Optimeal EU dataset

Methodology and data development

DATE: 14-2-2019

optimeal

Optimeal is a software package for optimization of diets on health and sustainability. It was developed by Blonk Consultants in cooperation with Voedingscentrum (the Netherlands Nutrition Centre). Optimeal and the included environmental data have been applied in several peer-reviewed scientific papers.

Title Optimeal EU dataset

Date 14-2-2019

Place Gouda, NL

Authors	Roline Broekema	Blonk Consultants
	Hans Blonk	Blonk Consultants
	Elena Koukouna	Blonk Consultants
	Mike van Paassen	Blonk Consultants

Optimeal EU dataset

Methodology and data development

optimeal

Summary

This document describes the basic principles of Optimeal, and it explains the methodology to derive the background datasets in Optimeal and specifically how the EU dataset has been derived.

The Challenge

The world's food system faces a great balancing act. By 2050 it must feed around 10 billion people in a more sustainable way. In addition, diets should prevent both malnutrition and non-communicable diseases, like obesity and cardiovascular disease.

Optimeal is developed to support organizations to grasp the full picture of possible changes to come to healthy and sustainable diets. It identifies the possibilities to improve product performance to make food products more future proof (healthy and sustainable)

Optimeal

Optimeal is a tool that uses optimization to solve dietary questions that involve sustainability as well as nutritional parameters. The tool identifies new opportunities and helps to elevate the level of discussion on eating better for a healthy and sustainable future.

Using optimization requires many data. Optimeal comes with a default dataset for the EU which is mainly built on EFSA data. The EU dataset consists of:

1. Reference diet (chapter 2)
2. Nutritional constraints (chapter 3)
3. Nutritional properties for the products in the reference diet (chapter 4)
4. Environmental properties (LCA impacts) for the products in the reference diet (chapter 5)

An optimal diet is a diet that complies to the constraints that have been set for nutrition and environment. This optimal diet can be derived by two optimization methods: Linear (LP) or Quadratic programming (QP). A penalty is attributed for every change and the goal of the optimization is to minimise the amount of penalties.

Reference diet

The reference diet (EU) is the starting point of the optimization. It is based on Food Consumption Surveys in Europe and is a representation of the average EU diet. The diet is constructed for doing environmental oriented optimizations with a synoptic and limited set of products (173 products). To derive the EU reference dataset the EFSA Comprehensive European Food Consumption Database (EFSA, 2018a) was used. It is a source of information on food consumption across the European Union and contains detailed data for many EU countries.

Nutritional constraints

The nutritional constraints define if a diet can be considered healthy or "nutritionally sound". The upper and lower limits of the nutritional properties are the boundaries used in the optimization. If the nutrition provided by the diet falls outside one of the boundaries, it will be corrected during the optimization to fit the nutritional constraints. Two reports of EFSA substantiate the nutritional constraints for the EU: Dietary Reference Values for Nutrients (EFSA, 2017) and Tolerable Upper Intake Values for Vitamins and Minerals (EFSA, 2006).

Nutritional properties

The nutritional properties of the products in the EU database are based on the EFSA Food Composition Data (EFSA, 2018b). This database contains over 2500 products with multiple preparation methods (e.g. cooking in water, baking, cooking in oil, steaming) reported by 10 European countries[1]. For each nutrient, an average was calculated based on the reporting countries. Missing nutrient data were supplemented with data from the NEVO

[1] Denmark, Finland, France, United Kingdom, Iceland, Netherlands, Portugal, Serbia, Sweden, Slovenia.

(Dutch Food Composition Database), the USDA Food Composition Databases, or a similar product or preparation method from the EFSA database was used as a proxy.

Environmental properties

The environmental properties of products are important for determining the environmental sustainability of a diet. Environmental properties of all the products in the reference diet are determined using the LCA methodology. This methodology captures the impact of a product (or service) through-out its life cycle. The list of impact categories assessed for the EU Optimeal dataset are listed here:

Impact category	unit
Global warming - excl LUC	kg CO_2eq
Fine particulate matter formation	kg PM2.5 eq
Terrestrial acidification	kg SO_2 eq
Freshwater eutrophication	kg P eq
Marine eutrophication	kg N eq
Land use	m^2a crop eq
Fossil resource scarcity	kg oil eq
Water consumption	m^3

The system boundary in this database is defined as from Farm-to-Fork, including all activities taking place at the farm (cultivation or husbandry), all the way through processing, retail and consumption. The LCAs carried out for Optimeal are in line with the the ISO 14040/44 series (ISO, 2006a, 2006b). For the life cycle stages from processing to plate the Product Environmental Footprint (PEF) guidance (European Commission, 2017) and PEF default data have been used.

Limitations

There are a couple of limitations of the EU Optimeal dataset which should be considered:

Scope

The scope of the EU Optimeal dataset is the European Union, including the United Kingdom at the time of publication. This is a large region with high dietary variation and therefore not representative of individual countries. The EU Optimeal dataset comes with several nutritional profiles specified per gender, age and activity level, but only one EU average diet. This EU average diet should be adapted to the target group of the study and its nutritional profile. The EU Optimeal dataset fits for use in the Optimeal context but should not be the starting point for dietary advice on a more individual level.

Compliance and data quality

The EU Optimeal dataset is not fully compliant to the PEF guidance and the PEFCRs per product category. Since the PEFCRs are not consistent in terms of allocation, using the PEFCRs as a starting point would lead to an internal inconsistent database. For analyses, using the EU Optimeal dataset, consistency is very relevant and valued more than compliance to the PEF guidance and PEFCRs. Data quality has not been monitored for the EU Optimeal dataset. We are working on implementing data quality rating in the database development and wish to include this rating in a future release.

Table of Contents

1 Introduction

This report is part of the Optimeal software package for the EU. Blonk Consultants developed Optimeal in 2012 to support the Netherlands Nutrition Centre (Voedingscentrum) in defining their dietary guidelines at that time. Taking account of more diverse dietary habits and sustainability aspects were new challenges for which optimization is the most appropriate method. Optimeal is a tool that uses optimization to solve questions that involve sustainability as well as nutritional parameters. Optimeal gives understanding of the full picture of healthy and sustainable nutrition and allows assessment of a multitude of options. It identifies new opportunities and helps to elevate the level of discussion on eating better for healthy and sustainable future.

1.1 Sustainable and healthy nutrition

The world's food system faces a great balancing act (World Resources Institute (Searchinger & et al., 2013). By 2050 it must feed around 10 billion people (United Nations Department of Economic and Social Affairs Population Division, 2017) in a more sustainable way: without increasing the area of agricultural land, using less natural resources and emitting less greenhouse gases. In addition, diets should be healthier, reduce disease risks and meet human nutritional needs. They should prevent both malnutrition and non-communicable diseases, like obesity and cardiovascular disease. This research area is at the center of recent studies like the Eat Lancet report (Willett et al., 2019). Sustainable nutrition attempts to provide answers on how to meet these challenges.

1.2 Why Optimeal?

A main challenge for all food and beverage producing companies is to become more "future proof" with respect to nutrition, environmental and other sustainability concerns. Making food and beverage products more future proof means improving the balance between the nutrients provided and the environmental impact. Optimeal is developed to help companies create insight in their product's position regarding the balance between nutritional and sustainability aspects. It supports identifying the possibilities to improve the performance of products.

Optimeal came about from the fact that food and beverage items all have their specific nutritional contribution and cannot be simply compared. For instance, milk and soy drink are marketed as alternatives but are from a nutritional viewpoint not comparable. These differences need to be considered when replacement is studied, for health or sustainability reasons. Another example is the comparison between meat and meat alternatives. This comparison is often made in analyses related to the shift from animal protein to vegetable protein. The nutritional profile of meat products and meat alternatives is not similar and thus their environmental profiles should not be simply compared on the mass basis. Their nutritional content should be considered for a fair comparison.

Optimeal analyses the impact of shifts between products in a diet or changes of a product's consumption by evaluating the effect on the complete diet and how the diet should optimally be adapted to these changes. The starting point can be an average diet based on national food consumption surveys or any other realistic and relevant diet for a target group. When changes in the reference diet occur, for instance by changing from milk to soy drink, Optimeal will find the optimal adjustment to the new diet so it meets all the nutritional (and environmental) boundaries that have been set. During an optimization, products are added and excluded from the diet to make this happen, compensating for the nutritional changes due to the shift in product consumption.

1.3 How does Optimeal work

Using optimization to gain insight into sustainable nutrition requires a lot of data. Optimeal comes with a default dataset for the EU. A dataset consists of:

1. Reference diet
2. Nutritional constraints
3. Nutritional properties for the products in the reference diet
4. Environmental properties for the products in the reference diet

1.3.1 Reference diet

The reference diet is the starting point of the optimization. It is based on Food Consumption Surveys and is representative of the average diet in the region of focus. For the EU the EFSA Comprehensive European Food Consumption Database has been used. It is a source of information on food consumption across the European Union. It contains detailed data for many EU countries.

For the EU dataset, an average has been made from the EFSA Comprehensive European Food Consumption Database (EFSA, 2018a), resulting in an average EU diet. Products can be added to the reference diet/dataset as well.

1.3.2 Nutritional constraints

Nutritional constraints determine whether a diet is healthy. The nutritional constraints are upper and lower boundaries for all the nutritional properties (e.g. consumption of dietary fibre should be over 25g per person per day). The optimal diet falls in between the upper and lower boundaries. Additional constraints can be set for other properties, like environmental properties or price.

The nutritional constraints are based on EFSA Dietary Reference Values (EFSA, 2017)(EFSA, 2006).

1.3.3 Properties

Various properties of the products are needed to be able to optimize a reference diet. About 60 nutritional properties (e.g. gram protein, microgram vitamin D and milligram magnesium per 100 gram of food product) as well as 8 environmental properties (e.g. impact on climate change and water depletion per 100 gram of food product) are part of the default dataset. Properties can also be added to the default dataset, for instance on price.

Nutritional properties of all the products in the reference diet are based on EFSA Food Composition Data (EFSA, 2018b). Environmental properties of all the products in the reference diet are determined using Life Cycle Assessment (LCA).

1.3.4 Optimization

The optimal diet is a diet that complies to the constraints that have been set for nutrition and environment, and that is as similar as possible to the reference diet. Reasoning behind this is that people find changing their dietary habits quite difficult and adoption of dietary changes is likelier to happen when the suggested diet is close to the reference diet.

Optimeal uses either Linear (LP) or Quadratic programming (QP) for the optimization. A penalty is attributed for every change and the goal of the optimization is to minimise the amount of penalties. Using LP a specific amount of changes comes with a set amount of penalty, but with QP the penalty increases with the amount of changes per product. This results in more changed products than when applying LP. It is also possible to approach a goal, either directly or using stepwise optimization.

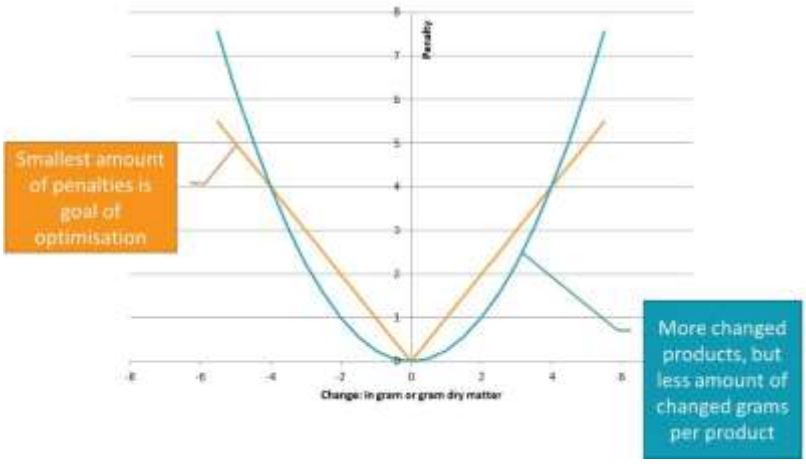


Figure 1 Linear vs Quadratic programming

1.3.4.1 Optimization example

The figure below shows how a 'starting' diet is optimized to a 'low carbon diet' that still meets all nutritional constraints, for instance for a recommended caloric input and vitamin, folate and iron sufficiency.

