. calcium).

The macronutrient in the substitution product is protein. As currently there is no protein problem from a nutritional point of view, there are no requirements with respect to the type of protein. Currently, most replacement foods contain a mixture of predominantly soy and wheat and some milk and egg protein. However, new developments take sustainability issues into account by using protein sources such as lupin and peas and not using conventional animal sources. For example, the dried egg white protein extract in meat substitutes is ecologically inefficient (Blonk et al., 2008). Another source of protein being developed further for sustainability reasons is that from insects. Some product developers specifically also take gluten and milk protein allergy into consideration, by not using wheat and milk sources. These ‘new’ sources may influence the quality of protein intake, but when a varied diet is consumed, this is not expected to be a negative influence. To quantify protein intake including its quality in real diets would currently not be possible, however, as food composition data are scarce (see next section).

*Opportunity.* It is recommended to incorporate a mixture of amino acids sources into meat and dairy substitutes. Soy beans may be most efficiently used for flour and tahoe, to have the additional benefits of their high micronutrient content.

Among the micronutrients that are characteristic for meat and dairy, current intakes of vitamin A, vitamin B1 (women), iron (women) and zinc (all) are already rather low. Thus, in the transition towards less meat and dairy consumption, these require extra attention. The selected micronutrient in substitution products (VCN, 2011) needs to supply 10% of the RDA per 100 gr. In cases where this would be higher than the product to be substituted, the criterium is 5%. This is the case, for example, for iron, B1 and B12 in meat, where the reference is an average of beef, pig and chicken.

For ready-made *meat* substitutes the guidelines are, per 100 g of product:
0,13 μg vitamin B12, 0,06 mg B1 and 0,7 mg iron (where for B1 and B12 at least one but not necessarily both need to be added).
For a product to be a *milk* substitute, it needs to contain 80 mg of calcium/100 g and 0,25 μg vitamin B12/100 g; for a *cheese* substitute this is 500 mg calcium/100 g and 0,25 μg vitamin B12/100 g.

In practice, vitamin B12 is chosen to fortify meat substitutes and not vitamin B1 (as only one is mandatory).

*Opportunity.* Acknowledging that the intake of vitamin B1 is relatively low in the population and among those not consuming meat, it may be worthwhile to consider requiring the addition of *both* vitamin B1 and B12. Another route to increase the intake of vitamin B1 (and other micronutrients) is to stimulate the consumption of *whole* grains.  To quantify micronutrient intake from substitution products would currently be difficult however, as food composition data here too are scarce.

## 5.2 Food composition data and monitoring.

Nutritional information for 6 types of ready-made meat replacers is currently available in the Dutch Food Composition Table, based on information from the producers. This is on the level of macronutrients, sometimes including fibre and sodium. Information on the exact micronutrient content is not availabe (unless for nutrients that a food is fortified with, such as iron, vitamin B1, vitamin B2, or vitamin B12). Via the information on the macronutrients, the ingredient list and an assumed composition, the corresponding level of micronutrients can be estimated.  However, the exact quantity of the different ingredients is not known and often industrial ingredients are used (such as rehydrated protein, protein isolates and concentrates, modified starch etc.), which are not in the Dutch Food Composition Table (NEVO, 2011)). This means that while the macronutrients will be in the correct range of magnitude, the calculated micronutrient content will be less reliable. As a consequence, the currently available data are not suitable to study the detailed nutritional composition of meat replacers, but the possible deviations will have less influence when studying daily or weekly menus are studied (especially since for fortified products, the added micronutrients are known).

Currently, we are unable to monitor whether the amino acid composition provided by real Dutch diets will change with potentially changing future food supply. Amino acids are completely lacking from the Dutch Food Composition Database (NEVO, 2011). A reason to calculate amino acid intake could be to scientifically underpin sustainable protein policy or to monitor population subgroups with little variation in a plant-based diet. As obtaining analytical amino acid data for all products in the database will be very costly, a good alternative approach would be to use data from other countries. In this report, we got an indication of the amino acid composition of relevant products from information on the protein content and the ingredients (source of the protein) and from collecting amino acid data, starting with those amino acids most likely to be limited in plant foods. This was done by using amino acid databases from Denmark (Saxholt et al., 2008), USA (USDA, 2011), UK (McCance & Widdowson, 2006), Germany (Souci et al., 2008) and FAO (FAO, 1970). In general, the data are rather outdated. There was some variation in amino acid composition of similar foods between the databases, which can be due to natural variation and processing practices in sampled products or to differences in analytical methods. In general, however, the amino acid patterns were quite comparable.

The Danish food composition table is currently the preferred option for RIVM/NEVO to use data from. The data are provided with good background documentation, are (internationally) regarded as highly reliable and are easily available. Also, the Danish situation is best comparable to the Dutch situation in terms of climate, products etc. It has to be said that some of the Danish data have their source in the tables from the UK or USA. Some countries collect data on meat replacers and dairy replacers (USDA, 2011, Arnemo et al., 2007). These data cannot easily be used from foreign composition tables, because these foods are country-specific. More basic foods like tahoe, lupin and quorn, are a possible exception.

*Opportunity:* Calculation of the nutritional value of ready-made meat or dairy replacers can be improved by:
-more elaborate ingredient lists, including quantities/percentages of the main ingredients
-information on the moisture content of the ingredient and the product as a whole
-nutrient data on industrial ingredients
-information on the physical form of the ingredients (dried, powder, fresh, etc.)
Also, a wider diversity of more sustainable, plant-based products could be included in the food composition table, including “new” ingredients such as lupin.

## 5.3 Consumer preferences and communication

The ready-made meat and dairy substitutes and hybrid meats take the current Dutch dietary practice as the basis and replace meat and dairy products as more sustainable product look-a-likes. The advantage is that consumers can stay within their own culturally defined ways of eating. Hoek et al, concluded that meat substitutes could be made more attractive, by significantly improve the sensory quality and resemblance to meat and not focussing on the communication of ethical arguments (Hoek et al., 2011). Bakker and Dagevos investigated which market strategies and change routes are most promising to promote a protein transition, taking consumer perception into account (de Bakker & Dagevos, 2010). They indicate that plant-based meal concepts with no, less or hybrid meat are a promising strategy.

Outside the culturally defined ways of eating in the Netherlands are the incorporation of insects in the diet. Some considerations on the possible role of insects in modern urban lifestyle are the following (den Hartog, 2011): insects have a low social status; many western societies have a strong culinary heritage; there is a trend of dislike for globalisation and re-appreciation for indigenous foods, insects could become a delicacy; and appreciation of insects as high-quality foods could be stimulated through the education system; however, in Jewish and Islamic religion, only very few types of insects are allowed to be eaten.

Meal concepts with no meat will require a change in eating habits but would not cause insurmountable problems for at least part of the consumer population. In the daily diet, the protein-rich sources and their nutritional value and sustainability potential are not the only issues that need to be taken into account. It matters whether the rest of the diet consists of whole-grain products, lots of fruits and vegetables, etc. or mainly processed, energy-dense, nutrient-low foods because in the end the total diet determines the total intake. For a daily diet it is important to consume sufficient amounts of whole grains, potatoes, vegetables, fruits, and legumes. This aspect of 'variation' may not become sufficiently clear from food based dietary guidelines.

*Opportunity.* In the communication towards consumers, care needs to be taken not to visualize the part of dairy, meat, fish, egg and meat replacers unnecessarily large; it may also be argued to include legumes and nuts in this group, as the combined diet will supply protein of sufficient quality. And to clearly visualize the rule of 'variation'. From the perspective of sufficient nutritional intake, variation is the key word both within and between food groups.

## 5.4 Closing remarks

In this report, the focus was on possible downsides of replacing animal protein by plant protein; risk of micronutrient deficiencies, for example for selenium or vitamin B1, can be solved by a diverse diet which includes legumes and whole grains. The same exercise can be done for the beneficial effects, of which now only saturated fatty acids, fibre and energy intake have been addressed. There appear to be many win-win situations between nutritionally and ecologically healthy foods.

For a better idea of the impact on public health, however, the effects on health and disease need to be evaluated.

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# Appendix 1: Background in protein quality and quantity

In this section we provide background knowledge about the requirements of protein quantity and quality.

**Protein quantity and quality**

Proteins are chains of amino acids. Proteins are digested into amino acids in the stomach and small intestine. After absorption, the amino acids are synthesized into protein (proteinogenic function) or function in regulatory processes (non-proteinogenic function). Amino acids are classified as either dispensable or indispensable (see Table A1). Indispensable are those amino acids that the body cannot synthesize itself and need to be ingested by food; otherwise the distinction between the two is not black-and-white. As excess of amino acids will be oxidized and eliminated, a balance between dispensable and indispensable amino acids acids is the favourable metabolic situation and not predominance of indispensable amino (EFSA, 2012, Millward et al., 2008). A smaller part of the protein reaches the colon, where it is mostly degraded by colonic bacteria.