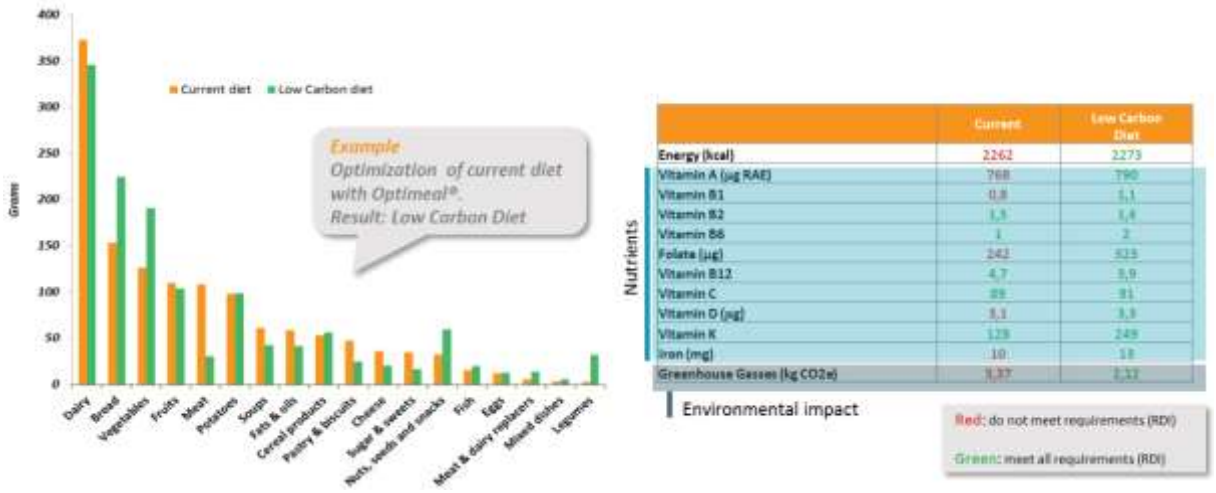


Figure 2 Example of an optimization

1.4 Reading guidance

This document describes the basic principles of Optimeal, and it explains the methodology to derive the background datasets in Optimeal and specifically how the EU dataset has been derived. It also describes the sources of the data used and the assumptions made. The overall methodology is justified in the following chapters. This report serves as a guidance and supporting document to the Optimeal datasets provided with the software. The chapters are built around the type of data that is part of the EU dataset: a reference diet, nutritional constraints, nutritional properties and environmental properties.

1. Reference diet (Chapter 2)
2. Nutritional constraints (Chapter 3)
3. Nutritional properties for the products in the reference diet (Chapter 4)
4. Environmental properties for the products in the reference diet (Chapter 5)

2 Reference diet

The reference diet (EU) is the starting point of the optimization. It is based on Food Consumption Surveys and is representative of the EU average diet. The diet is constructed for doing environmental oriented optimizations with a synoptic and limited set of products. To derive the EU reference dataset the EFSA Comprehensive European Food Consumption Database (EFSA, 2018a) was used. It is a source of information on food consumption across the European Union and contains detailed data for many EU countries.

The EU reference diet is an average diet over all age categories, activity levels and gender. The EU reference diet is composed of 173 products (see chapter **Error! Reference source not found.**) out of 4000+ products.

2.1 EFSA Comprehensive European Food Consumption Database

The EFSA Comprehensive European Food Consumption Database has been built from existing national information on food consumption at a detailed level, as explained in EFSA (2011). Competent organizations in 19 European Union 's Member States provided EFSA with data from the most recent national dietary survey in their country, at the level of consumption by the individual consumer. The countries are:

Austria	Germany	United Kingdom	Latvia
Belgium	Denmark	Greece	Netherlands
Bulgaria	Spain	Hungary	Romania
Cyprus	Finland	Ireland	Sweden
Czech Republic	France	Italy	

2.2 Defining the EU reference diet

The EFSA Comprehensive European Food Consumption Database describes food consumption using the food classification and description system FoodEx. This system is aimed at covering the need to describe food in data collections across different food safety domains. The FoodEx system uses an exposure-oriented hierarchy. It is designed to facilitate the grouping of food items for exposure (for instance to toxins) calculations. The exposure hierarchy consists of 4 445 terms, including hierarchy terms (134 terms) and reportable terms (4 311 terms). The exposure hierarchy is structured in six levels with 21 groups at the top level. The top level are very generic food groups like 'dairy and dairy products', 'legumes, nuts and oilseeds' and 'grains and grain-based products'. At this level the products are too generic to attribute nutritional and environmental properties to, because the diversity within the groups is too big. At the most detailed level however there are too many products to attribute nutritional and environmental properties to. At the same time the differences between the products at this level can be very small in terms of composition, nutrition and environmental impact. This level of detail might not be sensible for the analysis.

We've composed the EU reference diet based mostly on level 2 of FoodEx. For some level 2 product groups we've selected one level 3 product to represent the whole product group. For instance, for level 2 'grains for human consumption' we have selected rice. Rice represents over 95% of the EU consumption of 'grains for human consumption'. For other level 2 product groups we've selected multiple level 3 products. For instance, for level 2 'bread and rolls' we selected wheat bread and rolls, rye bread and rolls, mixed wheat and rye bread and rolls and multigrain bread and rolls. These 4 types of bread and rolls represent over 85% of the EU consumption for 'bread and rolls'. The coverage per product group (level 2) is at minimum 80%, but for some product groups the

coverage is close to 100%. Chapter 9 provides more inside in the decisions that were made in composing the reference diet.

2.3 Product constraints

Product constraints help to ensure that the optimized diet is acceptable to the general consumer. It ensures that the optimized diet does not contain large amounts of individual products which are generally not consumed in large quantities. The EFSA Comprehensive European Food Consumption Database (EFSA, 2018a) was used to define these product constraints. For the maximum consumption the 99th percentile of Food consumption was multiplied by two. This allows for reasonable dietary changes in the light of healthy, sustainable and adoptable diets.

3 Nutritional constraints

The nutritional constraints define if a diet can be considered healthy or "nutritionally sound". The upper and lower limits of the nutritional properties are the boundaries used in the optimization. If the nutrition provided by the diet falls outside of one of the boundaries, it will be corrected during the optimization to fit the nutritional constraints. Two reports of EFSA substantiate the nutritional constraints for the EU: Dietary Reference Values for Nutrients (EFSA, 2017) and Tolerable Upper Intake Values for Vitamins and Minerals (EFSA, 2006).

3.1 Dietary reference values

Dietary Reference Values (DRVs) is the umbrella term for the complete set of nutrient reference values which include population reference intakes (PRIs[2]), the average requirements (ARs[3]), adequate intakes (AIs[4]) and reference intake (RIs[5]) ranges for macronutrients. These values indicate the amount of a nutrient which must be consumed on a regular basis to maintain health in an otherwise healthy individual (or population) (EFSA, 2017).

PRIs, ARs, AIs and RIs were not all available for all the nutritional properties. When a choice was to be made between PRIs, ARs and AIs; PRI was chosen over AR and AI, and AR was chosen over AIs. RIs were used for macronutrients like 'fat' and 'carbohydrate' which were given as energy% referenced to the total dietary energy.

When DRVs were defined per age groups, the age categorization did not always match between the nutrients. This was especially the case for the younger age categories (up to 18 years of age), where many adjustments would be needed to align the DRVs per age categorization. This is one of the reasons why the younger age categories are not included as part of the default software package for the EU.

3.2 Different nutritional profiles

The Optimeal EU database comes with a set of nutritional profiles specified for gender, age and activity level. There are different profiles for males and females. The age categories included are: 19 to 30 years of age, 31 to 50 years of age & 51 to 70 years of age.

We can provide profiles for younger than 18 and over 70 years of age, but these are not part of the default package. This is because the data from EFSA had to be adjusted quite extensively for the younger age categories, as the age categories were not equal between different nutrient requirements. Also, the EU Optimeal dataset comes with one default average EU diet and diets for the young and elderly can deviate largely from this average EU diet. Therefore, the provided average EU diet is less compatible with these age categories.

The nutritional profiles are specified per physical activity level (PAL). In EFSA (2017) PAL is defined as the ratio of total energy expenditure (TEE) to resting energy expenditure (REE) per 24 hours and reflects the part of TEE that is due to physical activity. Accordingly, TEE is predicted as PAL x REE. Nutritional profiles have been defined for two physical activity levels: 1.4, 1.6.

[2] the level of (nutrient) intake that is adequate for virtually all people in a population group.
[3] the level of (nutrient) intake that is adequate for half of the people in a population group, given a normal distribution of requirement.
[4] the value estimated when a Population Reference Intake cannot be established because an average requirement cannot be determined. An Adequate Intake is the average observed daily level of intake by a population group (or groups) of apparently healthy people that is assumed to be adequate.
[5] the intake range for macronutrients, expressed as % of the energy intake. These apply to ranges of intakes that are adequate for maintaining health and associated with a low risk of selected chronic diseases.

4 Nutritional properties

The nutritional properties of the products in the EU database are based on the EFSA Food Composition Data (EFSA, 2018b). This database contains over 2500 products with multiple preparation methods (e.g. cooking in water, baking, cooking in oil, steaming) reported by 10 European countries[6]. For each nutrient, an average was calculated based on the reporting countries. The nutrients included in the EU database are:

Energy	Trans fatty acids	Retinol eq.	Calcium	Tryptophan
Protein total	Fatty acids n-3	Vitamin B1	Phosphorus	Threonine
Protein vegetable	Fatty acids n-6	Vitamin B2	Iron total	Isoleucine
Protein animal	Cholesterol	Niacin	Haem iron	Leucine
Fat total	Carbohydrates total	Vitamin B5	Sodium	Lysine
SAFA	Polysaccharides	Vitamin B6	Fluoride	Methionine
MUFA	Mono- and disaccharides	Folate eq.	Manganese	Cystine
PUFA	Lactose	Vitamin B8	Iodine	Valine
Linoleic acid	Fibre	Vitamin B12	Potassium	Histidine
ALA	Water	Vitamin C	Magnesium	Grams
EPA	Alcohol	Vitamin D	Zinc	Dry matter
DHA	DHA+EPA	Vitamin E	Selenium	
		Vitamin K total	Copper	

Missing nutrient data were completed with data from the NEVO (Dutch Food composition database), the USDA Food Composition Databases, or a similar product or preparation method from the EFSA database was used as a proxy.

Proteins are reported in the EFSA database as total protein, plant protein and animal protein. Some inconsistencies were found between the three. In some cases, only the total protein was reported, but not specified to plant or animal protein. When the considered product is made of either plant or animal material, the total protein was allocated to the plant or animal protein, respectively. When the considered product consists of both plant and animal products (e.g. meat and vegetable soup), the ratio was taken from NEVO and applied to the EFSA total protein to make the distinction between plant and animal protein. In other cases, the sum of the plant protein and animal protein did not match the total protein reported. This inconsistency was solved by taking the ratio plant: animal protein and applying it to the total protein to get to a new value for plant protein and animal protein, respectively.

A correction for outliers was applied to the EFSA data. For example, in some cases data implied that more than 100 grams of a nutrient was present per 100 grams of product. In other cases, a country reported a quantity that was far out of the range reported by other countries. For example, one country reported 10 grams of nutrient, while other countries reported within a range of 10-15 milligrams. In these situations, it was assumed the country misreported the unit of measurement.

There are a few products in the Optimeal database that represent food groups, for example condiments, vegetable oil, or tree nuts. These are a mix of two or more products and their nutritional properties are therefore compiled as such. Condiments, for example, is compiled of 1/3 mustard, 1/3 ketchup and 1/3 mayonnaise.