**Table A1: 20 proteinogenic amino acids**

| Human body can synthesize | Human body cannot synthesize |
|---|---|
| Alanine | Phenylalanine** |
| Arginine# | Histidine |
| Asparagine# | Isoleucine*** |
| Aspartic acid | Leucine*** |
| Cysteine* | **Lysine** |
| Glutamine# | **Methionine*** |
| Glutamic acid | **Threonine** |
| Glycine# | **Tryptophan** |
| Proline# | Valine*** |
| Serine# | |
| Tyrosine** | |

*sulfur amino acids; cysteine is a metabolic product of methionine catabolism, and is dependent on sufficient amount of methionine to supply needs for both
**aromatic amino acids; tyrosine is metabolic product of phenylalanine catabolism, and is dependent on sufficient amount of phenylalanine to supply needs for both
***branched chain amino acids
#conditionally indispensable (limiting under special physiological or pathological conditions)
**in bold**: characteristically limited in certain plant foods

Protein requirement is aimed at the ability to meet maintenance needs, plus special needs for children and pregnant or lactating women and is defined as:

> "the lowest level of dietary protein intake that will balance the losses of nitrogen from the body, and thus maintain the body protein mass, in persons at energy balance with modest levels of physical activity, plus, in children or in pregnant or lactating women, the needs associated with the deposition of tissues or the secretion of milk at rates consistent with good health" (WHO, 2007).

It is established by means of nitrogen balance studies as a function of intake: nitrogen is lost via urine, feces, hair, nails, and skin; the amount of protein needed to reach zero nitrogen balance is established (for growth, pregnancy and lactation, additional estimates are needed)(EFSA, 2012). So far, health outcomes have been considered insufficient for establishment of dietary reference values by the Dutch Health Council (Health Council of the Netherlands, 2001, Health Council of the Netherlands, 2006) and the EFSA Panel on Dietetic Products, Nutrition and Allergies (EFSA, 2012). Protein requirement estimates take both digestibility and amino acid composition into account, see Box A1. Both these concepts are relevant when looking into increasingly plant-based diets, therefore some attention is directed to it here.

**Box A1: key terms in establishing protein requirement (EFSA, 2012, WHO, 2007)**

- *nitrogen conversion factor*:
  factor used for the calculation of the (crude) protein content of a food from the total nitrogen content. The amount of nitrogen per amount of protein varies with the types of amino acids and thus the nitrogen conversion factor is specific to the amino acid content of a protein/meal. The average nitrogen content is 160 mg/g protein, i.e. a conversion factor of 6,25. If the objective of use is to indicate a product's potential to supply amino acids, the use of specific coefficients based on amino acid-derived nitrogen content is more relevant (EFSA, 2012). For dairy the conversion factor is higher, for plant foods it is generally lower.

-*net protein utilization:*
  % of ingested nitrogen that is retained in the body; estimates recently changed from 70% to 47% (58% for growth in children (EFSA, 2012)). It is determined by:
  --Digestibility: % of food protein/nitrogen which is absorbed
  --Biological value: % of absorbed nitrogen that is retained in the body/effectiveness with which absorbed dietary nitrogen can be utilized (among others due to suitability of amino acid pattern).

-*PDCAAS (predictor of net protein utlization):*
  protein digestibility corrected amino acid score, measure of effectiveness with which absorbed dietary nitrogen can meet the indispensable amino acid requirement at the safe level of protein intake
  =digestibility x (mg amino acid in 1 g protein of interest / mg amino acid in requirement pattern)
  for a lacto-ovovegetarian and a vegan dietary pattern, it is assumed to be 0.84 ad 0.77, respectively (Health Council of the Netherlands, 2001).

-average requirement (AR):
  -median value for nitrogen balance in meta-analysis g/kg body weight/day(Rand et al., 2003), or
  -(nitrogen loss + nitrogen need for growth,) x 6,25 / (protein utilization at 0.70 x PDCAAS) (Health Council of the Netherlands, 2001)

-population reference intake (PRI)*:*
  AR + 2*standard deviation (from meta-analysis)(EFSA, 2012) or AR + 15% (Health Council of the Netherlands, 2001) for usual mixed diets in Europe

It has long been recognized that the aspect of quantity, or 'how much protein?', is related to the aspect of quality, or 'what sort of protein?'. The current internationally accepted method for protein *quality* assessment is the protein digestibility-corrected amino acid score (PDCAAS) approach (WHO, 2007, EFSA, 2012). This approach compares the amount of potentially limiting amino acids in the protein of interest with their respective content in the appropriate age-specific reference pattern (see Table A2; in practice, 3 are used: <0,5 yrs, 3-10 yrs, adults), resulting in the identification of the single most limiting amino acid that determines the score. The amino acid score is assumed to predict biological value, the anticipated ability of the *absorbed* protein of interest to fulfill amino acid requirements. Net protein utilisation is then predicted by correction of the score for digestibility, resulting in the PDCAAS value. A more precise, but very intense, method is to measure the specific ileal digestibility of individual amino acids (EFSA, 2012).

**Table A2: Scoring pattern[1] (indispensable amino acid reference profiles) for infants, children, adolescents and adults, in mg/g protein (EFSA, 2012)**

| | Infants, children, adolescents | | | | | Adults |
|---|---|---|---|---|---|---|
| | **0.5 y** | **1-2 y** | **3-10 y** | **11-14 y** | **15-18 y** | |
| Histidine | 20 | 18 | **16** | 16 | 16 | **15** |
| Isoleucine | 32 | 31 | **31** | 30 | 30 | **30** |
| Leucine | 66 | 63 | **61** | 60 | 60 | **59** |
| Lysine | 57 | 52 | **48** | 48 | 47 | **45** |
| Methionine +cysteine | 28 | 26 | **24** | 23 | 23 | **22** |
| Phenylalanine + tyrosine | 52 | 46 | **41** | 41 | 40 | **30** |
| Threonine | 31 | 27 | **25** | 25 | 24 | **23** |
| Tryptophan | 8.5 | 7.4 | **6.6** | 6.5 | 6.3 | **6** |
| Valine | 43 | 42 | **40** | 40 | 40 | **39** |

[1]Reference pattern for adults is established by requirement of amino acid per kg body weight per day divided by average requirement for protein per kg body weight per day; age-specific scoring patterns are derived by using data from selected age groups; except for infants: the amino acid pattern of human milk is used.

Since in practice dietary proteins are likely to be limited only by lysine (most grain proteins), the sulfur amino acids (legume proteins), tryptophan (some grains such as maize) or threonine (some grains), in calculating scores it is usually only necessary to use a pattern based on these four amino acids. After the age of 2 years there is very little further change in requirement or pattern until adulthood is reached. Thus, for children aged over 2 years and adolescents, given the minor contribution that growth makes to the requirement for these age groups, the scoring pattern differs from that of adults to only a minor extent. For this reason, when judging protein quality for schoolchildren and adolescents, it is probably more practical to use just one pattern, i.e. that derived for the age group 3–10 years (EFSA, 2012).

Generally, in meals or during the day, several different protein sources are consumed together; the score is then calculated from the amino acid pattern of the digested protein mixture. Calculation of PDCAAS value for a mixture entails first calculating the individual digestible quantities of the amino acids in the foods in the mixture, then adding up the digestibility-corrected amino acids in the mixture, and then comparing them with the appropriate reference pattern. The PDCAAS value for an average Dutch diet is 1,00 .

It is important to realize that the amino acid score of a protein source is indicative of which essential amino acid is least present, but does not indicate malnutrition unless it is the sole protein source in the diet; as people daily consume a number of protein sources, unless in extreme poverty, it is important to view the total diet.

**Dietary reference values**

The most recent Dutch dietary guidelines with respect to protein date from 2001 (Health Council of the Netherlands, 2001). The most recent report on Dutch food-based guidelines, which is based on the 2001 dietary guidelines, dates from 2006 (Health Council of the Netherlands, 2006). The 2006 report uses the 2001 nutrient guidelines and does not propose to adapt these. More recent recommendations are provided by WHO/FAO/UNU (WHO, 2007) and the EFSA NDA-panel (EFSA, 2012). EFSA recommends the same values as WHO. The reference values are summarized in Table A3, relevant reports in Box A2.