[6] Denmark, Finland, France, United Kingdom, Iceland, Netherlands, Portugal, Serbia, Sweden, Slovenia.

5 Environmental properties

5.1 Introduction

The environmental properties of products are important in determining the environmental sustainability of a diet. Environmental properties of all the products in the reference diet are determined using the Life Cycle Assessment (LCA) methodology.

5.2 Life Cycle Assessment (LCA) framework

The calculated environmental performance in the background analysis of Optimeal, is based on environmental data analysis with the use of LCA methodology. This methodology captures the impact of a product (or service) through-out its life cycle. Examples of environmental impacts are climate change, fossil depletion, water use, and land use. The list of impact categories assessed for the EU Optimeal dataset are listed in Table 1.

Table 1 Impact categories assessed for the EU Optimeal dataset.

Impact category	unit
Global warming - excl LUC	kg CO_2eq
Fine particulate matter formation	kg PM2.5 eq
Terrestrial acidification	kg SO_2 eq
Freshwater eutrophication	kg P eq
Marine eutrophication	kg N eq
Land use	m^2a crop eq
Fossil resource scarcity	kg oil eq
Water consumption	m^3

The system boundary in this dataset is defined as from Farm-to-Fork, including all activities taking place at the farm (agriculture or husbandry), all the way through processing, retail and consumption. These activities are more elaborately discussed in Chapter 5.3.

The life cycle assessments carried out for Optimeal are in line with the ISO 14040/44 standards (ISO, 2006a, 2006b)[7]. For the life cycle stages from processing to plate the Product Environmental Footprint (PEF) guidance (European Commission, 2017) and PEF default data have been used.

Product Environmental Footprint Category Rules (PEFCRs) are available for various products in this dataset. These PEFCRs have not always been the basis for the modelling. It is in our view more important that the environmental profile of the products within the EU Optimeal dataset are generated in a consistent way to make meaningful analyses possible. However, the PEFCRs are not consistent amongst one another. They opt for instance for different allocation methods.

[7] The ISO 14040 series (ISO, 2006a) describe the basic requirements for performing an LCA study. This includes, amongst others, directions on how to define the functional unit of a product, how to determine which processes need to be included or excluded, and how to deal with co-production situations where elementary flows need to be allocated to the different products.

5.3 Scope

5.3.1 Included products

The average EU diet is modelled based on EFSA (2011). The products in scope are classified in the following product groups[8]:

Table 2 Classification of the product groups which are used to categorize the food products

FoodEx codes	Product group
A.01.000001	Grains and grain-based products
A.01.000317	Vegetables and vegetable products
A.01.000467	Starchy roots and tubers
A.01.000486	Legumes, nuts and oilseeds
A.01.000544	Fruit and fruit products
A.01.000727	Meat and meat products (incl. edible offal)
A.01.000876	Fish and other seafood
A.01.000948	Milk and dairy products
A.01.001252	Eggs and egg products
A.01.001267	Sugar and confectionary
A.01.001346	Animal and vegetable fats and oils
A.01.001394	Fruit and vegetable juices
A.01.001470	Non-alcoholic beverages
A.01.001534	Alcoholic beverages
A.01.001573	Drinking water
A.01.001580	Herbs, spices and condiments
A.01.001715	Composite food
A.01.001748	Snacks, desserts and other foods

5.3.2 Function, functional unit and reference flow

The primary function of food products is to provide nutrition to consumers. Food products with different nutritional profiles satisfy different nutritional needs. Of course, social determinants and personal satisfaction also affect the food patterns, but there is no parameter reflecting these functions in the present analysis. Optimeal uses the dietary context to compare products and diets based on equal functions. The functional unit is defined on a mass basis and the environmental impact is displayed in the dataset per 100g of product.

5.3.3 Allocation method

The ISO14044:2006 standard (ISO, 2006b), provides guidelines on the allocation procedure. The first guideline is that allocation should be avoided whenever possible by dividing the unit multioutput process into two or more sub-processes and collecting the inventory data related to these sub-processes separately. If this is not possible allocation may be avoided by expanding the product system to include the additional functions related to the co-products. If allocation cannot be avoided, the inputs and outputs of the system should be partitioned between its different products or functions in a way that reflects the underlying physical relationships between them; i.e. they should reflect the way in which the inputs and outputs are changed by quantitative changes in the products or functions delivered by the system. If physical relationship alone cannot be established or used as the basis for allocation, the inputs should be allocated between the products and functions in a way that reflects other relationships between them. For example, input and output data might be allocated between co-products in proportion to the economic value of the products or another property.

System expansion as such is not applied in Optimeal because no consistent approach exists and aspects of consequential LCA are introduced. Also, allocation based on a (bio)-physical mechanism is generally not used, as these mechanisms are generally not well quantified. An exception is the PEF Cattle model working group (JRC &

[8] A full list of products available in Optimeal are listed in Chapter 8.

European Commission, 2015) compliant versions of the dairy production process, where the biophysical allocation according to IDF methodology (IDF, 2010) is implemented.

It should also be realised that allocation based on physical keys of the outputs is not the same as allocation based on (bio) physical mechanism but could be considered as a proxy for this approach. Likewise, economic allocation may be regarded as a proxy for a market-based approach (substitution through system expansion). If allocation keys are not directly related to a physical mechanism, they should be treated as allocation based on another causality (ISO step 3).

In Optimeal, economic allocation is applied in all multifunctional processes, except for the dairy farm, where biophysical allocation (IDF) is implemented, in accordance with the Product Environmental Footprint Category Rules (PEFCR) for dairy products (Technical Secretariat Dairy PEF, 2018). However, Optimeal is not in line with the PEFCR for dairy products, which opts for mass or dry matter allocation[9] of raw milk and transport from farm to processing plant. In the future it would be possible to develop an EU Optimeal dataset with other allocation methods consistently applied, like mass allocation or energy allocation.

Allocation is applied without the use of cut-offs for so called residual product streams whenever possible. There are a couple of exceptions to this allocation rule:

- Citrus pulp dried, from drying, at plant
- Brewers' grains, wet, at plant
- Animal manure
- Nut shells

The reason for these exceptions is pragmatism. Most of these products are required for the LCI of a couple of animal production systems and are taken from Agri-footprint (Durlinger, Koukouna, Broekema, van Paassen, & Scholten, 2017b, 2017a). This may be adapted in a future update of Agri-footprint. Dried citrus pulp and wet brewers' grain do not include any inputs from previous life cycle stages. Dried citrus pulp only includes the energy required for drying. Animal manure is a residual product of the animal production systems and does not receive part of the emissions of the animal production system when animal manure is applied.

5.4 Data generation and quality procedure

5.4.1 Workflow in dataset development

Data are generated via a workflow with pre-defined steps.

Step 1. Defining the origin of agricultural products

The market mixes of production countries of agricultural raw materials are determined with the 'crop mix tool', which uses FAO trade statistics (2009-2013) to map the origin of raw materials. Sometimes the FAO trade statistics are not available, consistent or complete. In this case Eurostat, product specific literature on trade statistics or production mixes are used to determine a reliable market mix.[10] These exceptions are reported in chapter 5.5.2.

Step 2. Data collection for agriculture and processing

Once the origin of agricultural production countries is known, the data collection starts. The methodology for modelling cultivation systems is the same as the Agri-footprint methodology (Durlinger et al., 2017a). Animal

[9] Mass allocation is using the dry weight (i.e. dry matter content) of the product under study and its co-products (e.g. skimmed milk powder and cream).

[10] FAO statistics be disturbed for instance by second degree trades, for instance when a country possesses a port which is of importance for receiving trade for a large region (eg. avocadoes are shipped to Belgium and from there distributed throughout the EU, which makes it seem like Belgium is a relevant avocado producer for the Netherlands). In this case the crop mix tool is used to determine the product origin and determine the final market mix.

cultivation systems are modelled based on literature review and IPCC guidelines. The processing of the crops/ raw materials into final products is modelled based on general processing data as well as product specific data.

Step 3. The data for the final life cycle stages are added

The life cycles stages from processing till consumption are modelled based on fixed parameters and default methods via an automated procedure, called "processing-to-mouth" model, which concerns the following lifecycle stages:

a) Processing *(default for vegetables and fruits)*
b) Packaging
c) Distribution
d) Supermarket
e) Consumption
f) Final (food losses)

Where possible and meaningful the default parameters set by the PEF Guidance document 6.3 (European Commision, 2017) are used. These concern energy use and losses at retail, as well as energy use and food losses during cooking and consumption. Other data concerning food preparation (i.e. cooking procedure) and the amount of packaging material, as well as assumed packaging disposal scenarios. Raw-to-cook ratios are mostly based on publicly available data. All parameters and default data are further elaborated in chapter 5.5.

5.4.2 Data quality assessment and review

The environmental impact results are reviewed internally at the cultivation stage (qualitative review), at the processing stage (quantitative review) and at the end of life stage (i.e. after consumption) (quantitative review).

No data quality rating (DQR) matrix was developed yet. Furthermore, the EU Optimeal dataset is not reviewed by an external party.

5.5 Methodology and data used

The life cycle inventory is modelled in the LCA software SimaPro. The impact results are calculated by applying the lifecycle impact assessment method ReCiPe Midpoint (H) 2016. This chapter describes the methodology and methods for collecting and analysing the data.

5.5.1 Agriculture and animal husbandry

Crop cultivation (Figure 3) is modelled on country level, with the Agri-footprint methodology (Durlinger et al., 2017a) (with country/ region specific crop yields, fertilizer composition, fertilizer application rates and energy use) which is also compliant to the EC PEF methodology (European Commision, 2017). Carbon storage in crops and animal products is not included because this carbon is part of the short-term carbon cycle. The carbon dioxide emissions at the end of the life cycle (e.g. emitted during fermentation or digestion) are also not modelled except when the stored carbon is released as methane due to enteric fermentation or manure management and storage, which is inventoried as 'methane, biogenic'.

Data collection and analysis for cultivation are elaborately discussed in Chapter 3 of Agri-footprint data report (Durlinger et al., 2017b). This section covers issues with regards to land use change, water use for irrigation, artificial fertilizer application rates, manure application and emissions from managed soils. Pesticides production and use is included when Agri-footprint processes are used but are out of scope for processes which have been created specifically in the context of the development of the EU Optimeal dataset.

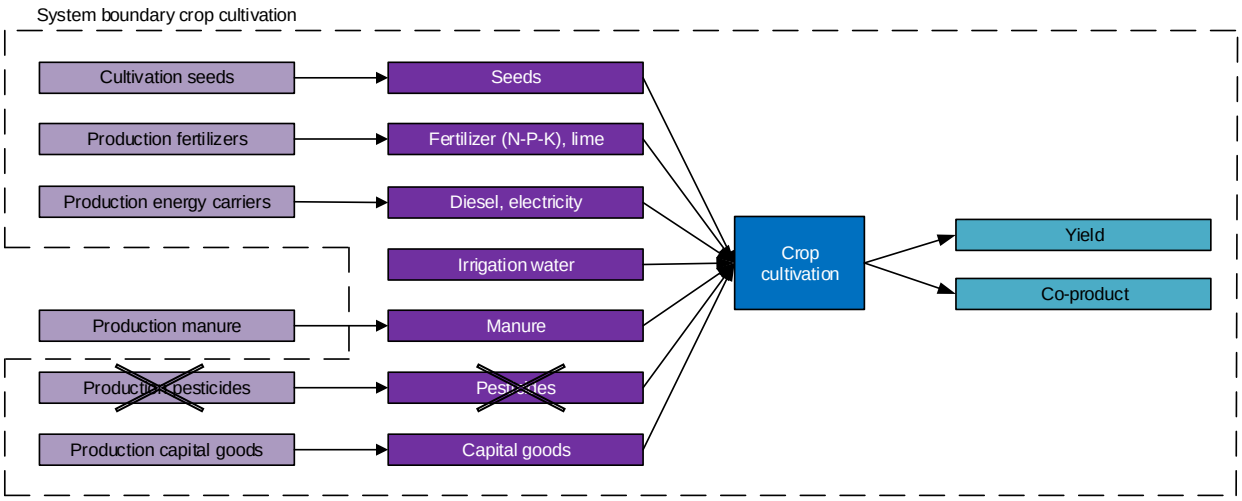


Figure 3 System boundary for crop cultivation (taken from Agri-footprint 4.0 methodology report)

5.5.2 Market mix and transport of raw ingredients to processing plant

The market mixes of raw materials are determined based on Blonk Consultants' crop mix tool. For some crops trade statistics were not available, in this case the global production mix or global export mix statistics were used instead (Table 3). The assumption is made that these mixes are a good estimate of the European market share.