**Box A2: Relevant reports on protein requirements**

-Dietary reference intakes: energy, proteins, fats and digestible carbohydrates. 2001. The Hague, Health Council of the Netherlands. Publication no. 2001/19R. In Dutch: Voedingsnormen energie, eiwitten, vetten en verteerbare koolhydraten. 2001. Gezondheidsraad, Den Haag. 2001/19
- Protein and amino acid requirements in human nutrition: report of a joint FAO/WHO/UNU expert consultation WHO technical report series; no. 935. 2007. WHO, Geneva, Switzerland.
- EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA): Scientific opinion on dietary reference values for protein. EFSA journal 10(2), 2557, 2012.

**Table A3: Health Council of the Netherlands (HCN), WHO (World Health Organization) and European Food Safety Authority (EFSA) recommendations**

| age | HCN-AR[1] g/kg/d [g/d] male | HCN-AR[1] g/kg/d [g/d] female | WHO/EFSA-AR[1] g/kg/d male | WHO/EFSA-AR[1] g/kg/d female |
|---|---|---|---|---|
| 1-3 yr | 0.8 | 0.7 | 1:0.95<br>1.5:0.85<br>2:0.79<br>3:0.73 | 1:0.95<br>1.5:0.85<br>2:0.79<br>3:0.73 |
| 4-6 yr | 0.7 | 0.7 | 4-5: 0.69<br>6: 0.72 | 4-5: 0.69<br>6: 0.72 |
| 7-8 | 0.7 [17] | 0.7 [16] | 7:0.74<br>8:0.75 | 7:0.74<br>8:0.75 |
| 9-13 yr | 0.7 [28] | 0.7 [28] | 9-11:0.75<br>12:0.74<br>13:0.73 | 9-10:0.75<br>11:0.73<br>12:0.72<br>13:0.71 |
| 14-18 yr | 0.7 [43] | 0.6 [38] | 14-15:0.72<br>16:0.71<br>17:0.70<br>18:0.66[2] | 14:0.70<br>15:0.69<br>16:0.68<br>17:0.67<br>18:0.66 |
| 19-30 yr | 0.6 [47] | 0.6 [40] | 0.66 | 0.66 |
| 31-50 yr | 0.6 [45] | 0.6 [39] | 0.66 | 0.66 |
| 51-70[3] yr | 0.6 [46] | 0.6 [40] | 0.66 | 0.66 |
| >70 yr | 0.6 | 0.6 | 0.66 | 0.66 |

[1]AR: estimated average requirement by kg body weight; Multiplying by reference weights gives the average requirement in g per day, shown in brackets; for usual European diet, with PDCAAS=1; [2]WHO: 0.69; [3]WHO/EFSA categories are 18-59 and >60 years

Over the past years there have been many developments in the understanding of protein requirements. A number of difficulties relating to protein quality assessment have not been fully resolved (EFSA, 2012, WHO, 2007). Some of these, specifically related to this project, concern:

-reduced bioavailability due to food processing, e.g. lysine

-PDCAAS values: truncation and restriction to one amino acid

-specific nitrogen conversion factors

-role of energy: protein utilization and deposition are energy-dependent at all stages of amino acid transport and interconversion, protein sysnthesis and proteolysis (WHO, 2007). The protein:energy ratio has been explored as a measure of dietary quality and in relation to definition of reference values for requirements with which the adequacy of diets could be evaluated. However, calculating and using such ratios have been warned to be very complex (WHO, 2007).

# Appendix 2: List of foods, in English and Dutch

**Table A4: Food names in English and Dutch**

| **Legumes** | **Peulvruchten** |
|---|---|
| soya bean | sojabonen |
| soya meal | sojameel |
| lupin | lupine |
| white beans | witte bonen |
| brown beans | bruine bonen |
| green peas | groene erwten |
| lentils | linzen |
| mung beans | mung bonen |
| chickpea | kikkererwten |
| **Grains** | **Granen** |
| wheat flour | tarwebloem |
| wheat flour, wholemeal | volkoren tarwemeel |
| rice, polished | rijst witte rauw |
| rice, brown | zilvervliesrijst |
| corn flour | maismeel |
| rolled oats | havermout |
| **Nuts** | **Noten** |
| hazel nuts | hazelnoten |
| brazil nuts | paranoten |
| cashew nuts | cashew noten |
| walnuts | walnoten |
| macademia nuts | macadamia noten |
| tahoe | tahoe |
| quorn (mycoprotein) | quorn |
| vegetarian nuggets | nuggets, vegetarisch |
| vegetarian schnitzel | schnitzel, vegetarisch |
| **Meat** | **Vlees** |
| beef | rundvlees |
| pork | varkensvlees |
| chicken | kip |
| **Dairy** | **Zuivel** |
| cow's milk | melk |
| yoghurt | yoghurt |
| cheese | kaas |
| **Egg** | **Ei** |
| egg chicken white | kippenei eiwit |
| egg chicken yolk | kippenei eigeel |

# Appendix 3: Food Composition Codes

**Table A5: Food Composition Table codes[1]**

| | Food | Food code |
|---|---|---|
| **Plant sources** | | |
| Legumes | Brown beans, white beans | 968 (c); 117 (d) |
| | Green peas | 972 (c); 118 (d) |
| | Lentils | 970 (c); 120 (d) |
| | Mung beans | USDA SR24 16081 (c); DK 485 (d) |
| | Chickpeas | 1095 (c); USDA SR24 16056 (d) |
| | Lupin | USDA SR24 16077 (c); 16076 (d) |
| | Soya beans | 971 (c); 839 (d) |
| | Soya flour (full fat) | 869 |
| Grains | wheat flour, white (75% extraction) | 220 |
| | wheat flour, brown (50% extraction) | 222 |
| | Rice, polished, white | 658 (c); 5 (r) |
| | Rice, brown | 1014 (c), 712 (r) |
| | Corn flour | 696 |
| | Rolled oats | 213 |
| Nuts | Hazel nuts | 200 |
| | Brazil nuts | 203 |
| | Cashew nuts | 199 |
| | Walnuts | 206 |
| | Macademia nuts | 2844 |
| **Plant sources, meat replacers** | | |
| | Tahoe | 687 |
| | Quorn (mycoprotein) | 2030 |
| | Vegetarian nuggets | 2951 (recipe) |
| | Vegetarian schnitzel | 1512 (recipe) |
| **Plant sources, milk replacers** | | |
| | Soy based drink | USDA 16120 / 1381 |
| **Animal sources** | | |
| Meat | Beef (<5% fat) | 1663 |
| | Pork (5-14% fat) | 1668 |
| | Chicken | 1305 |
| Dairy | Cow's milk (full fat) | 279 |
| | Cow's milk (semi-skimmed) | 286 |
| | Yoghurt (semi-skimmed fat) | 1502 |
| | Cheese 48+ | 513 |
| Egg | Egg chicken whole (raw) | 83 |
| | Egg chicken whole (dried) | 87 |
| | Egg chicken white raw | 358 |
| | Egg chicken yolk raw | 85 |
| | Egg chicken white dried | DK7ed 1031 |

[1]NEVO 2011 codes, unless stated otherwise; different sources may use different analytical methods. For amino acid composition, the Danish Food Composition Table was used (available via authors).