Table 3 Crops for which global production or export statistics were used to model the market mix

Crop (FAO name)	Type of statistics	Year
Almonds, with shell	Global production	2009 - 2013
Hazelnuts, with shell	Global production	2009 - 2013
Peppermint	Global production	2009 - 2013
Groundnuts, with shell	Global production	2009 - 2013
Rice, paddy	Global export	2013 - 2017
Sugar cane	Global production	2009 - 2013

5.5.3 Processing

Processing based on Agri-footprint data are: Cereal dry milling, rice parboiling, sugar production, oilseed crushing and refining and animal slaughtering.

Processing data for vegetables and fruits have been collected. These data include energy and water consumption for processing vegetables and fruits for fresh consumption or for processed foods. Energy consumption is modelled according to Sanjuán, Stoessel and Hellweg (2014). Six types of vegetables' and fruits' processing are applied; fresh, canned, in jar, peeled, scraped and frozen. Water consumption is modelled according to Lehto et al. (2014), from which an average water consumption is used for all vegetables and fruits at processing.

For products other than vegetables and fruits, processing is modelled manually in the LCA software based on the sources as shown in Table 4 and Table 5.

Table 4 Main sources used for processing (from raw material to product/co-product) products other than vegetables and fruits

Relevant processes	Source
Oat and Wheat flaking	Energy use based on McDevitt & i Canals (2009). Flaking yield based on Welch (1995).

Tree nuts	Tree nuts drying and deshelling energy use based on various sources: (almond: (Kendall, Marvinney, Brodt, & Zhu, 2015), cashew nuts: (Jekayinfa & Bamgboye, 2006) , hazelnuts: (China Win Tone Machinery, 2014)&(Anil, Kurt, Akar, & Köse, 2018), walnuts: (Thompson & Elkins, 2009)). Kernel/shell ratio based on FAOstat. A cut-off approach was applied for shell: neither impact, nor benefit was allocated to the shell (with exception of cashew shell and cashew shell liquid co-products).
Black tea and herbal tea	Drying and moisture loss based on Taulo & Sebitosi (2016) and Tarhan, Telci, Tuncay, & Polatci (2011).
Black pepper drying	(Joy, Peter Pittappillil, & Jose, 2002)
Fish cleaning and degutting	(Broekema, Kuling, & Scholten, 2015b)
Meat processing	Intensive and extensive processing[11] based on (Broekema, Kuling, & Scholten, 2015a).
Milk pasteurization	(Sheane et al., 2011)
Honey	(Arena, Barón, Piastrellini, Curadelli, & Civit, 2014).

Table 5 Main sources used for processing (assembling) products other than vegetables and fruits

Relevant processes	Source
Baking of bread and rolls, pastries and cakes, biscuits, pizza, pretzels	Energy use from Therkelsen, Masanet, & Worrell (2014), recipes from "Het Nieuwe Kookboek".
Pasta production	(Technical Secretariat of the PEF dry pasta Pilot 2004)
French fries and potato crisps	(Ponsioen & Blonk, 2011) & (Broekema, Kuling, & Koukouna, 2016)
Jam, fruit compote, liquorice candies, ready to eat-meals.	Energy use default (heated mixing) based on Andersson, Ohlsson, & Olsson (1998).
Peanut butter	(Center for Agricultural and Rural Sustainability, 2012)
Margarine	(Broekema et al., 2016)
Sauces, mustard, dressing and mayonnaise	Energy use default (ingredient mixing) based on average between peanut butter and margarine
Tomato puree/paste	(Manfredi & Vignali, 2014).
Soups	(Milà I Canals et al. 2011)
Chocolate	(Recanati et al., 2018) & (Konstantas, Jeswani, Stamford, & Azapagic, 2018)
Olive oil	(Technical Secretariat of the olive oil PEF pilot, 2016)
Concentrated fruit juice (used for juice production)	(Pluimers, Blonk, Broekema, Ponsioen, & van Zeist, 2011) & (Lekkergezond, 2016)
Soft drinks	Recipe based on Ercin, Aldaya, & Hoekstra (2011), energy use based on Pluimers et al. (2011).
Coffee beans and instant coffee	(Humbert, Loerincik, Rossi, Margni, & Jolliet, 2009)
Alcoholic drinks (and related)	Beer: (Broekema & Scholten, 2015), wine: (Thecnical Secretariat of the PEF pilot on wine, 2015), cider: (Iannone, Miranda, Riemma, & De Marco, 2016), spirits: (Broekema et al., 2016), vinegar: (Bartocci, Fantozzi, & Fantozzi 2017)
Vegetable burger	(Broekema & Blonk, 2009)
Fish cakes and fish fingers	(Broekema et al., 2015b)

[11] A differentiation was made between intensive processed products and extensive processed products. Extensive processed products are chopped into consumer parts and packed at the processor but are not mixed with other ingredients/ seasoned and prepared at the processor. Extensive processed products are: steak, chicken fillet, hamburger, lamb, minced beef and pork. An example of intensive product is sausage, chorizo etc.

Cheeses	Mass and energy based on Broekema et al. (2015a).
Other dairy production	Yoghurt, ice-cream, pudding and custard production based on (Sheane et al. (2011), evaporated milk energy use based on Fox, Akkerman, Straatsma, & Jong de (2010), butter and buttermilk production based on Technical Secretariat Dairy PEF (2018).

5.5.4 Packaging

The type and weight of packaging material is estimated based on own estimates. The production of packaging is based on background datasets, shown in Table 6. All background datasets are from the Ecoinvent 3 database, except from aluminium, which is taken from the ELCD database. The amount of packaging is based on measurements of representative products[12],. The transport distances and modalities for specific packaging types modelled are based on PEF default data from the PEF Guidance document 6.3 (European Commision, 2017). Default transport distance of packaging materials is determined from manufacturing plants to filler plants. For all materials, except glass, the following transportation distances are used: 230 km by truck, 280 km by train, 360 km by ship. For glass, this transportation requirements are based on empty bottles and are: 350 km by truck, 39 km by train and 87 km by ship. The background datasets used to model the modalities (i.e. inland and sea transport) are shown in Thermoforming (Ecoinvent 3: Thermoforming, with calendering {RER}| production | APOS, S) is used for making packaging from plastic granulates.

Table 7Table 7.

Table 6 Overview of background dataset used for various packaging material

Packaging material	Background dataset
Cardboard	Corrugated board box {RER}| production | APOS, S
PP	Polypropylene, granulate {RER}| production | APOS, S
Paper: 50%	Kraft paper, bleached {RER}| production | APOS, S
Paper: 50%	Kraft paper, unbleached {RER}| production | APOS, S
Chromium steel	Steel, chromium steel 18/8, hot rolled {RER}| production | APOS, S
Modified starch	Maize starch {RER}| citric acid production | APOS, S
EPS	Polystyrene, expandable {RER}| production | APOS, S
Glass	Packaging glass, white {RER w/o CH+DE}| production | APOS, S
PET	Polyethylene terephthalate, granulate, bottle grade {RER}| production | APOS, S
LDPE	Polyethylene, low density, granulate {RER}| production | APOS, S
HDPE	Polyethylene, high density, granulate {RER}| production | APOS, S
LPB	Liquid packaging board container {RER}| production | APOS, S
Aluminium	Aluminium sheet, primary prod., prod. mix, aluminium semi-finished sheet product RER S System - Copied from ELCD

Thermoforming (Ecoinvent 3: Thermoforming, with calendering {RER}| production | APOS, S) is used for making packaging from plastic granulates.

Table 7 Background datasets used to model transportation modalities of packaging materials

Transport mode	Background dataset
Truck	Transport, truck >20t, EURO5, 80%LF, default/GLO Economic
Train	Transport, freight train, electricity, bulk, 80%LF, hilly terrain, default/GLO Economic
Ship	Transport, barge ship, bulk, 5500t, 80%LF, default/GLO Economic

[12] A representative product is a product of same or similar properties and specifications to the product in scope.

5.5.5 Distribution

Supermarket and distribution phases are modelled predominantly based on PEF default data from the PEF guidance document (European Commision, 2017). Default data are defined for cooling, freezing, lighting and heating during distribution (Table 8). These parameters depend on the defined storage time (i.e. short, average and long) as well as the products density (Charrondiere, Haytowit, & Stadlmayr, 2012) (i.e. the volume that the product occupies per kg product) (Table 9). The use of storage time and density as parameters to estimate the energy use is explained in the text box. A minimum product density of 0.3 kg/l is used. Lower product densities lead to unrealistic large energy use for these products. The product losses at retail (i.e. distribution and supermarket) are modelled based on PEF default data from the PEF Guidance document 6.3 (European Commision, 2017), as shown in Table 17.

Table 8 Overview of defaults used for distribution phase

Parameter	PEF default (2015)
Distance to distribution	150 km
Losses at distribution	0%
Cooling at distribution	2.31 kWh/ton
Freezing at distribution	6.15 kWh/ton
Lighting at distribution	See Table 9
Heating at distribution	See Table 9
R-404a emissions	See Table 9

Table 9 Calculated energy demand, water use and R404a emissions per cubic meter of product for distribution phase

Type of delivery	Storage volume (volume/ product)	Storage time (weeks)	Storage demand (m^3-week)	Lighting (kWh/m 3)	Heating (MJ/m3)	Cooling (kWh/m 3)	R404a (kg/m3)	Water use (L/m3)
Ambient short term	4	1	4	1.15	13.85	NA	NA	0.468
Ambient average	4	4	16	4.61	55.38	NA	NA	1.872
Ambient long term	4	7	28	8.08	96.92	NA	NA	3.276
Chilled	3	1	3	0.87	10.38	2.31	0.000837	0.351
Frozen	2	4	8	2.31	27.69	6.15	0.002231	0.936

How product's life time and density relate to the energy consumption at the distribution:

The energy requirement of products at distribution are determined in unit energy per m^3, in the PEF Guidance Document. So, each product needs to be allocated some occupied space and time. An average distribution centre can store 60000 m^3 of product. The storage period on a year basis is 52 weeks, i.e., 3120000 m^3-weeks/year. The total capacity is then allocated with the following storage volumes and times:

1. For ambient products: 4 times the product volume * 4 stored weeks
   - For ambient products Blonk Consultants developed 3 different options:
     - Ambient short term: 4 times the product volume * 1 stored weeks
     - Ambient average: 4 times the product volume * 4 stored weeks
     - Ambient long term: 4 times the product volume * 7 stored weeks
2. For chilled products: 3 times the product volume * stored 1 week
3. For frozen products: 2 times the product volume * stored 4 weeks

5.5.6 Supermarket

Supermarket and distribution phases are modelled predominantly based on PEF default data from the PEF guidance document (European Commision, 2017). Default data used at the supermarket are listed in Table 10.