# Appendix 4: Macronutrients in selected sources

**Table A6: Macronutrients (per 100 g edible food) in selected plant and animal sources**

| | product (c/d/r)[1] | Energy (Kcal) | Carbo-hydrates (g) | Fat (g) | Saturated fatty acids (g) | Fibre (g) |
|---|---|---|---|---|---|---|
| **Plant sources** | | | | | | |
| Legumes | Brown/white beans (c) | 131 | 17.2 | 0.8 | 0.1 | 11.4 |
| | Green peas (c) | 126 | 17.2 | 0.8 | 0.3 | 8.2 |
| | Lentils (c) | 99 | 11.6 | 0.7 | 0.1 | 5.3 |
| | Mung beans (c) | 105 | 11.6 | 0.4 | 0.1 | 7.6 |
| | Chickpeas (c) | 123 | 13.1 | 3.0 | 0.4 | 6.7 |
| | Lupin (c) | 119 | 7.1 | 2.9 | 0.3 | 2.8 |
| | Soya beans (c) | 251 | 9.5 | 11.2 | 1.7 | 13.2 |
| | Soya flour | | | | | |
| Grains | Wheat flour, white | 352 | 71 | 1.1 | 0.1 | 4.0 |
| | Wheat flour, brown | 328 | 62 | 2.0 | 0.3 | 11 |
| | Rice, polished (c/r) | 146/352 | 32.3/78 | 0.3/1.0 | 0.1/0.2 | 0.7/1.3 |
| | Rice, brown c/r) | 131/357 | 26.4/73.5 | 1.0/2.6 | 0.2/0.6 | 2.1/3.0 |
| | Corn flour | 368 | 74 | 3.0 | 0.7 | 4.4 |
| | Rolled oats | 377 | 62 | 7.0 | 1.2 | 7.1 |
| Nuts | Hazel nuts | 717 | 6.0 | 69 | 4.9 | 8.2 |
| | Brazil nuts | 692 | 5.0 | 67 | 17.2 | 4.3 |
| | Cashew nuts | 615 | 20.8 | 48.9 | 8.8 | 3.8 |
| | Walnuts | 708 | 5.4 | 68.1 | 6.1 | 4.6 |
| | Macademia nuts | 785 | 13.4 | 76.1 | 11.9 | 8.0 |
| **Plant sources, meat replacers** | | | | | | |
| | Tahoe | 113 | 1.0 | 6.9 | 1.0 | 0.3 |
| | Quorn (mycoprotein) | 127 | 10 | 2.0 | 0.5 | 5.5 |
| | Vegetarian nuggets[2] (r) | 255 | 14 | 15 | 2.3 | 2.0 |
| | Vegetarian schnitzel (r) | 196 | 9.9 | 9.1 | 1.1 | 5.0 |
| **Plant sources, milk replacers** | | | | | | |
| | Soy-based drink (fresh) | 38 | 2.3 | 1.8 | 0.3 | 0.5 |
| **Animal sources** | | | | | | |
| Meat | Beef (<5% fat, r) | 113 | 0.1 | 2.8 | 1.1 | 0 |
| | Pork (5-14% fat, r) | 158 | 0 | 8.2 | 3.2 | 0 |
| | Chicken (r) | 139 | 0 | 6.3 | 1.8 | 0 |
| Dairy | Cow's milk (full fat) | 61 | 4.5 | 3.4 | 2.1 | 0 |
| | Cow's milk (semi-skimmed) | 46 | 4.6 | 1.5 | 1.0 | 0 |
| | Yoghurt | 51 | 4.3 | 1.5 | 1.0 | 0 |
| | Cheese 45+ | 368 | 0.0 | 30.4 | 20.5 | 0 |
| Egg | Egg chicken whole, raw | 137 | 1.5 | 9.1 | 3.1 | 0 |
| | Egg chicken whole, dried | 574 | 3.0 | 42.0 | 13.8 | 0 |
| | Egg chicken white raw | 44 | 0.4 | 0 | 0 | 0 |
| | Egg chicken yolk raw | 361 | 0.2 | 32.6 | 10.7 | 0 |
| | Egg chicken white, dried[3] | 363 | 7.8 | 0 | 0 | 0 |
| **Insects** | | | | | | |
| Mealworms | Tenebrio molitor larvae[4] (r/d) | 206/590 | NA | 13.4/26.6 | 4/NA | 8.2/7.0 |
| Buffalo worms | Alphitobius laevigatu | NA | NA | NA | NA | NA |
| Locusts | Locusta migratoria[5] (d) | 509-569 | NA | 18.6-29.6 | NA | NA |

[1]food composition codes are presented in appendix 3; where applicable: c=cooked, d=dried, r=raw, NA=not available; [2]basic recipe for meat replacers in NEVO; [3]used in vegetarian products, but not available in NEVO; [4]source: Finke 2002, source for dry values: Oonincx 2010 (values from Despins 1995 are comparable); [5]source: Oonincx 2011

# Appendix 5: Prevalence of food allergies

This appendix provides an overview of the available prevalence rates of food allergies relevant to this report (see Table A7). These include food allergens from plant sources, and possible cross-reactive food allergens. Prevalence is based on studies that have performed oral food challenges, which provide the most reliable data for clinical relevant food allergy. There were no prevalence data published for legumes, with the exception of peanut and soy. The prevalence of the different food allergies has not been studied widely and prevalence data from the Netherlands that are based on oral challenge tests (the best prediction for clinical food allergy) are lacking.