Table 10 Overview of defaults used for retail phase

Item	PEF default
Distance to supermarket	50 km
Losses at supermarket	See Table 17
Cooling at supermarket	219.23 kWh/ton
Freezing at supermarket	415.38 kWh/ton
Lighting at supermarket	See Table 11
Heating at supermarket	*Not considered*
R404 emissions	See Table 11

Table 11 Calculated energy demand and R404a emissions per ton of product for retail phase

Type of delivery	Storage volume (volume/product)	Storage time (weeks)	Storage demand (m^3-week)	Energy (kWh/m3)	Cooling (kWh/m3)	R404a (kg/m3)	Water use (L/m3)
Ambient short term	4	1	4	30.77	NA	NA	140.4
Ambient average	4	4	16	123.08	NA	NA	561.5
Ambient long term	4	7	28	269.23	NA	NA	1228.4
Chilled	3	2	6	46.15	219.23	0.001673	210.6
Frozen	2	4	8	61.54	415.38	0.002231	280.8

5.5.7 Consumption

Food preparation methods and product characteristics with regards to inedible parts and raw-to-cooked ratios are determined for the consumption stage. At this point, the pre-defined packaging material is also disposed. The disposal scenario depends on the type of packaging. The packaging disposal scenarios and background datasets (Ecoinvent 3.4) are shown in Table 12. Food preparation at consumer is modelled according to default data and relate to the defined preparation/ cooking scenarios per product. The type of preparation is based on most common practices per food type.

Table 12 Packaging disposal scenarios and background datasets per packaging material

Packaging material	Disposal scenario	Background dataset
Paper	Waste incineration with energy recovery	Waste paperboard {Europe without Switzerland}| treatment of waste paperboard, municipal incineration | APOS, S
Plastics	Waste incineration with energy recovery	Waste plastic, mixture {Europe without Switzerland}| treatment of waste plastic, mixture, municipal incineration | APOS, S
Steel	Waste incineration with energy recovery	Scrap steel (waste treatment) {CH}| treatment of scrap steel, municipal incineration | APOS, S
Aluminium	Waste incineration with energy recovery	Scrap aluminium (waste treatment) {CH}| treatment of scrap aluminium, municipal incineration | APOS, S

Glass	Waste incineration with energy recovery	Waste glass {Europe without Switzerland}| treatment of waste glass, municipal incineration | APOS, S

5.5.7.1 Energy for cooking

Energy for cooking is determined by several factors, such as the:

- Type of preparation technique, i.e. 9 preparation techniques are considered (Table 13)
- Mass of food (and water) input for preparation (Table 16)
- Electricity and natural gas share to the energy consumed (Table 13,
- Table 14 and Table 15)

Some types of food preparation, such as the deep frying or microwave are considered to use 100% electricity. The rest are using a ratio of 25% and 75%, for electricity and natural gas respectively.

Table 13 Overview of preparation techniques and amount of input per kg of input.

Preparation technique	Electricity (kWh/kg)	Natural gas (MJ/kg)	Oil	Water
Deep frying	0.667 *(default value)*	n/a	Yes	-
Pan frying (See Table 14 for cooking times)	(25%)	(75%)	Yes	-
Boiling (See Table 15 for cooking times)	(25%)	(75%)	-	Yes
Water cooker	0.127 *(default value)*	n/a	-	Yes
Oven	Not considered			
Microwave	1100 W * time unit	n/a	-	-
Chilled at consumer	0.0777 0.0111 *(for bottled water)* 0 *(for tap water)*	n/a	-	-
Freezing at consumer	0.294	n/a	-	-
No preparation	-	-	-	-

Table 14 Baking time on low and high heat for "Pan frying" preparation option.

Product category	Baking time low (600 W)	Baking time high (3500 W)
Meat	4 min	7 min
Fish	8 min	0 min
Vegetables	3 min	7 min
Potatoes	3 min	17 min

Table 15 Boiling time and added water per kg of product for "Boiling" preparation option.

Product category	Boling time	Added water (L/kg)
Meat	120 min	0.2
Fish	10 min	0.05
Eggs	5 min	5
Vegetables	11 min	0.7
Potatoes	20 min	0.8
Rice	15 min	1.5
Pasta	10 min	5

Table 16 Inputs and added water for beverages prepared at consumers.

Beverage	Input (kg/kg)	Water added	Comment
Coffee	0.05833	1.10	Based on PEF data (7g/120 ml)
Coffee drink, espresso	0.1325	1.10	Based on PEF data (5.3g/40 ml)
Coffee drink, café americano	0.05833	1.10	Based on PEF data (7g/120 ml)
Instant coffee, liquid	0.05833	1.10	Based on PEF data (7g/120 ml)
Tea	0.01	1	
Black tea, infusion	0.01	1	
Fruit tea, infusion	0.01	1	
Lemonade	0.12	0.88	
Lemonade (light)	0.08	0.92	

5.5.8 Final (food losses)

Avoidable food losses are determined per product group, in the last life cycle stage marked as "final". These losses refer to the edible food not consumed and therefore wasted (i.e. food waste at consumption phase). Food losses at consumption are determined based on PEF default data from the PEF Guidance document 6.3 (European Commision, 2017), as shown in Table 17.

Table 17 Loss rate for various product categories at distribution and consumer phase (European Commision, 2017).

Product category	Loss rate retail	Loss rate consumer
Fruits and vegetables	10%	19%
Meat and meat alternatives	4%	11%
Dairy products	0.5%	7%
Grain products	2%	25%
Oils and fats	1%	4%
Prepared/processed meals (ambient)	10%	10%
Prepared/processed meals (chilled)	5%	5%
Prepared/processed meals (frozen)	0.6%	0.5%
Confectionery	5%	2%
Other foods	1%	2%

6 Limitations of the EU Optimeal dataset

1. Limitations of the LCA method applied:
   The applied LCA method is meant to generate a database of average EU products which is internally consistent and good enough for optimization studies in Optimeal. A limitation is that variability and uncertainty is not captured yet. In Optimeal, however the impact of variability can be well studied with Monte Carlo analysis. With this method the implications of variability on EU level can be explored.

   The emissions due to use of pesticides are not considered. Therefore, the toxicity indicators are not included in the dataset.

   The LCA data are not useful for analysis specific for a country within the EU and do not take seasonality into account.

   The EU Optimeal LCA data are not compliant to the PEF guidance and the PEFCRs per product category. Since the PEFCRs are not consistent in terms of allocation between them, using the PEFCRs as a starting point would lead to an internal inconsistent database. For the purpose of the analyses performed using the EU Optimeal dataset consistency is very relevant and valued more than compliance to the PEF guidance and PEFCRs.

   Data quality has not been monitored for the EU Optimeal dataset. This means that the environmental impact indicators do not come with a data quality rating. We are working on implementing data quality rating in the database development and wish to include this rating in a future release.

2. The scope of the EU Optimeal dataset is the European Union. This is a large region with high dietary variation and therefore not representative of individual countries.

3. The EU Optimeal dataset comes with several nutritional profiles specified per gender, age and activity level, but only one EU average diet. This EU average diet should be adapted to the target group of the study and its nutritional profile.

4. Products in the dataset have been based on EFSA Comprehensive European Food Consumption Database. This is a compilation of Food Consumption Surveys of many European countries. The database has been used as a starting point to come to a more aggregated set of food products using the FoodEx classification system. The EU Optimeal dataset fits for use in the Optimeal context but should not be the starting point for dietary advice on a more individual level.

7 References

Andersson, K., Ohlsson, T., & Olsson, P. (1998). Screening life cycle assessment (LCA) of tomato ketchup: a case study. *Journal of Cleaner Production*, *6*(3–4), 277–288. https://doi.org/10.1016/S0959-6526(98)00027-4

Anil, S., Kurt, H., Akar, A., & Köse, Ç. B. (2018). *Hazelnut culture in Turkey*. Instanbul, Turkey. https://doi.org/10.2460/ajvr.72.5.634

Arena, A. P., Barón, G. N., Piastrellini, R., Curadelli, S., & Civit, B. M. (2014). Environmental profile of the life cycle of honey production from small scale in Mendoza, Argentina. Retrieved from http://lcafood2014.org/abstracts/202.pdf

Bartocci, P., Fantozzi, P., & Fantozzi, F. (2017). Environmental impact of Sagrantino and Grechetto grapes cultivation for wine and vinegar production in central Italy. *Journal of Cleaner Production*, *140*, 569–580. https://doi.org/10.1016/j.jclepro.2016.04.090

Broekema, R., & Blonk, H. (2009). *Milieukundige vergelijking van vleesvervangers*. Gouda, the Netherlands: Blonk Milieu Advies, Gouda.

Broekema, R., Kuling, L., & Koukouna, E. (2016). Life Cycle Inventories of nuts , potatoes and beverages consumed in the Netherlands Also includes some types of vegetables , breads and fish, 8–9.

Broekema, R., Kuling, L., & Scholten, J. (2015a). Life Cycle Inventories of dairy- and animal products consumed in the Netherlands. Gouda, the Netherlands: Blonk Consultants.

Broekema, R., Kuling, L., & Scholten, J. (2015b). Life Cycle Inventories of fish products consumed in the Netherlands.

Broekema, R., & Scholten, J. (2015). *Product Environmental Footprint (PEF) screening report of beer*.

Center for Agricultural and Rural Sustainability. (2012). National Scan-level Life Cycle Assessment for Production of US Peanut Butter. University of Arkansas; American Peanut Counsil.

Charrondiere, U. R., Haytowit, D., & Stadlmayr, B. (2012). Food Density Database Version 2.0. *Fao/Infoods*, *2*, 24. Retrieved from http://www.fao.org/docrep/017/ap815e/ap815e.pdf

China Win Tone Machinery. (2014). Hazelnuts Dehulling and Separating Machine. Retrieved from http://www.grain-processing.org/PRODUCTS/Seed-Dehulling-and-Separating-Machine/646.html

Durlinger, B., Koukouna, E., Broekema, R., van Paassen, M., & Scholten, J. (2017a). Agri-footprint 4.0 - Part 1: Methodology and basic principles.

Durlinger, B., Koukouna, E., Broekema, R., van Paassen, M., & Scholten, J. (2017b). *Agri-footprint 4.0 - Part 2: Description of data*. Gouda, the Netherlands.

EFSA. (2006). *Tolerable Upper Intake Levels for Vitamins and Minerals*. Brussels.

EFSA. (2011). Use of the EFSA comprehensive european food consumption database in exposure assessment. *European Food Safety Authority Journal*, *9*(3), 2097. https://doi.org/10.2903/j.efsa.2011.2097.

EFSA. (2017). Dietary Reference Values for nutrients - summary report. https://doi.org/10.2903/sp.efsa.2017.e15121

EFSA. (2018a). EFSA Comprehensive Food Consumption Database. Retrieved from http://www.efsa.europa.eu/en/food-consumption/comprehensive-database

EFSA. (2018b). EFSA Food Composition Database. Retrieved from https://www.efsa.europa.eu/en/microstrategy/food-composition-data

Ercin, A. E., Aldaya, M. M., & Hoekstra, A. Y. (2011). Corporate Water Footprint Accounting and Impact Assessment: The Case of the Water Footprint of a Sugar-Containing Carbonated Beverage. *Water Resources Management*, *25*(2), 721–741. https://doi.org/10.1007/s11269-010-9723-8

European Commision. (2017). *Product Environmental Footprint Category rules Guidance - Version 6.3*. Brussels, Belgium.

European Commission. (2017). *Product Environmental Footprint Category Rules Guidance - version 6.1*.

Fox, M., Akkerman, C., Straatsma, H., & Jong de, P. (2010). Energy reduction by high dry matter concentration and drying. *New Food Magazine*, (2), 60–63. Retrieved from https://www.newfoodmagazine.com/article/474/energy-reduction-by-high-dry-matter-concentration-and-drying/

Humbert, S., Loerincik, Y., Rossi, V., Margni, M., & Jolliet, O. (2009). Life cycle assessment of spray dried soluble coffee and comparison with alternatives (drip filter and capsule espresso). *Journal of Cleaner Production*, *17*(15), 1351–1358. https://doi.org/10.1016/j.jclepro.2009.04.011

Iannone, R., Miranda, S., Riemma, S., & De Marco, I. (2016). Improving environmental performances in wine production by a life cycle assessment analysis. *Journal of Cleaner Production*, *111*, 172–180. https://doi.org/10.1016/j.jclepro.2015.04.006

IDF. (2010). The IDF guide to standard LCA methodology for the dairy sector. *Bulletin of the International Dairy Federation*, *445*, 1–40.