- The prevalence of peanut allergy has predominantly been studied in children and ranges from 0.2-0.5% in Denmark to 0.64-1.8% in the UK and Canada. Peanut allergy often develops in childhood and rarely resolves.
- Soy allergy is believed to be a childhood allergy that in the majority of cases develops in the first year of life and gradually resolves when children grow older (Bock, 1987). Soy allergy resolves in almost all children between the ages 3 – 10 years (Bock, 1987, Savage et al., 2010).
- Wheat allergy is a childhood allergy with a prevalence of 0.2-0.3% in the first year of life in the UK. In Denmark wheat allergy was absent in children and adults.
- Allergy to nuts has not been widely studied. Studies from Germany have shown that the prevalence of hazelnut allergy is 1.7% and that of 0.8%. In the EU funded FP6 project Europrevall it has been shown that hazelnut is the most common food allergen in adults. In almost all cases the allergic reaction occurs in subjects with birch pollen allergy (unpublished data). In the UK, 0.1% of the 6 year old children suffered from almond allergy. The prevalence of other nut allergies has not been published.
- Shellfish allergy is a food allergy that develops later in life and affects predominantly adolescents and adults and is absent in children. Studies from the UK show a relatively high prevalence of 1.3% in adolescents, whereas in Denmark 0.2-0.3% of the adults has a shellfish allergy.

**Table A7: Prevalence rates of food allergies relevant to this report**

| Food allergen | Country | Age (years) | Prevalence (%) |
|---|---|---|---|
| Peanut | UK | 3-4 | 0.64 |
| | UK | 3 | 1.7 |
| | UK | 4-5 | 1.8 |
| | UK | 6 | 0.96 |
| | Denmark | 3 | 0.2 |
| | Denmark | 4-22 | 0 |
| | Denmark | 0-6 | 0.7 |
| | Denmark | 6 | 0.5 |
| | Denmark | adults | 0.4 |
| | Canada | 5-9 | 1.5 |
| Soy | Denmark | 3 | 0 |
| | Germany | 0-14 | 0.7 |
| Hazelnut | Germany | all ages | 1.7 |
| Walnut | Germany | all ages | 0.8 |
| Almond | UK | 6 | 0.1 |
| Wheat | UK | 1<br>2<br>3<br>6 | 0.3<br>0.3<br>0.2<br>0.3 |
| | UK | 11 | 0 |
| | UK | 15 | 0.1 |
| | Denmark | 3 | 0 |
| | Denmark | adults | 0 |
| Shellfish | UK | 1 | 0 |
| | UK | 2 | 0 |
| | UK | 3 | 0 |
| | UK | 6 | 0 |
| | UK | 11 | 0.13 |
| | UK | 15 | 1.3 |
| | Denmark | 3 | 0 |
| | Denmark | Adults | 0.2-0.3 |

*Prevalence data are derived from Rona et al. (2007), Zuidmeer et al. (2008), Sicherer (2011) and Venter & Arsha (2011).

# Appendix 6: Novel foods regulation

According to the EU Directive 258/97 on “Novel foods and novel food ingredients” (1997), novel foods and novel ingredients are defined as those foods or ingredients which have not been consumed to any significant degree in the EU before May 1997. They include foods and ingredients that are newly-developed, such as foods produced by new production processes like genetic modification, but also foods or ingredients isolated from plants or animals using new techniques. These novel foods and ingredients must undergo a safety assessment before being marketed, as part of the authorisation procedure. Benefits for health or the environment are not included in this procedure.

One of the issues in the Novel foods directive is the risk of IgE-mediated food allergy. To minimize the risk of new food allergens entering the market, a weight-of-evidence approach market for the assessment of allergenicity has been developed. One of the first steps is to assess if the proteins have structural similarities with known allergens. Secondly, the allergenicity of a food protein is determined by its abundance and the stability to processing and digestion. When novel proteins are from an allergenic source, assessment of binding to specific IgE present in sera from patients allergic to this specific protein can be used. In addition to these endpoints, several other methods can be considered, including animal models. However, these approaches are not yet applicable, because they are not thoroughly evaluated or validated for predicting protein allergenicity (Ladics, 2008).

Quorn has been on the market in the EU before 1997 and is not considered a novel food.

With respect to insects as a food, there is currently lack of clarity as to whether these fall within the scope of the authorisation procedure for the admission of novel foods to the market (van Wagenberg et al., 2012).

The development and marketing of insect protein and other new sustainable protein sources as food ingredients is considered to be impeded by the complex procedures (van Wagenberg et al., 2012).

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