ISO. (2006a). *ISO 14040 Environmental management — Life cycle assessment — Principles and framework*.

ISO. (2006b). *ISO 14044 - Environmental management — Life cycle assessment — Requirements and guidelines*. ISO.

Jekayinfa, S. O., & Bamgboye, A. I. (2006). Estimating energy requirement in cashew (Anacardium occidentale L .) nut processing operations, *31*, 1305–1320. https://doi.org/10.1016/j.energy.2005.07.001

Joy, C. M., Peter Pittappillil, G., & Jose, K. (2002). Drying of Black Pepper (Piper nigrum L.) Using Solar Tunnel Dryer. *PertanikaJ. Trap. Agric. Sci*, *25*(1), 39–45.

JRC, & European Commission. (2015). Baseline Approaches for the Cross-Cutting Issues of the Cattle Related Product Environmental Footprint Pilots in the Context of the Pilot Phase.

Kendall, A., Marvinney, E., Brodt, S., & Zhu, W. (2015). Life Cycle-based Assessment of Energy Use and Greenhouse Gas Emissions in Almond Production, Part I: Analytical Framework and Baseline Results. *Journal of Industrial Ecology*, *00*(0), n/a-n/a. https://doi.org/10.1111/jiec.12332

Konstantas, A., Jeswani, H. K., Stamford, L., & Azapagic, A. (2018). Environmental impacts of chocolate production and consumption in the UK. *Food Research International*, *106*(October 2017), 1012–1025. https://doi.org/10.1016/j.foodres.2018.02.042

Lehto, M., Sipilä, I., Alakukku, L., & Kymäläinen, H. (2014). Water consumption and wastewaters in fresh-cut vegetable production, (March), 246–256.

Lekkergezond. (2016). Appelsap, gezond alternatief voor appel? Nee! Retrieved from https://lekkergezond.nl/2014/07/25/appelsap-gezond-alternatief-voor-appel-nee/

Manfredi, M., & Vignali, G. (2014). Life cycle assessment of a packaged tomato puree: A comparison of environmental impacts produced by different life cycle phases. *Journal of Cleaner Production*, *73*, 275–284. https://doi.org/10.1016/j.jclepro.2013.10.010

McDevitt, J. E., & i Canals, L. M. (2009). Life Cycle Assessment for the Ecodesign of Uk Porridge Oat Plant Varieties., 1–8. Retrieved from http://conference.alcas.asn.au/2009/McDevitt and Canals.pdf

Milà I Canals, L., Sim, S., García-Suárez, T., Neuer, G., Herstein, K., Kerr, C., … King, H. (2011). Estimating the greenhouse gas footprint of Knorr. *International Journal of Life Cycle Assessment*, *16*(1), 50–58. https://doi.org/10.1007/s11367-010-0239-5

Pluimers, J., Blonk, H., Broekema, R., Ponsioen, T., & van Zeist, W. J. (2011). *Milieuanalyse van dranken in Nederland*.

Ponsioen, T., & Blonk, H. (2011). *Case studies for more insight into the methodology and composition of carbon footprints of table potatoes and chips*. Gouda, the Netherlands.

Recanati, F., Marveggio, D., & Dotelli, G. (2018). From beans to bar: A life cycle assessment towards sustainable chocolate supply chain. *Science of the Total Environment*, *613–614*, 1013–1023. https://doi.org/10.1016/j.scitotenv.2017.09.187

Sanjuán, N., Stoessel, F., & Hellweg, S. (2014). Closing Data Gaps for LCA of Food Products: Estimating the Energy Demand of Food Processing. *Environmental Science & Technology*, *48*(2), 1132–40. https://doi.org/10.1021/es4033716

Searchinger, T., & et al. (2013). *Creating a Sustainable Food Future - World Resources Report 2013–14: Interim Findings*. Washington, USA.

Sheane, R., Lewis, K., Hall, P., Holmes-Ling, P., Kerr, A., Stewart, K., & Webb, D. (2011). *Identifying opportunities to reduce the carbon footprint associated with the Scottish dairy supply chain*. Edinburgh.

Tarhan, S., Telci, I., Tuncay, M. T., & Polatci, H. (2011). Peppermint drying performance of contact dryer in terms of product quality, energy consumption, and drying duration. *Drying Technology*, *29*(6), 642–651. https://doi.org/10.1080/07373937.2010.520421

Taulo, J. L., & Sebitosi, A. B. (2016). Material and energy flow analysis of the Malawian tea industry. *Renewable and Sustainable Energy Reviews*, *56*(February 2018), 1337–1350. https://doi.org/10.1016/j.rser.2015.11.072

Technical Secretariat Dairy PEF. (2018). Product Environmental Footprint Category Rules for Dairy Products, 168. Retrieved from http://ec.europa.eu/environment/eussd/smgp/pdf/PEFCR-DairyProducts_2018-04-25_V1.pdf

Technical Secretariat of the olive oil PEF pilot. (2016). *PRODUCT ENVIRONMENTAL FOOTPRINT CATEGORY RULES FOR OLIVE OIL - 3RD DRAFT*.

Technical Secretariat of the PEF dry pasta Pilot. (2004). PRODUCT ENVIRONMENTAL FOOTPRINT SCREENING REPORT: Dry Pasta, *21*(3), 111–147.

Thecnical Secretariat of the PEF pilot on wine. (2015). *PEFCR Pilot on Wine. PEF screening report (Final draft)*.

Therkelsen, P., Masanet, E., & Worrell, E. (2014). Energy efficiency opportunities in the U.S. commercial baking industry. *Journal of Food Engineering*, *130*, 14–22. https://doi.org/10.1016/j.jfoodeng.2014.01.004

Thompson, J., & Elkins, R. (2009). Sample costs to hull and dry walnuts.

United Nations Department of Economic and Social Affairs Population Division. (2017). World Population Prospects The 2017 Revision Key Findings and Advance Tables. *World Population Prospects The 2017*, 1–46. https://doi.org/10.1017/CBO9781107415324.004

Welch, R. W. (1995). *The Oat Crop - Production and utilization*. (R. W. Welch, Ed.) (First Eiti). Chapman & Hall.

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., … Murray, C. (2019). Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems - Supplementary Appendix. *Lancet*, *6736*(18), 3–49. https://doi.org/10.1124/pr.58.3.10

8 Annex 1 List of food products

The Optimeal EU dataset contains 173 products. The products included in this dataset are:

Almond, sweet
Apple
Bacon
Bananas
Beans
Beans, green, without pods
Beans, with pods
Beef meat
Beer and beer-like beverage
Beer, regular
Beetroot
Biscuits
Bitter chocolate
Black tea, infusion
Bottled water
Brown sauce
Butter
Buttermilk
Carrots
Cashew nuts
Cereal flakes
Cheese
Cheese, Camembert
Cheese, Cheddar
Cheese, Danbo
Cheese, Edam
Cheese, Gouda
Cheese, Mozzarella
Cheese, processed spreadable
Chicken egg
Chicken meat
Chocolate (Cocoa) products
Cider
Cod and whiting
Coffee
Cola beverages, caffeinic
Concentrated fruit juice
Condiment
Confectionery (non-chocolate)
Cooked smoked sausage
Cow milk
Cream
Cucumbers
Cultivated mushroom
Curry sauce
Custard
Dressing
Dry sausage
Egg-based meal
Evaporated milk
Fats of mixed origin
Fermented milk products
Fish fingers
Fish products
Fish roe
Fishcakes
Flavoured milk
French fries
Fresh and lightly cooked sausage
Fruit and vegetable juices
Fruit compote
Fruit juice
Fruit nectar
Fruit sauce
Hake
Ham, pork
Hazelnuts
Head cabbage
Herbal tea, infusion
Herring
Honey
Ice cream, milk-based
Iceberg-type lettuce
Ices and desserts
Instant coffee, liquid
Jam
Juice, Apple
Juice, Orange
Juice, Tomato
Kiwi
Leaf vegetables
Leek
Lentils
Lettuce, excluding Iceberg-type lettuce
Liquorice candies
Main-crop potatoes
Mandarins
Margarine, low fat
Margarine, normal fat
Mayonnaise, > 50% oil

Meat and meat products

Meat balls

Meat burger

Meat stew

Meat/poultry soup

Meat-based meals

Melons

Milk chocolate

Mixed beef and pork meat

Mixed wheat and rye bread and rolls

Molasses and other syrups

Multigrain bread and rolls

Mustard, mild

Mutton / lamb meat

Olive oil

Onions, bulb

Oranges

Parsley, herb

Pasta, cooked

Pasta, wheat flour, without eggs

Pastries and cakes

Pate, pork liver

Peaches

Peanut

Peanuts butter

Pear

Peas

Peas, green, without pods

Pepper, black and white

Peppers, paprika

Pizza and pizza-like pies

Pork / piglet meat

Pork liver

Pork meat loaf

Potato based dishes

Potato boiled

Potato crisps

Potatoes and potatoes products

Prepared mixed vegetable salad

Pretzels

Quark

Ready to eat soups

Rice

Rice-based meals

Rye bread and rolls

Salmon and trout

Salt, iodised

Sandwich and sandwich-like meal

Sausages

Savoury sauces

Shrimps

Snack food

Soft drink, flavoured

Soft drink, fruit content

Spinach (fresh)

Spirits

Squid

Starchy pudding

Still mineral water

Strawberries

Sunflower oil

Sunflower seed

Tap water

Tomato ketchup

Tomato purée

Tomatoes

Tree nuts

Tuna

Turkey meat

Veal meat

Vegetable oil

Vegetable sauce

Vegetable/herb soup

Vegetable-based meals

Vinegar, wine

Walnuts

Wheat bread and rolls

Wheat milling products

White sauce

White sugar

Wine, red

Wine, white

Yoghurt, cow milk, plain

9 Annex 2 Building the reference diet

The starting point for composing the EU reference diet is level 2 of FoodEx. When a level 2 product represents less than 1% of the level 1 food categories, we've decided to neglect it. We've also decided to omit the level 1 food categories 'Food for infants and small children' and 'Products for special nutritional use'. They represent respectively 0.1% and 0.9% of the mass consumed per person per day on average.

For the other level 2 product groups we've selected one level 3 product to represent the whole product group at level 2, when that product represents over 80% of all the level 3 products within that group. For instance, for level 2 'grains for human consumption' we have selected rice. Rice represents over 95% of the EU consumption of 'grains for human consumption'.

For other level 2 product groups we've selected multiple level 3 products. For instance, for level 2 'bread and rolls' we selected 'wheat bread and rolls', 'rye bread and rolls', 'mixed wheat and rye bread and rolls' and 'multigrain bread and rolls'. These 4 types of bread and rolls represent over 85% of the EU consumption for 'bread and rolls'. The coverage per product group (level 2) is at minimum 80%, but for some product groups the coverage is close to 100%.

Some descriptions of level 3 products are not very precise. An example is 'wheat milling products'. A more specific product was selected to represent it in terms of environmental impact and nutritional profile. This is mentioned in the remarks. For 'wheat milling products' we selected white wheat flour to represent it. There are also products which are represented by a mix of the other products in that product group. 'Tree nuts' for instance is represented by a mix of almonds, cashews, hazelnuts and walnuts.

Foodex code L1	Foodex code L1	Foodex code L2	Foodex code L2	% within Foodex code L1	Foodex code L3	Foodex code L3	% within Foodex code L2	Remark
A.01.000 001	Grains and grain-based products	A.01.000 001	Grains and grain-based products	0.0%				
		A.01.000 013	Grains for human consumption	5.9%	A.01.000 030	Rice		
		A.01.000 043	Grain milling products	7.1%	A.01.000 044	Wheat milling products		White wheat flour
		A.01.000 098	Bread and rolls	52.2 %	A.01.000 099	Wheat bread and rolls	64%	
					A.01.000 118	Rye bread and rolls	13%	

					A.01.000 129	Mixed wheat and rye bread and rolls	14%	
					A.01.000 140	Multigrain bread and rolls	9%	
		A.01.000 168	Pasta (Raw)	7.5%	A.01.000 174	Pasta, wheat flour, without eggs		
		A.01.000 184	Breakfast cereals	7.3%	A.01.000 185	Cereal flakes		
		A.01.000 252	Fine bakery wares	20.0 %	A.01.000 253	Pastries and cakes	80%	Croissant
					A.01.000 302	Biscuits (cookies)	20%	
A.01.000 317	Vegetables and vegetable products	A.01.000 317	Vegetables and vegetable products	0.5%				
		A.01.000 318	Root vegetables	13.9 %	A.01.000 320	Beetroot	8%	
					A.01.000 321	Carrots	92%	
		A.01.000 331	Bulb vegetables	7.1%	A.01.000 333	Onions, bulb		
		A.01.000 337	Fruiting vegetables	43.3 %	A.01.000 338	Tomatoes	61%	
					A.01.000 339	Peppers, paprika	11%	
					A.01.000 343	Cucumbers	21%	
					A.01.000 346	Melons	8%	
		A.01.000 350	Brassica vegetables	9.9%	A.01.000 354	Head cabbage		
		A.01.000 359	Leaf vegetables	11.1 %	A.01.000 359	Leaf vegetables	43%	mix of kale and endive
					A.01.000 361	Lettuce, excluding Iceberg-type lettuce	35%	
					A.01.000 362	Iceberg-type lettuce	9%	
					A.01.000 369	Spinach (fresh)	14%	
		A.01.000 382	Legume vegetables	2.7%	A.01.000 383	Beans, with pods		

		A.01.000 385	Stem vegetables (Fresh)	3.3%	A.01.000 391	Leek		
		A.01.000 395	Sugar plants	0.6%				
		A.01.000 399	Sea weeds	0.0%				
		A.01.000 404	Tea and herbs for infusions (Solid)	0.1%				
		A.01.000 418	Cocoa beans and cocoa products	0.6%				
		A.01.000 423	Coffee beans and coffee products (Solid)	0.4%				
		A.01.000 431	Coffee imitates (Solid)	0.0%				
		A.01.000 440	Vegetable products	4.4%	A.01.000 443	Tomato purée		
		A.01.000 453	Fungi, cultivated	2.0%	A.01.000 454	Cultivated mushroom		
		A.01.000 458	Fungi, wild, edible	0.2%				
A.01.000 467	Starchy roots and tubers	A.01.000 467	Starchy roots and tubers	0.2%				
		A.01.000 468	Potatoes and potatoes products	99.6 %	A.01.000 468	Potatoes and potatoes products	25%	
					A.01.000 470	Main-crop potatoes	10%	
					A.01.000 471	French fries	13%	
					A.01.000 474	Potato boiled	52%	
		A.01.000 480	Other starchy roots and tubers	0.2%				
A.01.000 486	Legumes, nuts and oilseeds	A.01.000 486	Legumes, nuts and oilseeds	0.1%				
		A.01.000 487	Legumes, beans, green, without pods	37.3 %	A.01.000 488	Beans, green, without pods	28%	
					A.01.000 489	Peas, green, without pods	72%	
		A.01.000 491	Legumes, beans, dried	48.4 %	A.01.000 492	Beans	47%	

					A.01.000 493	Lentils	23%	
					A.01.000 494	Peas	13%	
					A.01.000 512	Peanut	17%	
		A.01.000 513	Tree nuts	11.5 %	A.01.000 513	Tree nuts	25%	mix of almonds, cashews, hazelnuts and walnuts
					A.01.000 514	Almond, sweet	15%	
					A.01.000 517	Cashew nuts	12%	
					A.01.000 520	Hazelnuts	26%	
					A.01.000 525	Walnuts	23%	
		A.01.000 527	Oilseeds	2.7%	A.01.000 532	Sunflower seed		
		A.01.000 543	Other seeds	0.0%				
A.01.000 544	Fruit and fruit products	A.01.000 544	Fruit and fruit products	0.3%				
		A.01.000 545	Citrus fruits	14.4 %	A.01.000 547	Oranges	65%	
					A.01.000 550	Mandarins	35%	
		A.01.000 552	Pome fruits	39.4 %	A.01.000 553	Apple	85%	
					A.01.000 554	Pear	15%	
		A.01.000 562	Stone fruits	6.9%	A.01.000 573	Peaches		
		A.01.000 575	Berries and small fruits	8.5%	A.01.000 578	Strawberries		
		A.01.000 606	Oilfruits	0.0%				
		A.01.000 611	Miscellaneous fruits	19.3 %	A.01.000 619	Kiwi	12%	

					A.01.000 626	Bananas	88%	
		A.01.000 647	Dried fruits	0.9%				
		A.01.000 657	Jam, marmalade and other fruit spreads	4.6%	A.01.000 658	Jam		strawberry jam
		A.01.000 682	Other fruit products (excluding beverages)	5.8%	A.01.000 701	Fruit compote		apple compote
A.01.000 727	Meat and meat products (including edible offal)	A.01.000 727	Meat and meat products (including edible offal)	2.2%	A.01.000 727	Meat and meat products (including edible offal)		
		A.01.000 728	Livestock meat	37.9 %	A.01.000 729	Beef meat	42%	
					A.01.000 730	Veal meat	6%	
					A.01.000 731	Pork / piglet meat	47%	
					A.01.000 732	Mutton / lamb meat	5%	
		A.01.000 736	Poultry	20.6 %	A.01.000 737	Chicken meat	85%	
					A.01.000 738	Turkey meat	15%	
		A.01.000 744	Game mammals	0.6%				
		A.01.000 751	Game birds	0.1%				
		A.01.000 760	Mixed meat	2.6%	A.01.000 761	Mixed beef and pork meat		
		A.01.000 766	Edible offal, farmed animals	1.1%	A.01.000 769	Pork liver		
		A.01.000 791	Edible offal, game animals	0.0%				
		A.01.000 795	Preserved meat	11.3 %	A.01.000 796	Ham, pork	79%	
					A.01.000 802	Bacon	21%	
		A.01.000 811	Sausages	20.7 %	A.01.000 811	Sausages	18%	
					A.01.000 812	Fresh and lightly cooked sausage	24%	

					A.01.000 826	Cooked smoked sausage	36%	
					A.01.000 844	Dry sausage	22%	
		A.01.000 857	Meat specialities	1.0%	A.01.000 858	Pork meat loaf		
		A.01.000 867	Pastes, pâtés and terrines	1.5%	A.01.000 871	Pate, pork liver		
		A.01.000 873	Meat imitates	0.3%				
A.01.000 876	Fish and other seafood	A.01.000 876	Fish and other seafood	0.3%				
		A.01.000 877	Fish meat	76.9 %	A.01.000 878	Herring	13%	
					A.01.000 883	Salmon and trout	37%	
					A.01.000 891	Tuna	18%	
					A.01.000 894	Cod and whiting	25%	
					A.01.000 895	Hake	6%	
		A.01.000 910	Fish products	10.6 %	A.01.000 910	Fish products	32%	mix of fish fingers and fish cakes
					A.01.000 912	Fishcakes	15%	
					A.01.000 913	Fish fingers	53%	
		A.01.000 916	Fish offal	1.0%	A.01.000 917	Fish roe		
		A.01.000 919	Crustaceans	6.0%	A.01.000 924	Shrimps		
		A.01.000 927	Water molluscs	5.0%	A.01.000 928	Squid		
		A.01.000 942	Amphibians, reptiles, snails, insects	0.1%				
A.01.000 948		A.01.000 948	Milk and dairy products	0.0%				

	Milk and dairy products	A.01.000 949	Liquid milk	60.8 %	A.01.000 950	cow milk		
		A.01.000 963	Milk based beverages	3.8%	A.01.000 964	Flavoured milk		
		A.01.000 973	Concentrated milk	1.0%	A.01.000 974	Evaporated milk		
		A.01.000 985	Whey and whey products (excluding whey cheese)	0.2%				
		A.01.001 000	Cream and cream products	2.0%	A.01.001 001	Cream		
		A.01.001 027	Fermented milk products	20.7 %	A.01.001 027	Fermented milk products	35%	mix of buttermilk and yoghurt
					A.01.001 028	Yoghurt, cow milk, plain	49%	
					A.01.001 041	Buttermilk	16%	
		A.01.001 049	Milk derivatives	0.0%				
		A.01.001 053	Cheese	10.5 %	A.01.001 053	Cheese	26%	
					A.01.001 054	Quark	27%	
					A.01.001 057	Cheese, processed spreadable	3%	
					A.01.001 094	Cheese, Camembert	4%	
					A.01.001 102	Cheese, Cheddar	5%	
					A.01.001 112	Cheese, Danbo	9%	
					A.01.001 117	Cheese, Edam	6%	
					A.01.001 133	Cheese, Gouda	13%	
					A.01.001 173	Cheese, Mozzarella	8%	
		A.01.001 240	Milk and milk product imitates	0.8%				
A.01.001 252		A.01.001 252	Eggs and egg products	0.1%				

	Eggs and egg products	A.01.001 253	Eggs, fresh	99.9 %	A.01.001 254	chicken egg		
		A.01.001 263	Eggs, powder	0.0%				
A.01.001 267	Sugar and confectionary	A.01.001 267	Sugar and confectionary	0.4%				
		A.01.001 268	Sugars	33.1 %	A.01.001 269	white sugar		
		A.01.001 280	Sugar substitutes	0.4%				
		A.01.001 295	Chocolate (Cocoa) products	34.6 %	A.01.001 295	Chocolate (Cocoa) products	60%	
					A.01.001 296	Bitter chocolate	13%	
					A.01.001 303	Milk chocolate	28%	
		A.01.001 310	Confectionery (non-chocolate)	19.0 %	A.01.001 310	Confectionery (non-chocolate)	82%	mix of strawberry jam and liqourice
					A.01.001 321	Liquorice candies	18%	
		A.01.001 328	Dessert sauces	2.6%	A.01.001 329	Fruit sauce		strawberry sauce
		A.01.001 333	Molasses and other syrups	4.7%	A.01.001 333	Molasses and other syrups		
		A.01.001 340	Honey	5.1%	A.01.001 340	Honey		
A.01.001 346	Animal and vegetable fats and oils	A.01.001 346	Animal and vegetable fats and oils	1.5%				
		A.01.001 347	Animal fat	28.2 %	A.01.001 348	Butter		
		A.01.001 358	Fish oil	0.0%				
		A.01.001 362	Vegetable fat	1.6%	A.01.001 363	Peanuts butter		
		A.01.001 367	Vegetable oil	28.2 %	A.01.001 367	Vegetable oil	19%	mix of rapeseed, sunflour and soybean oil
					A.01.001 375	Olive oil	54%	

					A.01.001 384	Sunflower oil	27%	
		A.01.001 388	Fats of mixed origin	6.5%	A.01.001 388	Fats of mixed origin		mix of butter and vegetable oil
		A.01.001 389	Margarine and similar products	34.0 %	A.01.001 390	Margarine, normal fat	70%	
					A.01.001 391	Margarine, low fat	30%	
A.01.001 394	Fruit and vegetable juices	A.01.001 394	Fruit and vegetable juices	2.3%	A.01.001 394	Fruit and vegetable juices		mix of tomato and apple juice
		A.01.001 395	Fruit juice	79.1 %	A.01.001 395	Fruit juice	11%	
					A.01.001 396	Juice, Apple	48%	
					A.01.001 397	Juice, Orange	41%	
		A.01.001 418	Concentrated fruit juice	4.9%	A.01.001 418	Concentrated fruit juice		
		A.01.001 434	Fruit nectar	4.4%	A.01.001 434	Fruit nectar		
		A.01.001 442	Mixed fruit juice	7.6%				
		A.01.001 453	Dehydrated/powdered fruit juice	0.0%				
		A.01.001 454	Vegetable juice	1.1%	A.01.001 455	Juice, Tomato		
		A.01.001 463	Mixed vegetable juice	0.0%				
		A.01.001 467	Mixed fruit and vegetable juice	0.6%				
A.01.001 470	Non-alcoholic beverages	A.01.001 470	Non-alcoholic beverages	0.1%				
		A.01.001 471	Soft drinks	23.3 %	A.01.001 472	Soft drink, fruit content	24%	
					A.01.001 494	Soft drink, flavoured	46%	
					A.01.001 510	Cola beverages, caffeinic	30%	

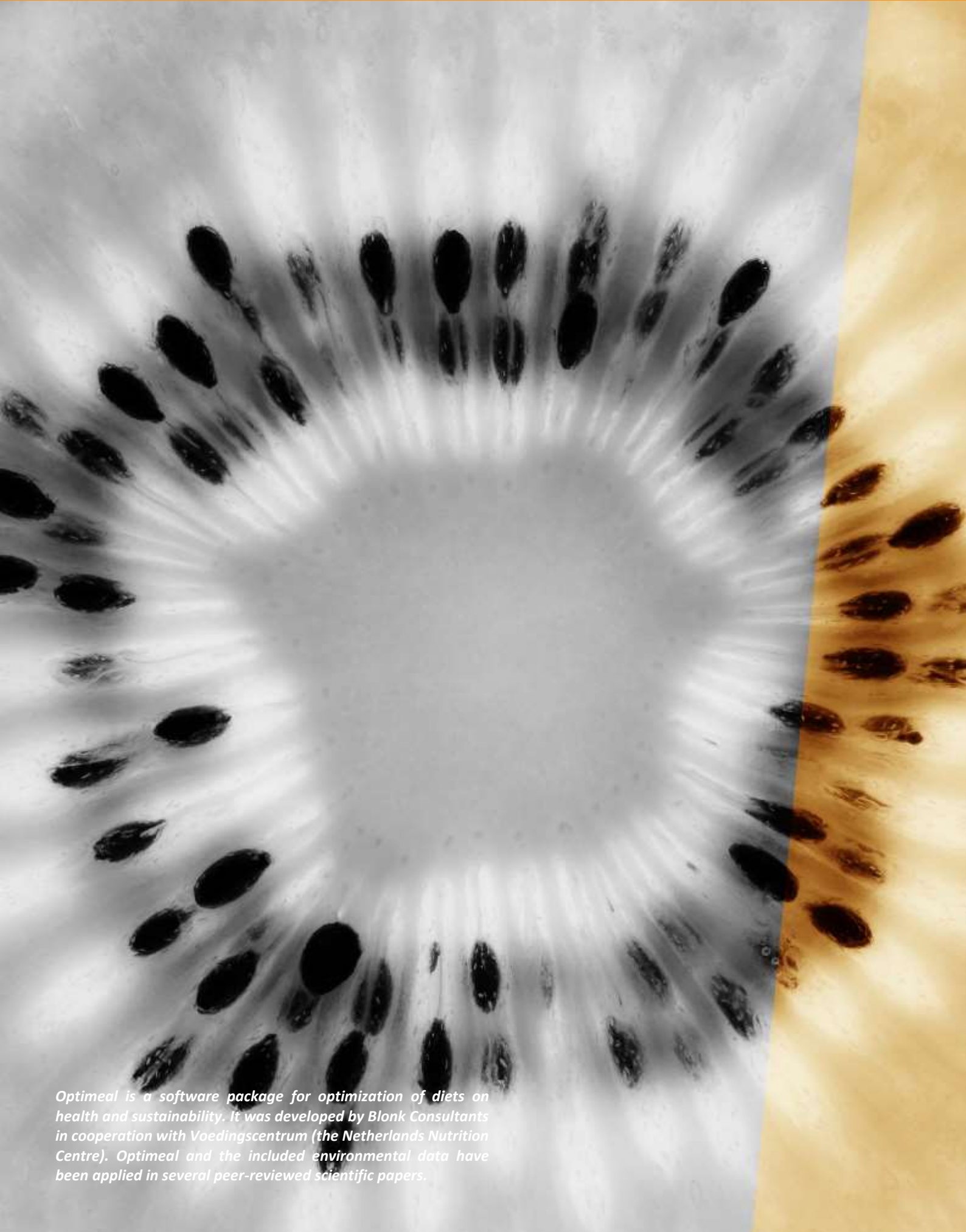
		A.01.001 515	Tea (Infusion)	32.7 %	A.01.001 516	Black tea, infusion	77%	
					A.01.001 519	Herbal tea, infusion	23%	
		A.01.001 522	Coffee (Beverage)	42.8 %	A.01.001 522	Coffee (Beverage)	85%	
					A.01.001 529	Instant coffee, liquid	15%	
		A.01.001 530	Coffee imitates beverage	0.3%				
		A.01.001 531	Cocoa beverage	0.8%				
A.01.001 534	Alcoholic beverages	A.01.001 534	Alcoholic beverages	0.3%				
		A.01.001 535	Beer and beer-like beverage	69.4 %	A.01.001 535	Beer and beer-like beverage	20%	
					A.01.001 537	Beer, regular	80%	
		A.01.001 541	Wine	24.7 %	A.01.001 542	Wine, white	31%	
					A.01.001 544	Wine, red	69%	
		A.01.001 546	Fortified and liqueur wines	0.5%				
		A.01.001 549	Wine-like drinks	2.4%	A.01.001 550	Cider		
		A.01.001 552	Liqueur	0.4%				
		A.01.001 561	Spirits	1.5%	A.01.001 561	Spirits		
		A.01.001 569	Alcoholic mixed drinks	0.9%				
A.01.001 573	Drinking water	A.01.001 573	Drinking water	4.4%				
		A.01.001 574	Tap water	56.0 %	A.01.001 574	tap water		
		A.01.001 575	Well water	0.0%				

		A.01.001 576	Bottled water	39.6 %	A.01.001 576	Bottled water	75%	
					A.01.001 577	Still mineral water	25%	
		A.01.001 579	Water ice (for consumption)	0.0%				
A.01.001 580	Herbs, spices and condiments	A.01.001 580	Herbs, spices and condiments	0.4%				
		A.01.001 581	Herbs	2.3%	A.01.001 586	Parsley, herb		
		A.01.001 593	Spices	1.5%	A.01.001 621	Pepper, black and white		
		A.01.001 625	Herb and spice mixtures	0.2%				
		A.01.001 632	Seasoning or extracts	6.6%	A.01.001 635	Salt, iodised		
		A.01.001 649	Condiment	17.1 %	A.01.001 649	Condiment	13%	mix of mustard, tomato ketchup and mayonaise
					A.01.001 651	Mustard, mild	11%	
					A.01.001 653	Vinegar, wine	9%	
					A.01.001 655	Tomato ketchup	58%	
					A.01.001 661	Curry sauce	9%	
		A.01.001 665	Dressing	18.8 %	A.01.001 665	Dressing	65%	
					A.01.001 669	Mayonnaise, > 50% oil	35%	
		A.01.001 672	Chutney and pickles	0.5%				
		A.01.001 684	Savoury sauces	50.9 %	A.01.001 684	Savoury sauces	23%	tomato based sauce
					A.01.001 685	White sauce (Bechamel sauce, Cheese sauce)	11%	
					A.01.001 686	Brown sauce (Gravy, Lyonnais sauce)	44%	

					A.01.001 694	Vegetable sauce	22%	
		A.01.001 695	Flavourings or essences	0.0%				
		A.01.001 704	Baking ingredients	1.6%				
A.01.001 715	Food for infants and small children	A.01.001 715	Food for infants and small children	0.1%				
		A.01.001 716	Infant formulae, powder	1.5%				
		A.01.001 722	Follow-on formulae, powder	0.8%				
		A.01.001 728	Cereal-based food for infants and young children	4.0%				
		A.01.001 733	Ready-to-eat meal for infants and young children	18.0 %				
		A.01.001 739	Yoghurt, cheese and milk-based dessert for infants	1.1%				
		A.01.001 743	Fruit juice and herbal tea for infants and young c	2.8%				
		A.01.002 000	Infant formulae, liquid	52.6 %				
		A.01.002 010	Follow-on formulae, liquid	19.2 %				
A.01.001 748	Products for special nutritiona l use	A.01.001 748	Products for special nutritional use	0.2%				
		A.01.001 749	Food for weight reduction	13.1 %				
		A.01.001 752	Dietary supplements	9.2%				
		A.01.001 765	Food for sports people (labelled as such)	69.3 %				
		A.01.001 771	Dietetic food for diabetics (labelled as such)	2.9%				
		A.01.001 784	Medical food (are specially formulated and intende	5.2%				
A.01.001 789	Composit e food	A.01.001 789	Composite food (including frozen products)	0.7%				

	(including frozen products)	A.01.001 790	Cereal-based dishes	16.0 %	A.01.001 791	Sandwich and sandwich-like meal	20%	
					A.01.001 800	Pizza and pizza-like pies	38%	
					A.01.001 809	Pasta, cooked	42%	
		A.01.001 816	Rice-based meals	2.4%	A.01.001 816	Rice-based meals		
		A.01.001 820	Potato based dishes	2.1%	A.01.001 820	Potato based dishes		
		A.01.001 825	Beans-based meals	1.0%				
		A.01.001 829	Meat-based meals	12.2 %	A.01.001 829	Meat-based meals	32%	
					A.01.001 830	Meat burger	22%	
					A.01.001 831	Meat balls	20%	
					A.01.001 833	Meat stew	26%	
		A.01.001 834	Fish and seafood based meals	0.9%				
		A.01.001 839	Vegetable-based meals	7.9%	A.01.001 839	Vegetable-based meals		
		A.01.001 847	Egg-based meal (e.g., omelette)	5.5%	A.01.001 847	Egg-based meal (e.g., omelette)		
		A.01.001 855	Mushroom-based meals	0.1%				
		A.01.001 856	Ready to eat soups	43.9 %	A.01.001 856	Ready to eat soups	48%	mix of vegetable/herb soup and meat/poultry soup
					A.01.001 857	Vegetable/herb soup	35%	
					A.01.001 860	Meat/poultry soup	16%	
		A.01.001 866	Prepared salads	7.3%	A.01.001 868	Prepared mixed vegetable salad		
A.01.001 877	Snacks, desserts,	A.01.001 877	Snacks, desserts, and other foods	0.0%				

	and other foods	A.01.001 878	Snack food	20.1 %	A.01.001 878	Snack food	19%	Mix of chocolat, potato crisps and tree nuts
					A.01.001 879	Potato crisps	69%	
					A.01.001 884	Pretzels	12%	
		A.01.001 888	Ices and desserts	78.8 %	A.01.001 888	Ices and desserts	22%	mix of ice cream, yoghurt and custard
					A.01.001 889	Ice cream, milk-based	41%	
					A.01.001 891	Starchy pudding	13%	
					A.01.001 892	Custard	25%	
		A.01.001 896	Other foods	1.1%				



Optimeal is a software package for optimization of diets on health and sustainability. It was developed by Blonk Consultants in cooperation with Voedingscentrum (the Netherlands Nutrition Centre). Optimeal and the included environmental data have been applied in several peer-reviewed scientific papers.

Optimeal

Gravin Beatrixstraat 34

2805 PJ Gouda

(+31) 0182 579970

www.optimeal.info

info@optimeal.info

optimeal